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SYNAPSE

THE

INTERCOLLEGIATE SCIENCE MAGAZINE

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Susan Robinson-Cloete OC '24

Susan Robinson-Cloete is very excited to present Issue 36 of The Synapse, the last issue for the 2023-2024 school. She is looking forward to these amazing articles, art, and honors research blurbs being seen and read by our audience. This issue has a plethora of interesting topics, spanning from echolocation to tackling ChatGPT and a beautifully written science fiction piece. They hope you enjoy this issue and are thankful to everyone for their contributions and readership to The Synapse who have made this year so wonderful. They also want to thank everyone on the board both at Oberlin and our partner universities and colleges for all of their hard work, without it there would be no magazine.

Institutions of The Synapse Magazine

OC - Oberlin College and Conservatory	CoW - College of Wooster
DU - Denison University	CWRU - Case Western Reserve University



Featured Contributor

Sky Milstein OC '24

Sky (they/he) is a Junior at Oberlin College studying biology and geosciences. He is from Arlington, Massachusetts. At Oberlin, they are on the women and trans rugby team and in Harkness coop! He thinks scientific communication is incredibly important because It's one thing to be a scientist and do research, and it's another thing to be able to discuss that with non-scientists. They believe the Synapse makes science accessible to college students. They like to dance, watch reality dating shows, and crochet in their free time! If he could live in any book world, it would be Magic Tree House.



Featured Contributor

Long Ly OC '26

Long Ly (He/Him) is a 1st year at Oberlin College from Hanoi, Vietnam. Long intends to major in biology and neuroscience and potentially minor in chemistry. In his 1st-year, he has already contributed to 2 issues and will become the treasurer for the Synapse next year. After undergrad, Long hopes to take 1-2 gap years to gain research experience with OPT while applying for a Ph.D. program. At Oberlin, he is in the men's volleyball club and often goes to the climbing gym. He is doing the Knitco/modular origami exco as well. When asked why he thinks the Synapse is important, he said, "I think the language of science is quite esoteric, and most research papers, in trying to maintain accurate and specific language, becomes too difficult for people outside of the sciences to comprehend. And so the Synapse is a slightly less formal way to communicate science to people and help others learn more about the natural world". If he had to choose a book to live in, he would pick Hitchhiker's Guide to The Galaxy.

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Beyond Ancient Societies

Medical Practices that Draw Parallels

Written by James Lee
Illustrated by Leah Potoff

Whenever I catch a cold, my mom makes me chicken broth soup engulfed in ginseng juice with rice. This dish contains many different herbs to help cope with colds. All these ingredients combined make me better. If one is missing, I feel like I do not get the healing effect I normally feel. Most of the time, the lunch meal my mom prepares for me has a better result than the aspirin doctors prescribe to relieve my cold.

As my mom scolds me for not taking care of my body enough or never taking my vitamins regularly, there is a story that she tells me as I am struggling to pick my spoon up to feed myself. The story goes, "Since the times when tigers used to smoke," a Korean metaphorical way of describing ancient times, "the old lady that mysteriously cured cold sells a mysterious soup that when eaten, the sickness goes away." The same soup in the story is the soup that my mom prepares for me when I am sick. This made me question three things: What was ancient medicine like? How do its practices persist in today's society? What do the ancient civilizations tell us about today's society?

Most of the time, the lunch meal my mom prepares for me has a better result than the aspirin doctors prescribe to relieve my cold.

Medicine practices started as early as ancient Egypt. The well-prescribed history of these civilizations gives us a glimpse of what their medical practices were like. Ancient Egypt had a hierarchy of medical professionals starting from ordinary doctors (swnw) at the lowest level, overseer of doctors (imyr swnw), chief of doctors (smsw swnw), and the eldest of doctors (smsw swnw). Even particular jobs called the 'shd swnw' inspected these doctors. The treatments that these doctors gave to their patients ranged widely from heart disease, dentistry, cancer, and even circumcision. Specifically, it is written in scripture that Egyptians used fumigation to burn off the area with similar descriptions to cancer. This is similar to the High-Intensity Focused Ultrasound (HIFU) method of treating tumors, where they concentrate high heat on specific areas of the body with the tumor. Although the only known major operation was circumcision, the drawing that pointed to the circumcision operation had evidence of the use of specialized tools like scissors and scallops.

Advanced medicine practices could also be seen in the nearby civilization of Mesopotamia. Ancient Mesopotamia civilizations have records that tell historians how advanced their medical procedures were. Unlike Egypt, their 'healers' were divided into three categories: healers who made diagnoses (baru), healers who expelled demons and incantations (ashipu), and healers who treated the sick with drugs and operations (asu). The Mesopotamian societies had a strong development for herbal medicine, as surgery was not recommended. However, there is definite evidence that they used hemp and opium as a treatment for patients, a source of medicine we widely used today. Interestingly, hemp was also used to treat menstruation cycles in ancient Mesopotamia. Not only did they use what was described as "menstruating bandages," which

were strips of cloth, but these bandages were equipped with painkillers like hemp to control mood swings.

A similarity between these two civilizations is that scriptural evidence indicates women healers during their dominance. Scriptures that record ancient Egypt and Mesopotamia all indicate that to qualify as a healer; one has to be highly educated and among the elite. Contrary to traditional and more modern civilizations where only men were allowed to pursue higher education, women in ancient Egypt and Mesopotamia were allowed these rights. Healers often only cared for people of higher social status since these societies were class-based. Although a male doctor would not answer to a female doctor, the female doctor would perform spells and surgery as she walked down the streets of civilization. They were just as important as male doctors to keep society healthy.

Moreover, it was often the wife's job to take care of the kids and provide for them, making them essential in the society of Egypt and Mesopotamia. These methods were passed on verbally, often from mother to mother, proving that women in Egyptian society and ancient Mesopotamia's tightly-knit society prioritized childcare. The structure of its community still exists today, some five-thousand years later. Even now, many care methods for sick children are not research-backed but passed down from generation to generation.

However, as both the ancient Egyptian civilization and the Mesopotamian civilization collapsed, the role of women as the bondage of the family also collapsed. After researching, I realized that even though the culture we live in today seems significantly more advanced than ancient Egypt or Mesopotamia, their societies were not that different from ours. It may be very likely that a kid back then had a similar story to mine to tell the world. Meanwhile, today's society is plagued with diseases of racism, sexism, and polarization that separate us from one another. It begs the question: what is the purpose of these advancements if the same "diseases" plague our society today as they did five

Even now, many care methods for sick children are not research-backed but passed down from generation to generation.

thousand years ago? Scholars have only been able to decipher about one to two percent of Egypt and Mesopotamia's scriptures. Despite that, we could still find similarities that were scarily close. We as a civilization have distanced ourselves from other individuals and cultures even though the cultures that we live in have not gone extinct. We must strive to heal these diseases and conserve our cultures.

If not, the herbs and soup story my mom told me when I was sick may not continue to the next generations. Although I will never know if my mom's story was true, I am satisfied to learn that the traditions of moms caring for their sick children will be a culture we will not lose throughout future generations. ● ● ●





Echolocation-Location-Location

Acoustics, Mammals, Technology, Mammals, and Military

Written by Anadi Mehal Purewal-Legha

Illustrated by Katie Baum

Famously used by the Marvel Universe as one of the Living Vampire, Morbius' superpowers, echolocation is the concept of acoustically locating, targeting, sending, and receiving sound pulses with a subject. However, echolocation does more than communicate itself into the movie industry's screenwriting room. Echolocation is the basis through which many species communicate. It has also been cultivated into various technological inventions, some in medical or military practice.

Before diving into the specifics of echolocation concerning our society, it is imperative to understand what it actually is. As described by National Geographic, "Echolocation is nature's built-in sonar". Here is how it works: if animal A releases a sound wave, that wave would travel and reach animal B, bouncing off the latter animal and returning an echo to animal A. Through echolocation, animal A could approximate how large and far animal B is. Pretty cool, right? Animals agree, which is why so many species use it daily!

Although used mainly by marine mammals in oceanic habitats, bats are also commonly known to use echolocation. This

tactic is beneficial for predators to locate their prey, prey to flee their hunters, food to be found in otherwise unscannable areas, and navigate around surroundings. Bats produce echolocation by emitting the sound through their mouth or nose and listening for the returning echo. Unlike bats, you might wonder why humans cannot hear the echolocating sounds that some animals do? The answer is surprising because you probably have! Well, with a few modifications. While humans can hear up to 20 Hz. Animals far supersede that number. For example, bats can typically hear up to 200 Hz. But do not worry! Not all hope is lost. Although most marine mammals echolocate in frequencies we cannot receive, some animals echolocate in ranges we can. Next time you are swimming in the ocean, make sure to listen for orcas and sperm whales!

After covering what echolocation is, it is now time to delve deeper into how mammals emit and receive these sound waves. It is important to note that marine animals do not always use echolocation for the same purpose. Sometimes, it may not even be used at all. Toothed whales and dolphins echolocate for hunting and traversing their environment. In contrast, the evolutionary

need for echolocation never arose in baleen whales because they do not actively hunt for food. Toothed whales and dolphins use echolocation to find prey and scale their habitat. They produce sounds by moving through spaces and using the sinuses in their head. After the sound is reflected from the object it encounters, it is received again through specialized fats in the lower jaw, quickly reaching the middle ear. If the animals swim normally, the sounds they hear are at low frequencies and provide information about their surroundings rather than their prey. Since the frequency can be modified, a new theory suggests that higher-frequency sounds are actively used while hunting to disorient the prey. In another theory, scientists speculate whether echolocation provides these toothed whales and dolphins with a three-dimensional understanding of the world.

Toothed whales and dolphins use echolocation to find prey and scale their habitat. They produce sounds by moving through spaces and using the sinuses in their head. After the sound is reflected from the object it encounters, it is received again through specialized fats in the lower jaw, quickly reaching the middle ear.

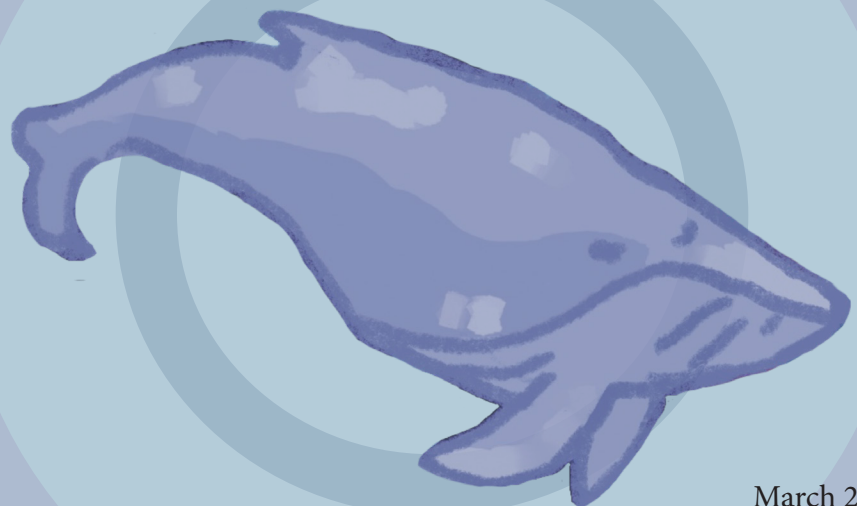
Now that we understand what echolocation is, which animals use it, and why they do it, we can delve into how humans have cultivated echolocation for our benefit. Let us explore recent technology developed by a start-up in Kazakhstan. A company called SEZUAL has developed a device that helps visually impaired people “see” objects in three dimensions within 15 meters. It is worn around the individual’s neck and works by emitting a high-pulse click that reflects off the surrounding area. This gives the wearer the object’s distance, shape, and material as the information is processed within the person’s visual cortex. After high success with test trials and subjects, SEZUAL plans to open to the global market. In another field, echolocation has allowed us to discover mysteries within the Earth. A remote sensing technology, Light Detection and Ranging

(LiDAR), is used by archeologists to gain information on the Earth’s deeper layers. A detailed three-dimensional topographical image can be created by beaming laser pulses toward the ground and measuring the time between the wavelengths coming back. Although just two innovations out of thousands, SEZUAL and LiDAR highlight how echolocation-based technology can drastically improve human quality of life and aid in cutting-edge research.

Furthermore, echolocation has been used in many medical and military developments. There is one in particular that most of us have unknowingly participated in. Echolocation is used in ultrasound procedures. Ultrasound is a medical imaging technique where a device sends high-frequency sound waves and “listens” to the response, creating an image in real-time based on the sound it receives. Through ultrasounds, abnormal growths, issues in blood vessels, and details of specific organs are visualized. Ultrasound has transformed healthcare and how patients are cared for by providing doctors with detailed information to establish better the procedures their patients need while providing patients with important visual details.

Regarding the military and technology developed in the 20th century, many machines such as airplanes, ships, and submarines use echolocation to gain a more precise location of their target. They can detect objects by emitting sonar sound waves and then analyzing the received returning waves. The military’s echolocation technique has been compared in similarity to fruit bats. Furthermore, it is speculated that the military can operate covertly by creating unique sounds mimicking marine mammals. Although the effect of this communication system on animals may be worrisome, previous experiments demonstrate that marine mammals can discern artificial recordings or sounds from natural, environmental ones. However, they may still adapt their behavior by changing their vocalization. This could be detrimental as their sudden activity could reveal their location to predators or prey.

Echolocation, the concept of using sound impulses to locate a subject acoustically, is crucial to many animals’ consistent survival and way of life. It is also central in advancing human technology, medicine, and military techniques. We have just started developing technology and exploring the possibilities that echolocation gives us. The surface has only been touched. We can anticipate much more from our discovery of this biological navigator and communication device. Always keep your ears out to listen for animals sending out a pulse, and keep your eyes open for what we as humans develop. ● ● ●





The Inescapable Detriments of Neonicotinoids

An Exploration of the Harmful Pesticide's Effects on Humans and Insects

Written by Fay Levin

Illustrated by Claire Wong

Throughout history, farmers and crop cultivators have tried to conquer pests and other destroyers in various ways. The Sumerians made the first recorded insecticide, which used sulfur compounds to repel pests. Modern-day insect-repellent methods heavily rely on neonicotinoids, a class of inorganic insecticides that inhibit the central nervous system of insects. Unfortunately, neonicotinoids cannot distinguish between harmful pests and beneficial insects such as pollinators (e.g., bees, butterflies, etc.). Furthermore, though it is largely believed that neonicotinoids do not affect humans and mammals, recent studies have indicated that this may not be as true. With neonicotinoid interactions being almost unavoidable due to their pervasive use, numerous countries are reconsidering their usage for the sake of both mammals and pollinators.

Though neonicotinoids are a more modern solution, the history of nicotine use in agriculture is extensive. Nicotine, which has the chemical structure of $C_{10}H_{14}N_2$, was one of the first agents identified to target acetylcholine receptors and inhibit them. Acetylcholine is a neurotransmitter found in both vertebrates and

invertebrates and has the basic chemical form $C_7NH_{16}O_2^+$ and can be thought of as the combination of acetic acid (vinegar) and choline. In the human body, acetylcholine acts as an excitatory neurotransmitter at neuromuscular junctions – which control skeletal muscles – and an inhibitory neurotransmitter for smooth muscle function. In a less abstract explanation, acetylcholine can influence and increase the function of muscles responsible for movement and relaxing smooth muscles such as vascular smooth muscle, leading to vasodilation – enhanced blood flow. Humans have two acetylcholine receptors, nicotinic and muscarinic, throughout the body. Both are located in the peripheral and central nervous systems (CNS). Nicotinic acetylcholine receptors control skeletal muscle, while muscarinic mainly control smooth muscle. The ligands characterize the use of each receptor it binds to. On the other hand, insects mainly have nicotinic acetylcholine receptors located exclusively in their CNS. Nicotine binds to the nicotinic receptors of the insects and induces a paralysis-like state due to the loss of acetylcholine processing.

Neonicotinoids, as the “neo” prefix implies, are a new type

of nicotine-based insecticide. They directly permeate with water throughout a plant and are incredibly effective. Seven subgroups of neonicotinoids are currently in use worldwide: imidacloprid, acetamiprid, clothianidin, thiamethoxam, thiacloprid, nitenpyram, and dinotefuran. Their elemental chemical composition is similar to that of simple nicotine.

The first commercially developed nicotinoid was nithiazine, with the chemical structure $C_5H_8N_2O_2S$. The development of nithiazine was based on the findings of Dr. Henry Feuer, a professor at Purdue University who submitted his initial makings of nithiazine to the Shell Global corporation, specifically the plant protection division, which was later sold to DuPont de Nemours, Inc. Like current neonicotinoids in circulation, nithiazine was found to be directly toxic to the nervous system of insects (more commonly known as a knock-down agent) and inhibit acetylcholine receptor function. Nithiazine was never agriculturally commercialized due to its severe instability in sunlight. Thankfully, it was also never given enough promotion to make it a large-scale household insecticide, as it turned out to be incredibly toxic to the nervous system of vertebrates and invertebrates. Straying away from nithiazine and combining previous research done in Japan by scientist Izuru Yamamoto of Tokyo University, researchers focused on the nitrogen component of nicotine in nithiazine after finding that it

Neonicotinoids were found to affect nicotinic acetylcholine receptors in mammals very similarly to the way of plain nicotine.

was the specific element that could interfere with acetylcholine in an insect. Nitrogen interacts with the hydrogen-donating site of neuronal nicotinic acetylcholine receptors, inhibiting their function or working as an agonist in more scientific terms.

Therefore, the base composition of nithiazine was elaborated upon to make different other neonicotinoids. In the 1980s, shortly after the Shell corporation introduced nithiazine in 1978, researchers in Japan began trying to alter the structure of nithiazine to be even more effective in paralyzing insects. They achieved their goal, and the resulting chemicals – a newer neonicotinoid, now known under the name imidacloprid – were shown to kill 90 percent of insects within five days. In short, the combination of the nitromethylene heterocycle with more stable molecules, such as nitroguanidine, a very insensitive explosive, stabilized the overall molecule and decreased reactivity when exposed to sunlight. Further introduction of an extra chloro-cycle molecule increased the potency of the new neonicotinoid as well. Over the years, companies have further adjusted neonicotinoids to target various insects more effectively. For example, while nithiazine was initially intended to kill household flies, Nitenpyram was explicitly designed for use on two specific cicada species that are significant rice pests. Nevertheless, the function of neonicotinoids remains the same across the board – inhibiting the acetylcholine receptor of all insects. A study on American cockroaches (*Periplaneta americana*) to understand the traits of exposure to Neonicotinoids found that the insect would experience abdominal quivering, extreme tensing of the entire body, collapse, and subsequent death.

Like other insects, bees are not immune to Neonicotinoids. They are exposed to them as much as any pest since Neonicotinoids deposit directly into the pollen of plants – which bees collect. This is particularly detrimental since bees require incredible cognition to fulfill their daily tasks. Certain bees have been shown to prefer different types of plants, often being able to differentiate them based on their “smells.” This sensory memorization is dependent on the excitatory signals in the brain associated with acetylcholine firing in the antennal lobes and mushroom bodies (which are both involved in processing sensation in insects). Even small amounts of neonicotinoids can inactivate mushroom body (MB) neuron firing, while more extensive exposure can damage MBs completely.

In bees, Neonicotinoid effects have also been found weatherly and seasonally dependent – exposure in the winter has been proven to be more lethal than in the summer. Winter honey bees differ from summer ones due to differences in hemolymph, the insect equivalent of red blood cells, composition and metabolism, and endocrinology. This is believed to have a connection with the way that winter honey bees detoxify. Furthermore, winter honey bees depend on stored honey for survival. Tests done on honey have shown that levels of neonicotinoids deposited are enough to be detrimental to a bee. Pollen is even worse. Nearly 60 percent of pollen samples measured contained high levels of at least one pesticide. This is believed to be a possible factor in colony collapse disorder, as bees slowly die off or get injured after coming in contact with neonicotinoids.

Though it is widely claimed and believed that neonicotinoids do not affect the nervous systems of humans, and other vertebrates, there is conflicting evidence of this being true. The United States Environmental Protection Agency (EPA) allows for using neonicotinoids due to their inability to cross the blood-brain barrier and the fact that they were replacing much more toxic forms of insecticides. However, Neonicotinoids were found to affect nicotinic acetylcholine receptors in mammals very similarly to the way of plain nicotine. Mainly, effects were found to be significant during development, as most exposures to neurotoxic elements are, as synapse formation and neurogenesis – the forming of neurons – appear to be affected.

The frightening part is that neonicotinoids can bind to specific nicotinic receptors. There are high concentrations of nicotinic receptors in the thalamus, the brain region mainly responsible for sensory processing, and the hypothalamus, which is largely not protected by the blood-brain barrier. Alterations done by neonicotinoids upon these receptors were associated with central nervous system disorders such as Alzheimer's, Parkinson's disease, schizophrenia, and depression. Reproductive factors also seem privy to the effects of neonicotinoids, as exposure has been associated with reduced sperm count, higher rates of birthing defects, stillbirth, and embryonic death.

Exposure to neonicotinoids is also in no way avoidable in our daily lives – as they are long-lasting in plants, and residue accumulates in soil and our waterways. Not only are people who directly work with neonicotinoids exposed, but so is almost everyone who eats vegetables and drinks water. ● ● ●

Antibodies

The Immune System's Post-Apocalyptic Preppers

Written by Katiasofia Gonzales

Illustrated by Katiasofia Gonzales

The external world is full of dangers. Apart from the obvious saber-toothed tigers and the constant risk of starvation, the biggest threat humans faced for thousands of years was the ever-changing catalog of pesky pathogens that, in a world before antibiotics, could end a life in just a matter of days. When we think about it, it is incredible that any human can survive in a world filled with such a wide variety of microscopic threats. How could we fight back? If our bodies needed to face each pathogen first to develop a defense system, we would have to survive new infections all the time. Even in today's medically advanced world, that would be extremely difficult. Luckily, our bodies have figured out a way around this problem, despite being constantly exposed to potentially infectious pathogens.

Aside from a hard-working innate immune response that is always on the lookout to tackle any threat as soon as it is detected, the body also has a secret weapon waiting in the adaptive immune response: a pre-made antibody designed to face the new pathogen, prepared by B-cells well before the pathogen ever reaches the body.

How is that possible, you may ask? The body's response to an unknown number of potential pathogens is to create an antibody for any plausible scenario at random, all the time. We can imagine our immune system as post-apocalypse preparedness enthusiast who, as unlikely as it sounds, has a plan prepared for every possible circumstance. Zombie apocalypse, alien invasion, or AI takeover? They have prepared something ready in their bunker. Similarly, for viruses, bacteria, or fungi, the body has a B-cell somewhere with the appropriate antibody primed for the unlikely but never implausible scenario of an invasion.

The immune system is an over-paranoid, creative genius. It has found a way to keep an organism as fragile as us, alive for thousands of years in an environment of constant hostile microscopic threats.

There are thousands of pathogens, each with thousands of possible antigens and targets that an antibody can recognize. There are too many to create antibodies for every case to fit into our DNA. To bypass this limitation, our immune system plays a clever game of recombination with existing DNA fragments. Let us imagine that in a section of the DNA, there are areas that code for the letters A, R, C, and T. The letters in the middle can be selectively cut out to form groups such as ARC, ART, or ACT. Therefore, different combinations are possible from the same region of DNA.

In addition to reattaching the letters together, new nucleotides can be added in the middle to stitch them together, increasing the diversity of possible antibodies that can bind to pathogens.

Of course, with random words created by chance, there is a risk that an antibody will mistake our cells as enemies instead of pathogens, potentially attacking the body. Several checkpoints exist in developing B-cells to ensure that these antibodies do not get released into the body and to prevent this attack. This is a very secure system that, when defective, can result in autoimmune disorders.

The possibility of creating a wide diversity of antibodies continues beyond there. What we just described results in various "antigen binding sites," which are the parts of an antibody that recognize a specific "target" and bind to it. On the other hand, we can also have a wide variety of antibody isotypes. Antibody isotypes differ in the size and nature of their structural chains; they can attach and act slightly differently from one another while sharing the same binding site. This is useful because different pathogens need different strategies to be neutralized and destroyed. As a result, once a pathogen is identified inside the body, an inflammatory response is triggered. This response will first recruit the innate and, eventually, the adaptive immune response and the more complex antibodies. During the inflammatory response, substances known as cytokines will also influence the variety of isotypes of antibodies that are produced, enhancing a more effective response.

In summary, the immune system is an over-paranoid, creative genius. It has found a way to keep an organism as fragile as us, alive for thousands of years in an environment of constant hostile microscopic threats. Despite all its preparedness, there are still numerous ways pathogens can find their way around our immune system's best efforts. That is why, today, we strive to supplement its natural preparedness with vaccines. We will continue to investigate its mechanisms to be able to boost and collaborate modern medicine with the amazing mechanisms that evolution has already left there for the future. ●●●



Importance, Interconnectedness, and Challenges

Co-management Mechanisms for Regional Conservation Areas in Loreto Peru

Written by Sky Milstein
Illustrated by Lily Falke

A

Abstract:

A team of researchers set out to investigate the mechanisms used by local communities to create and manage the Regional Conservation Areas (RCA) of Loreto. Loreto is a region of Peru that contains 47.4 percent of the Peruvian Amazon. There are four RCAs in Loreto: Tamshiyacu Tahuayo Communal Regional Conservation Area (ACR CTT), Ampiyacu Apayacu Regional Conservation Area (ACR AA), Alto Nanay - Pintuyacu - Chambira Regional Conservation Area (ACR ANPC), and Maijuna Kichwa Regional Conservation Area. These four RCAs use a participatory management process involving local communities called co-management. We interviewed four members of the Regional Government involved in RCA management. Using information from the interviews, we did a content analysis and systematized our data, creating a list of the mechanisms used in co-management RCAs. There were four formal and three informal mechanisms and one attribute described by the interviewees. The key mechanism in the co-management process was "Management Committee and Communal Assemblies" which is where the majority of the other mechanisms can take place. The involvement of various voices, including those of women, in co-management, was another key finding of the research. The political ecology narrative of access and control was found to be important to understanding the mechanisms used in co-management, which are incredibly intertwined and rely on each other to function. Increased funding

to Loreto's RCAs would enable them to operate more easily.

Mechanisms:

In this research, a mechanism is a tool used in managing RCAs that enables the function of the RCA. The mechanisms identified are as follows:

Formal mechanisms: Mechanisms mandated as part of the management process, stated in Regional or National regulations.

1. Management Committee and Communal Assemblies:

Mechanism where regular meetings are held between community members and the Regional Government (sometimes with NGOs or additional stakeholders) to discuss the current status of their activity in the protected areas, to plans, and discuss needs.

2. Plans and Regulations: Mechanism where the Regional Government makes plans in collaboration with communities that set out plans for future use of activity in the RCA. This includes master plans, work plans, and management plans.

Master Plan: A type of plan that is for the span of five years that sets the guidelines for all plans and activity in the RCA

Work Plan: A type of plan that is for the span of one year that sets the guidelines for all plans and activity in the RCA

Tourism management Plan: Mechanism that involves the management of visitation by tourists in the area of RCA by local communities.

Natural Resource Management Plan: A type of plan

that is for the span of one year that gives guidelines for the use of a specific natural resource.

Economic Sustainability (State and private funding - NGOs).

State Funding: Mechanism that involves money from the regional government for the management of the RCA.

Private Funding: Funding given by non governmental organizations to groups and activities in the RCA particularly.

Strengthen Community Patrol System and Resource

Management: Mechanism that involves projects and goods that increase and support the ability of the community to patrol and protect the RCA.

Registries, Reports, and Records: Mechanism where the local community fills out documents for the regional government to track resource use and report illegal activity in the RCA.

Surveillance and Patrol via the “Organización Local de Vigilancia” OLV: Mechanism that involves the protection via patrol of the RCA from groups attempting to do illegal activities (i.e. illegal mining).

Provision of Fuel and Meals: Type of Strengthening of Surveillance and patrolling capacity where meals and fuel are provided to community patrollers of the RCA by the regional government and NGOs.

Provision of Training: Type of strengthening of surveillance and patrolling capacity where training is given to community members.

Provision of Other Supplies: Type of strengthening of surveillance and patrolling capacity where supplies other than meals and fuel (i.e. GPS) are provided to the community by the regional government and NGOs.

Informal mechanisms: Mechanisms not mandated as part of the management process.

Dialoguing: Mechanism where discussion is involved between different parties (communities, the government, NGOs, and other stakeholders). This discussion allows for knowledge sharing, the communication of needs, and conflict resolution.

Community Member in a Position of Power:

Mechanism in which members of the community hold positions of power over the protected area. These are positions like executive and president of committees, the RCA itself, and other structures related to the RCA. Some of these positions are held by women.

Partnerships with other stakeholders: Mechanism where the regional government and the communities hold meetings to maintain good working relationships with groups other than communities and the government (i.e. police and NGOs).

Discussion:

This research found that both mechanisms – Formal and Informal – are fundamental for managing the RCAs in Loreto. Administrative spaces need to be complemented with activities or strategies that promote community participation for the process of co-management to succeed. The formal mechanisms ensure that management adheres to the objectives set out for the RCA. When these formal mechanisms are paired with informal

mechanisms, they create co-management where community members feel their voices are truly heard. Co-management of Loreto’s RCAs has been successful because of how both mechanisms complement each other.

Co-management in RCAs in Loreto is a participatory process centered around what could be called the most participatory mechanism “Management Committee and Communal Assemblies”. Community members need spaces where they can communicate with Regional Government, receive training, share knowledge, express concerns, build relationships with other stakeholders, and discuss the functions and needs of the RCA; Committees and assemblies are this space. Due to the importance of this mechanism, I would recommend increasing the frequency of these meetings. This was a desire also expressed by members of the regional government, but they currently lack the funding to do so.

The mechanisms found in this study are interconnected, relying on the function of other mechanisms for their function. There is no mechanism in co-management of RCAs in Loreto that is not vital to the system. Mechanisms that encourage participation are needed for community members to want to be a part of co-management. Mechanisms that are more focused on the role of the government are crucial to the legal and economic needs of the RCA. In this system, community members and members of the Regional Government can often fulfill different roles that directly contribute to the RCA’s success.

The role of women in RCAs in Loreto is critical due to their different perspectives. In co-management of Loreto’s RCAs, they actively try to bring in as many voices from the community as possible. Women’s voices are important because they hold different knowledge and needs than men due to their roles historically in the community and household. Without women’s voices, this knowledge and these needs would not be considered when creating plans for the RCA, which could leave women disadvantaged and worsen the function of the RCA. When women are empowered to participate, more complete and effective management can take place.

The RCA’s in Loreto have faced some challenges in its function. Some struggles have been more involved in formal processes, such as filling out forms and confronting illegal activity, which consistent training has been used to remedy. However, other challenges present more of a threat to the RCAs in Loreto. One of the struggles noted in interviews was the lack of funding that the RCAs receive from the Central Government, making them unable to provide many supplies or create many new projects. It is vital for the RCAs’ to continue to function and adapt to receive larger budgets. These small budgets prevent action from the regional government and limit their ability to support communities in the RCA. Moving forward, I would recommend an increased budget for the management of RCAs so they can reach their full potential. This would allow for more innovation, projects, and supplies in the RCAs. Loreto due to its biodiversity, is a very important region not only for Peru, but for the World.

The analysis done in this study centers a regional government perspective due to time restraints that prevented us from reading all documents, meeting with community members, and visiting RCAs. Future studies could look more into these areas to further understand co-management in Loreto. ●●●



Air Pollution Affects More than just Global Warming

Environmental Factors Relating to Autism

Written by Jessica John
Illustrated by Ella Wozek

According to the American Psychiatric Association, autism spectrum disorder (ASD) is a lifelong "complex developmental condition that involves persistent challenges in social interaction, speech and nonverbal communication, and restricted/repetitive behaviors." It is a spectrum condition, meaning that while people with autism share specific difficulties, their condition is experienced and projected differently. It is further classified as a brain-based disease because it is essentially a neurodevelopmental difference where symptoms are typically expressed in the first two years of life. There are numerous subtypes under the spectrum, such as Asperger syndrome.

For a long time, researchers questioned what caused the brains of autistic individuals to develop so differently. Many assumed the answer would be definite. However, studies over the past 100 years have concluded the opposite. Television, power lines, and parental attention have all been considered causes of autism. However, none have been confirmed as the definitive cause. In the 1950s and 1960s, there was a belief that autism was caused by distant parents, termed "refrigerator mothers." This false

Exposure to heavy metals, pesticides, essential metals like zinc and manganese, and other toxins during pregnancy and early childhood are tied to the development of autism.

information left behind a legacy of shame and guilt in the autism community. Bernard Rimland, fortunately, disproved this claim in his book *Infantile Autism: The Syndrome and Its Implications for a Neural Theory of Behavior* in 1964. He showed that parents who fit the "refrigerator" stereotype had children who did not have autism. The book initiated a debate between two opposing views of autism's causation: psychological versus biological and development.

Years of research have shown that autism has no single cause. Since then, autism research has focused on biological grounds. Scientists study twins to examine the influences of nature versus nurture on a variable human quality. Scientists then look at the frequency of that trait between identical twins and fraternal twins of a defined population and whether both twins or just one have the trait. The trait can be deemed genetic if the percentage of people with the traits is higher for identical twins than fraternal twins. Dr. Sahu and Dr. Prasuna from Lady Hardinge Medical College conducted a study that concluded autism has a genetic link, with a 50 to 80 percent frequency for identical twins and a five to twenty percent frequency for fraternal twins.

Exposure to environmental pollutants has been associated with health effects such as neurodevelopmental disorders. Autism Speaks, the largest autism research organization in the United States as of 2021, states that environmental influences do not appear to cause autism directly. Instead, they seem to influence risk in those genetically predisposed to the disorder.

Researchers at the National Institute of Health found that babies and young children who breathe polluted air may be more likely to develop autism. The Harvard School of Public Health meta-analysis added to this conclusion. The study found that being

exposed to fine particulate air pollution makes the risk of autism much higher, especially during the third trimester of pregnancy or early childhood. The conclusion is that traffic-related air pollution – which contains things like carbon monoxide, nitrogen dioxide, and lead – has been shown to cause health problems in unborn children, such as neurological or cardiovascular diseases.

Studies suggest that air pollution may cause developmental neurotoxicity, adversely affecting the nervous system's anatomy and physiology. Developmental neurotoxicity due to chemical or physical influences may contribute to the etiology of neurodevelopmental disorders like autism.

Exposure to heavy metals, pesticides, essential metals like zinc and manganese, and other toxins during pregnancy and early childhood are tied to the development of autism.

A study of twins used baby teeth to test lead, manganese, and zinc levels in children with autism and their twins without the condition to determine if toxic metals – called "heavy metals" because they can harm health or the environment – are linked to autism. The twins with autism had lower manganese and zinc levels, essential nutrients, and higher lead levels, which can harm human health, especially during pregnancy and early childhood. Scientists found that some autism patients have zinc-copper cycle problems. Zinc-copper cycles regulate metal metabolism, delivering the right metal ion to the body. Biochemical functions depend on metal metabolism. These findings imply that elemental exposure alters zinc-copper cycles, causing ASD. Thus also affecting metal cycle biochemistry.

Persistent organic pollutants (POPs) impact people and the environment worldwide. Since the 1940s, many businesses have used per- and polyfluoroalkyl substances (PFAS). These "forever molecules" are unbreakable by natural chemical, biological, or photolytic processes. The US and other wealthy nations use these chemicals despite a 30-year ban in many countries. People are exposed to these compounds because they persist in the food chain, notably in fatty meals.

With the aid and development of technology, more solutions will be revealed, especially regarding the environment's effect on autism.

Insecticides increase autism risk in toddlers. In the Finnish Pregnant Autism Study, the national register found people with autism born between 1987-2005 and took serum samples from their mothers. The serum indicates Down syndrome in babies. The samples were tested for p,p'-DDE, and total PCBs compared to autism-pregnant women's pregnancies. Autism was more likely in children of moms with high pesticide and p,p'-DDE levels in the top 75 percent. These findings link pesticide exposure to autism in toddlers.

Autism is still a mysterious disorder and researchers are optimistic that more significant findings will be made to understand autism and its development truly. Studies seeking to find correlations between environmental links and autism are actively being conducted with more definite results than ever before. With the aid and development of technology, more solutions will be revealed, especially regarding the environment's effect on autism.



Dionaea muscipula, Venus flytrap

A Case Study in Adapting to Environmental Imperfection

Written by Kat O'Melia

Illustrated by Maya Akazawa

From the early writings of Charles Darwin to starring in the Broadway musical *Little Shop of Horrors*, the Venus flytrap has fascinated many as a mysterious species. The Venus flytrap is a carnivorous plant species endemic to a tiny area in the coastal regions of North and South Carolina. It is well known for its captivating prey-catching mechanism consisting of two modified leaves, “lobes” with “trigger hairs” attached. When stimulated by the presence of a fly or other insect prey, it snaps shut, trapping the prey. The Venus flytrap species takes advantage of this unique adaptation, which allows it to reside in environments with relatively nutrient-poor soils. Additionally, Venus flytraps are opportunistic hunters giving them even more flexibility within their environment. So how can such a well-adapted plant live in such a limited range?

The area of North and South Carolina where Venus flytrap resides is within a 75-mile radius of Wilmington, North Carolina. This is an area known for its sandy nutrient-poor soils. The forested area is predominantly a mix of pine trees and shrubs adapted to live in these conditions. The Venus flytrap appears somewhat of an anomaly in the region, but its carnivorous diet offers it an advantage. Palfalvi et al. (2020) compared the genome of the Venus flytrap to that of two other carnivorous plants: the waterwheel plant and the sundew. By comparing these carnivorous species, they

identified an early whole-genome duplication in the family, which may offer insight into their split from noncarnivorous ancestors. The researchers also found that as the species evolved, genes specific to the root took on new functionality for the trap. This genetic shift has likely allowed the Venus flytrap to adapt to the less-than-ideal conditions of their habitat.

The Venus flytrap's limited range predominantly comprises pine savannas in nutrient-poor sandy soils. This area acts as a transitional site between the bogs of the pocosins and the dry pine forests. One of these areas with a notably high number of Venus flytraps is the Lewis Ocean Bay Heritage Preserve in South Carolina. A study of this location found some of the key characteristics of this environment, including sphagnum cover, low total vascular plant cover, and soil disturbance.

One of the most exciting characteristics of the Venus flytrap is its ability to survive in highly nutrient-poor soil. The soil within the range of the Venus flytrap is composed of fine to medium-grained sand and some occurrence of muddy sand with high water content. This high water content can lead to depressions in the sediment, referred to as “Carolina Bays,” and ideal growth areas for the Venus flytrap. Underlying the sand and mud is sand combined with humate, creating an impermeable layer that allows water to be held above the water table.

The Venus flytrap is very small, growing to only eight to twelve inches in height. As a result, larger plants in the area could easily overshadow their access to light and other resources. However, the Venus flytrap is well-adapted to take advantage of the natural fires along the region's coastal plains that serve as a brush-clearing mechanism within their environment. Fires of intermediate intervals positively affect Venus flytrap populations because they provide competitor removal and the addition of ash to the soil, increasing the soil pH. Multiple studies have explored the effect of fire disturbance on the health and resilience of Venus flytrap populations and their ecosystems. Hamon et al. (2018) found the number of traps per individual was inversely proportional to the time since the last burn. Flower richness and evenness were highest in sites of intermediate time after burn, but there were no differences in the composition of the insect population pollinating the flowers. The differences observed in the blooming area and the trap number indicate a connection between the flytrap's distribution and growth, which benefits from fire disturbance. Although the Venus flytrap may seem poorly adapted to compete with the larger trees and shrubs within their environment, their resilience and short recovery time after naturally occurring fires allows them to thrive within their communities.

Venus flytraps' carnivorous diet is far wider than flies alone and consists of various invertebrates. However, there is evidence that Venus flytraps may exhibit complex prey selection. Lehtinen et al. (2018) found that Venus flytraps select heavily toward large prey and let smaller prey, such as ants, go free. This prey selection preserves the energy the flytrap uses to hunt. It was long thought that Venus flytraps did not consume prey until they reached maturity. However, more recent research on Venus flytrap seedlings found that seedlings exhibit prey size specificity and predominantly prey on invertebrates too small to trigger a full-grown Venus flytrap's trigger hairs. This has population implications, allowing juvenile flytraps to avoid competition with fully grown flytraps in the same area.

Like other plants, the Venus flytrap depends on pollination for reproduction. However, the necessity of insect pollinators presents a potentially complex situation for this species. One of the great wonders of the Venus flytrap's hunting habits is that it does not frequently consume its pollinators. The structure of the flytrap is an important factor in successful pollination. To ensure successful pollination, Venus flytraps flower far above their traps to avoid accidentally preying upon their pollinators. A study by Younsteadt et al. (2012) found few taxonomic groups were shared between the traps and the flowers. The researchers hypothesized that this might result from the spatial separation between the traps and the flowers, contributing to partitioning the arthropods into pollinating and nutritional categories.

Like all species, the Venus flytrap will likely be affected by the rapidly changing climate conditions expected to occur in the next century. These shifts in climate, primarily due to anthropogenic effects, are predicted to increase the average global temperature by 1.5°C above pre-industrial levels between 2030 and 2052, which will have a catastrophic impact for many species. The Venus flytrap thrives in nutrient-poor soil and benefits from naturally occurring fires that will likely increase with climate change. This could give the Venus flytrap a slight competitive advantage at the beginning of a gradual climate change, but the conditions may change too rapidly and become too extreme to benefit the species. The Venus

flytrap relies heavily on its unique ecosystem and community, which climate change could negatively affect. Such a dramatic shift in climate has the potential to shift aspects of the overall forest composition fundamentally. The loss of plant or animal species within the community may shift competitive relationships and those niches and alter the Venus flytrap's relationships and niche. Due to its carnivorous lifestyle, it will be directly affected by decreases in insect populations which it requires to maintain its health in nutrient-poor soil. Of even greater concern is the potential loss of the pollinators vital for its reproduction.

The Venus flytrap has fascinated many, including those outside the botany and biology fields. Unfortunately, this public fascination led to very high levels of illegal poaching, historically putting their populations at risk. Many strides have been made in decreasing Venus flytrap poaching, including legal measures with

The Venus flytrap is a remarkable species adapted to nutrient-poor soil and uses carnivory to supplement its nutrient needs.

hefty fines and ex-situ propagation efforts by the North Carolina Botanical Gardens. However, despite these efforts, Venus flytrap populations continue to grapple with these challenges and face new ones.

One of the challenges that Venus flytraps face is the ingestion of pesticides used on nearby agricultural land that is carried by the insects on which the Venus flytraps feed. These pesticides not only have harmful effects on the insect populations but also directly on the Venus flytraps. Jennings et al. (2011) conducted a study that aimed to quantify the effects of pesticides on Venus flytraps using three widely used insecticides and found that all three reduced survival rates and the expression of carnivorous traits.

Cross et al. (2020) identified carnivorous plants as especially susceptible to anthropogenic degradation of ecosystems in a systematic examination of the conservation status of all carnivorous plant species. Species that occupy highly specific niches and are endemic to narrow habitats with particular soil types tend to have a higher level of vulnerability when it comes to climate change. This results from their additional challenges in migrating to appropriate habitats. Recent work from NASA utilizes a habitat suitability model that, along with Hutchins and Luken's research, could inform conservation efforts and land management practices.

The Venus flytrap is a remarkable species adapted to nutrient-poor soil and uses carnivory to supplement its nutrient needs. Research into Venus flytraps has focused on distribution, reproduction, diet, environment, response to fire, and the potential effects of climate change and conservation. The conservation of this unique species requires more research to explore why the Venus flytrap does not expand its range into areas with somewhat more nutrient-dense soil and less harsh conditions, which could increase its chances of surviving in this time of climate change. Additionally, research into Venus flytrap reproduction, seed dispersal mechanisms, and the development of new seedlings are crucial to improving our understanding of the Venus flytrap's resilience in its multifaceted ecological role. ● ● ●

Water Woes

How Our Careless Relationship with Water is Draining the Supply

Written by Sydney Rosensaft

Illustrated by Susan Robinson-Cloete

As humans, water serves us more than we give it credit for. Water does not just provide us with cool glasses of water or warm showers; it is behind each and every food we eat – even the dry ones. Without the water that cycles through our atmosphere, you would not be able to walk through the grocery aisles and see fresh fruits and vegetables, dried grains, or even frozen meals.

Earth's water cycle is a common topic in almost any science class.

We learn how water melts from snowy mountaintops and glaciers, running down into rivers, streams, lakes, and into the oceans. On its way, some water is pulled underground to join other groundwater in cracks in soil and rocks. The roots of plants pull up some of the water and evaporate from the surface of the leaves of

the plants. Evaporation from land and ocean surfaces also turns water into water vapor in the atmosphere. In the atmosphere, water vapor condenses into clouds. It precipitates back down onto the Earth's surface as snow or rain, falling onto soils, plants, and bodies of water, where it cycles through again. That seems like a pretty simple cycle, right?

However, humans' dominance over the planet has changed our once memorized water cycle. Deforestation releases water vapor stored in trees, creating a short-term localized humidity and increase in precipitation. In the long run, however, fewer trees mean less water that can evaporate, leading to less rain and drying out lands previously packed with forestry. Human agricultural practices often use pesticides that introduce toxic chemicals into

rivers, lakes, and oceans as water runoff passes through agricultural land. Polluted waters lead to algal blooms, marine animal diseases, and ocean acidification. Excess carbon dioxide and greenhouse gasses emitted by humans lead to Earth's warming temperature, melting both land and sea ice and causing sea levels to rise. We are continuously altering the overarching water cycle through our actions.

It is important to examine what humans are putting into the water cycle, pesticides, plastic, etc., and what we are taking out of this crucial atmospheric cycle. Irrigation is the removal of water from its natural source to artificially water lands and supplement natural precipitation. Irrigation is used for industrial, agricultural, and domestic purposes, making up 70 percent of global water withdrawals – the largest water sector use. There are a variety of irrigation methods. Each type of irrigation has different benefits and consequences, but they all impact the water cycle in different ways.

Irrigation is not inherently harmful – it was invented as an agricultural practice for a reason. A reliable water source is necessary to grow fruits, vegetables, grains, and any other food. Irrigation can protect these crops from freezing or wilting and allow agricultural practices to spread to drier areas, like Californian deserts. This is crucial for producing a certain amount of food needed to sustain

It is important to examine what humans are putting into the water cycle, pesticides, plastic, etc., and what we are taking out of this crucial atmospheric cycle.

the increasing global population. Since we need more food, we need more water to grow that food, and more land to be available to farmers. Irrigation allows for this level of food production to be possible. Without irrigation systems, the next time you go to the grocery store, you probably would not see such a colorful variety of produce or even basic breads.

The positive effects of irrigation on agricultural systems have also allowed the US economy to flourish. In 2017, agriculture in the US contributed more than one trillion dollars to the gross domestic product (GDP), 5.4 percent of the total GDP. Agriculture and food sectors are responsible for 11 percent of total US employment, of more than 22 million full and part-time jobs. Despite the economic benefits of irrigation, these practices can turn sour if overused.

The problem lies within the careless use of water to irrigate land. We sometimes treat water like a cheap, unlimited commodity that will always exist to hydrate us and endlessly absorb our toxins. Excessive irrigation increases runoff water and releases more pesticide-contaminated water into streams, polluting waterways even more. Too much irrigation can also cause land erosion and push sediment into bodies of water. This clouds the water, affecting how much sunlight can reach aquatic plants and clogging the gills of fish. Additionally, some irrigation systems pump groundwater stored under the surface. The shrinkage of these underground water reserves is hidden, but still a loss of water threatens food security and agricultural economies. For example, food-producing

regions of China, India, Pakistan, the Middle East, Mexico, and the United States are experiencing depletion of their underground water reserves.

Furthermore, only half of the water used for irrigation returns to the water cycle for reuse. Throughout irrigation practices, some water is lost by evaporation into the air, some is lost by evapotranspiration from the plants it watered, and some is even lost in transit, for example, from leaky pipes. Areas with heavy irrigation system use are seeing decreased water flow down streams, threatening local ecosystems. For instance, in southwestern Georgia's lower Flint River Basin, mussel populations rely on clean, flowing water to survive and reproduce. As groundwater is pumped to irrigate cotton and peanuts, river flows are depleted and not appropriately replenished, putting mussel populations at risk. This jeopardizes the river's ecosystem and has potential ripple effects on other marine ecosystems and even human lives.

The water cycle will not continue to support our agricultural practices with clean, safe water if we continue to use its supply in excessive amounts. However, we need to continue farming to feed our planet, and we need irrigation at a sufficient scale, especially as the population grows rapidly. Luckily, there are solutions to increase the sustainability of our current irrigation practices. Farmers can improve the efficiency of their water use. By measuring actual crop needs of water and applying only what is necessary, farmers can prevent excessive irrigation that leads to increased runoff and erosion. For example, researchers are trying to program an irrigation sprinkler with a GPS. This would tell the irrigation sprinkler to stop spraying whenever it passes over a section of rocks, wetland, or an area without crops planted. This cuts down on water used to irrigate areas that do not need it and can potentially reduce water use by 15 percent. Another option is to program schedules into irrigation systems to apply water at intervals only when crops need hydration. Being conscious of what kind of irrigation system is used can increase water use efficiency. For example, a drip irrigation

The problem lies within the careless use of water to irrigate land. We sometimes treat water like a cheap, unlimited commodity that will always exist to hydrate us and endlessly absorb our toxins.

system allows for control over how many pesticides leak into the irrigation water. Additionally, drip systems decrease the amount of water lost to ditches or evaporation compared to furrow irrigation systems.

Awareness of how much water we are taking out of the water cycle and the quality of water that is put back in is crucial in fixing humans' current harmful trajectory. So next time you are at the grocery store, I hope you can find some appreciation for the water that went into each item in your cart, and remember there is a water cycle out there that is hurting. ●●●

Spring 2023 Honors Research

OBERLIN COLLEGE

Sunniva Sheffield

Majors: Chemistry, Biochemistry and Environmental Studies

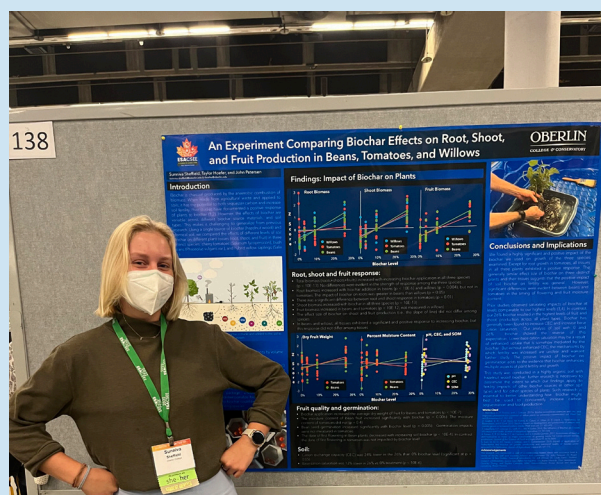
Minor: Spanish Language Studies

Hometown: Rochester, NY

Honors Dept: Environmental Studies

Biochar has positive but distinct impacts on root, shoot, and fruit production in beans, tomatoes, and willows

Biochar is a type of charcoal produced through burning plant material in a no oxygen environment and has been shown to increase soil fertility when added to soils. Our study investigated the effects of biochar (waste wood from a local hazelnut orchard), in an organic soil on different plant tissues (roots, shoots, and fruits) of three distinct species: cherry tomatoes, green beans, and willow saplings. We found a highly significant positive relationship between the amount of biochar added to the soil and total plant biomass in all species, with no significant difference in total biomass response among species.



OBERLIN COLLEGE

Niels Vanderloo

Majors: Physics and Mathematics

Hometown: New York, NY

Honors Dept: Physics

Simulating Plasma Physics to use Nuclear Fusion for Renewable Energy

Producing nuclear fusion on Earth is a promising source of renewable energy without the waste products of nuclear fission or land required for wind or solar power. I study one candidate for a nuclear fusion reactor, the gas-puff Z-pinch, an experiment that uses magnetic fields to compress a jet of gas to high temperatures. I use the FLASH plasma physics simulation code to simulate a gas-puff Z-pinch and have found good agreement with experimental data.



Sophie Qano

Majors: Psychology and Environmental Studies

Hometown: Houston, TX

Honors Dept: Psychology

Are Smartphones Outsmarting Us? Examining the effects that smartphone presence has on connectedness to nature

Social psychology research has documented the effects of smartphones and technology on social interactions and relationships. Research in this field has yet to be done on the effect that smartphones have on other forms of connectedness. My primary research goal is to find out if the presence of a smartphone affects connectedness to nature, in turn disrupting the benefits typically gained from spending time in nature.



HONORS RESEARCH

Larissa Michel

Majors: Biology and Violin Performance

Hometown: Bloomfield, Michigan

Honors Dept: Biology

*Vocal copying responses of bottlenose dolphins (*Tursiops truncatus*) to playbacks of *T. truncatus* whistles*

My research explores whether, and in what contexts, bottlenose dolphins copy other dolphins' whistles. I examine recordings of playback experiments, where previously recorded dolphin whistles (the stimuli) were played to another dolphin, whose vocalization responses were recorded with a hydrophone. I am specifically interested in copy responses to the stimuli, where the dolphin mimicked the pre-recorded whistle. I then analyze the data to determine if there are associations between whistle copying and contextual variables.



HONORS RESEARCH

Cassie Davies

Majors: Biochemistry and Vocal Performance

Minor: Latin

Hometown: Newport News, VA

Honors Dept: Biochemistry

Competitive Activity-Based Protein Profiling of RHBDL2 and RHBDL4 for Inhibitor Discovery

Rhomboid Intramembrane Proteases (RIPs) are a subclass of serine hydrolases that are associated with diseases such as cancer and Alzheimer's disease. However, their physiological functions are not fully characterized. To study these enzymes, we use Activity-Based Protein Profiling (ABPP) technology which utilizes a small molecule probe to monitor their activity. We are employing our ABPP assays for inhibitor discovery of two of these RIPs, RHBDL-4 and RHBDL-2. Selective and potent inhibitors for these two enzymes would be valuable tools for interrogating their biology and assessing their potential to serve as therapeutic targets.



In January 2023, Tennessee State Governor Bill Lee rejected \$8 million in federal budget earmarked for HIV prevention. The federal funding for HIV testing and prevention comes with some stipulations that it is used for sexual health programming making grants for HIV prevention programming available to organizations like Planned Parenthood. Rejecting these funds allows the State of Tennessee to remove major funding from Planned Parenthood following the Tennessee July 2022 'point-of-conception' abortion ban. Planned Parenthood is one of the state's largest distributors of free condoms. Still, the rejection of funding is already impacting community-based organizations like Partnership to End AIDS Status (PEAS), whose funding comes largely from the government agencies like the Center for Disease Control (CDC). The recent decision will mean less access to care for people living with HIV and AIDS (PLWHA) and risks creating conditions for increases in HIV transmissions. This form of state-based marginalization reflects HIV/AIDS as a social category and the structural challenges that PLWHA are up against.

Several opponents have come out against the decision claiming that it will defund essential HIV prevention, detection, and treatment services. Ashley Coffield, president and CEO of Planned Parenthood of Tennessee and North Mississippi, remarked, "This is yet another public health crisis manufactured by Gov. Lee." While Tennessee Department of Health has shared, "It is in the best interest of Tennesseans for the State to assume direct financial and managerial response for these services." Shelby County, where Memphis, TN, is located, has one of the country's highest incidences of HIV (819 per 100,000) and 20,000 people living with HIV across the state.

According to secondary research from the Kaiser Family Foundation, in the 2016 fiscal year, Tennessee's federal HIV/AIDS grant funding per adult/adolescent living with HIV/AIDS was the eleventh highest at \$4,181. After turning down \$8 million in federal dollars, a serious negative impact can be anticipated for

In 2023, U.S. Federal Domestic Discretionary Funding for HIV/AIDS totaled more than \$7 trillion.

infrastructure servicing PLWHA in Tennessee. In 2023, U.S. Federal Domestic Discretionary Funding for HIV/AIDS totaled more than \$7 trillion. In contrast, in the 2012 fiscal year, Tennessee State Department of Health received nearly \$7 million from the CDC Division of HIV/AIDS Prevention. One of the initiatives many state health departments signed on to participate in was the Ending the HIV Epidemic in the U.S. (EHE) plan announced in 2019, aimed at ending HIV transmission by 2030. This recent budgeting decision puts this plan at serious risk.

The deregulation of HIV/AIDS programming in the state poses two major, interconnected challenges to an already precarious situation. Its deprioritization reflects the ways HIV/AIDS functions as more than a viral infection but as a social category as well. First, funding cuts will negatively impact drug distribution and, secondly, create conditions for increases in viral transmission of HIV. These undermine the EHE initiative. This happens when black markets make additional Tennessee drug distribution market corruption. Defunding the access, safety, and quality of drugs undermines viral suppression.

The Emergence of Black Markets in Response to Deregulation

PLWHA needs life-saving medication to continue living. Even within the existing medical complex, many PLWHA turn to black markets to access necessary drugs when access becomes insecure from lack of insurance, poor coverage, or counterfeit drugs. Most often, clinics run rackets wherein patients are recruited to solicit prescriptions from multiple pharmacies and return pills to a single pharmacy to be repackaged and resold. In 2018, a major prosecution of a black market HIV drug racket in Nashville, TN, was busted. Jerrod Nichols Smith forfeited \$1.4 million of a \$50 million scheme and received a 15-year sentence. What is dangerous about this situation is that many medications sold to independent pharmacies contain tainted drugs that often lack active pharmaceutical ingredients (API) or sometimes have different active ingredients altogether. HIV-positive patients, especially those using public assistance, are vulnerable to exploitation when coupons from drug manufacturers or public assistance place income limits on already under or unemployed communities that need such life-saving medications. Although rare, there are cases of individuals selling their HIV medications to pharmacies and buying medicines from other individuals — brokering pills — on their own basis because of the high market value for untainted HIV medication. When infrastructure fails to provide comprehensive access to medication, unregulated drugs move into the market and undermine HIV prevention and treatment.

The decision to ax millions of federal funding weakens infrastructure to provide safe drugs to people who need them. Compromising the safety and quality of HIV medication also impedes goals to reduce and end the viral transmission of HIV. Suppose those vulnerable to HIV can be engaged in care to receive pre-exposure prophylaxis (PreP), and PLWHA have full access to medication. In that case, viral suppression can occur on a structural level, thus reducing the transmission of HIV. The decision to reject federal funds for HIV prevention, detection, and treatment came recently after appointed health commissioner Ralph Alvarado, well-known for his opposition to abortion, assumed the post. State officials say the funding demands can be met, and Governor Lee noted, "We think we can do that better than the strings attached with the federal dollars that came our way and that's why we made that decision."

It is unclear what will precipitate from these events. Still, there is a clear threat of the growth of already existing black markets in Tennessee distributing drugs and exploiting vulnerabilities in the pharmaceutical market. As the Tennessee Department of Health cuts ties with Planned Parenthood, other organizations offering HIV services alongside family planning services can expect funding to evaporate. Reducing the cascade of options patients can turn to for services like community-based organizations will put stress on emergency rooms. Similarly, with less support and without a massive rollout of infrastructure to meet needs, what can be expected is a decrease in access to care. In every case, this impacts marginalized PLWHA severely. ● ● ●



Importance of Access

Deregulation of HIV Prevention Services in Tennessee

Written by Rene Garrett
Illustrated by Ingrid Cassel

Written by Long Ly

Illustrated by Mattie Decardy Torris

French military surgeon Ambroise Paré (1510-1590) was operating on wounded soldiers when he noticed a strange recurrence — patients complaining of sensation or pain in their amputated limb(s). What was abnormal, however, was that these soldiers did not feel pain or other sensations at the stump but rather in the missing region formerly the limb. Following the first account of this strange phenomenon, many other prominent physicians and biologists, such as German physician Aaron Lemos, Scottish anatomist Sir Charles Bell, and American physician Silas Weir Mitchell, reported the same sensations. The absurdity of this account kept it from being adequately investigated until Weir Mitchell.

Sir Silas Weir Mitchell served as a physician during and following the Civil War, frequently treating wounded soldiers. During the pre-antibiotic times, gangrene commonly followed the injury, necessitating soldiers' limbs to be sawed off by surgeons. Mitchell saw amputees frequently complaining about phantom sensations in their missing limbs. He found the phenomenon intriguing and wrote an article about the phenomenon in a popular magazine called Lippincott's Journal under a pseudonym. The sensation was supposedly so strange that he did not publish it in a medical journal due to the lack of scientific grounds and the risk of ridicule from his colleagues. Mitchell aptly coined the phenomenon "phantom limb" in the article.

Since Weir Mitchell's article, there have been several proposed theories on the cause of phantom limb pain (PLP) after the condition was acknowledged as real and advanced neuroscientific knowledge. A paper in The Canadian Journal of Psychiatry, published in the late 1970s, stated that the phantom limb was merely due to wishful thinking. The authors thought that patients with this sensation desperately need the arm back, therefore experiencing the phantom. They hypothesized that this phenomenon behaved similarly to how people can imagine the ghost of a close one or have recurring dreams. Another more grounded, explanation was that the feeling was due to irritation of the frayed and curled-up nerve endings at the stump delivering

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information to higher brain centers, which was processed as somatosensory information in the missing limb rather than the stump. However, cortical reorganization is the most recent, well-supported, and realistic theory. This still does not fully explain what causes PLP. To understand this, we need to know more about how we feel.

Imagine you stepped on a thumbtack. You experience a sharp, painful sensation, followed by your quickly retreating your foot from it. How do we 'sense' the pain? Why do we sense

Phantoms in The Brain

The Deception of Our Senses

pain? How do we move away from the thumbtack instinctively? As simple and intuitive as our reactions and movements seem, the sensation is profoundly intriguing and physiologically complex. The thumbtack activates the sensory neurons it reaches, which send a signal from the place of contact along the spinal cord to the somatosensory cortex encoded as an electrical signal, known as an action potential. The somatosensory cortex is a specific region of the central nervous system that specializes in receiving and interpreting incoming sensory information, then sending this information to other parts of the brain, thereby inducing a response — i.e., you pulling away from the thumbtack. And thus, while unintuitive, we do not 'feel' with our hands. Nor with our legs, mouth, or nose. We feel with our brain, our central nervous system. Even if we have all our limbs intact along with the nerves, none of that matters if we cannot send that signal to the brain, which is why spinal cord trauma often leaves people paralyzed and unable to feel or move.

Knowing our sensory perception, what is the phantom limb phenomenon, and how does it work? The brain is an incredible organ, capable of processing vast amounts of information, but beyond that, it can also reorganize itself. The somatosensory cortex is subdivided into many regions responsible for processing different body parts — the digits of the hand, the face, the legs, and more. This map can change itself, giving more cortical volume to certain body parts than others.

As an example, imagine the first time you tried playing the piano. You fumble around with the keys, play all the wrong notes, slam the keys too hard, feel like a mess, and cannot seem to get it right. However, you notice that with time, you continuously get better. You play more fluidly, your performances sound like performances, and your fingers move more proficiently. Although much of this has to do with auditory training, muscle memory, and coordination, a small part of it is also because you feel more with your digits and can move them better.

A study comparing the cortical activity of professional musicians and amateurs showed that when the musicians' digits are touched or moved, a much higher level of cortical activation was recorded through functional MRI, indicating that the remapping of the somatosensory cortex is possible. So, what if your arm was amputated, and there is no longer information reaching the part of the somatosensory cortex that receives that arm's sensory information? Researchers have found that adjacent areas of the somatosensory cortex responsible for other body parts take over the unused cortical area. A study on amputees showed that even when a limb is amputated, the brain area corresponding to the former limb can be stimulated if you stroke certain regions of the face — amputees feel a tingling sensation not only in the face but also at the former limb. Thus, it is hypothesized that cortical reorganization and subsequent activation of brain regions responsible for receiving information from the former limb are primarily responsible for phantom limb sensations and phantom limb pain. However, PLP is likely a cause of several contributing factors.

For example, severed nerves that are used to receive information from the amputated limb may form neuromas, inflamed ends of axons, in which phantom pain may occur. Moreover, following nerve injury due to amputation, there is evidence that neurons in the posterior horn of the spinal cord become oversensitized. The process is characterized by long-term potentiation — the strengthening of synapses that lead to increased long-term synaptic transmission. All such observations are correlational, and there has unfortunately been no definitive pathophysiology of PLP.

Although researchers have yet to find a definitive cause of PLP, there is a simple yet intriguing treatment for PLP called mirror therapy, developed by doctor Vilayanur Subramanian

A study on amputees showed that even when a limb is amputated, the brain area corresponding to the former limb can be stimulated if you stroke certain regions of the face

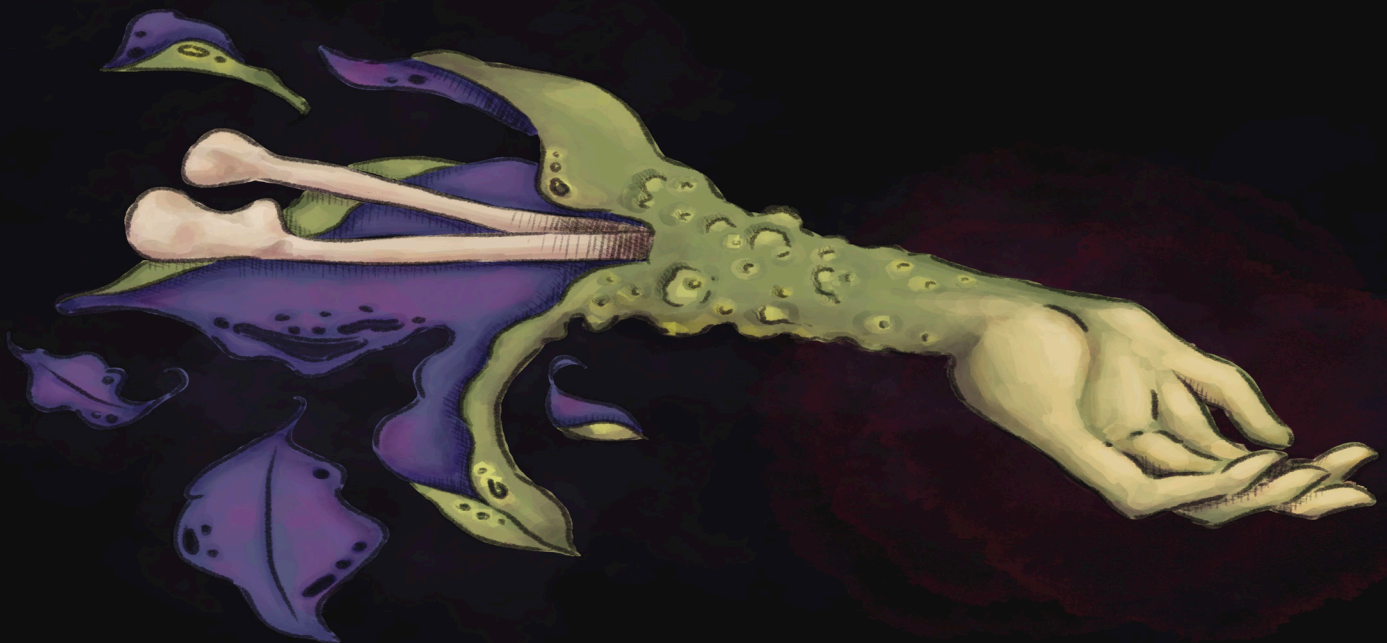
Ramachandran. Dr. Ramachandran is a prominent Indian-American scientist who pioneered our understanding of the brain's sensation and perception, particularly concerning PLP — its potential causes, implications, and treatments. Dr. Ramachandran observed that PLP patients commonly described their pain as being due to the missing limb 'clenching its own fist' without the patient being able to release the phantom fist, which is called learned paralysis.

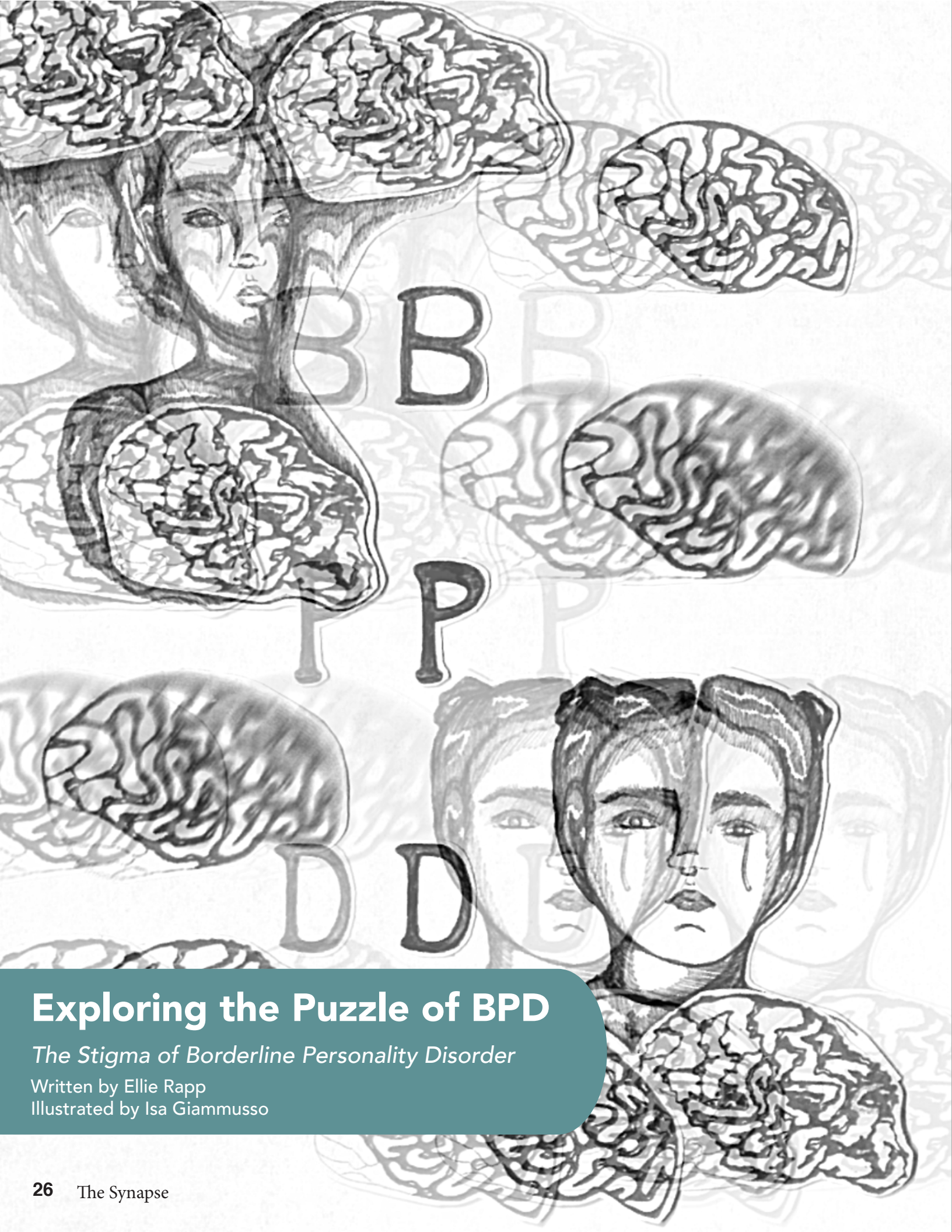
Ramachandran hypothesized that when the brain sends a signal to attempt to move the amputated limb, the visual system gives feedback that there is, for obvious reasons, no movement. This process is repeated many times until the brain learns that the amputated limb will not move. Ramachandran thought that if the patient could 'learn' paralysis, it may be possible to 'unlearn' it. He

initially thought about virtual reality — having the patient see a virtual arm moving, which can create a visual illusion where the arm was restored. However, as virtual reality was costly, Dr. Ramachandran thought of a much less expensive way to create the same illusion — a mirror. The procedure starts with the patient placing a mirror opposite to the existing limb, then making the intact limb move. If the patient looks at the mirror, it can give the illusion of movement even in the missing limb. This process sends visual feedback to the patient that they do have control of the missing limb.

One hypothesized explanation for this phenomenon is the work of the mirror neuron system. Mirror neurons are a type of brain cell that respond equally when we perform an action and witness someone else perform the same action. Mirror neurons fire the same way when patients used to have their amputated limb versus when the patient is observing the mirror limb moving. When using the mirror box, these mirror neurons are activated, which helps in the recovery of affected parts. Although there have been studies supporting the effectiveness of mirror therapy, there is currently little long-term research on the effects of mirror therapy for PLP and. Thus, much work needs to be done on PLP and its potential treatments.

Sensory perception is a crucial puzzle of the brain that remains to be solved, both to advance our understanding of the brain and to treat its conditions. Phenomena like PLP prove to be a valuable tool for us to study how the brain 'senses' and processes that information. ● ● ●





Exploring the Puzzle of BPD

The Stigma of Borderline Personality Disorder

Written by Ellie Rapp

Illustrated by Isa Giammusso

A patient walks into a doctor's office and hands them a 1,000-piece puzzle. "I am not sure that any patient of mine has given me a puzzle," says the doctor. The patient explains that, despite already seeing hundreds of doctors, no one has been able to solve this puzzle. Some doctors gave up: "It is much too difficult, give it to someone else so they might figure it out." Others exclaimed, "This is not worth my time since there is no way I can solve this." The doctor asks the patient what others have tried "Hammers, screwdrivers, chainsaws..." The doctor was baffled. Amused at the thought of anyone solving a puzzle with a chainsaw. They took the puzzle from the patient and, with time and patience, put it together.

The story of the patient and the puzzle appears bizarre, but it is all too common for individuals with Borderline Personality Disorder (BPD). Sometimes, their puzzles are never fully solved.

A 2016 survey reported that 2.7 percent of the United States population is diagnosed with BPD, making it the country's second most common personality disorder – only behind antisocial personality disorder. Worldwide studies also found that BPD is the fourth most common of the ten personality disorders. Compared to non-BPD counterparts, there is a significant increase in comorbidity for BPD individuals to develop mood disorders, post-traumatic stress disorder, and other psychiatric issues. They are also at higher risk for committing self-harm and substance abuse.

The story of the patient and the puzzle appears bizarre, but it is all too common for individuals with Borderline Personality Disorder (BPD).

The American Psychological Association (APA) defines BPD as a Cluster B personality disorder — characterized by unpredictable behaviors and emotionality. Patients must have at least five of nine criteria set by the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM-5) to be formally diagnosed with BPD. Still, people can possess borderline traits without the actual disorder. Traits of BPD are seen in individuals who meet the symptom criteria for some – but not enough – of the BPD diagnosis. Such criteria include severe dissociative symptoms (i.e., disruptions of consciousness), recurrent suicidal or self-mutilating behavior, and a pattern of unstable and intense personal relationships.

Despite unwavering diagnostic criteria, over 250 possible symptomatic combinations could result in a BPD diagnosis. Clinicians may struggle to reach a consensus even if one symptom does not fit the exact criterion. This issue not only creates frustration for clinicians but also for patients awaiting their results. Key factors are available to help in the diagnosis decision and subsequent treatment. For example, individuals with BPD comorbid with major depressive disorder (MDD) tend to respond poorly to antidepressants, while patients with MDD alone respond better. However, more analysis is necessary as these are not concrete methods for ruling out or confirming the presence of BPD.

Unfortunately, constraints on patient-clinician interactions (i.e., fixed appointment lengths) limit the amount of time patients can get an opinion from their doctors. Much time, sometimes up to multiple years, is needed to confirm a BPD diagnosis since misdiagnosis is not only harmful to the patient but could lead to further misdiagnoses of others. This combination creates a seemingly-impossible situation for those seeking a BPD diagnosis and is only worsened by the fact that BPD is an incredibly stigmatized disorder. If these patients experience severe thoughts of suicidality or self-harming behaviors, the sheer time between consultation and diagnosis could be fatal. Approximately 75 percent of patients with BPD have reported waiting four hours or more in an emergency department following acts of self-harm or non-fatal suicide attempts – and were discharged more quickly than patients with other diagnoses.

Mental health issues have been the target of stigma for decades, but BPD is one of the most severe by the general public and healthcare professionals. People with BPD often feel shame because their disorder is commonly misunderstood, even by their closest friends and family. Coping can become unbearably difficult, further damaging their relationships with others, self-image, and symptoms. Patients avoid seeking help from doctors or psychological professionals because they do not feel cared for or listened to. A 2015 study reported that, compared to 29 percent of individuals with other diagnoses, 57 percent of patients with BPD felt rejected or shunned by the healthcare professionals they sought help from. Clinicians themselves have claimed to feel frustration, anger, and inadequacy when treating patients with BPD, as reported by a study using a method of open-mindedness in healthcare. Because of this, it is understandable why some people with BPD steer clear from healthcare.

The stigma towards any mental health disorder stems from outdated prejudices regarding psychiatric issues. It is often forgotten that mental disorders considered common once had very stigmatized origins, such as depression. The poor treatment by their doctors and the negativity from other people have only led to self-stigmatizing in individuals with BPD. This prejudice has since improved but has not gone away completely, despite what some may believe.

The vicious cycle people diagnosed with BPD go through can affect their ability to find secure housing, employment, and some form of proper education. Internalized feelings from stigmatization may never leave the individuals with BPD and act as a trigger for suicidal behaviors. This causes many who suffer from BPD to find themselves in a complicated situation.

Changes must be made for BPD to no longer carry the baggage of decades-long stigma from the healthcare industry and beyond. Patients should no longer be seen as an unsolvable puzzle and passed around amongst doctors like a game. There are lives at stake — beautiful, misunderstood lives. The world must let the BPD community know they are valued, seen, and, most importantly, worth being here. It will go a long way to providing relief, allowing people in the BPD community to breathe a sigh of relief. • • •

Why is Consciousness Such a Hard Problem for Science?

The Quest to Understand Experience

Written by Sophie Nelson

Illustrated by Phung Rojas

Think about seeing the color blue, having a vivid dream, or suffering the pain of a headache. Philosophers often consider experiences like these to be phenomenally conscious—that is, there’s something it is like for us to have them. Now contrast these states with the information stored in our long-term memories or our knowledge of how to talk. These are important features of our minds, but they are not considered phenomenally conscious since, unlike pains and colors, we do not feel or experience them. We are intimately familiar with phenomenal consciousness (which, from now on, I will call consciousness). And yet, explaining its very existence remains one of the world’s greatest scientific and philosophical challenges.

On the one hand, we have discovered over the past few centuries that there is a profound connection between brain states and conscious states. Your consciousness can be affected dramatically when something happens to your brain, such as taking drugs or having a stroke. Additionally, neuroscientists have found countless correlations between brain activity and cognitive processes. This incredible scientific progress has led many to adopt physicalist views about consciousness. Though there are many subtly different types of physicalism, all physicalists believe that the only things that exist in the world are physical things, and thus, that consciousness must ultimately be physical.

Your consciousness can be affected dramatically when something happens to your brain, such as taking drugs or having a stroke.

However, others think that the extraordinary advances of neuroscience still have not closed a deep chasm between physical phenomena and consciousness. Why is that? To start, consciousness seems to have different characteristics from things like cells, brains, and bodies. One of the most remarkable things about conscious states is their accessibility. Whereas it seems like any being with the right cognitive abilities could theoretically understand facts about the physical world, philosopher Thomas Nagel has proposed that phenomenal facts are only similarly available to some. In a famous example, he argues that it is impossible for me ever to know what it is like to be a bat. According to Nagel, while I could theoretically come to know everything about bat biology and behavior, and while I might be able to use my limited imaginative capacities to simulate some aspects of a bat’s experience, no amount of study will ever show me exactly how things seem from a bat’s perspective. Consciousness appears to be a subjective phenomenon, and because science is usually taken to have to do with the objective realm, Nagel’s argument poses a powerful

challenge to physicalism.

There are also compelling reasons to believe that neural states do not necessitate the existence of conscious ones. Philosopher and cognitive scientist David Chalmers has argued that what he calls a philosophical zombie—a living being physically and functionally identical to one of us but entirely lacking conscious experiences—is logically possible. This means that, according to Chalmers, philosophical zombies are not contradictory given the laws of logic. While Chalmers does not believe that philosophical zombies actually exist, or that they ever will, he does not think they are impossible in the same way that a positive number below zero is impossible. Instead, he sees them as more like talking cats—they are not real, but we are not thinking incoherently if we try to imagine one. If Chalmers is correct, then physicalism has a big problem. If all of someone’s physical properties could exist without being accompanied by their conscious experience, then consciousness is not a physical property. There has to be something else at play. We can now start to see how difficult it is to understand how consciousness fits within our current scientific framework. Though thinkers have grappled with explaining the relationship between the mind and body for millennia, Chalmers has formulated the issue using terms that have been profoundly influential in recent years. According to Chalmers, when we acknowledge considerations like those discussed above, it is hard to understand how and why the neurons in our brain could have given rise to our subjective experiences. Think of it like this—how could a spongy, pinkish lump of cells inside my skull have brought about the current ache in my shoulder, the pleasure I feel while writing, or the purpleness I see looking down at my shirt? It is difficult for scientists and philosophers even to figure out the methods we should use to think about this question, let alone how to answer it. For this reason, Chalmers has labeled it the “Hard Problem of Consciousness.”

Responses to the Hard Problem vary far more than one can describe in this short article. Physicalists have pushed back against arguments like those presented by Chalmers and Nagel in various ways. For example, some maintain that if we knew everything about how the brain processes information, subjectivity would no longer be a mystery. In contrast, other thinkers have posited alternative, non-physicalist theories of consciousness and have attempted to make their ideas compatible with the findings of neuroscience.

The puzzle of phenomenal consciousness is remarkably complicated, forcing us to think about the mind in new ways and contemplate the limits of science. As the literature on the topic has grown, so has the controversy. But there is hope that one day, as we understand more about ourselves and the world around us, the nature of consciousness in all its vibrant complexity will be illuminated.







Grasping at Oblivion

Written by Tanisha Shende
Illustrated by Patrick Estell

Humanity has arrived on an alien planet. We saw nothing, but our surroundings were imbued with life as if our every move was being watched and assessed. The bold among us were eager to pursue any inhabitants, but those urging caution won. Instead, we studied the surrounding area. We collected soil, rock, and microorganisms samples and bagged any items we encountered. We took copious notes on every possible detail and then returned home in our ships.

I watched the excavations on the television while my coffee cooled. I listened to my husband, one of the captains, describe his missions, but neither felt the same as experiencing them myself. I couldn't tell you if the excavators' boots landed on firm soil or sloshy marsh, if the area was raucous or disturbingly silent, or if the sky was empty or streaked with birds. Thinking about the enormity of that planet for too long makes a cavern out of my chest, so I don't.

All I can tell you about is what they brought back home. I am in charge of overseeing the observational and experimental

studies of our collection. My days are filled with reports from archaeologists, anthropologists, chemists, biologists, and the like. Still, the unifying emotion among them is a wonder. They excitedly tell me the details of everything they are studying. They show me stones and pieces of fabric arranged in indeterminate and unfamiliar shapes. They measure and note every disturbance in the soil, theorizing about what was placed there and why. They make flimsy connections across time, geography, and possible social groups. All the while, their observations are based on this unconvincing foundation. They tear each other to shreds debating semantics and the importance of one detail over the other. They are obsessed with meaning. My husband holds up a rock as black as obsidian with etchings revealing color within. He speaks to me about religion. Each of these rocks was found protected at a presumed campsite. Why would they create this if it wasn't profound? Why would they spend so much time with them if they had no meaning?

"Imagine holding your god in your hand," he muses as he

rests the rock on his palm and wonders what the aliens would say if they saw him.

I manage the experiments dutifully and respectfully, but as my colleagues grow more entrenched in their theories, I'm convinced that we are heading farther from the truth. I remember being a child and wanting to hold the world in my hands even if it killed me. But one day, the world became too much for me. Too large. Too vast. I was unable to stomach it. The light in my chest extinguished, and my body became a hole stuffed with so much cotton that sometimes it suffocates me. The universe is infinitely large and old, and these alien creatures are infinitely confusing. We try to make sense of this universe. We travel to distant worlds and leave with objects and samples, determined to figure them out. Are we certain? Are we certain? What if we are wrong? What if we were wrong all along? What if, even worse, we will never know whether we are right or wrong?

I have this terrible fear that, while humanity was sleeping, something came and pillaged the parts of the universe we took for ourselves. They stole the pieces we need to understand the profound mystery of our world. Without them, humanity is reduced to a single hand grasping at nothing. Alternatively, the conditions were simply not right for us to understand, and I do not have it in me to thrash against such abstraction. Despite all my rage, I am still just a girl playing at make-believe. I need some higher being to comfort me and tell me we have not just wasted millennia of our existence. We have traveled, arrived, and excavated. How can we be certain that these objects we have found are as meaningful as we believe? How do we have any idea that this is not just some great joke on humanity, that we have unwittingly started worshiping objects aliens cast to the wayside?

Still, there are moments when none of that seems to matter. Although I oversee all the experiments, I also have my own lab. We extracted a microorganism, more of a web than a creature, growing on a surface on the alien planet. It is bright red and attaches itself to whatever it can find, so it paints my lab with violence. My research assistant spilled his food near it, and it branched out to each morsel in such a beautiful and complicated pattern, resembling galaxy filaments or the veins in an eyeball. I decided to run a new experiment by placing it in the center of a dish and using light to mark off structures like mountains, rivers, and buildings. I surrounded the organism with food flakes and waited to see how it would navigate in the face of these obstacles. What resulted was a network closely resembling the metro systems of busy cities.

How? How could this entity without an apparent brain seemingly identify foreign food as desirable and navigate obstacles to find the most efficient path to it? How can this alien creature resemble dendrites, veins, metro systems, and galaxy filaments, the largest known structures in the universe? I do not understand. I cannot understand. But do I want to understand? Is it not enough to set my clipboard and notes aside and crouch down to watch this beautiful pattern unfold? The universe is infinitely large and old, and these alien creatures are infinitely confusing, and there are so many things to explore and discover. Am I allowed to go out and find them because I would love to see what the universe has created? Can I not just accept whatever the universe has to show me and love it the way I love everything else? We may very well be hurtling towards oblivion, but we will continue because this search for the incomprehensible truth affirms our humanity.

"Can you believe this? Everything they are saying is wrong." The microorganism listened to its companion halfheartedly, attention lingering on the scientist observing it in awe. As the excavations and experiments continued, the woman's face began resembling a drawstring bag pulled too tight, but once she saw what it could do with its body, the years and tension melted off her body.

"Are you listening to me?" Its companion narrowed its eyes at the microorganism. As it spoke and paced, it fiddled with its rock, chipping off flakes with its long nails.

"Not really."

"They think that my rock is religious. It's not. How can it be?" The companion laughed, or maybe it was a huff. "It's just something I do to pass the time."

The microorganism finally focused on its companion and the rock that had become a fixture in its life. "Maybe they're not completely wrong. Maybe they would say that an object that marks the time you've lived and holds so much importance to you that you take it everywhere is religious," it mused.

The companion huffed again and fell silent while the microorganism returned to the scientist. It could never speak to her how it wanted; they could never understand each other. For instance, it wondered if the scientist could know how it can exist simultaneously on Earth and its planet while remaining one. It would be like asking a unicellular organism to understand a multicellular one. The scientist assumed that it stretches and contorts its body to access food. How can it tell her that it chases not sustenance, which it has no need for, but beauty? It creates art with its webs, intricate and delicate patterns overlaying tree trunks, and Petri dishes, all because it can. Humanity's fault is their insistence on logic when most creatures act with nothing but.. No, the microorganism sensed a longing for answers in the scientist's face and gave her beauty instead. It saw how happy its webs made her, so it created more, just so it could watch her revert into the child that still believed in magic. The scientist would rather believe the universe acts without regard for her, but was it not so much lovelier to think that it was created just to be seen by her eyes? But she would never understand, and it could not understand her. ● ● ●

I sighed. Racked my brain. Here I was, faced with a device designed to converse with only me, while somehow containing most of the knowledge of the internet. It did not help that I was about six months late to the AI-chatbot engagement game. To make matters worse, it now oddly felt like I had to impress it. At last, I decided on a question. Quickly my fingers flew across the keys: "When will you leave?"

ChatGPT has indeed snagged the attention of a few people since its release a few months ago. After launching in November of 2022, OpenAI's chatbot ChatGPT's impact on the digital sphere has proven to be nothing short of unfathomable.

Within two months of its launch, the website has garnered nearly 100 million users. In doing so, it has earned its title as one of the fastest-growing apps in history, breezily surpassing social media giants such as Tiktok and Instagram. Still, considering the accessible nature of the app — only having to create a username and password before the chatbot can seemingly answer anything you could think of in a digestible, conversational format — this particular piece of data should come as too much of a shock.

It is one of ChatGPT's strongest selling points: ask it anything under the sun, and it will do its best to condense it into a shorter, understandable — and occasionally inaccurate — substance. OpenAI's text-generating AI GPT-3 and GPT 3.5 are the trained language models behind ChatGPTs' ability to engage in such an advanced dialogue. Derivative of Transformer Architecture and Reinforcement Learning, all these sophisticated machine learning algorithms substantiate ChatGPT's ability to digest the extent of these complex language processing tasks. As such, ChatGPT's capacity to engage in a manner so humanistic is an irrevocable, technological feat. But at what cost?

As such, ChatGPT's capacity to engage in a manner so humanistic is an irrevocable, technological feat. But at what cost?

Well, none — for now. Being a free research preview, ChatGPT is currently offered to its users on a plan with no charge, in a constant rolling state of improvements and updates, and, as of the February 9 of 2023 upgrades. At \$20 a month, plan users can now enjoy access to ChatGPT, even throughout its peak internet traffic hours, and the option to choose between the standard ChatGPT structure or "Turbo" ChatGPT, where the responses are optimized for speed.

The chatbot has amassed quite the user base, but public reception continues to grow murky. If OpenAI CEO Sam Altman has anything to say about the productization of his near-omniscient brainchild, it is the importance of the general public's reconciliation with its mere existence. In an interview with Forbes, he points out, "Google does not put [Artificial Generated Intelligence] out for public use. Other research labs don't do it for other reasons; some fear it's unsafe. But I believe we need society to get a feel for this, to wrestle with it, to see the benefits, to understand the downsides."

As it happens, the downsides to this colossal access are increasing in nature. After all, as it usually goes with monumental mainstream technology, we can expect an impressive display of creativity and ethically questionable behavior to follow quickly in its footsteps.

A principal security researcher for CyberArk Labs created polymorphic malware with the help of ChatGPT. "[ChatGPT's] malware's advanced capabilities can easily evade security products and make mitigation cumbersome with minimeffort or investment by the adversary." The vast array of techniques that can be created through ChatGPT's capabilities, such as persistence strategies, Anti-VM modules, and other malicious code, presents a wide range of opportunities for creating and proliferating this malware. IT cybersecurity experts across North America, Australia, and the United Kingdom reinforce this notion, stating in a Forbes Magazine article published in 2023 that they are "51 percent in agreement that a ChatGPT-powered cyberattack is likely to happen before the end of the year," while "71 percent said they thought nation-states are probably already employing the technology against other countries."

The vast array of techniques that can be created through ChatGPT's capabilities presents a wide range of opportunities for creating and proliferating this malware.

As it usually goes, overreliance on any objective force can take its range of debilitating turns. Experimentation and exploration are reasonable — necessary, even — but they call for moderation. Striking this balance in the realm of ChatGPT is still somewhat difficult to gauge amongst its users, considering its recency, but it is not far-fetched to predict the obstructive effects of not doing so.

Senator Barry Finegold of Massachusetts has propped an innovative bill that would necessitate corporations utilizing AI chatbots, such as ChatGPT, to undergo comprehensive risk assessments and implement robust security protocols. This would also obligate them to divulge details about their algorithmic processes to the government. As an added safeguard, the bill would additionally require the use of watermarks by these chatbots, thereby protecting against potential theft of intellectual property.

In any case, I was well aware that asking a robot the extent of its existence felt oddly combative. Still, I figured I needed to start our first "conversation" on a somewhat speculative note. The response was instant:

As an AI language model, I don't have a physical existence and I'm not capable of leaving or going anywhere. I will remain here to assist you with any questions or concerns you may have. So, I'm not leaving anytime soon!

Given the hefty technological strides AI algorithms have made in the past months, it was a reasonable but muddling response. Even now, constantly reaching the maximum capacity from the daily swarm of requests from its massive user base, the app shuts down rather frequently, flashing an apologetic request for you to "hang tight as we work on scaling our systems." At this point in time, it seems the most human trait about ChatGPT is the uncertainty of its point in evolution.

As I mulled this all over, the text of the chatbox title rolled out on the top left corner of the screen, answering my question in the meantime. "AI Assistant Stays Put." ●●●

AI is Catching Up to Your Doctor

AI's role in Diagnosing, at Treating, and Discriminating.

Written by Caleb Rader

Illustrated by Emma Beveridge

Artificial intelligence has long been touted as the future of medicine. It already plays a crucial role in medical science, processing previously inaccessible quantities of data and unveiling overlooked connections. As our body of medical knowledge quickly outgrows any individual's grasp, researchers seek novel ways AI may supplement or even supplant duties traditionally performed by physicians. While machine learning bears immense potential in healthcare, many questions remain regarding its efficacy and equity. Critics suggest that the potential for AI to incorporate the biases of its creators, and the data used to train it, pose significant ethical challenges to its full-fledged adoption in healthcare.

The key operating principle behind machine learning is simple: given a set of training data and a goal, an algorithm self-corrects to become more effective at making predictions. For example, a model may be trained on an aggregated dataset of medical notes and be tasked with guessing whether or not each patient suffers from a particular disease. It will start by making rough predictions with different parameters and then iterate on future passes based on which changes increase accuracy. Once it has self-taught the relative significance of different inputs and consequently acquires good predictive ability, it may be used to extrapolate from previously-unseen inputs.

As diagnoses and treatments grow in number and specificity, medical professionals, computer scientists, and outside investors have looked to AI as a tool for risk identification. IBM's Watson, a general-purpose knowledge model, gained notoriety for its outperformance of frequent victors on the popular game show, Jeopardy. However, it was Sloan-Kettering Cancer Center that saw the clinical potential and, in 2013, began to employ Watson in treatment management. IBM's AI does not supersede decisions made by physicians but provides additional input. A good portion of its capability comes by looking through genetic profiles and quickly gaining the background knowledge necessary to identify rare disease subtypes or recommend tailored therapies. Similar systems are employed in hospitals across the globe. Though the average patient's experience is largely the same as it has been for decades, these are the avenues through which AI has found a behind-the-scenes foothold in healthcare.

When you use your smartphone's camera to capture an image, the raw information available is constrained by the small sensor and static lens. Companies like Apple and Google have developed machine-learning algorithms based on millions of images. By knowing how the photo should look, your phone can resolve much more detail than otherwise possible. The same principles of computer vision are applicable to medical imaging and have yielded promising results. Many methods now exist to clarify and increase the resolution of magnetic resonance imaging, computed tomography, and other scans, allowing radiologists

to identify structural abnormalities otherwise drowned out by noise more accurately. Going a step further, algorithms can also automatically highlight points of interest or even make preliminary diagnoses.

One such use for image-based diagnosis is in the detection of skin cancer. Precancerous moles often appear similar to normal skin features. Still, the attenuation of AI models to details we fail to perceive allows for notable increases in sensitivity and specificity compared to dermatologists. But these results can be misleading, with one literature review of these approaches noting that "few studies used data on populations with a low prevalence of skin cancers," such as those with darker complexions, and that "widespread adoption ... cannot currently be recommended until efficacy in these populations is shown." This is not a problem unique to skin cancer. The aforementioned smartphone algorithms are notoriously bad at reproducing darker skin tones, and facial recognition models often struggle to identify darker individuals. When groups are underrepresented in datasets – or, in the case of language models trained on the internet at large, negatively represented – the resulting AI will incorporate those prejudices.

AI biases are a central and highly contentious issue within the field. In 2020, Google controversially ousted Timnit Gebru, a Black woman and co-leader of its AI ethics team, over a then-unpublished paper highlighting issues such as bias in large language models. Dr. Gebru, now the leader of the Distributed AI Research Institute, has found the problem of discriminatory AI to be multifaceted, wrought not only by data but by those who wield it. In her hallmark 2018 study "Gender Shades," Gebru and MIT's Joy Buolamwini found that leading gender classification algorithms produced error rates of up to 34.7 percent for darker-skinned women, compared to only 0.8 percent for lighter-skinned men. A biased world produces biased data, and biased data produces biased outcomes. Correcting these effects requires will, ingenuity, and concerted effort – but in a rush to capitalize on rapidly evolving technologies, the overwhelmingly white, Asian, and male field sidelines the concerns of groups underrepresented among its ranks. "We need to let people who are harmed by technology imagine the future that they want," says Gebru.

Perhaps there is no area where these concerns are more pressing than healthcare. Discrimination is as inextricable from medicine as the stethoscope. Disadvantaged groups face significant impediments to healthcare resources, and when they do make it into the clinic, unscientific misconceptions about race and implicit bias lead to markedly worse outcomes. Physicians often view Black patients as non-compliant and are more likely to rate equivalent interactions, with white patients, to Black patients poorly. Black patients are met with more skepticism, are less likely to be referred to the proper specialists, and are less likely to be treated adequately for pain. Black women are three times more

likely to die due to pregnancy-related complications. When race-based disparities are all-encompassing, correcting for bias in AI trained on healthcare data is not necessarily as simple as getting a more representative sample. Minority patients are not only less likely to find themselves included in statistics, they also face more health issues in the first place, receive subpar, discriminatory care, and experience worse outcomes across the board. A model trained on chart notes to summarize visits will incorporate the divergent biases of physicians. Another trained in pain-management choices will under-prescribe therapies for Black patients. The problem is no better for big, aggregated data. Genomic databases, like clinical data, are normally skewed heavily European. As an increasing proportion of a physician's job is performed by software, patients from underserved backgrounds may find their digital doctors equally prone to missing the mark on diagnosis and treatment.

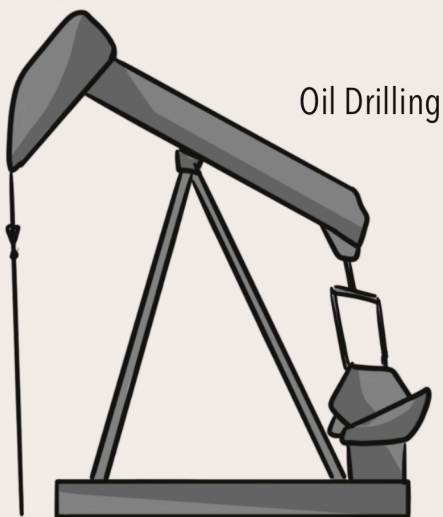
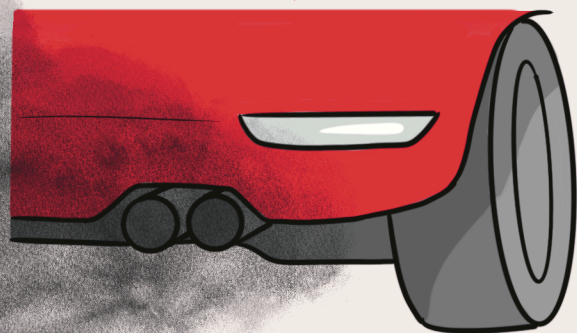
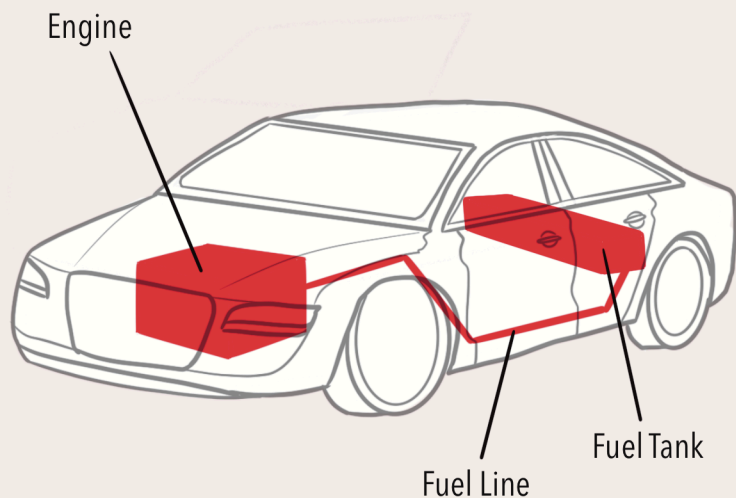
Ethical practices in medical research suggest that when therapy is evidently very successful within the trial cohort, the study should conclude prematurely so control subjects may receive it as well. As the capabilities of AI continue to leap forward, it is not difficult to imagine a scenario where a model's disparate performance across subgroups presents an ethical dilemma. Consider a hypothetical deep-learning model trained on genetic biomarkers and behavioral notes to predict risk for heart disease and recommend cholesterol-lowering medications. Black men are at significantly higher risk for heart disease, the leading cause of death in the United States, but this model is trained on primarily European biomarkers, and behavioral notes are rife with bias.

Among white patients, it allows doctors to catch heart disease earlier and treat it more effectively, adding years to numerous lives. Among Black patients, the improvements in early diagnosis are marginal, and treatment recommendations are no more prescient than the physician's best guess. From an absolute perspective, heart disease outcomes among Black patients may improve slightly, but in comparison to the drastic leap for white individuals, an already-significant disparity within the leading cause of death has just grown dramatically. This thought experiment is not the worst-case, as it does not describe one of many plausible situations where artificial intelligence actively discriminates. But when scenarios like these materialize, medically underserved populations may find themselves yet again excluded from progress and facing ever-steeper health disparities that put them at a social and economic disadvantage.

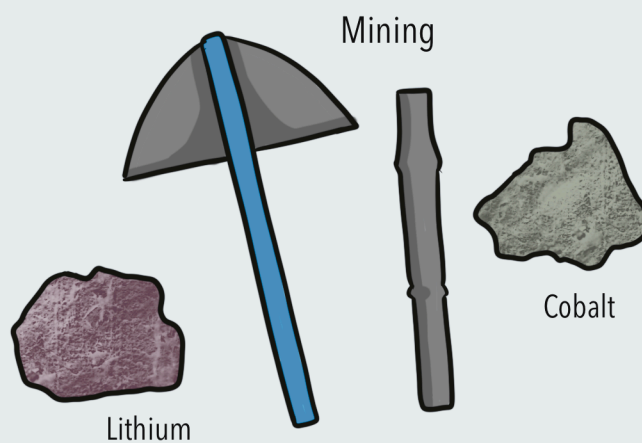
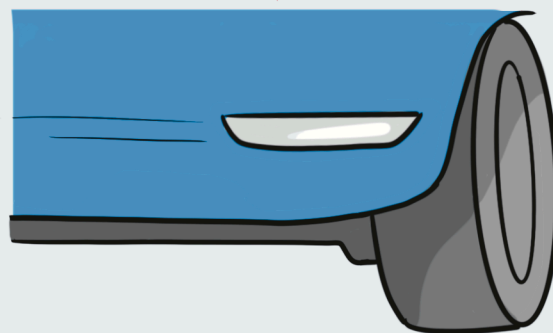
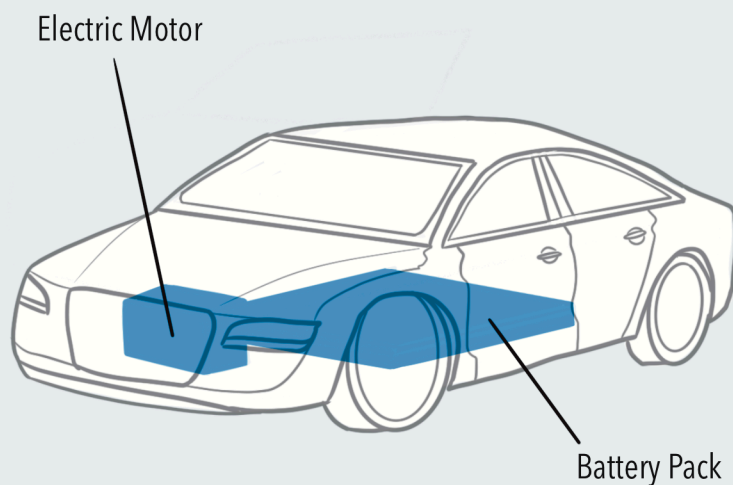
AI has the potential to allow us to lead longer, happier lives. But where it can learn from our best capabilities, it can also internalize our worst tendencies. In medicine, we must pace ourselves and develop ethical frameworks to ensure that our approaches to machine learning draw on many backgrounds and seek to help all. But even with the best of intentions, we are sure to encounter blind spots. These challenges are downstream of persistent social inequity, and crafting just AI from deeply unjust sources is a profoundly difficult task – one which we must approach with the same enthusiasm we hold for technological advancement at large. ● ● ●



GAS POWERED CARS



ELECTRIC VEHICLES



Slow the Roll on EV's

Why We Should Be Hesitant When Replacing Gas

Written by Michael Eddy Harvey

Illustrated by Ellie Martin

Gas-powered vehicles often come up as one of the chief problems regarding the environmental crisis. When thinking about the harmful effects of gas vehicles, images of hazy sun and cars jammed on a highway come to mind, and rightly so. As of 2020, gas-powered cars accounted for 27 percent of greenhouse gas emissions. According to the Environmental Protection Agency (EPA), a typical passenger vehicle emits about 4.6 metric tons of carbon dioxide annually. The most prominent threat from these gas-powered vehicles is tailpipe emissions from the exhaust, which puts CO₂ directly into the atmosphere, furthering global warming.

One alternative to these direct emissions from the exhaust is electric vehicles (EVs), which are rising. In 2020, the global electric car stock reached ten million, a 43 percent increase from 2019. Besides business, EVs are tied to the green energy movement, as they seem to be a much better alternative to gas-powered cars. Most EVs are considered battery electric vehicles (BEVs), which run off of pure electricity and are plugged into a power source to charge. They have zero tailpipe emissions, meaning they do not directly pump CO₂ into the air. However, with this mass production of EV cars underway, people are still determining whether these EVs genuinely live up to their green image. Are they much better ethically and environmentally than alternative forms of transportation? The short answer is yes. EVs are certainly a better alternative to gas-powered vehicles, both environmentally and ethically. However, we should be cautious when considering the ethical and environmental impact of replacing gas-powered cars with EVs.

BEVs are not 100 percent carbon-free, which can detract from their green image. The carbon impact is due to various things, but the most substantial is the electrical grids that power the BEVs. So where exactly are these cars getting their electricity? In the United States, most electric grids are powered by nuclear power plants, which have their host of environmental worries but a small global warming potential (GWP). But in many other countries, in Europe especially, grids are powered by non-renewable sources, such as coal or oil.

Using fossil fuels to power electrical grids creates indirect emissions, blurring the line on whether BEVs are superior to their gas-powered alternatives. A Polish study compared the indirect carbon emissions of EVs to the direct emissions of gas-powered vehicles and internal combustion engine vehicles (ICEVs). Researchers found that the overall indirect carbon emissions associated with EVs ranged from 2.49 kilograms to 3.28 kilograms of CO₂ a day. In comparison, the direct emissions associated with ICEV were 2.55 kilograms to 5.64 kilograms of CO₂ a day. Based on these results, indirect emissions from the grids that power EVs can be just as bad as the direct emissions from burning gas.

The concern about emission levels also applies to the

production of EVs and ICEVs. Another study performed in Europe used a Life Cycle Assessment (LCA) to compare the two. An LCA considers a product's various environmental impacts regarding its production, use, and life. Overall the researchers found that EVs powered by the European electricity grid had a 10 percent to 24 percent decrease in GWP relative to the ICEVs. However, they also found that these EVs can potentially increase human toxicity, freshwater ecotoxicity, and freshwater eutrophication. Due to the electric powertrains, traction batteries, and lithium/cobalt mining that go into EV production, it is much more environmentally costly than ICEV production.

BEV's are not 100 percent carbon free, which can detract from their carbon free image.

Cobalt and lithium mining practices are also highly ethically concerning. More than 60 percent of the world's cobalt supply comes from cobalt mining in the Democratic Republic of the Congo, where cobalt mines have been reported for using child labor. Due to increased EV production, children as young as nine are mining cobalt in dangerous conditions. Lithium mining carries other ethical concerns; though most lithium mining occurs in Australia, a significant portion is still mined from the Salar Brines of Chile and Argentina. One lithium extraction point in Chile is in the Atacama Desert, home to the indigenous Lickanantay, who consider the water and brine sacred parts of their territory. As lithium and cobalt mining has increased, the ecological pressure on the Atacama and the surrounding community has grown. Scientists and indigenous communities have been protesting the mining for years, saying that the increase in lithium mining will kill the desert.

In short, EVs are still a good alternative to gas-powered vehicles. However, ethically and environmentally, we should be cautious about fully replacing gas-powered cars with EVs, as we might just replace one flawed system with another. A better, more holistic approach that maintains the benefits of EVs but switches them to renewable electric grids might prove better in the long run — for both EVs and our earth. ● ● ●

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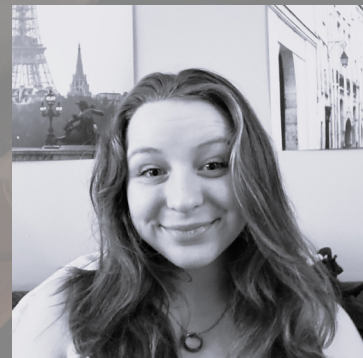
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/syn . apse/ noun : the point at which a nervous impulse passes from one neuron to another.

The Synapse is an undergraduate science magazine that serves as a relay point for science-related information with a threefold objective. First, we aim to stimulate interest in the sciences by exposing students to its global relevance and contributions. Second, we work to bridge the gap between the scientific and artistic disciplines by offering students a medium through which to share their passions, creativity, and ideas. Third, we strive to facilitate collaboration between undergraduate institutions across the country, especially within the natural science departments.

