Emma Rekate (OC ’24) is very excited to welcome you to Issue 35 of The Synapse. She is excited for everyone to see the wonderful articles and art in the magazine. This issue covers interesting and important topics that are paired with gorgeous pieces of art. The Synapse covers a wide array of topics ranging from microbial communities to free will to dancing rats. As Editor-in-Chief, Emma Rekate gets to work with all of the writers, artists, copy editors, content editors, layout editors, and board members to create this magazine.
**Featured Contributor**  
*Sofia Bielinski Leitao OC*

Sofia Bielinski Leitao is a second-year student at Oberlin College majoring in Chemistry and Biochemistry. She is from Rio de Janeiro, Brazil and has been working with The Synapse Magazine since Fall 2022 as a Content and Copy Editor. Sofia thinks The Synapse is important because it gives students the opportunity of exploring their areas of interest in a creative way. She also believes it provides to the readers scientific information in an easier way to understand. Outside of The Synapse, Sofia is a STRONG and Bonner Scholar, and loves to spend her free time cooking or dancing. After graduating, she plans on becoming a food chemist.

**Featured Contributor**  
*Ania Ocasio OC*

Ania Ocasio is a second-year student at Oberlin College majoring in Biology and History, and minoring in Environmental Studies. She is from Chicago, Illinois and this is her first time contributing to The Synapse as a writer. Ania thinks The Synapse is important because it minimizes the inaccessibility of science. Many people think that you need a rigid understanding of complex math and a deep love for stale graphs to deeply engage with science, but The Synapse demonstrates that there are many avenues in which science can be appreciated. Outside of The Synapse, Ania is a part of the Pyle-Inn Co-op, the Bike Co-op, and a member of the Oberlin Community Board. In addition to that, she loves to go on bike rides, read, bake, and meditate. After graduation, Ania plans to conduct environmental research before going to law school.
The Synapse

Do Muslim women view each other differently based on how they dress? In other words, have you ever wondered how Muslim women who do not wear the hijab (the Islamic headscarf) view their hijab-wearing compatriots? Likewise, how do most hijab-wearing Muslim women view hijabless Muslim women?

In a study by Norbert Meskó and Tamás Bereczkei at the University of Pécs, when asked to rate the attractiveness of women with varying lengths of hair, male participants rated women with long hair as more attractive. In light of this, most people would probably view the hijab, a headscarf that covers a woman’s hair, as an impediment to female beauty. However, a recently resurfaced study indicates much more to the story than this simple assumption.

In 2014, researcher Nausheen Pasha-Zaidi published a study that explored the “Hijab Effect,” a psychological phenomenon in which women who wear Islamic headscarves are more likely to receive higher ratings for personal characteristics in Muslim-majority communities. Pasha-Zaidi compared this to the “Halo Effect,” a well-known phenomenon in which people are more likely to attribute positive traits to physically attractive people. One might think that a cloth that covers all of a woman’s hair would drastically reduce her chances of being viewed as attractive. After all, hair is a crucial component of female identities around the globe.

However, others could view a woman’s hijab as a mark of her attractiveness by dedication to her religion. Throughout Islam’s history, the hijab has been viewed as a symbol of modesty and the concealment of one’s beauty. Today, although women are mandated by law to wear hijabs in only two Muslim-majority countries (Afghanistan and Iran), they continue to be imposed by social norms in a handful of others.

There are various reasons why Muslim women choose to wear hijabs. Some women may wear them out of self-esteem and pride in their religion, particularly following the September 11th, 2001 attack and the successive Islamophobic rhetoric. These women had to bear the burden of being the black sheep in many social situations, as their headscarves were dead giveaways to their membership in the religion that non-Muslim Americans came to associate with the deadliest terrorist attack on United States (U.S.) soil. Nevertheless, Muslim women continue to wear hijabs in the U.S. to combat stereotypes by honoring those who had died on September 11th, 2001 while championing their Muslim identities. One example of this advocacy is from Amirah Ahmed, a Muslim-American teenager who wore her American flag hijab during a speech she gave to her high school class commemorating the lives lost on September 11th, 2001, according to The Associated Press. Others wear hijabs as a defense against male sexual impulses.
These women often believe that hijabs are “a necessity that God has ordained to allow women to interact in the public sphere without being unduly harassed,” as Pasha-Zaidi put it in her study. On the other hand, Muslim women may abstain from wearing hijabs because they believe that it’s only male sexual impulses, rather than God, that create the need for the hijab. Also, non-hijabis are more likely to view the hijab as a product of politics and culture predating Islam, rather than as a traditional garment that rose in popularity after the religion was established. Most historians and researchers agree that head coverings for women have been worn as early as ancient Mesopotamia. However, they adopted their current role and function once Islam became a popular religion around the world.

Referencing a study conducted earlier, Pasha-Zaidi cited research from 2010 that surveyed both Muslim and non-Muslim men in Britain on the attractiveness of hijab-wearing women. The hijabis were rated lower in attractiveness and intelligence by both groups of men, prompting discussion into a Western bias towards hijab-wearing women. Nevertheless, the British study was an important milestone in research on how religious attire impacts perceptions of attractiveness in women.

According to the results, hijab-wearing participants in the U.S. were more likely than non-hijabi participants to rate hijab-wearing women as more attractive.

In her cross-national study involving attractiveness ratings for the hijab, Pasha-Zaidi used a participant pool of South Asian Muslim women living in the U.S. and United Arab Emirates (UAE). Unlike the previous study from Britain, her study wasn’t expected to achieve the same results. This is because women not only perceive each other differently than how men perceive women, but Muslim women often do not have to wear the hijab in front of other Muslim women as well. According to the results, hijab-wearing participants in the U.S. were more likely than non-hijabi participants to rate hijab-wearing women as more attractive. Also, both hijabis and non-hijabis in the UAE were more likely to rate hijab-wearing women as more attractive than non-hijabis.

On their own, the results of Pasha-Zaidi’s study shed light on the existence of the Hijab Effect. They show that regardless of whether Muslim women in the UAE, a Muslim-majority society, wear a hijab or not, women from both groups are more likely to view hijab-wearing women as more attractive.

These results make sense regarding the Hijab Effect’s implications for the U.S., a Muslim-minority society. If non-hijabi Muslim women grew up in a Western environment and became accustomed to its beauty standards, it wouldn’t be surprising if they’re less likely than hijabis to view hijab-wearing women as more attractive.

However, questions on why Muslim women perceive each other differently based on religious attire remain unanswered to this day. For Muslim women in the U.S. and UAE, their views could result from social pressure, pride in their religion, or a combination of both.

A similar study by researcher Mercedes Sheen was published four years after Pasha-Zaidi’s original publication, which complicates matters further. The most significant difference between Sheen’s study and Pasha-Zaidi’s study seemed to be Sheen’s exclusive use of native Emirati Muslim women, rather than Emirati and American Muslim women of South Asian ethnicity, in her participant pool. Extracting attractiveness ratings from native Emiratis instead of South Asian women living in the UAE (most of whom could have been Indian, Pakistani, and Bangladeshi immigrants giving in to social pressure), Sheen’s data contrasted sharply with Pasha-Zaidi’s results, with hijab-wearing native Emirati Muslim women rating non-hijabis as more attractive than both fully and partially covered women.

Being one of the most popular destinations for immigrants of diverse backgrounds (according to the Daily Vox), the UAE may seem like a Muslim-majority country with some of the most relaxed social norms regarding hijabs. Nevertheless, there have been reports of women who have been forced to both wear and discard hijabs in the country as a result of workplace guidelines. To truly confirm whether or not the Hijab Effect is real, research must be conducted in not just one, but multiple prominent Muslim-majority countries to be effective in the long run. Using a variety of methods, such as conducting both surveys and interviews, could be invaluable in future research in emphasizing the subjective experiences of Muslim women.

Moreover, for the Islamic community to achieve religious and social harmony, conversations on the significance of the hijab and its effects on perception must be had not only between hijab-wearing and hijabless Muslim women but the rest of society, Islamic or not, as well.
he deep sea has captivated the minds of humans for millennia. Along with outer space, it is a testament to our wonder and exploratory spirit, yet its closeness and darkness carry a more sinister weight. While the colorful coral reefs and fascinating ocean creatures are celebrated, once you go deeper, there is no telling what you will find. More than 80 percent of the ocean is unknown to humanity, so we must grasp blindly in the darkness for answers. However, some believe that the mysterious sounds from the deep sea may open our eyes to a great secret: that there is a gigantic creature living in our depths. This is a bold claim, one often disputed by scientists, yet it may tell us more about our oceans, and ourselves, than we would expect.

The Pacific Marine Environmental Laboratory (PMEL) is a branch of the National Oceanic and Atmospheric Administration (NOAA) dedicated to ocean observation. Their Acoustics Program detects and studies the sounds of the ocean using acoustic technologies, such as the hydrophone. Hydrophones can detect and record ocean sounds from any direction, and several hydrophones can be placed thousands of miles apart in an array to measure ocean sounds with greater sensitivity and precision than a single device.

The Equatorial Pacific Ocean autonomous hydrophone array has detected several powerful and mysterious sounds from the ocean. One such sound, dubbed the “Bloop”, was repeatedly heard across the Pacific during the summer of 1997. It lasted a minute and was loud enough to be heard over a range of 3,100 miles. The source was roughly triangulated to 50°S 100°W in the South Pacific, west of the southern tip of South America.

PMEL scientists were initially unable to explain the Bloop, leaving some scientists and the general public to wonder if the

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sound originated from an animal. In 2002, journalist David Wolman wrote an article about this theory entitled “Calls From the Deep”
in the science magazine New Scientist. In the article, Christopher Fox, a geophysicist at NOAA, and Phil Lobel, a marine biologist at Boston University, both stated that they believe the Bloop is biological in origin. According to Fox, the Bloop’s spectrogram—a visualization of a sound’s energy and pitch over time—resembles that of other marine animals. The problem is that since the Bloop was heard over thousands of miles, it must be louder than any known animal, including the blue whale, the current largest animal on Earth. Wolman muses that this must imply the existence of an animal that is either incredibly large or incredibly adept at making loud noises.

The suggestion of an unknown creature lurking in our depths enthralled the public. The Bloop became associated with an image of a gigantic sea monster several times larger than a blue whale. It has beady black eyes that lock onto its prey and thick fins to propel it forward, but the most prominent feature is the mouth of the beast: a gaping maw surrounded by sharp teeth, a window into the creature’s cavern of a body. Whenever the story of the Bloop was recounted, this picture and the claim that it is one of the ocean’s greatest mysteries were always linked.

It took on a Lovecraftian air as people grappled with the idea of forces much more significant than themselves at play. The term “Lovecraftian” is used to describe an unknown creature that is more terrifying than a person could imagine, often referring to the world that H.P. Lovecraft would tell in his stories. While the mystery unsettled some, others found comfort in it. One person stated on an online forum that “the universe would be utterly horrifying if we could perceive everything.” The connection to Lovecraft’s work is a literal one as well. The Bloop’s location was roughly determined to be about 1000 miles away from the location of R’lyeh, a fictional underwater city and the prison of the cosmic entity Cthulhu, according to Lovecraft’s most well-known short story, “The Call of Cthulhu.” Regardless of whether people believe the Bloop to be Cthulhu or not, this association demonstrates that the Bloop has been elevated to the status of an urban legend. It is now the property of the public and its love of mysteries, spectacles and the scientists that initially detected it.

In the meantime, PMEL’s researchers continued their work on the ocean’s sounds. From 2005 to 2010, an acoustic survey was conducted of the Bransfield Strait and Scotia Sea in the Antarctic Peninsula region, near the Bloop’s location off the tip of South America. Hydrophones placed in the Scotia Sea picked up several “icequakes.” Also known as cryoseisms, icequakes are seismic events caused by sea ice cracking or large ice chunks breaking away from a glacier. Such events occur tens of thousands of times per year, spurred on by global warming. The icequakes detected in this study were used to track iceberg A53a in early 2008, and their spectrograms were remarkably similar to that of the Bloop. Additionally, icequakes are loud enough to be heard by multiple hydrophones at a range of 3000 miles. Thus, NOAA concluded that the Bloop was most likely an icequake caused by one or more icebergs between Bransfield Straits and the Ross Sea or at Cape Adare.

Robert Dziak, a seismologist at NOAA and Oregon State University and one of the researchers involved in the acoustic survey, elaborated on the findings through an email to Wired.co.uk in a 2012 article. He said that most NOAA researchers never seriously believed that the Bloop was biological in origin and that the idea of some mysterious sea creature was more “fantasy than science.” Dziak also stated that most detected sounds from the ocean are not that mysterious. They almost always have known sources, such as weather and geophysical events (i.e., storms and underwater volcanoes), humanity (i.e., ships), ice, and animals; otherwise, they are most likely electronic interference.

Given NOAA’s disinterest in the Bloop being an unidentified creature, what explains the propagation of the myth among the general public? Dziak theorizes that the recording misled people. It is sixteen times faster than the original, and the recording played in real-time sounds more geophysical than biological. Perhaps the myth caught on even then because people want to believe in fantasy over reality.

The realization that the Bloop was an icequake may be satisfying to some who sought a final answer to a decades-old question. Still, it may be disappointing to others who believe it is too ordinary and sterile. In the video’s comment section comparing the sped-up audio recording with the original, one user remarked, “I honestly prefer to believe in a creature, even if it’s not real.” People are intrinsically drawn to fantasies. After all, isn’t it alluring to imagine that humanity is on the cusp of a great discovery? A quote from the television show, Altered Carbon, goes, “Humanity has spread to the stars. We set out like ancient seafarers to explore the limitless ocean of space. But no matter how far we venture into the unknown, the worst monsters are those we bring with us.”

Humans are drawn to the unknown, and we seek out the ocean the way we do outer space, imagining creatures much grander and more frightening than we can handle. The Bloop itself is a story about researchers designing effective acoustic technology to learn more about the Earth and its processes. The lore surrounding the Bloop demonstrates humanity’s need for fantasy and novelty.
Evolution, Free Will, and Determinism

Nature Controls Our Morality.

Written by Long Ly
Illustrated by Sonoko Asaoka

If you believe in free will, then you believe in god. The notion of humans being autonomous agents is deeply rooted in every aspect of our lives. The backbone of our society, based on which all our societal structures and forms aspire to achieve, is ethics: determination of right and wrong, virtue and vice, justice and crime. Ethics assumes that human beings can act on or not act upon their thoughts. Using this principle, we as a society determine what we ought to do or not to do. However, such a fundamentally important assumption may need to be revised. From an evolutionary perspective, the construct we conjured called 'ethics' may have derived from natural selection.

Evolution by natural selection is the cumulative change in the characteristics of a population over several generations, brought about by adaptation to selective pressure. The term 'adaptation' mentioned does not mean an organism, throughout its life, changes to better survive through a situation, like learning how to run faster, where to hide when predators are out, and where to look for food sources. Adapting to selective pressure does not involve an organism consciously learning about the environment at all. Picture a population of rabbits living in a forest. Due to variation in the gene pool (that is, the full variety of genes present in an interbreeding population), some are brown, some white, some gray, and some black. Unfortunately, white rabbits stand out far more than their darker-fur counterparts, which can blend with the brown color of bark, making them highly susceptible to predators. The white-fur rabbits are frequently eaten and cannot mate with other rabbits. Thus the characteristic does not get passed down, and rabbits with darker fur can survive and reproduce, making the general population contain more dark-colored rabbits. Reverse the situation: a population of rabbits is living in the Arctic. White-fur rabbits can much more easily blend into their white, snowy surroundings, making them the more suited individuals to live in that environment. This concept is not unique to physical characteristics. Historically, sociable and empathetic humans who cared more for their relatives and partners likely had a higher chance of survival. Assuming that brain chemistry at birth partially determines behavior, selective pressures eliminated those less sociable or altruistic. Therefore they became less likely to breed and produce offspring to spread the undesirable gene. Thus, genes encoding for 'altruism' would have spread through our population, eventually developing towards a specific social structure. The influence of this gene traces further than just the early survival of humans: our intrinsic tendency to behave cooperatively and take care of relatives may well account for how we developed our society around a series of ethical principles for appropriate interpersonal interaction, reward,
or punishment. From this point of view, ethics is the deterministic result of human evolution rather than an intelligent, autonomous human choice. Our brains seem wired for morality, and our ability to tell what is "right" or "wrong" is due to the culmination of changes in the gene pool that lead to our current behavioral tendencies. Scientific research supports the existence of inherent morality. Babies are the subject of research in this specific area, as they have not been subject to much influence from the environment.

Psychological research on babies' development shows that babies tend to pay attention and respond to social stimuli (such as voices and faces) and begin forming social relationships early on in life. At only three months old, infants more frequently paid attention to puppets that acted 'nicely' rather than those that acted 'negatively.' While some studies focus on studying early human development to examine innate human morality, others do so by attempting to discover brain regions critical to human morality. Lesion studies are when scientists observe patients with specific brain lesions to see if they are associated with certain behavioral defects that the patients have. These studies helped to identify an area called the ventromedial prefrontal cortex, which is important for certain aspects of human morality. Damage to this region early on in life makes a person more susceptible to committing morally questionable acts like inflicting harm on others.

Our brains seem wired for morality, and our ability to tell what is "right" or "wrong" is due to the culmination of changes in the gene pool that lead to our current behavioral tendencies.

More than an example of natural selection, however, human morality is analogous to an example of determinism. Determinism states that, given how things are at time t, subsequent events are fixed as a matter of natural law. The way things are at a specific time can be explained by a culmination of things that happened before. You 'chose' to buy ice cream instead of frozen yogurt last Sunday and thought you had a choice. In reality, you were running before this, and because of that, your brain wanted something rich in carbohydrates to satisfy your energy needs. On top of this, your brain was conditioned to like ice cream because the ice cream was the only affordable dessert option when you grew up in a small neighborhood. Your 'choice' is a result of several previous events, which were a result of events before that.

Similarly, the law resulted from ethics, which, tracing back a very distant time, may have resulted from random life-or-death scenarios humans faced. And so, the concept of choices, actions, on a grander scale, ethics, and free will, can be explained by determinism: all things have a previous natural cause independent of 'choice.' On a smaller scale, molecules bump into each other predictably, leading to other molecules bumping into each other. If this is true, why should the law exist? If humans did not have control over their own actions, should they not be punished? In reality, this is already a problem. People with certain mental health disorders are not charged with certain crimes, as it is difficult to blame them for predispositions that are out of their control. Bipolar personality disorder (BD) is a prominent example. People with BD experience mood swings from mood elevation (mania) to depression. In severe manic episodes, they may experience psychotic symptoms, such as hearing voices, delusions, or hallucinations. Their attention, processing speed, verbal learning, and fluency are greatly affected. In these episodes, they may experience 'blackouts,' having difficulty remembering their manic episodes. Researchers have analyzed the genomics of people with BD to be compared to controls and were able to correlate 19 significant genes that may make a person more susceptible to BD. Thus, it is questionable to charge someone with bipolar disorder for murder when their 'normal' state is unaware of what they did when they were hyper-aggressive and stabbed their wife. It is also difficult to blame them for being born with a genetic predisposition that automatically makes them more prone to BD. Applying this to a broader spectrum, more than just neurological disorders, what if you cannot control your actions? We choose not to press charges against people with certain mental health disorders due to their inherent issues that can be traced physically. Then, having a particular set of personality traits and tendencies traced to the physical — due to inherent genetics and brain chemistry — absolves us of our actions.

Knowing the existence of such a possibility, I may not have control over writing this article; there may be no point in writing it. We may not have control over ourselves; it's all just a jumble of molecules. But there is much importance in the word 'may' — this article is by no means proof. Going back to the evolution of the morality line of reasoning, people who were more sociable and caring tended to live. That, however, does not automatically mean that our genetic predisposition determines the tendency toward morality - it is possible that, above the physical, the metaphysical allows for the existence of choice. All we can do is live as we are and act as if we have free will, whether we do or not.
It’s a Rat! It’s a Kangaroo! It… Smells?

Musky Rat-Kangaroo Populations in Northeastern Queensland,

Written by Caroline Lee, Clay Ritter, and Kristine Shaw
Illustrated by Leah Potoff

Even if you know nothing about the “Land Down Under,” you can likely still picture the iconic kicking marsupial creature to which Australia holds such established ties. While the musky rat-kangaroo might not match up to the “conventional” idea of a kangaroo, even the smallest (and smelliest) marsupial deserves some love.

Coming in at 50 centimeters long and 700 grams, the rat-like marsupial prefers to spend its time satisfying an omnivorous appetite rather than challenging its other kangaroo relatives in the ring. As a diurnal species, they emerge with the sun from their nesting spots on the forest floors of northeastern Queensland. In a hopping stride that resembles a bunny’s, they use all four limbs to move along dense vegetation that borders lakes and streams. The animal’s primary import is seed dispersal. Like the American squirrel, the rat-roos stash fruit around the rainforest floor for later use; however, most of their buried fruits are forgotten, which means the seeds can germinate and replenish the forest’s vegetation. You might be lucky enough to catch these shy creatures in the act of feeding or sunbathing on open logs, but many hikers will walk popular transects without any idea of their ecological importance.

As a diurnal species, they emerge with the sun from their nesting spots on the forest floors of northeastern Queensland.

While staying on the Atherton Tablelands in North Queensland, a group of 18 student researchers split into small groups to complete walking transects across three different locations: Chambers Rainforest Lodge, Lake Eacham, and Lake Barrine. The two lakes form Crater Lake National Park, a protected plot of complex vine rainforest. With Chambers Rainforest Lodge (The Chambers for short) just a short hike from Lake Eacham, all three locations are ideal for spotting the musky rat-kangaroo. The group trekked along the transects with a watchful eye and careful steps, maintaining a steady pace so as not to miss the subtle signs and sounds of a nearby musky rat-kangaroo.

Eager to catch a glimpse of this up-and-coming Aussie celebrity, camera traps were set up around the Chambers path over the three days of our hike. Three cameras were placed near fruit trees to catch the kangaroo scavenging for fruit, and three more were placed roughly 300 meters apart from each other to ensure the entire 1.3-kilometer route was covered. One of the cameras was placed near a stream adjacent to the path with the intention of catching a musky rat-kangaroo in action quenching its thirst or heading home after its morning snack at the nearby lemon aspen tree. We retrieved the trail cameras and found that we had not captured a single photo of a musky rat-kangaroo. Yet we were not completely disappointed; plenty of other wildlife showed up, including a blurry picture of an elusive dingo (the Australian analog of a coyote).

Fortunately, the hours spent strolling around lakes and taking in the natural beauty (the primary method of data collection) were more successful.. Lake Barrine rendered musky rat-kangaroo sightings in the double digits, which was a relief after walking our first transect and spotting zero rat-roos. Although we never doubted the value of our study, as any data is useful data, we had begun to lose hope that we would produce satisfying results. But on our final walk around Barrine, we finished with a total of five sightings, and we were not the only ones; the other groups’ work brought the total sightings at Lake Barrine to 24 musky rat-kangaroos. The Chambers and Lake Eacham sites paled in comparison, the former having a total of two sightings and the latter having one. This gave us the following rates of musky rat-kangaroo sightings: nearly six per three hours spent at Lake Barrine, just over one per three hours at Chambers, and somewhere around a quarter sighting per three hours at Lake Eacham.

To put that in perspective, a previous study in 2018 of Lakes Eacham and Barrine found the rates of musky rat-kangaroo sightings to be 81 percent higher than ours on average. But do not fear, for the musky rat-kangaroo might not disappear! Studies show that musky rat-kangaroo populations typically fluctuate because their population density correlates with their reproductive patterns, which depend on fruit availability. Musky rat-kangaroos strategically mate so that after their offspring are born, they will emerge from their mothers’ pouches during peak fruit availability. Conducting this study during September meant we were almost at peak fruit availability, but not quite there yet. Peak fruit season occurs in October, so all the joeys were tucked away in their mothers’ pouches, which caused the population to appear lower.

If we had repeated the same surveying process a month later, we might have totals much higher than the six individuals we could spot as a small group. A stable musky rat-kangaroo population is important for successful seed dispersal and thus rainforest regeneration. The rainforests in northeast Queensland are threatened by deforestation and climate change, so we need all the help we can get to encourage forest growth. With a hopeful outlook for the future of these Australian underdogs, we hope that readers will come to consider the musky rat-kangaroos as just as important and endearing as their nationally celebrated relatives.

As a diurnal species, they emerge with the sun from their nesting spots on the forest floors of northeastern Queensland.
Are Jellyfish Actually Apex Predators?

The Potential of a Jellyfish-Dominated Ocean Ecosystem

Written by Jackie Brick
Illustrated by Ellie Martin
n the last two decades, jellyfish have been grabbing headlines. The increasing size and duration of jellyfish blooms (large aggregations of jellyfish usually for mating) have been closing beaches, wreaking havoc on fisheries, clogging industrial water intakes, and even shutting down nuclear power plants. In the Philippines, on December 10th, 1999, 50 truckloads of jellyfish that had been sucked into the cooling system of a power plant completely shut down the entire northern Philippines power grid. In 2019, a mass stranding of blue bottle jellyfish invaded Australia’s northeastern shores. This incident left 3,595 people with burning stings and painful welts and caused widespread beach closures. The causes of increasing jellyfish bloom intensity and what it means for ocean ecosystems are far from clear.

It is easy to see the devastating effects of human activity on our oceans as commercial, wild fish populations plunge, the coral bleaching leaves ghostly white graveyards, and eutrophication (excessive richness of nutrients in a body of water, usually due to human activity) creates ‘dead zones.’ There is so much focus on what we are destroying the question of what we have an equal hand in creating is often overlooked. Within nature, present destruction is usually a last act of creation. Each mass extinction event in Earth’s history is later preceded by a period of rapid species diversification as previously filled niches become available. According to some scientists, we are presently in a sixth human-caused mass extinction event. As ecosystems change, jellyfish seem ready to fill in the gaps.

The recent increase in the size and duration of jellyfish blooms is seen as a kind of canary in the coal mine - a symptom of an ocean in distress. However, in this case, the canary is a jellyfish and has caused millions of dollars of commercial damage. Jellyfish have been shown to thrive in many conditions associated with human-driven ecosystem change; lower O2 levels, warmer temperatures, eutrophication, and overfishing have all been associated with increases in jellyfish populations.

Jellyfish have been around for approximately 600 million years and are considered potentially the first multicellular ‘animals.’ Some researchers have started to speculate that the future of our oceans may be jelly-dominated. The theory suggests an alternative second food web called the jelly web or a ‘low energy’ food web constantly operates alongside what we would call the normal/high energy food web and represents a fundamental shift in how energy within an ocean ecosystem flows.

What we typically think of when it comes to the ocean is a high-energy food web. Phytoplankton (tiny photosynthetic organisms) are eaten by copepods (small zooplankton), which are eaten by krill, which are eaten by fish, which sharks, seals, and other high-energy predators eat. Each level of this food web represents larger, more energy-dense organisms. In a jelly web, on the other hand, phytoplankton are still eaten by copepods but are then consumed by jellyfish, and larger jellyfish consume those jellyfish. This web is fascinating because it is, in some ways, upside-down. Jellyfish consume ounce-for-ounce, energy-dense food sources but are a nutrient-poor food choice since they are 98 percent water, leading to a kind of ecological dead end that only supports hunters that exert little energy catching prey. While new research suggests that jellyfish may be an important food source for some penguins, fish, and turtles, it is reasonable to assume they cannot be the primary food source for high-energy predators.

Usually, these two food webs coexist and fluctuate seasonally, but human disturbances push ocean ecosystems toward a jelly web. Whether an ecosystem will be a high-energy web or a jelly food web starts at the very bottom of the food web, with what type of phytoplankton (tiny, microscopic plants) are present. Diatoms are microscopic unicellular algae that create glass-like capsules made of silicate, a naturally occurring mineral in the ocean, and are the basis of a high-energy food web. Flagellates, a different type of phytoplankton, are smaller and make no capsule but have flagella, long, whip-like tails that allow them to swim. Copepods will preferentially consume large diatoms to small diatoms or flagellates. Fed on a diet of large diatoms, copepods will grow larger and become easier prey for higher energy predators like small fish that hunt by sight, which are eaten by larger fish and support a higher energy food web. If copepods eat flagellates and remain smaller, they will be far better prey for jellyfish, which hunt passively, do not rely on sight, and expend little energy on movement - leading to an ecosystem dominated by jellyfish.

Many human activities are promoting conditions more favorable to flagellates and, therefore, jellyfish. Eutrophication, a major type of human pollution mentioned above, has led to excess nutrients, e.g., nitrogen, and low oxygen levels in coastal areas. This excess nitrogen also favors the proliferation of flagellates over diatoms, as the amount of silicate available in the water limits diatom growth. So diatoms do not benefit from the excess of nutrients. Flagellates not only exploit these nutrient pollutants to grow in mass quantities but are far more tolerant of lower oxygen levels as they can propel themselves to more oxygenated water, whereas diatoms generally sink and die. Combined with the fact that jellyfish are also tolerant of oxygen-poor environments, they have been doing exceptionally well in coastal regions, where they are causing the most trouble.

When flagellates bloom, they do so rapidly. This favors jellyfish fish proliferation as the jellyfish life cycle is highly adaptable and can rapidly increase in population to take advantage of these blooms. Other species, like mammals, require regularity of food sources as they have slower, less adaptable life cycles and generally put energy into raising a few offspring rather than putting little energy into raising many offspring. This means that jellyfish populations can rapidly adapt to changing conditions more quickly and take advantage of increasing flagellate blooms.

While this theory is relatively new and still in its scientific infancy, it is well worth considering the future ecosystems human activity in the Anthropocene is creating - and the potentially key role jellyfish will play in that future. Jellyfish have been around for approximately 600 million years and are considered potentially the first multicellular ‘animals,’ mindlessly drifting through the millennia. There is a beautiful irony in jellyfish, a mindlessly floating, gelatinous organism, inheritting a world polluted by human’s overproductivity.

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November 2022
**Did Trees Cause the Devonian Mass Extinction?**

*Root Evolution and Hypoxia*

Written by Isabelle Small  
Illustrated by Maya Akazawa

Mass extinction events have occurred five times in Earth’s history. Each time, catastrophic global conditions resulted in the loss of hundreds of species and countless individuals. The second extinction event occurred at the end of the Devonian Period (416 to 359 mya). It resulted in the loss of 60 percent of Earth’s total genera and 40 percent of its marine families. Low temperatures and oxygen depletion (hypoxia) are theorized to be the causes of this extinction, but it is still highly debated what produced these two conditions. However, a new study published on November 9, 2022, in the Geological Society of America bulletin suggests a mechanism to explain the deadly hypoxic waters that caused the extinction — the evolution of land plants, specifically trees.

The Devonian Period was characterized by the intense evolutionary transformation in which many organisms underwent massive physiological changes. For example, the first jawed fishes developed. At this time, all animals still lived solely in the ocean. Before the Devonian, the only life lived on land were small, soft, leafless plants lacking root systems. At the dawn of the Devonian, an immense diversification in land plants allowed them to take advantage of new niches, including developing vascular tissues and roots. In the Middle Devonian, plants started to move into the continental interiors, and trees began to evolve with their deep, complex roots.

**Before the Devonian, the only life lived on land were small, soft, leafless plants lacking root systems.**

When researchers from Purdue University and the University of Southampton looked into the causes of the Devonian extinction, they found that the evolution of plant roots caused large amounts of nutrients to be transported into lakes, causing an overgrowth of algae that depleted the oxygen of surrounding ecosystems. Researchers looked at sediments that accumulated during times of extinction in the Late Devonian that were in or near some of the characteristically large lakes. They looked at five sites, two in Greenland and three in Scotland, where they collected five to ten-gram samples from rocks containing sediment layers or sequences that showed evidence of depositional cycles. Powders from the samples were then tested for concentrations of phosphorus, aluminum, calcium, titanium, iron, copper, chromium, molybdenum, nickel, lead, rubidium, silicon, strontium, uranium, zirconium, total inorganic carbon, and total organic carbon, but they primarily focused on phosphorus. The researchers then used elemental ratios to determine phosphorus concentrations, terrestrial phosphorus delivery levels, weathering intensity, grain size, temperature, and humidity at the deposition time. In the end, they concluded that the climate during the Devonian was characterized by cycles of arid and wet conditions during which there was extensive weathering and transport of nutrients, like phosphorus, to the lakes.

They predicted that these wetter periods created ideal conditions for tree growth, prompting increased root development. To access nutrients, roots release acidic compounds into the soil to break down surrounding organic matter. This process releases phosphorus, an essential limiting nutrient, into the soil. Because it has no natural gaseous phase, it can only be accessed through the soil. However, despite its rarity, phosphorus holds a crucial role in the growth of all organisms. Phosphorus is the central player in producing energy in the form of the ATP molecule, which is required for cell function. As a result, if any organism receives considerable input of the element, it will be able to grow and reproduce more rapidly. While phosphorus is normally accessed gradually, it can be released at an increased rate in other conditions. Studies of ecosystems recovering after volcanic eruptions found that large amounts of phosphorus are liberated from the soil during early colonization of the substrate. This corresponds with an increase in algae and hypoxia when the lake floor and decompose, a reaction that consumes oxygen, rendering the water hypoxic and killing off organisms that require it for survival. Therefore, the evolution of trees very well may have been a significant player in the Devonian mass extinction, perhaps the root cause.

All puns aside, these results are not a conclusive explanation for the Devonian extinction. Nonetheless, they get us one step closer to understanding how it started and how to prevent something similar from happening soon. Today, runoff from agricultural fertilizers brings excess nutrients to water bodies worldwide. As in the Devonian, this input causes eutrophication which has disastrous effects on our ecosystems. These algal blooms cause millions of dollars of damage a year and can be lethal to humans and pets. The Devonian should be taken as an example and take action before it is too late. • • •
Have we Found the Key to Sustainable Farming?

Microbial Communities and Crops

Written by Michael Eddy Harvey
Illustrated by Ophelia Jackson

Here is no doubt that the United States agriculture system is not perfect. From monoculture to workers rights to the use of fertilizers, it is clear that there needs to be a change in the practices that are currently implemented for U.S. farming.

For fertilizers, in particular, which are heavily used in agriculture, half of their nitrogen is lost to the environment leading to eutrophication, water and air pollution, and hypoxic dead zones. The loss of nitrogen on this scale is detrimental to the fight for environmental protection. Furthermore, farmers lose, on average, $200 billion each year as a result of nitrogen loss and pollution. Fertilizers as we know them need an overhaul both environmentally and economically. Microbial communities may be the key to making such changes.

Microbes and microbial communities are complex and emerging areas of biology. Furthermore, soil microbes have recently taken center stage in sustainable farming. The microbes are called diazotrophs – bacteria that are classified as having biological nitrogen fixation (BNF). In short, the necessary steps to incorporate BNFs into farming would be to simply place it in the soil. When fertilizer is applied, the microbes bind to the nitrogen in the fertilizer, converting it to a more usable substance like ammonia, which benefits the soil. This would subvert the negative ecological effects as the nitrogen would not leach out into water and other environments. Furthermore, farmers would not have to spend as much money on fertilizers. Currently, research being done on the application and use of diazotrophs uses cereal crops as the model organism. A recent study, Enabling Biological Nitrogen Fixation for Cereal Crops in Fertilized Fields, explores the relationship of diazotrophs and cereal crops. If these microbes are so great and are beneficial to the environment as well as farmers’ profits, why have they not been used yet? There are a couple reasons. The main one being that a majority of these BNF diazotrophs operate in low nitrogen environments. They activate their nitrogen fixation whenever there is a lack of nitrogen. During a study at the South Dakota State University, they measured the wheat with four different nitrogen applications: zero pounds, 50 pounds, 100 pounds, and 150 pounds. Nitrogen fixation is very energetically taxing for the bacteria because it requires a lot of ATP. As a result, diazotrophs tightly control when they fix nitrogen as it is not prudent for them to do it often. Finding these bacteria that fixed nitrogen in high-nitrogen soil proved to be especially difficult. It was found that the number of BNF diazotrophs found was significantly less when more nitrogen was applied. Unfortunately, most crops are bred in high-nitrogen soils, which causes several issues. However, the use of genetic editing is a solution to the problem.

Since BNF diazotrophs found in high-nitrogen environments are scarce, they need to be genetically altered. A contributing explanation for the recent uptick in soil microbial research is that the technology to genetically alter microbes is available. In the ACS research study, they took a bacteria that was operating in a high-nitrogen environment, Klebsiella variicola, and genetically altered it. The DNA was changed so that it would activate and fix nitrogen even if it was in a high-nitrogen environment. Wen and Havens found increased nitrogen fixation activity by 122-fold when compared to its wild-type counterpart. Overall, though this process is time consuming and extremely complicated, the results support that this method still produced high yields for crops and it minimized nitrogen loss. In fact, Wen and Havens believe that the use of BNF diazotrophs could create a great shift in agriculture, as the Haber-Bosch process did over a century ago. The Haber-Bosch process converts nitrogen to ammonia and led to the global use of fertilizer and a spike in crop production. The microbes’ possess a remarkable ability to be edited and sold to farmers.

Though great progress has been made, further studies need to be conducted in order to fully implement this new technology and method. There are currently very few peer-reviewed studies surrounding nitrogen-fixing soil microbes. An explanation as to why so few articles have been published is because gene edited microbes that operate in high-nitrogen environments carry the risk of being susceptible to human pathogens. In order for these microbes to be released, there needs to be extensive biosafety parameters for future experiments. Furthermore, it is a new method of farming that will naturally be met with resistance and skepticism. However, despite the risks, this emerging field of biology has fascinating possibilities for sustainable farming and agriculture in general. If we can ensure that using these microbes are safe and efficient, there is a bright future for agriculture around the world.
In the winter of 2017, I gazed through the window into a field of nothing as the car thumped along the cracked cement roads. The soil in the field looked as if many small fault lines had fractured it, like how a mirror cracks. This was a weird sight to witness. Just last year, the road to my great-grandparents’ grave was filled with rich yellow rice crops, something I called edible gold. But this year, through the same window, on the same road, and on the same day, there was no gold in sight. Years later, I would learn that the broken soil was an effect of climate change—the lack of rain had caused a severe drought.

Every action in modern society has, to a degree, a consequence that either contributes to or mitigates climate change. For example, a cyclist’s decision to ride a bike instead of driving a car to work saves about 21 grams of carbon dioxide emissions per kilometer—that is 420 fewer grams of carbon emitted if you traveled from work back and forth for 10 kilometers. Nevertheless, individual actions are not the only contributor to greenhouse gas emissions. Large corporations are also culprits in climate change. For example, apple growers emitted about 23.2 million metric tons of carbon dioxide into the atmosphere in 2021. To put that into perspective, that is about the same amount of emissions as if the person mentioned above would travel to work and back 150 times a day every day for a year.

According to an article published in The Guardian, about 71 percent of all carbon dioxide emissions come from only 100 companies.

According to an article published in The Guardian, about 71 percent of all carbon dioxide emissions come from only 100 companies. With that in mind, the solution seems clear: stop using the products from these 100 companies, and the majority of emissions will disappear. Of course, the problem is not that simple. These 100 companies are rooted deeply in our lives because of daily tools like clocks and different facets of transportation, such as...
subways and cars. So, how can we, as individuals, work together to pursue a collective solution to climate change?

There are several problems when it comes to collective action. There are only two ways for collective action to happen: one, for someone with authority to force a mitigating action onto a group of people, and two, for like-minded individuals to form a collective voice and pursue a goal. Both methods come with caveats.

The first method may be easier and more plausible — elect an eco-friendly president. But it is in human nature to want to do things that require less effort and are simple. Because we as individuals in the 21st century are accustomed to this type of simple lifestyle – authoritative changes may create fear and pushback. Thus, fearing the public goes against an authoritative figure in a democratic society, creating a conflict of interest. Hence, we see very slow and often minuscule changes to our environmental laws. The main reason environmental laws fail is that the law often sets unreasonable expectations. An article published by the William and Mary Law and Policy Review titled Why Environmental Laws Fail mentions that “laws use an unrealistic model for humans.” For starters, laws can be anthropocentric, lacking perspective. In addition, these laws often expect humans to go out of their comfort zone, which goes against human nature.

Laws that encourage and incentivize sustainable habits could be greatly effective. For example, subsidizing the purchase of electric vehicles, as an alternative to gas-powered cars, has created an upshoot of electric vehicle purchases globally. In addition, creating long-lasting and effective public transportation infrastructure and incentivizing walking, biking, and the use of transit may discourage widespread car dependency.

The second approach is hard, but arguably the most sustainable and concrete solution. Every individual has different priorities. It can be challenging to place climate change on our list of personal priorities alongside family, friends, or careers; this is why it’s important to make climate change a personal problem.

A phenomenon called the tragedy of the commons — where a shared resource can be depleted when individuals are incentivized to act selfishly — could illustrate the importance of personalizing climate change.

In developed countries, the effects of climate change sometimes are not as severely felt. If the summer is too hot, some people can power on their air conditioning systems or drive to someplace cooler; if the winter becomes too cold, they can travel to a warmer region or put on another piece of clothing. But, for people in developing nations like Bangladesh and Haiti, the resources to deal with climate change are often scarcer. Citizens in these developing countries can feel the effects of climate change, like unprecedented extreme weather and sea level rise, first and most severely. Even though these countries contribute significantly less to climate change, they are the ones that end up the most devastated.
Dosi Weed is a

I actually created this for an old issue of Synapse! The article this was for was about the ILOVEYOU virus and human psychology, and I couldn’t resist the urge to draw some brains. This design didn’t make it to the final composition, but I still really enjoy the composition.
This was created during a summer internship in Konstanz, Germany where I spent 3 months working in a collective behavior lab. The “big picture” of my research was discerning how the startle response of a single insect could propagate through a swarm of thousands; it was hands-down some of the coolest.

Unlike the Anchiornis piece, this illustration of a juvenile Parasaurolophus isn’t based on a specific holotype—rather, it’s a bit of speculation inspired by the book Locked in Time, which had a chapter about fossil evidence of death during river crossings which stuck with me for too long to not draw something related to it.
The Synapse

Wacky Weather:

Climate Change Impacts on Ohio’s Most Important Crop: Corn

Written by Sydney Rosensaft
Illustrated by Orion Pendley

Corn, one of America’s most prolific and Ohio’s most beloved crops, will fare poorly in the dry growing seasons that come with climate change. Higher global average temperatures will lead to extended growing seasons, changing rainfall patterns, and causing extreme flooding and droughts, thus negatively affecting agricultural production. Corn is susceptible to heat when soil moisture is low, which is a direct effect of a hotter atmosphere. Climate scientists at Ohio State University estimate that on the current climate change trajectory, corn yields in Great Lake states like Ohio and Indiana could decrease 20–30 percent by 2049 and 40–80 percent by 2090. This decline in corn production would have direct effects on farmers and the agricultural landscape and the global food supply. Soil moisture’s impact on corn growth was examined by scientists Jaehyuk Lee and Nazif Durmaz in a study estimating the elasticity of corn production—a measure of how sensitive corn is to temperature and precipitation. By assigning a numerical relationship to corn, temperature, and precipitation, they calculated that more soil moisture leads to a two to ten percent increase in corn production, which translates to about three to fourteen bushels per acre. On the flip side, drier soil will lead to a decrease in corn production. They then used a range of global temperature predictions by the Intergovernmental Panel on Climate Change to estimate how severely corn production will decrease in the coming years. Best-case scenario, the global temperature is predicted to increase by one degree Celsius during the growing season, which would only decrease corn production by 15 bushels per acre. Conversely, a six-degree Celsius increase might decrease corn production by 91 bushels per acre.

The results showed that overall, from 1996–2008, the corn yield increased for sub-irrigated fields by 20.5 percent compared to free drainage fields.

Extreme precipitation wreaks just as much havoc on agricultural systems as droughts. The excess water can drown plants and cause stress. Heavy rain also naturally produces more runoff, causing more nutrients to leach the soil and depriving plants of crucial minerals. These minerals are then carried off to larger bodies of water, altering the chemical makeup of marine ecosystems. An example of this alteration is Lake Erie’s massive harmful algal blooms after phosphorus-rich runoff enters the water.

This meaningful relationship between drought and heavy precipitation happens more often than we think. Researchers at Princeton University found that in the last 70 years, eleven percent of droughts globally have been followed by at least one heavy precipitation event within the next three years. The exact link between these extremes is not entirely clear, but researchers have a faint idea: Warm air leads to higher soil evaporation rates, drying it out and causing droughts. At the same time, warm air encourages more evaporation from the oceans. The air, thick with moisture, makes its way to land and dumps the water all at once, causing intense precipitation.

Fortunately, there is a way to take advantage of this wacky cycle of extreme events to help the agricultural field adapt to climate change. It is done through sub-irrigation technology. Sub-irrigation systems capture excess water from heavy storms, filter it, and store it. Later, when the soil is dehydrated during dry growing seasons, the stored water is routed to crops for proper hydration. This water management strategy both alleviates stress from excess moisture in the soil and supplements the lack of water in growing seasons.

Sub-irrigation technology has proven successful in improving corn production during dry growing seasons. A research study published in the Agricultural Water Management journal aimed to measure the increase in corn crop yields using sub-irrigation technology. Researchers observed three crop sites with sub-irrigation technology over a 13-year field study. To establish a control, they looked at fields with free drainage and conventional subsurface drainage pipe systems where the outflow is unrestricted. The results showed that overall, from 1996–2008, the corn yield increased for sub-irrigated fields by 20.5 percent compared to free drainage fields. Applying this to future projections for 2041–2070 climate conditions in Northwest Ohio, researchers predicted that with sub-irrigation technology, farmers could raise their corn production 27.5–30.0 percent compared to if they did not install sub-irrigation systems.

Other studies have examined similar results regarding sub-irrigation crop yields. In Southwest Ontario, a 31 percent corn yield increase was seen when using sub-irrigation practices instead of free subsurface drainage. In Missouri, corn grain yields increased by up to 50 percent. Overall, research has concluded that sub-irrigation systems are a highly effective climate adaptation strategy, and these systems have the added benefit of improving water quality through filtration. This purifies the water that plants receive from this system during dryer seasons. It also prevents nutrient runoff downstream, which mitigates damage to lakes.

Adopting a strategy like sub-irrigation technology is vital for both farmers and the average person. From a farming standpoint, farmers’ livelihoods and job retention can be negatively affected as climate change inhibits corn production. Sub-irrigation technology can boost their businesses and allow them to maintain their livelihoods. From a broader perspective, global food chains and supplies are likely to be disrupted due to these predicted drops in corn production. This might inflate prices, exacerbating issues regarding food insecurity and the wealth gap. With an ever-growing global population to feed, it is essential to implement an adaptation strategy before the climate issue grows larger than corn production.

Illustrated by Orion Pendley
A mou Haji, a hermit from Iran who held the title of “world’s dirtiest man,” passed away earlier this year at age 94, mere months after taking his first shower in decades. Haji claimed to have avoided bathing for fear of getting ill. He managed to go over 60 years without using soap, breaking his streak only when villagers washed him.

While extreme, Haji’s embrace of the grime world represents a far-neglected aspect of immune strength: soil. Soil hosts an ecosystem of probiotics that can strengthen the microbiome, a part of the immune system found in the skin and gut. Although some people swear by hand sanitizer and flaunt their stubborn germaphobia, avoiding soil’s immune-boosting properties can perpetuate a weaker immune system by stripping away a protective microbiome layer.

This microbiome is the collective mixture of protective bacteria, protozoa, and fungi that live within the human body. While human cells cannot typically change their genes, the organisms making up the microbiome can swap genes with the harmful and protective bacteria that increase their resistance against disease. This cocktail of organisms in the microbiome assists with bodily functioning. It provides humans with a fully-staffed immune system, as their supplemental genetic material aids digestion, protection against harmful viruses, and vitamin extraction necessary for blood coagulation.

Bacteria are one of Earth’s oldest organisms; since mammalian genomes have constantly been exposed to these bacteria, they never needed to be independent. This relationship is understood under the “Old Friends” hypothesis: the theory that the constant presence of bacteria allows mammals to build their microbiomes after birth. This would be evolutionarily advantageous to the mammal by enabling them to construct an environment-specific microbiome that protects against specific conditions. In this instance of evolved dependence, bacteria, and mammalian cells share an endosymbiotic relationship where an organism lives

Soil Salvation
The Antidepressant Properties of Dirt

Written by Ania Ocasio
Illustrated by Megan Tiffany

He managed to go over 60 years without using soap, breaking his streak only when villagers washed him.
inside or on its mutual partner. The University of Washington Center for Ecogenetics and Environmental Health describes the organisms that make up this microscopic world as "not invaders but beneficial colonizers." The human microbiome is a defense against harmful illnesses and is essential in maintaining homeostasis. Habits like over-showering can be counterproductive to avoiding sickness, for they can disrupt the microbiome and throw the body’s immune system into a state of imbalance. Hygiene is critical for preventing sickness, but only within reason; over-cleanliness eradicates harmful bacteria along with the good.

Whether Amou Haji’s death coming months after his first shower in decades is correlated with microbiome health, the longevity of his life goes to show that dirt certainly did not harm him. Haji’s bathing avoidance was considered a coping mechanism for childhood troubles, and his solace in dirt points to the healing properties of soil. Soil is packed with bacteria called Mycobacterium vaccae that can trigger the production of serotonin: a type of neurotransmitter released by our brains that ease anxiety and symptoms of depression. On top of improving mental health, M. vaccae has also been found to improve immune system functioning and minimize symptoms of diseases like cancer and arthritis. Even our Midwestern region hosts communities that wield this immuno-resilience from dirt. An American Academy of Allergy, Asthma, & Immunology experiment found that Amish children living on farms have a 50 percent less chance of developing autoimmune diseases like asthma, allergies, and digestive disorders than children who grow up in more hygienic environments.

The miraculous effects of this bacteria were discovered by cancer scientist Dr. Mary O’Brien, who initially administered a serum of M. vaccae to lung cancer patients to boost their immune systems. Not only did their immune strength improve, but Dr. O’Brien also observed a noticeable increase in the happiness and pain relief in patients that were exposed to the bacteria. To further examine these findings, a team of researchers led by Dr. Chris Lowry from Bristol University tested the effects of Mycobacterium vaccae on mice. They hypothesized that M. vaccae improved mood because it released serotonin. Serotonin has been correlated with improved cognitive functioning and happiness at balanced levels. Dr. Lowry’s team tracked serotonin levels by measuring c-Fos, an amino acid released when neurons fired. Higher levels of this biochemical marker were found in the dorsal raphe nucleus, a part of the brain, and the gastrointestinal tract. Both of these areas are responsible for serotonin production. After exposure to M. vaccae, the mice in Lowry’s experiment appeared more relaxed. The tea concluded that exposure to the M. vaccae bacteria increases serotonin levels.

While serotonin is produced in the brain and gut, most are produced in the gastrointestinal tract, which hosts part of the body’s microbiome. The microbiome is vital to immune system function because its medley of bacteria helps defend against disease. As a neurotransmitter, serotonin’s job is to improve intercellular communication between the brain and the body. The brain gives the body directions on how to function, and an increase of serotonin aids in the reception of these directions. Therefore, the presence of serotonin in the gut effectively increases the functioning of the immune system by assisting in communication between the microbiome and the brain. M. vaccae increases the immune system’s strength because it triggers the production of serotonin, which allows for microbiome-brain communication.

| The human microbiome is a defense against harmful illnesses and is essential in maintaining homeostasis. |

Like serotonin increases the strength of the microbiome, the microbiome can increase the production of serotonin. The microbiome accounts for gut functioning, producing 90 percent of the serotonin in the human body. If an excess of antibiotics or over-cleanliness weakens the microbiome, serotonin production can drop. In this way, a strong immune system leads to improved mental health, and, conversely, how improved mental health can lead to a stronger immune system.

M. vaccae also increased serotonin levels in the prefrontal cortex, a part of the brain that controls mood. The prefrontal cortex creates the hormone corticosterone, released under the same feelings of stress that serotonin helps mitigate. The corticosterone hormone has also been found to suppress the function of T-cells and white blood cells, which account for immune strength. This symbiotic relationship between serotonin and the immune system demonstrates the importance of protecting the microbiome. Serotonin supports immune system functioning, which, in turn, supports serotonin production: a synergy dependent on the strength of the microbiome.

Soil is rich with Mycobacterium vaccae, and by getting your hands dirty, you too can improve your immune system and feel the antidepressant effects of this remarkable bacteria. Whether it be the joy a gardener feels after spending an afternoon in their backyard, the relaxation of the mice in Dr. Chris Lowry’s lab, or the long life of the dirtiest man in the world, everyone should take advantage of the miracles of soil.
Do Sleeper Cells Hold the Key to Immortality?

Senescent cells in cancer and aging.

Written by Kristin Aldridge
Illustrated by Orion Pendley

All organisms experience life and death, but what if you could find a way to shut down for a few years and wake up the same age and with the same memories as you had before? This is what senescent cells do. Senescent cells stop multiplying but remain viable, essentially “going to sleep,” sometimes for years, to be reactivated in the future. Some researchers believe senescent cells hold the secret to immortality and longevity. Others seek ways to use them in cancer research. The field is just starting to develop, and the possible implications of senescence could hold for the future of human healthcare is ever expanding.

Senescence cells were discovered in 1961 by doctors, Leonard Hayflick and Paul Moorhead of the Wistar Institute of Anatomy and Biology in Philadelphia, Pennsylvania. Dr. Hayflick and Moorhead discovered it when the serially subcultured human embryonic fibroblasts (connective tissue cells) they were working with lost the ability to replicate but were still viable. They termed these “senescent” cells. Very quickly, two hypotheses emerged about their discovery. The first is that these cells are anti-cancer and tumor-suppressive. Activities such as DNA damage caused by chemotherapies can move cells into senescence, eliminating the chance of uncontrolled cell proliferation (a hallmark of tumor growth) and decreasing the chance of accumulating gene mutations. The second hypothesis is that these cells are pro-aging. Since tissue regeneration slows down as we age and cellular repair decreases, they determined that the accumulation of senescent cells was the reason for this. Over time, these two schools of thought came together to create an overarching picture of cellular senescence and how it can be harnessed to better human healthcare.

The accumulation of senescent cells has also been correlated with aging, and the pro-inflammatory secretome may play a part in many age-related diseases.

Cell senescence during tumor formation sounds ideal, but unfortunately, these cells continue releasing chemicals that trigger inflammation, a common indication of cancer. The accumulation of senescent cells has also been correlated with aging, and the pro-inflammatory secretome may play a part in many age-related diseases such as osteoporosis, cardiovascular disease, and declines in eyesight, mobility, and thinking ability. Being able to eradicate these cells after they reach senescence would be an ideal treatment in addition to the chemotherapies and radiation that patients typically receive. It would also help reduce the accumulation and risk of diseases in aging patients.

So, how can we use senescent cells to our benefit without incurring their risks? The key to this is what research scientists are calling the “one-two-punch” treatment. For people with cancer, first hit the tumor cells with radiation and chemotherapy (first punch), then hit the tumor again with senotherapeutic compounds, which are compounds created to kill senescent cells (second punch). Senotherapeutics block secretory expression, a collection of pro-inflammatory cytokines, tissue remodeling proteins, and inflammation. Since tumors are heterogeneous or diverse within cell populations and between tumors, examining the genetic and molecular profile of the tumor after treatment is key to creating an effective second punch of senotherapeutics. Being able to deliver a treatment that targets the major signaling pathways of the senescent cells in a patient’s particular tumor will create a more profound and overarching impact and eliminate a higher number of senescent cells. These second-punch treatments may need to be repeated over the course of months or years because senescent cells sometimes become reactivated and signal to their neighbors to become damaged again or proliferate, leading to tumor recurrence. This one-two-punch treatment, however, is only beneficial for cancer therapies, and further research will need to be completed on targeting other diseases, such as neurodegenerative or mobility and eyesight diseases.

We can also harness the use of senotherapeutics for aging or age-related diseases. Since unresolved clearance of senescent cells and their secretory phenotypes can result in changes to the tissues and organs characteristic of aging, being able to target and eliminate them from specific areas would greatly reduce the risk of disease. One example is in skin aging, where DNA damage from the sun accumulates in cells in the epidermis and dermis of the skin. This can lead to inflammation, fibrotic changes, and fat atrophy causing wrinkle formation and possible melanoma. Senolytics, which selectively kill senescent cells, and senomorphics, which rejuvenate senescent cells, are both treatment types that should be analyzed depending on the therapeutic aim. Senolytics do not have the ability to tell which senescent cell types they are targeting, some of which may be beneficial. Senomorphics may require repeat applications and may retain some features of aging. These therapies are still in pre-clinical trials and need further exploration before developing into human treatments.

Overall, senescent cells exhibit positive and negative impacts, depending on what stage you are in your life. They are positive for reducing tumor growth but negative because they can increase inflammation and are associated with age-related diseases. This research avenue is still in its infancy and has a long way and many trials to go before being marketed to the public. For now, discovering the intricacies of senescent cells and targeting them more completely with senotherapeutics, especially in cancer treatment, would bring scientists a long way in understanding the potential therapeutic use of these cells.
"he rats don’t run this city, we do,” Jessica Tisch, the commissioner of the New York City Department of Sanitation, said during a news conference mid-October about the city’s rat invasion issue. Humans have long thought that because we are smarter, we are far more complex than other creatures on Earth. We know that animals such as birds and bees can recognize and respond to songs. Until a couple of months ago, we believed that humans were the only species that could syncopate to music as a natural instinct. However, a new study reveals that rats can also bop their heads to a musical beat. A study at the University of Tokyo included ten humans and twenty rats. It studied the position of downbeats (beats one, two, three, and four) in songs with a 4/4 time signature. Researchers created several hypotheses for this study. The scientists first hypothesized that movement is based on perceived physical time. 13.8 rat days is the equivalent of one human year for aging, which meant that rats would bop to faster songs than humans because they generally move faster. It was also hypothesized that syncopation is delivered through a fixed time of processing in the brain. This suggests that humans and rats would bop to the same beats per minute (bpm). They later found that the highest stimulation of the brain and dancing that was most present in both humans and rats was between 120 and 140 bpm.

Rat subjects had electrodes implanted into their heads to measure neural activity and wore wireless accelerometers on top of the electrodes, showing brain activity whenever music played. Out of the 20 rats, seven were used to test music stimuli, nine were used for rhythmic (metered) click sequences, and five were used for random click sequences. The rhythmic clicks were played for 15 seconds, whereas the random ones had five different millisecond intervals, each with a probability of 50 percent over five minutes. Researchers first played one-minute clips of Mozart’s classic Sonata in D Major for Two Pianos (K.448) at four different tempos: 75 percent (99 bpm), 100 percent (132 bpm), 200 percent (264 bpm), and 400 percent (528 bpm) of the original speed, with one minute of silence between each tempo. There was also a playback speed of 300 percent (396 bpm) for the electrophysiological experiment to test conditions.

Afterward, they played more modern and groovy songs like “Another One Bites the Dust” by Queen (114 bpm), “Billie Jean” by Michael Jackson (117 bpm), “Born This Way” by Lady Gaga (124 bpm), and “Sugar” by Maroon 5 (124 bpm). For 45 minutes, each song was played twice in random order. After collecting video recordings of the rats’ reaction to the music, researchers went back in with software for animal pose estimation to measure the displacement of the rats’ bodies, examining the eyes, nose, ears, neck, and tail of each. Researchers also measured the rate of change in acceleration, also known as a jerk, of the rats’ heads rather than acceleration. The researchers also recorded some human participants and measured displacement with an accelerometer tracked by a Python code and red marker. Displacement and jerk were fitted to a mathematical model to look at neural activities (beat contrast, multi-unit activities, and interstimulus intervals).

The results demonstrated that rats had the most spontaneous syncopation and movement for songs with a playback speed of 120-140 bpm. Within a short timeframe, rats could quickly find the pulse of the music and move to it. Researchers discovered that movement is determined by the time constant of neural dynamics, which supports the second hypothesis that music is on a fixed time. This explains why the rats also acted similarly to humans synchronizing – bopping their heads to the downbeat of the song. The optimal playback speed range also encompasses the most frequently used tempos in music composition, further proving that synchronization is innate in animals. When analyzing the predicted versus randomized clicks, the time between one stimulus to the other was 200 milliseconds for predicting movement in the auditory cortex. After the 132 bpm mark, jerks decreased, showing less movement to the beat. This poses a question of whether or not syncopation in rats is reactive, responding to the music as it goes along, or predictive, foreshadowing where the next downbeat of the song will be.

During the press release from the University of Tokyo, Professor Hirokazu Takahashi, head of the study, further explained his findings.

“Music exerts a strong appeal to the brain and has profound effects on emotion and cognition,” Takahashi said. “To utilize music effectively, we need to reveal the neural mechanism underlying this empirical fact. ... Our results suggest that the optimal tempo for beat synchronization depends on the time constant in the brain. This demonstrates that the animal brain can be useful in elucidating the perceptual mechanisms of music.”

This is just the beginning of much more research to come about studying animals and their intuitive relationship to music. There could be more species out there that have this same pulse instinct as we do. After all, the rats don’t run this city quite yet.
In recent years, meditation has become incredibly trendy in the West, inspiring the production of documentaries, books, classes, and instructional YouTube channels. However, meditation has existed for thousands of years, with the earliest records dating back to 1500 BCE. Meditation formed an integral part of the Chinese Taoist and Indian Buddhist traditions and later spread to other parts of Asia and eventually to the West due to colonialism. Despite its long history and eventual widespread influence, an understanding of the neural mechanisms behind the benefits of meditation remained elusive until the late 20th century. With the advancement of technologies such as brain imaging, scientists can look at what is happening in the brain and body both during meditation and after months or even years of practice.

At its core, meditation is about sitting in mindful awareness, but it encompasses a wide range of practices and techniques that fall under the umbrella of meditation. "Mindfulness" is one practice related to connecting with the present and observing what is happening around us without affective reaction or attachment. Many forms of mindfulness meditation emphasize breathing as a tool to reconnect with the present moment. Still, breath is not the only object of attention to which mindfulness can be applied. The primary goal of mindfulness meditation is to focus on a specific object of attention: the meditator’s breath, bodily sensations, or the sounds and smells around them.

While science can offer insights into how and why meditation has such profound benefits, many different religious traditions have appreciated the spiritual power of meditation for thousands of years. According to Dr. Andrew Huberman of the Huberman Lab at Stanford, "There wasn't that much mechanistic understanding of how meditation works, but of course there was a deep understanding from cultures outside of the United States that meditation was extremely useful." Buddhist teachings surrounding meditation developed long before any scientific understanding of the nervous system or the effects of chronic stress on the body and mind. In Buddhism, meditation forms a core part of the "Way of Mindfulness," which, according to Nyanaponika Thera, a Buddhist monk, and scholar, is critical to liberation from suffering. He describes this liberation as "the highest goal of the Buddha's teaching," a goal that cannot be achieved without meditation.
Much of the rationale for meditation in spiritual traditions such as Buddhism has been validated by research into meditation’s psychological and physiological benefits.

The systematic and scientific study of meditation was difficult to achieve until the late 20th century. While researchers could now measure behavioral changes, it was difficult to standardize, quantify, and authenticate the observed changes and establish a causal relationship, as is standard in scientific research. This further complicated the difficulty in determining what was happening at the neural level, which was only possible with technologies such as functional magnetic resonance imaging (fMRI). Neuroimaging techniques like fMRI allow researchers to determine activity in different parts of the brain with a high degree of accuracy. Even after developing these techniques, there was still the question of performing research in a noninvasive way to not disrupt meditation and potentially impact results. According to Robert Keith Wallace, “Investigators have reported difficulty in obtaining expert practitioners of meditation and in taking measurements in a way that did not interfere with the subjects’ contemplative or concentrative efforts.” Despite these limitations, studies have demonstrated meditation’s psychological and physiological effects, especially as these techniques continue to evolve.

Both the acute or immediate and long-term effects of meditation have been subject to scientific study. Acutely, meditation has been shown to induce changes in both the cardiovascular and nervous systems. These changes can be observed during and immediately after meditation. In both novices and experienced practitioners, meditation reduces blood pressure and produces characteristic electroencephalography (EEG) changes. During meditation, there is also increased activation of the prefrontal cortex, the brain region responsible for executive functioning. Other research has documented the modulatory effects of the cardiovascular and respiratory systems on the autonomic nervous system. These immediate changes give insight into the calming effects of meditation on two body systems involved in the stress response.

The effects of short and long-term meditation practice have also been studied. Short-term meditation training of just eight weeks caused a reduction in amygdala reactivity, a specific brain area associated with the stress response. Short-term training also led to increased connectivity between the amygdala and the ventromedial prefrontal cortex (VMPFC), a brain region implicated in emotion regulation. The heightened amygdala-VMPFC connection is a potential mechanism by which meditation produces salutary effects on emotion regulation ability. There is also evidence that meditation increased changes in white matter in the cingulate gyrus, which, like the amygdala, is part of the limbic system. The cingulate gyrus is associated with self-regulation, meaning that changes to this structure could have implications for interventions in mental disorders. Research suggests that the broad mechanism by which meditation induces positive changes is improved self-regulation, both in the short and long term; observed changes in these brain areas provide further evidence for this claim.

As a result of these benefits, meditation has become widely used in medical and psychological therapies for stress-related physical and mental disorders. One study found that meditation was as effective as standard antidepressants in treating depression. Mindfulness meditation programs caused a reduction in the symptomatology of individuals with anxiety and panic disorders. Meditation has also been shown to reduce negative symptoms of schizophrenia, such as apathy, and cause an increase in positive emotions. Mindfulness-based stress reduction (MSBR) courses are now recommended as a therapeutic intervention for many with debilitating stress due to chronic pain or other conditions. For thousands of years, meditation has been used to alleviate suffering, and the development of modern technology has confirmed its psychological and physiological benefits to our lives. Meditation has been shown to be an effective therapy for individuals struggling with mental health disorders. Still, it can be incredibly beneficial for anyone, whether they are struggling with mental health and other emotional concerns or not. Meditation practice is accessible to all and can be easily brought into your life.

Meditation practice is accessible to all and can be easily brought into your life.
ven though I’ve been training for the high-pressure environment, when I step out of the lander, I think my suit has jammed. My movements are forced, like I’m pushing against years of rust in the servos, shuffling toward a world that we have only ever looked at through a telescope or probe’s camera. Early readings showed the weather here changing rapidly, if predictably. A sector will be at a steady low pressure, 50 or 60 psi, then shoot up to 1,000 or higher in minutes. Hence, the heavy pressurized suit designed to regulate internal pressure and temperature while withstanding rapid external changes. It’s a blistering 462 degrees celsius here, on average, so in addition to the mass of pressure seals and dense plating, I’m carrying half my weight in coolant. The ground is blanketed in a dense layer of tubes and tendrils that fracture as I land. Their moldy grays and greens crack to reveal bright red and orange ridges inside hissing like ruptured oxygen pipes. Might be life. Might not.

I’m here for a 48 hour run, awake the whole time on modafinil, a stimulant medication, after a seven month nap aboard The Messenger. NASA has samples from an unmanned mission five years ago, but those spent months in a vacuum-seal burning toward Earth, leaving some doubt as to whether the silicone ribbed fragments that arrived were viable for testing. So this time, they gave me an onboard mobile lab that I get to use for myself, along with the ship computer I named Geoffrey. If you halve the pounds of meat shipped into space you halve the cost of the ship. Which was a deal that looked so good to Congress, they kept cutting people until I was the last one. If they could, they’d have a brain in a jar here instead of me. But, Geoffrey knows my vitals and emotional tics better than I do, and has all the right drugs stockpiled to keep them in the green, so I can’t say I hate him.

My body begins to adjust to the pressure as I slog along the ground around the lander, checking for damage and unloading a rover complete with saws, sterile containers, and backup parts for the suit, although sadly too small to ride. Around the landing site, the edges of Helen Planitia draw a jagged horizon, only visible as a bright peach outline, through the current 800 psi of atmosphere, contrasting with the dim mold-green of the tendrils sprawled across the land. In some places the tendrils curve tightly upward, spiking into the air, three or four of which are clearly visible from our site. I have two tasks today: collect geological and xenobiological samples, and stay alive. As I work, I rattle off observations for the record:

“Suit readings are stable, and so are the pressure readings for now. I’m expecting some atmospheric activity in a few days moving in slowly from the East, but I’ll be long gone by then.”

Geoffrey’s voice buzzes in response, as a spindly arm unfolds from the side of the lander:

“Please stay clear. I am going to take some borings from our site.”

The tendrils snap and hiss, revealing their bright insides before being obscured by dust as a boring drill unfolds from the arm and disappears into the ground. It is still not clear whether these are things we could call plants or whether it even makes sense to refer to them in the plural. They are networked to each other almost like trees on Earth are connected with mycelium, but it’s all one organism encompassing the entire planet. For all we know it could be intelligent.

I break off a tendril beside Geoffrey’s bore continues talking into my recorder: “They seem to break okay, but I bet it’s like squeezing an egg. At high pressure from all angles, they’ve been stable at when I would be mashed potatoes.”

After being on the ground for about 15 minutes, the rover is loaded, and I’m on the way to the closest spike. Around 40 minutes later it towers over me, emerging at almost a right angle with the ground, and the tip disappearing into the orange sky. There are openings the size of my fist, along the sides of the tendril, spiraling up its length at semi-regular intervals. I reach into one of these with a small electric saw and begin to cut in deeper. The edges are rough, and my gloves keep snagging on bits that I’ve cut into. The farther I get, the reds and oranges become brighter as if this thing was some melancholy artist with a deep passion for the sublime that it was embarrassed to show.
I’m three hours in when Geoffrey’s voice comes over coms: “We have an unexpected high pressure front coming in. Please return to the lander.”

I pause. “I’m two kilometers out and on foot. How fast do I need to get back?”

“It is unlikely you will make it. Please move quickly.”

I turn toward the lander when the wind suddenly knocks me forward. I get up just in time to see the structure behind me shiver, the hole I cut in its side splits wide open like a torn seam or a knife wound. There is a moment of total stillness, the slightest straining, and then it disappears, exploding completely, in a fraction of a second. There are no fireworks, only a sudden absence and a sudden weight.

Geoffrey comes in over coms again: “What did you do?!”

“Got knocked over. I’m pretty sure the sample I took out of this spike compromised the structure enough that it collapsed when the storm front came in. I’m okay, on the way back.”

“Not the spike. The weather. It just changed again. Pressure is dropping surrounding Helen Planinia. Expect heavy winds.”

As I walk, I am watching the ground, little sparks of bright red blink into existence in the tangled mass of moldy green, then it disappears again. I watch the trail of crushed tendrils collapse and then reinflate as the pressure seesaws, like something taking a quick breath. I open coms, “Geoffrey, I think this is us.”

“I am ten steps ahead of you, but proceed with your epiphany.”

“If the vines here are holding some pressure, we release it when we break them. We disrupt the network even just a little, and then it corrects. I think that it’s responding to us. It’s speaking.”

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Imagine you are a planet. Micro-ecosystems are your organs. Your timescales exist in the millions of years instead of tens. Your moods sweep across you in stormfronts, the molecular friction in clouds roughly equivalent to what you imagine a synapse to be. Well, not really. But for the sake of imagining …

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When the object touches down it is not a good time for us. We want to be working on a harmonic, and instead here is this cold thing which softens and depresses where it touches. It itches, like a meteor but smaller. If it were a meteor it would land, soften where it landed, itch, but settle quickly and we would begin the work of putting ourselves back together. But instead this thing lands and keeps landing, zipping around, trailing hissing wounds on our surface. We are annoyed where it has landed and must re-regulate the surrounding space to accommodate, lightening our mood. It will take a long time to heal the bits of us it has broken.

But this new thing is interesting, nothing has left such a trail of bother on our surface before. It moves like a mood, so perhaps it is like a mood in other ways as well. If we greet it, will it inflate, crumple? Will it respond with its own mood, pushing back, or pulling? We open along our ridges and release a chord of introduction. Mood sweeps across us, interrupting the subtle patterns of our harmonic, heavy excitement pooling in our valleys and solidifying into anger and desire at low points, lightness and ease slipping in along the outskirts. Where the object has landed we are just heavy enough to be curious, desirous. It’s a simple song, but we don’t know this object. It’s best to start easy, complicate as we become familiar. If it sings back perhaps we can make this work, communicate at the least. Perhaps we have happened across another musician. Instead it moves again, trailing itch across us more quickly now making it difficult to control our release where it has passed. We feel our introduction and welcome dipping into desire and almost anger, and quickly re-regulate, opening ourselves across the plains and pulling mood through ourself away toward the surrounding space. Its shape has not changed but ours has as though it was taking something from us. Jealousy haunts our valleys and the beginnings of fear. We do not think that it knows what it is doing, but nonetheless it is doing it. We begin to complicate our song.

Much later it is still, and we reach toward it like vines reclaiming something dead.

Written by Caleb Rader
Illustrated by Claire Wong
Elon Musk’s Questionable Treatment of Animal Test Subjects

Where Neuralink closely resembles a venture-capital-funded tech startup with aspirations of radical disruption, Neuropace is more clinical, both literally and figuratively. Neuropace performed much of the research at the University of Pennsylvania, where decades of epilepsy research have been conducted. Scientists from multiple disciplines tested strong hypotheses on neurostimulation’s role in interrupting seizures, finally leading to clear clinical outcomes.

At Neuralink, goals are lofty and broad. Musk speaks of dramatic medical advances, aiming for the remediation of ills such as paralysis and blindness, but also conceives of the device as a universal brain-computer interface. To the true believers in the polarizing tech mogul, Neuralink’s presentation appears to confirm the forthcoming realization of this grand vision. But to field experts like Yoshor, Neuralink has built novel hardware and employs some of the brightest industry minds. Still, it is progressing toward these goals at a pace no faster than academic and medical-industrial ventures with less limelight.

This is where the ethical violations of Neuralink become pronounced. A dogmatic belief in innovation may help startups produce timely results, but in this case, it appears to overrule animal welfare considerations. Musk has assured the public that animal testing is only used when necessary, but both the volume of tests and internal records tell a different story. Autumn Sorrells, the director of Neuralink’s animal care program, ordered the term “exploration” removed from all publications. This indicates that she intends to create the public impression that animal trials were reserved only to confirm hypotheses with prior solid evidence. Employees complained that this was misleading and designed to improve the company’s image.

The decision to expose sentient animals to untested surgeries, brain damage, confined living conditions, and euthanasia should not be taken lightly. All other preliminary research methods, such as computer modeling, in vitro testing, and the use of simpler model species, should be exhausted prior to pig and primate trials, and the harms inflicted on these animals should be weighed against the potential benefits. When surgery is performed, it should bear the patience and attention expected in human procedures. In the case of Neuropace, animal trials have dramatically improved the quality of life of many suffering from epilepsy. For Neuralink, these benefits are both far off and unclear.

It is important, however, to not write off animal testing of neuro devices as entirely evil, as these trials can provide a marked improvement in the lives of many. At the same time, Neuralink has demonstrated a callous disregard for the wellbeing of its test subjects. Its organizational ethos and a disproportionate amount of media hype have given license to premature and dangerous trials that fail to produce benefits equivalent to their harms. Implantable neuro devices are a new frontier. While we should be excited about their potential, we must be realistic about our current capabilities, lest we develop moral blindspots that lead to ethical transgressions.

Musk has assured the public that animal testing is only used when necessary, but both the volume of tests and internal records tell a different story.

Defenders of Neuralink suggest that animal experimentation is nothing new, that it is the cost of scientific research, and that neuroscientific trials often yield complications. On their faces, these arguments are true. Should trials of other brain implants face as much public scrutiny? They may be considered similarly barbaric. It is standard in most settings to keep animals in small enclosures, intentionally induce brain trauma, and euthanize them once they exhaust their usefulness. Surgeries are usually novel and lack the quality standards and practiced physicians performing comparable human procedures. These revelations have placed Neuralink under investigation by the United States Department of Agriculture — an uncommon measure in research.

However, just as Neuralink’s treatment of animal subjects is not unique, neither are their purported breakthroughs. A cognitively-controlled computer cursor — the latest advancement touted by Musk — was first achieved in 2006. “These are incremental advances,” said the neurosurgeon Daniel Yoshor of the University of Pennsylvania in an interview with The New York Times. Yoshor implanted a device called Neurpace, which uses electrical stimulation to treat epilepsy in human patients. Neuropace, like Neuralink, is a California-based private company that manufactures implantable neuro devices.

Elon Musk’s Neuralink touts technology straight out of science fiction, advertising itself as a leader in implantable brain-computer interfaces. A “show-and-tell” for the tech startup on November 30th, 2022, included videos showing monkeys telepathically interacting with an on-screen keyboard to win treats from researchers just out of frame. Musk heavily emphasized the organization’s care for these primate test subjects — a clear Public Relations (PR) move — while being careful not to directly address recent allegations of animal cruelty. Neuralink, despite its image of cutting-edge technology, is under fire for its haphazard experimental practices.

Nearly 1500 animals have been euthanized in connection with Neuralink studies. Compared to similar trials at other institutions, this figure is significantly higher and was taken in a much shorter time frame. Leaked documents and testimony from employees reveal a pressure to deliver on unrealistic time frames, leading to rushed surgeries and catastrophic errors. In one study, 26 out of 60 pigs were implanted with devices of the wrong size. An additional two had devices placed into the wrong vertebra entirely. In other surgeries, simple errors, such as using the wrong surgical adhesive, led to the death of multiple primate subjects. In all cases, these animals died due to surgical errors that detractors suggest were avoidable and were made to suffer without advancing any scientific goals.

The Synapse

Written by Caleb Rader
Illustrated by Claire Wong

Technology
or years, affordable and cruelty-free lab-grown meat has been just out of reach of most companies. With their recent Food and Drug Administration (FDA) approval of their “slaughter-free” chicken, Upside Foods may have made this dream a reality. Soon, consumers may see their products on supermarket shelves next to tofu and other meat substitutes. Companies in the business of lab-grown meat belong to a larger cutting-edge industry known as biodesign. This multi-billion dollar industry seeks to combine elements of biology, technology, engineering, and design to solve global problems relevant to consumers. This up-and-coming industry includes companies working to reduce dependence on animals and their environmental impact. However, these projects also raise concerns about the ethics of genetic modification and force consumers to consider what it truly means for products to be “cruelty-free.”

Geltor, a Bay Area startup, claims that their biodesigned proteins can eliminate the beauty and food industry’s reliance on bovine and marine collagen. Collagen is found in the bones of animals and is a common ingredient in cosmetic products. Currently, collagen primarily comes from cows and pigs. Raising cattle releases large amounts of methane, a gas that contributes to global warming. Geltor’s product, HumaColl21, is sourced from microorganisms and has a lighter environmental footprint than its animal-dependent counterparts. In 2019, Geltor developed HumaColl21 using “precision fermentation.” According to the Good Food Institute, precision fermentation is a method that “uses microbial hosts as ‘cell factories’ for producing specific functional ingredients.”

Geltor has since created three additional products. One product, Elastapure, is similar to human elastin, a stretchy protein in your skin and ligaments. Geltor’s synthetic version is said to have anti-aging and antioxidant benefits for the skin. Another product, PrimaColl, is synthetic collagen for the food industry and potentially an ingredient in future supplements. According to Geltor, their products speak to current consumer demand for “sustainable, ethically sourced, and effective protein ingredients created simply and quickly.”

Just north of Geltor in Emeryville, CA, MycoWorks uses Mycelium, a fungi component, to disrupt the fashion industry's current avenue for producing textiles. Today, the fashion industry contributes up to 10 percent of global carbon dioxide emissions. Their solution, if widely adopted, could significantly reduce the 11.3 million tons of textiles that end up in landfills. The company uses their patented Fine Mycelium product to form a synthetic leather textile called Reishi that can be used in clothing or accessories. The product is made by feeding specific fungi species sawdust and controlling its growing environment. Instead of sprouting mushrooms, the fungi grow into large, densely intertwined, fibrous sheets. These sheets can then be treated to have the properties of animal leather. The company claims their product is more durable and better for the Earth than traditional leather and most plastic-based vegan leathers. The company has raised over $187 million in funding and collaborated with the luxury fashion brand Hermès in 2021. While Reishi is not yet accessible to the average consumer, increases in crowdfunding aim to lower prices and attract buyers with hopes of reducing fashion’s reliance on animal products.

With every new advancement in biotechnology, ethicists must ask important questions about the true costs of this technology. Novel lab-grown meat innovations have recently sparked questions about what it means for a product to be “cruelty-free.” In production, muscle tissue is harvested from live animals, where it is then cultured in a laboratory. Since the tissue comes from live animals, many vegans and vegetarians do not believe that lab-grown meat should be considered “cruelty free.” While innovations like Geltor’s and MycoWorks’ claim to reduce harm to animals and the environment, their methods of manipulating organisms have the potential for harm in the form of intentional bioterrorism or the unintentional extinction of native species. The same technology that Geltor uses to edit yeasts’ genomes and then culture large amounts of the organism could theoretically also be used to transform a harmless microbe into a lethal pathogen on a massive scale. Furthermore, genetically altered organisms, like those produced by MycoWorks, could end up in the wild as an invasive species that causes harm to native species. While there certainly are many positive outcomes of these biodesigned innovations, unrestricted synthetic biology may open Pandora’s box and welcome technology that, in the wrong hands, could cause great destruction to our world.
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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.