The Synapse

Intercollegiate Science Magazine

Volume 6 Issue 3

April 2018

Gravity. Force. Power. Energy.

As scientists, science writers, and citizens on a planet where all these concepts are essential, these are ideas we think about a lot. But for all of this thinking, *The Synapse* has never featured a section specifically dedicated to Physics. We welcome this new category in this, our 16th issue, with two articles. As two biology majors, we both find physics intimidating, but Loubna El Idrissi's article *Knockout Science* makes the discipline fun — and kickass — by explaining the physics of boxing. Physics may not be an elementary subject, but if you're interested in the nitty-gritty of the subject, be sure to check out Patrick Banner's article *Building Blocks* to learn about elementary particles too!

The addition of a Physics category to the magazine is not the only change to *The Synapse* this semester. We are both sad and proud to say that, as we will both be graduating in May, this will be our last issue as Editors-in-Chief of *The Synapse*. Post-graduation, Tara will be attending New York University's Science, Health & Environmental Reporting Program (SHERP), and Victoria will be working in book publishing with YA and children's literature. We are thrilled to have been able to work with and grow alongside *The Synapse* over the past three years in the various capacities we have worked with the magazine, and we know the new Editors-in-Chief, Rachael Branscomb (OC '19) and Leah Treidler (OC '20), will do an amazing job with the 2018–19 issues.

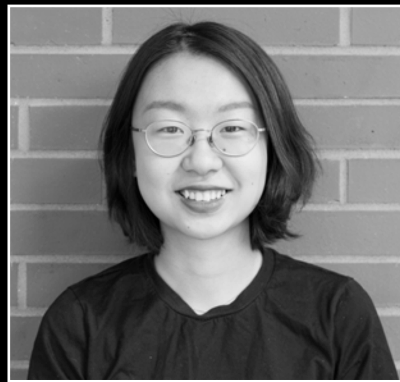
We have several thank-yous to give, the first to Chief Layout Editor Rachel Dan and Art Coordinator Elena Hartley for being incredible co-workers and dedicating so much time, effort, and creativity to the magazine! They will also be graduating in May and have chosen to pass on their positions to Yue Yu (OC '20) and Steven Mentzer (OC '20), respectively. Secondly, we would like to thank and welcome Professor Chris Howard onboard as our new advisor for *The Synapse*.

It has been an honor to work with *The Synapse* and the amazing students from Oberlin and Denison that have contributed their energy, scientific curiosity, and immense creativity to the magazine. Throughout our time with *The Synapse*, we have excitedly watched the Denison branch of the magazine grow in leaps and bounds and are very proud to work in partnership with another Ohio liberal arts college. We have seen the magazine layout become more complex and beautiful, student artists have pushed the limits and created gorgeous pieces, authors have written diverse and essential articles about everything from policy to activism to game-changing research, and editors have taken articles from good to their peak. As the magazine continues to grow and change, we will remember our contributions proudly and cannot wait to see where *The Synapse* will go!

Victoria Albacete & Tara Santora
Editors-in-Chief

Nathalie Weiss is a first year Ohio native, studying Biochemistry at Denison University. She has written articles for the past three issues and is a fan of the magazine because she thinks it encourages the general public to read about science in an accessible way, as well as allowing students to express their creativity. Outside of her work with *The Synapse*, Nathalie volunteers her time with animals at the Licking County Humane Society and with people at Licking Memorial Hospital, and plans to attend medical school post-undergrad. Catch her article in this issue: *.01%: The Germs that Hand Sanitizers Don't Kill*.

Hailing from Phoenix, AZ, Zoe Swann is a third year Neuroscience major, with a concentration in Linguistics and a minor in Chemistry at Oberlin College. She thinks *The Synapse* is important because it gives readers and writers the ability to learn and connect over scientific issues both hugely related to current events and our shared histories; to contribute to that mission, Zoe has worked with the magazine as a writer, content editor, and copy editor. After graduating from Oberlin, she plans to take a gap year and then return to school to earn an MD/Ph.D. in neurotrauma. As part of this issue of the magazine, Zoe explores the connections between the brain and the liver in *Fighting a 50-Year-Old Failure*.



Han Shao is an Oberlin second year, working through the challenging 3-2 Engineering program. Originally from Nanjing, China, she's worked with *The Synapse* for the past five issues, including Issue 16, as a layout editor. Han is proud to be a part of the magazine because it has great artists and writers, and offers the opportunity for STEM majors to use creativity outside of the sciences; she loves the moment when her thoughts and ideas get to be manipulated into a gorgeous layout! Find her own layout skills at work in this issue on *Natural Climate Change: Refuting Climate Deniers*.

Second year Della Copes-Finke studies Neuroscience as part of the pre-med track at Oberlin College, and hopes to earn an additional Religion minor. A contributing artist for the three most recent issues of *The Synapse* — plus a recruitment poster for Issue 16 — she also works at the Peer Support Center and is a WOBC talk show DJ. Della thinks that the magazine is a special medium for connecting the humanities and STEM, especially on college campuses where those environments can be pretty sharply divided. Post-Oberlin, the Belmont, MA native plans to take some time off — maybe with the Peace Corps — and then attend medical school. This issue, find Della's art featured on the front and back covers!

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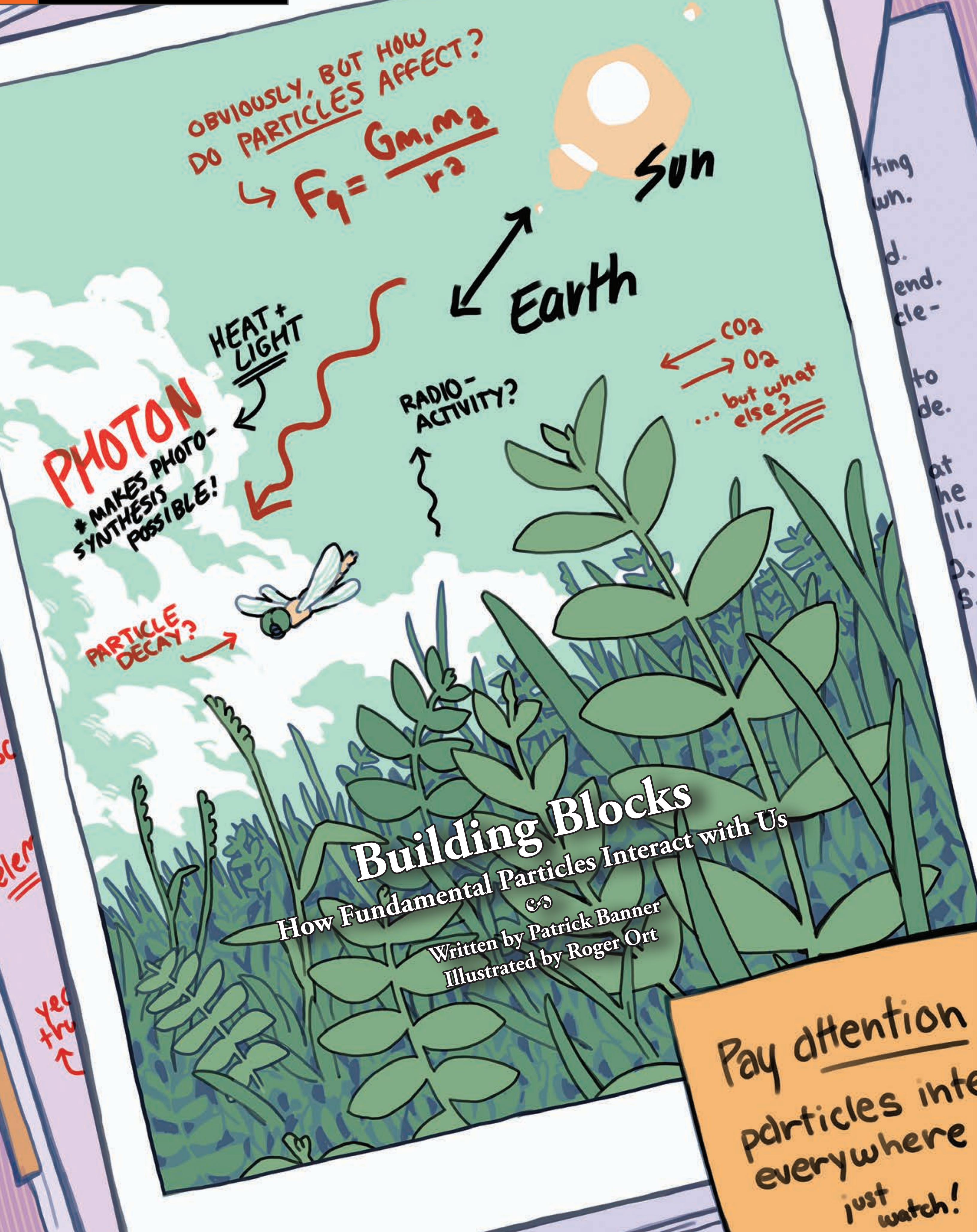


Building Blocks

How Fundamental Particles Interact with Us

Written by Patrick Banner
Illustrated by Roger Ort

As humans, our interactions with the world around us — such as exploring forests and deserts, studying plants and animals, using technology, and more — are myriad, varied, and, at best, limited. The objects we can see with our naked eye are, at the very least, a tenth of a millimeter or so in size. The numbers we can comprehend are at most a thousand or ten thousand. The speeds at which we exist and move are rarely above a hundred miles per hour. But the world around us is made of objects far smaller, far faster, and far more numerous than we can understand. At its most basic level, nature is composed of fundamental particles, the tiniest bits of matter. These particles not only make up everything around us; they are produced by us, collide with us, decay inside us, and determine how objects behave as we interact with them in our daily lives.

Fundamental particles are incredibly tiny, much smaller than we can see. These include atoms, protons, quarks, and electrons. For example, there are likely around a septillion (1024) electrons inside the period at the end of this sentence. You would have to spend a dollar every second for a million lifetimes of our universe in order to spend a septillion dollars. If you take an atom and enlarge it to the size of an average classroom, a proton's radius is about the same as that of a human hair, and if you enlarged a proton to the size of an average classroom, the top and bottom quarks that make up the proton would again have a radius roughly the size of a human hair.

Because they are so tiny, fundamental particles obey many counterintuitive rules and display unusual behaviors. The two most crucial types of particle interactions are collisions and decays. Collisions often result in the colliding particles being destroyed, and laws such as conversation of energy and momentum dictate how the total energy of the reagents is spread between a set of new particles. Decay is a probabilistic process that causes high-mass, unstable particles to be destroyed and lower-mass, stable particles to be created in their place.

> If you take an atom and enlarge it to the size of an average classroom, a proton's radius is about the same as that of a human hair.

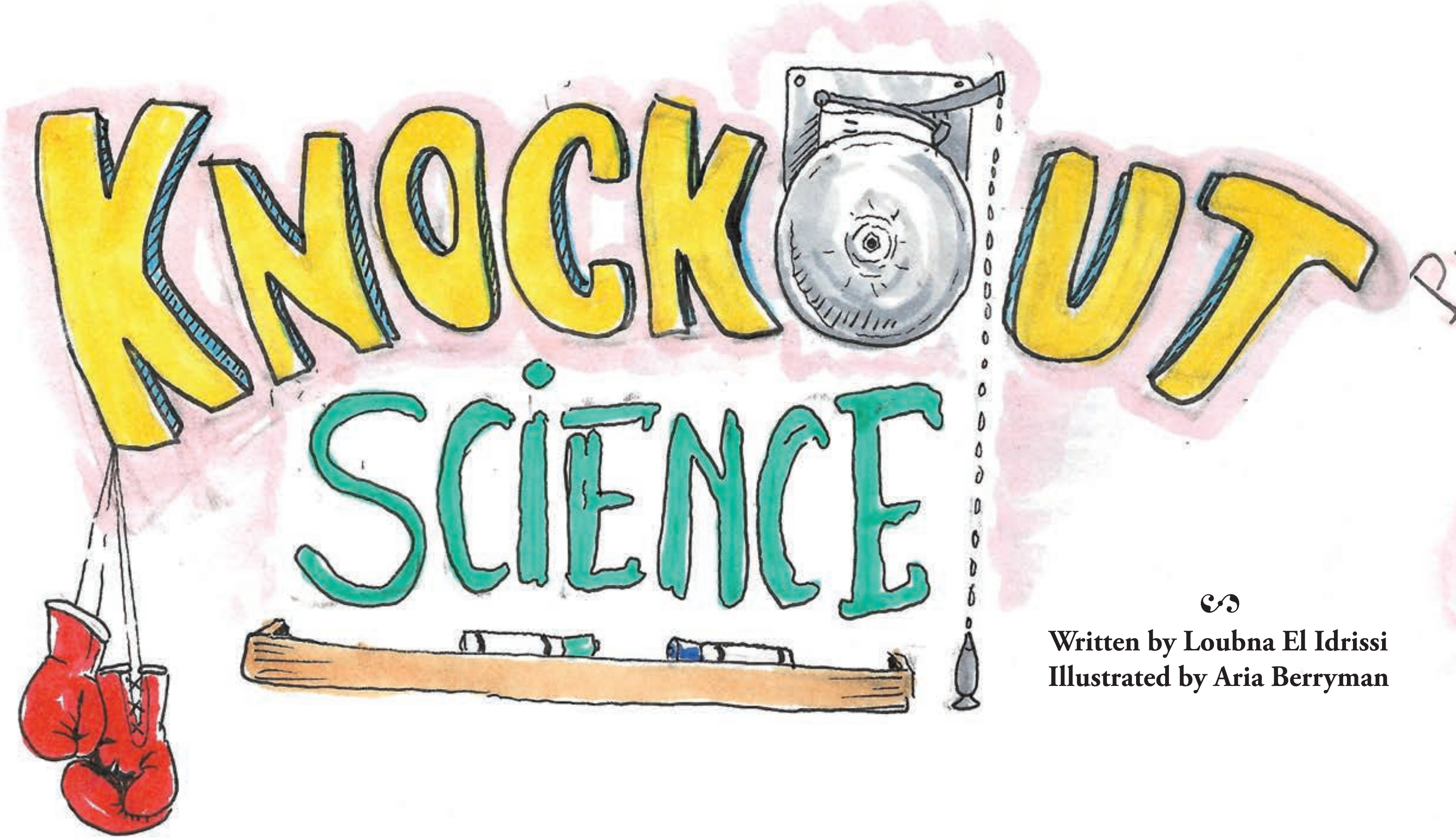
Both processes do something rather unexpected: they destroy mass. When particles interact, they use and abuse Einstein's famous equation, $E=mc^2$. This equation is a statement that mass and energy are one and the same, and, because they are equivalent, particles can be and often are created (made from energy) or destroyed (turned into energy). Often the particles that went into the interaction are unrelated to the particles that come out; anything can happen as long as the process conserves total energy. This is a surprising idea, rather like throwing a glass vase at a wall and having bouncy balls come back at you. Yet this behavior is the norm in collisions, decays, and many other fundamental particle interactions

These counterintuitive behaviors, however, connect directly to the behaviors of the macroscopic world that we naturally understand. One example — something that many of us take for granted — is the solidity of solid objects. If you push against a wall, you almost certainly will not so much as bend it. But the wall is made of molecules, which are composed of atoms, which are mostly empty space. Why don't our atoms just pass through the atoms of the wall? It is tempting, if you know a little atomic physics, to invoke electromagnetic repulsion of electrons. Electrons all have negative charge and repel; in this way, atoms may not be able to overlap because their electrons would prevent it. Even this, however, is not strong enough. The explanation for this evidently not-so-simple phenomenon lies in two counterintuitive rules obeyed by fundamental particles: the uncertainty principle and the Pauli exclusion principle. The uncertainty principle says that we cannot know both the position and the momentum of a particle precisely, not because of poor measuring instruments, but because of the unbreakable laws of physics. As we push on the wall, we squeeze the electrons in our hand closer to the electrons in the wall, which, in some sense, represents a "measurement" of where the wall's electrons are. Our pushing is resulting in greater constraints on the momentum of the electron, and therefore on the atom, which means that our knowledge of the position of the atom is increasingly poor. The Pauli exclusion principle states that no two electrons may occupy the same quantum state. This means that an electron in your hand cannot occupy the same volume as the electron in the wall. The laws of physics guarantee your inability to break through the atoms of the wall; this macroscopic behavior, which we take for granted, is fundamentally determined by the laws of physics that apply only at the atomic scale.

> Our bodies, having unstable materials in them, are churning out antimatter all the time.

There are stranger and less obvious phenomena at the particle level, as well. Imagine you have eaten a banana (or, if you prefer, potatoes, or red meat). As the banana gets digested in your body, potassium-40 atoms are released. This atom has a slightly heavier nucleus than it requires due to its extra neutrons, and this high-energy configuration is subject to decay. About 90% of the time, the decay of a neutron in potassium-40 produces a proton, which remains bound to the nucleus (making a calcium atom), and an electron. Note that this is not a particle breaking into its constituent pieces, since neutrons are not made from protons and electrons. The new particles simply appear due to the interactions of nuclear forces during particle decay. The other 10% of the time, the nucleus of potassium-40 follows a different decay pattern: one of the protons decays into a neutron. This creates stability because the smaller number of protons makes the atom into an argon atom, which has a full valence electron shell. In this decay, a positron is emitted. Positrons are antiparticles to electrons; that is, they are antimatter. Our bodies, having unstable materials in them, are churning out antimatter all the time. The antiparticle simply finds a normal-matter particle and annihilates it. This is another example of the many strange events happening around us at the particle level.

There are many more phenomena like this. Particles from space, with their enormous energies, enter our atmosphere as "cosmic rays" which cause a rain of fundamental particles to constantly bombard us and our atmosphere. Our sun produces a flux of tiny fundamental particles called neutrinos, and the flux is so large that billions of neutrinos pass through you every minute without you or your particles noticing. The particles in your atoms are being held together by forces whose natures are not fully explained, despite all of the theories and data currently available. Physics at this fundamental level is highly unusual, extremely interesting, and still not completely understood. Not only do fundamental particle physics lead to the macroscopic behaviors we have come to take for granted, but fundamentally weird and extremely interesting processes are happening around, on, and inside us all the time, without our suspecting a thing.



Written by Loubna El Idrissi
Illustrated by Aria Berryman

As a first year, I am frequently asked about my academic interest. Most of the time, when I express my enthusiasm in pursuing a physics major, I notice that people are often fascinated by the subject, yet scared of its difficulty. During my 2018 Winter Term project, I brought the abstract concepts of my Physics 110 class to life with the help of something less complex: sports. Since this helped me better understand those concepts, maybe it can help others as well. Inspired by the Housemate Questions from the infamous Wednesday problem set, this article intends to make physics more accessible by explaining some of the laws and concepts that I learned during the fall 2017 semester and applying them to boxing.

Basic physics is just as intuitive as boxing. During this Winter Term, I wanted to work on my boxing moves and technique to become more efficient. In other words, I wanted to punch harder. Some think that giving good punches is about developing more force and power. In everyday life, force and power are interchangeable words. However, in both physics and boxing, they have distinct meanings. Strength or force is a component of power. To make a punch efficient, you have to be both fast and strong; that's power. Power, as explained by my kickboxing coach, is the ability to develop a maximum force as quickly as possible. The scientific definition of power is the rate at which work is done, or the rate at which energy is transferred from one place to another, or transformed from one type to another. Work is done when a force that is applied to an object moves that object:

$$P = \frac{Work}{time} = force.\frac{displacement}{time} = force.velocity$$

A fast punch will not hit hard unless there is a force or weight behind that speed, in the same way that a strong arm will not throw a strong punch without a great velocity. For this reason, knowing the difference between power and force is key in both boxing and physics.

Now, let's look at punching from the view of kinetic energy. Kinetic energy is the energy of motion, observable as the movement of an object, particle, or set of particles. Any object in motion has kinetic energy. The movement will be exerted by a body of mass not neglected and a rectilinear trajectory. This corresponds to the kinetic energy stored during the movement in the equation $E_c = ½mv^2$. The kinetic energy during the shock will be converted into deformation energy. The more energy, the more important the shock will be.

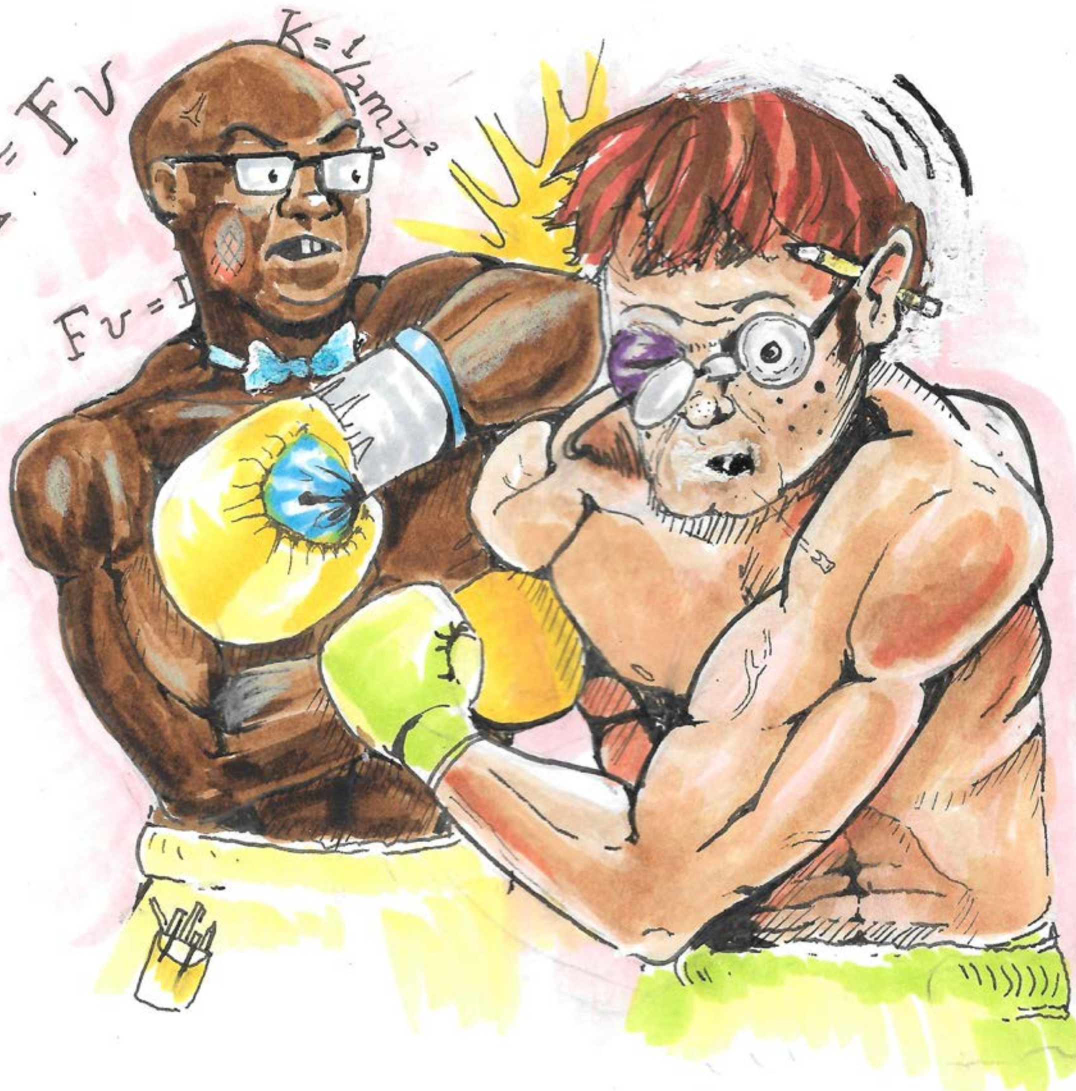
How do we store the most energy in the first place? Well, if the value of the mass is increased, the value of the kinetic energy increases; it is multiplied by the same factor multiplying the mass. If we multiply the speed, the value of the kinetic energy will be multiplied by the square of the factor multiplying the speed. It would therefore be more judicious to increase the speed of the punch, knowing that it allows a greater enlargement of the kinetic energy generated by this shot.

To increase speed is not only a matter of exercising a quick lever with the arm (a lever arm is the line perpendicular to the line of action to your reference point), but it is the whole body that is used to perform the movement. The boxer will try to give a punch storing as much kinetic energy as possible. For this, he will move his body as quickly as possible

> Knowing the difference between power and force is key in both boxing and physics.

to gain maximum speed. This gain in speed will amplify the punch exerted by the boxer, which will generate more kinetic energy stored, and thus transmit a greater shock. For this, we must determine and work on the body parts that can be used to gain speed. It is important to know which joints can be used to make this move; some joints exercise movements that others cannot achieve. So, it is important to keep in mind that the whole body can be used to make the most powerful punch possible.

The most powerful punch starts at the level of the legs. They act like a spring by exerting a force on the ground. It is explained by Newton's third law. Formally stated, Newton's third law is: For every action, there is an equal and opposite reaction. The more the boxer exerts a significant force on the ground, the more the ground will propel the body of the boxer forward, thus allowing the boxer to gain speed. According to Newton's second law of motion: Acceleration is produced when a force acts on a mass. The force exerted in return will create acceleration. The energy will then be amplified at the hips, which will rotate towards the opponent. The chest will do the same, as well as the shoulders, and the speed will be further amplified. Next, the muscle contraction in the arm is important to create the fastest movement possible. It will be placed at the back of the body when the boxer is in profile so that it has a greater margin of acceleration. As soon as the shoulders have finished their rotation, the arm will exert this movement of leverage amplified by all the displacement of the body, and it is at this point that the blow reached its pinnacle of speed.



In boxing, the concept of undulatory movement of the body and kinetic energy plays in a big role in developing the proper technique. An example given by my instructor of how a punch works is the example of the whip. Whipping a whip gives kinetic energy to the lash. This energy propagates along the lash to the other end of the whip, which we can refer to it as energy flux. The kinetic energy is then concentrated in the extreme end and the speed of the latter can exceed the speed of sound. Researchers have even observed that the speed of the end of the whip could be twice that of the speed of sound!

We have seen the physics of throwing a punch. Now let's look at something on the other end: the physics of taking a hit in the face. When collisions happen, in this case between a boxing glove and the face of the opponent, the two concepts that come into play are momentum and impulse:

- Momentum is an object's tendency to resist change in acceleration, and its formula is: *Momentum (P) = Mass * Velocity*.

- An impulse is the change in momentum of a certain object and is determined using the formula: *Impulse = Force * Time*.

Here again we can see that physics equations apply to boxing techniques. Trainers often know the strike force damage is caused by the speed of the arm multiplied by muscular and body weight. Using the physics equation of momentum, boxers know that they can improve their performance by increasing muscular mass. One of the most important techniques that one learns in boxing is moving the entire body to get the maximum force (weight) behind a punch, as mentioned in the previous paragraph. The trick is not to focus on moving your body a great distance, but rather to move it all at the same time. Moving your whole body one inch produces a much harder hit than moving your arm one foot. When a boxer hits his opponent, the momentum of the fist transfers to the face, which was previously stationary and had zero momentum. The steps of a punch explain the concept of conservation of momentum (when considering the two boxers as a system). Momentum refers to the motion that an object has. One of the most powerful laws in physics is the law of conservation of momentum. It tells us that the total momentum of a collection of objects (a system) remains unchanged. To reduce the impact of the punch on his face, the opponent boxer moves his head away. Even if the boxer is still hit, moving their head away increases the time interval in which the strike happens. Since it only takes a boxer a fraction of a second to throw a punch, a small reduction in the time interval can produce large results. However, the change in momentum or the impulse is still the same. By knowing how to exercise one's strength while remaining relaxed, one will have mastered 99% of the striking technique. "Letting go" allows one's shot to accelerate quickly by creating a devastating explosion when weight is added.

Physics is everywhere in our daily lives. I hope this article showed you how you can love physics by relating it to something you enjoy doing!

.01%

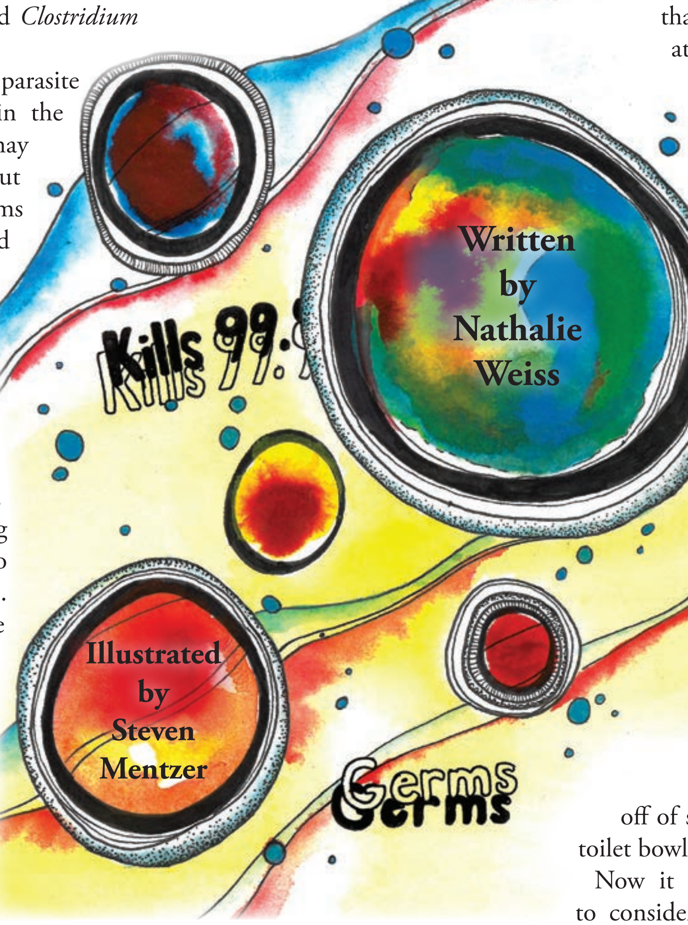
The Germs that Hand Sanitizers Don't Kill

To many, the word "hand-sanitizer" immediately brings to mind the familiar message displayed prominently across the front of almost every bottle ever sold. We've all seen this message: "Kills 99.99% of germs!" plastered across the fronts of the bottles. But have you ever stopped to consider what germs aren't being eliminated? Considering the bacteria that are immune to hand-sanitizer can be a bit scary. It's not pleasant to learn that your mini bottle of hand-sanitizer may not be as effective at protecting you against the microbes on your hands as you previously thought! Thus, for your own sanity, it's for the best that you learn what types of bacteria can't be killed by your trusty bottle and how you can keep yourself in good health.

First and foremost, it is important to note that unless a hand-sanitizer is at least 60 percent alcohol, bacteria will develop resistance to the sanitizing agent because it will simply reduce their numbers instead of killing them all off. Thus, within this article, the hand-sanitizer being referenced is at least 60 percent alcohol. All of this said, a few common species of bacteria that certain types of hand-sanitizers have less of an effect on are *Cryptosporidium*, norovirus, and *Clostridium difficile*.

Cryptosporidium is a microscopic parasite that can cause uncomfortable symptoms in the digestive system of its victims. This may sound like your typical stomach flu but *Cryptosporidium* is anything but. Symptoms of *Cryptosporidium* can also cause fever and weight loss because the small intestine is the organ affected. It really stinks to get *Cryptosporidium* because these symptoms usually persist for 1–2 weeks in people with healthy immune systems, but can be fatal for people with compromised immune systems.

If you do pick up *Cryptosporidium*, hand-sanitizer is not effective at eliminating this hardy microbe because it is resistant to chlorine disinfection and usual disinfectants. Its outer shell allows it to survive outside the body for long periods of time and protects it against chlorine. 3 percent hydrogen peroxide has been shown to kill 99 percent of a population of *Cryptosporidium*, according to studies recorded by the Centers for Disease Control and Prevention (CDC). Hydrogen peroxide is not an ingredient in hand-sanitizers because it is a known irritant of flesh and eyes. Thus, the best defense against *Cryptosporidium* is to avoid touching known infected surfaces, such as doorknobs, railings, and public phones and treating said surfaces daily with hydrogen peroxide.



Norovirus, also known as the common stomach flu, is a parasite that causes the stomach and intestines to become inflamed. When someone infected with norovirus vomits or defecates, particles of the virus are shed and can be passed to anyone who makes contact with the bodily fluids. Like *Cryptosporidium*, most people do not require professional treatment for norovirus infection. Fortunately, hand-sanitizers are more effective in killing norovirus than they are in *Cryptosporidium* because alcohol affects the survival rates of norovirus, but soap and water are proven to be more effective. A study reported by the U.S. Library of Medicine reveals that "staff in facilities that experienced norovirus outbreaks were six times more likely to use hand sanitizers equally or more than soap and water for routine hand hygiene" (Vogel). In spite of this finding, using hand-sanitizer against norovirus is still better than nothing because it has been found to reduce the number of bacteria found on one's hands by 100 times.

Finally, *Clostridium difficile* is a bacterium that causes symptoms that range from diarrhea to a life-threatening infection due to colon inflammation. A study conducted at Loyola University Chicago on the effectiveness of alcohol-based hand rubs for removal of *C. difficile* spores from hands concluded that "washing with soap and water is significantly more effective at removing *C. difficile* spores from the hands of volunteers than are alcohol-based hand rubs." The reason that hand-sanitizer is not effective at reducing the survival rates of *C. difficile* is because it forms spores in the feces of its victims. These spores look like bulls-eyes — but are much more dangerous than a game of darts because they have thick walls that enclose the microbe's DNA and cytoplasm, allowing it to resist environmental conditions, such as the presence of hand-sanitizer. Spores form in vegetative cells only when conditions are unfavorable and thus are harder to kill because the cells require less energy to function in a vegetative state. Although slightly nauseating to think about, the best way to avoid contracting these spores is to make sure all infected fecal matter is completely cleaned off of surfaces such as the inside of your toilet bowl.

Now it is important to take a moment to consider all of the life present on your hands. It is estimated that there are 5,000 germs on your hands at any given time, and hand-sanitizer can bring down approximately 4,999.5 germs. Although science has progressed greatly to the point of almost completely protecting our hands against all germs, nature is still stronger. The spores formed by bacteria in times of trouble, the extreme conditions that certain microbes can withstand, and the adaptability of life to survive in even the most detrimental environments reveals a truth: the 0.01% of hand-sanitizer resistant germs are both tough and worthy of study. ●

Jack of Some Trades

How Trade-offs Allow Organisms to Succeed Where it Counts

Written by Philip Hurst
Illustrated by Caitlin McCuskey

Why doesn't every animal run as fast as a cheetah, see with the precision of an eagle, and wield the jaws of a shark? If natural selection pushes creatures to edge out their competitors, why doesn't nature consist of only the fastest, most vigilant, and most powerful organisms possible? The answer is simple: trade-offs.

Trade-offs describe the give-and-take between multiple forces. One is improved at the expense of others. Trade-offs are not unique to ecology. For instance, compromising one option in favor of another is referred to as an "opportunity cost" in economics. Mittens may provide more warmth than gloves, but the former limits the wearer's dexterity. High-definition movies may provide a better viewer experience, but this is at the expense of a greater file size than their standard definition counterparts. Nuclear power provides an efficient energy source, but results in high levels of radioactive waste. Trade-offs are everywhere.

Trade-offs are plentiful in ecology. A seed that is light, and therefore easily dispersed long distances, almost always lacks the nutrient qualities of larger seeds. The vibrant plumage of a male peacock attracts not only mates, but also predators. The existence of these trade-offs demonstrates that a single species quite simply cannot be the best at everything. A trait that may be beneficial in one realm can be a liability in another.

Given all these forces tugging in opposite directions, how does an organism balance trade-offs? The answer is tied closely to the concept of fitness, essentially the "ecological currency" that all organisms strive to maximize. Ultimately, the goal of all living creatures is to survive long enough to pass along their genes to the next generation. Fitness is a metric used to evaluate an organism's ability to achieve this mission. Natural selection is the process that tends to reward high-fitness individuals with more offspring.

How does an organism or a population navigate the competing forces of a trade-off? The answer is an unsatisfying one that rears its head far too often in ecology: it depends. A combination of genetics and the unique environmental conditions each individual faces dictate how it negotiates trade-offs, but the ultimate priority is to optimize fitness. In a setting where competition for mates is fierce, brilliant peacock feathers may give you a leg up over another male, but in a scenario where predators are abundant, that plumage is quite the liability. Therein lies the beauty of natural selection: it is a dynamic, responsive process that often shapes populations to match the precise conditions of their environment.

Plants are a group of organisms that experience a great number of trade-offs. Plants are constantly under attack by herbivores, so many have evolved mechanisms to defend themselves against herbivore attacks. Some of these defenses are always present and are referred to as "constitutive defenses," such as thorns, which mechanically deter predators. Chemical constitutive defenses make plant tissue distasteful or harmful to herbivores; these chemicals include classes of molecules such as tannins, phenolics, and alkaloids.

While many plants have omnipresent constitutive defenses, they also have the ability to summon inducible defenses during crisis situations. The presence of a herbivore can cause a plant to ramp up the production of inducible defensive compounds to respond to the imminent herbivory threat. There is also evidence that plants can eavesdrop on the chemicals of neighboring plants to determine if they, too, should ramp up their inducible defenses.

Why do plants not simply have extra strong constitutive defenses that prevent herbivores from threatening them in first place? Yet again, trade-offs are the answer. Defensive compounds are extremely carbon-rich, but carbon is also the main elemental component of sugars that provide energy for a plant's growth and reproduction. Sinking large amounts of carbon into constitutive defenses may defend against herbivores, but it does so at the cost of hindering other crucial functions. Inducible defenses partially solve this issue by only being present when absolutely necessary, limiting the waste of precious carbon. The downside is that by the time inducible defenses are produced in appreciable numbers, the plant may already have experiences substantial damage. Natural selection weighs the pressures and intricacies of each environmental situation in an attempt to balance the constitutive and inducible defenses that give a population the best likelihood of surviving and flourishing in future generations.

Growth and reproduction also trade off in plants. Resources and energy that a plant allocates toward growth are no longer available to contribute to fruiting, flowering, cone formation, and other reproductive structures. Since reproduction is a direct representation of fitness, this behavior is of particular importance. While most plants have both male and female reproductive structures, some species are dioecious, meaning that individuals are either male or female, making these species an ideal test subject for this trade-off. One study sampling several dioecious species found that males were significantly larger than their female counterparts. This is the vegetative-reproductive trade-off in action: since females have larger reproductive obligations by producing fruit, they have fewer resources to contribute to growth than males do, constricting the size of females. While this dynamic is most clearly illustrated in dioecious plants, the growth-reproductive trade-off influences all plants to some extent.

It is clear that trade-offs fundamentally shape the behavior of the ecological world. Natural selection has an amazing capacity to shift a population of organisms along the continuum of a trade-off in order to match the environmental pressures of a particular moment. This fluidity enhances the resiliency of a population and increases its likelihood of outcompeting its rivals. Ultimately, a deep understanding of trade-offs illuminates not only the behavior of a particular species, but also the complex ecological interactions that make the biological world so engaging. So, even if a peacock or dioecious plant might not be the best at everything, it is best where it counts.

The Curious Case of *Dictyostelium discoideum*

How Slug Farming Bacteria Could Teach Us About Epigenetics

Written by Carson McCann
Illustrated by Claire Segura

Agriculture is well known as one of the most significant innovations to aid in the success of human development. However, the practice of preparing a food source for future use is not unique to humans. Organisms such as fungus-growing ants, termites, and ambrosia beetles have similarly adapted the ability to cultivate crops. Simpler agricultural methods, with fewer associated adaptations, have been found in microorganisms that show sophisticated social behaviors as well as symbiosis with their environment.

Indeed, the social amoeba, *Dictyostelium discoideum*, engages in primitive farming of bacteria, to allow for future consumption. The single-celled amoebas, which can aggregate together to form a multicellular slime mold, reveal a fascinating behavior when food becomes scarce. This strain of soil-dwelling amoeba normally grazes on bacteria, but as the collective slime mold exhausts its bacteria food source, the slime mold aggregates tightly into a motile slug. The cells of the *D. discoideum* slug then undergo a morphogenesis in which they sacrifice part of their own network of cells within the slug body to form a fruiting stalk. This fruiting body contains asexual, differentiated spores that the stalk disperses. The dispersed spores can then populate a new area. The agricultural aspect of this mechanism became evident when studies found that some of *D. discoideum's* fruiting bodies contain the bacteria they normally eat. Thus, not only do *D. discoideum* spores arrive in a new area, but they also carry a bacterial food source along with them. The bacteria will then be seeded and subsequently harvested by *D. discoideum*, their predacious carrier.

Some strains of *D. discoideum* can farm their food and others cannot. Under conditions of food scarcity, farmer strains of *D. discoideum* have been found to produce significantly more spores than the non-farmer strains. These results suggest the farming strains have a greater advantage for future survival during food shortages.

Burkholderia is a genus of bacteria that is considered to be inedible to *D. discoideum*. However, it is also found to be carried by the slug during the farming process. This curious finding brings forth questions relating to why the slugs carry this type of bacteria if Burkholderia does not directly serve as a nutritious resource for the new colony. Interestingly enough, studies have shown that Burkholderia bacteria can actively influence the farming behavior, and overall survival, of certain strains of *D. discoideum*. Specifically, the species Burkholderia xenovorans has the ability to harm non-farmer *D. discoideum* but not the farmer clones.

> Similarities in bacteria can be examined all the way down to the structural level, and they can provide information relating to both evolutionary biology and epigenetics.

When farmers carrying the *B. xenovorans* bacteria are mixed with non-farming *D. discoideum*, the farmers tend to outcompete the non-farmers in spore production. Thus, the farming amoeba and bacteria appear to engage in a mutualistic symbiotic relationship in which the farming *D. discoideum* is ensured a bountiful harvest free from competition with other *D. discoideum*, and Burkholderia is given the opportunity to hitchhike to a new environment. This facilitates both the survival of the amoeba and the bacteria.

Recent literature has further elucidated this relationship. Due to the prevalence of inedible bacterial species in farming colonies of *D. discoideum*, the role of Burkholderia bacteria was inspected under a finer lens. Studies have shown that Burkholderia can induce non-farming *D. discoideum* strains to farm bacteria, their genus included. This finding led to a surge of research exploring the capacity of Burkholderia to influence the farming behavior of non-farmers. Studies questioned if the bacteria could promote carriage in the second generation of induced *D. discoideum*, and indeed it was found to induce secondary bacterial carriage. Since there exists this transgenerational persistence of farming in non-farming strains of *D. discoideum*, the scientific community believes that Burkholderia may induce epigenetic changes in the amoeba. However, there is not yet evidence as to the extent of Burkholderia's inducible effects across a third generation. The epigenetic effects of bacteria are a sure route for future studies.

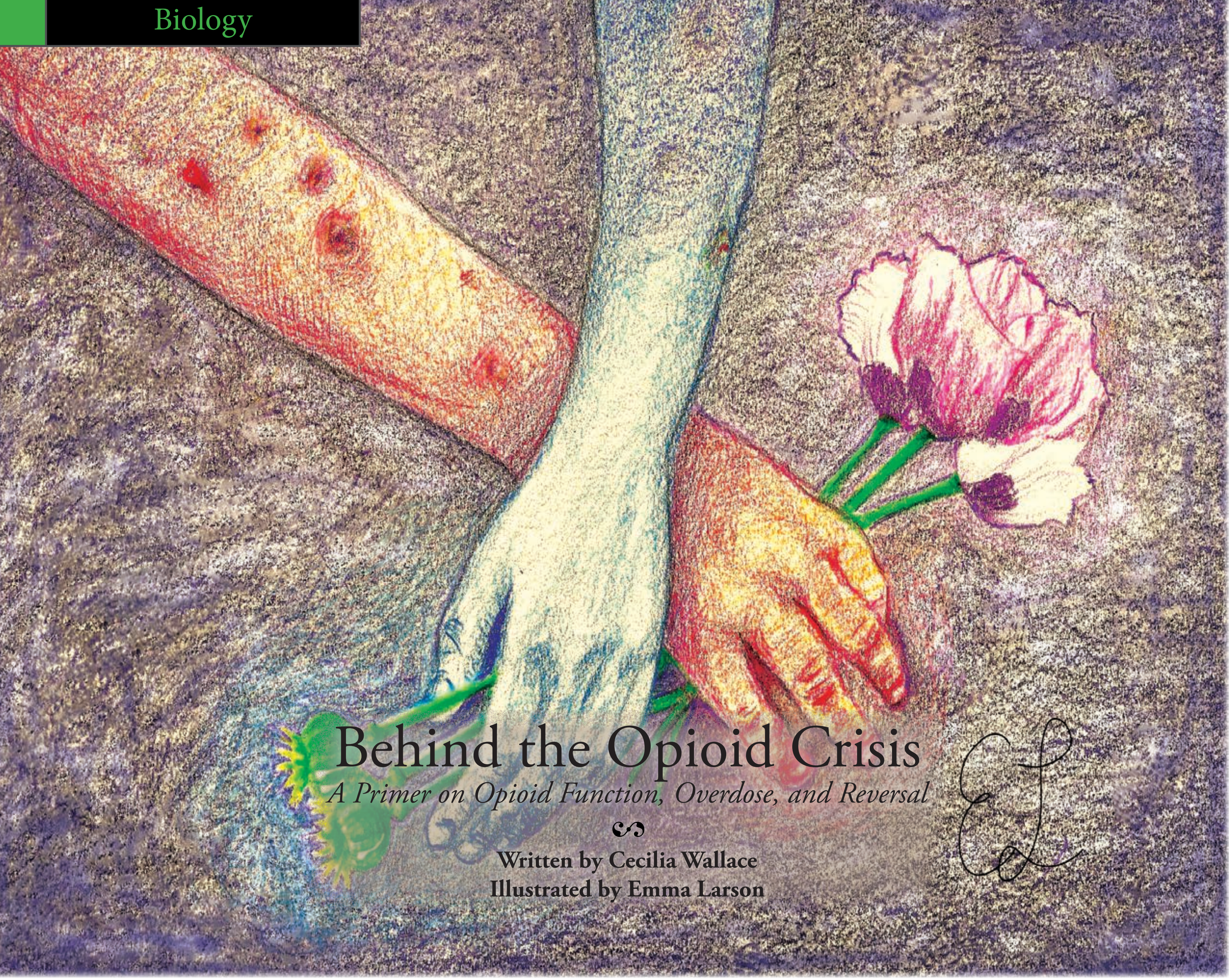
The aforementioned relationship appears to be one that is unique to a specific strain of Burkholderia bacteria. However, research has also observed the farming behavior to be associated with another genus of bacteria, Flavobacterium. This genus has similarly been suggested

> Not only do *D. discoideum* spores arrive in a new area, but they also carry a bacterial food source along with them. The bacteria will be seeded and subsequently harvested by *D. discoideum*.

to induce farming in non-farming *D. discoideum*. The extent to which Flavobacterium are farmed and induce farming is not yet understood. Further, it is not yet known how or why certain bacteria are carried instead of consumed by the amoeba.

Understanding which bacteria are able to induce farming will help uncover the mystery behind the primitive farming behavior of *D. discoideum*. As of now, all that is known is that the bacteria evade consumption, assemble and encourage sporulation, and are carried off to a new environment along with the spores and amoeba. If a common denominator among farming-associated bacteria is identified, it will open future opportunities to discover why specific strains of bacteria are farmed. Then the similarities in bacteria can be examined all the way down to the structural level, and they can provide information relating to both evolutionary biology and epigenetics. This would allow for a clearer history of multicellular development and possibly provide insight on how we could manipulate the biological future. By using *D. discoideum* as a potential model organism for transgenerational epigenetic modifications, it is possible we may learn about our own DNA and heritage. Slug or no slug, these amoeba have a lot to tell us. ●

To learn more about this topic see: "Primitive agriculture in a social amoeba" by Debra Brock, Tracy Douglas, David Queller, and Jan Strassmann, published in *Nature* in 2011.



Behind the Opioid Crisis

A Primer on Opioid Function, Overdose, and Reversal

Written by Cecilia Wallace
Illustrated by Emma Larson

Here's what matters: since 1999, the number of deaths due to opioid overdose in the US has quintupled to over 40,000. In 2016, Ohio saw more than 4,300 casualties — the second highest overdose death rate after West Virginia. In addition to deaths, thousands struggle with their own addiction as well as with the addictions of loved ones. Opioid problems have slowly elicited national media attention, as well as state and federal responses like alternative sentencing proposals and funding for recovery programs.

Caring recovery initiatives will be crucial for addressing the crisis. Understanding the biological mechanisms behind opioid trouble is important too: it can inform policy and aid in emergency decision-making. Opioids, the substance behind the crisis, are a class of drugs encompassing opium, oxycodone, heroin, fentanyl, and their naturally-occurring counterparts, endorphins. All opioids share key structural similarities that allow artificial opioids to take advantage of pathways in the body originally developed for natural endorphins. Three such pathways interweave to form the crisis seen today: opioids reduce pain and are thus prescribed frequently; they release dopamine (the body's reward messenger), so they are addictive; and they suppress respiration, so overdose can kill people. This article aims to better understand these key effects. How do opioids block pain and cause addiction? How do opioids cause overdose deaths? And, importantly, how can an overdose be reversed? As more and more people struggle with opioid dependence, hopefully these questions might fortify understanding of the problem.

First: How do opioids block pain and cause addiction?

The body's natural opioids, endorphins, are produced at times of stress such as childbirth, combat, and exercise. These endorphins work to reduce pain and release dopamine — a relieving effect that some evolutionary biologists speculate may have helped individuals overcome trying times and survive better. Artificial opioids are used medically for their pain relief properties, but their undesired side effect of dopamine release causes addiction. Both effects arise from a basic mechanism common to many drugs:

1. An opioid (endorphin or artificial) bumbles around in the bloodstream and fluid between cells until it nears an important pain or dopamine control region.
2. It binds to a "G-Protein Coupled Receptor" (GPCR) embedded in a neuron membrane. The particular GPCR of interest regarding opioids is a μ-receptor, found in neurons involved with pain processing and dopamine release.
3. When the opioid outside the cell binds to the μ-receptor, the receptor

activates inhibitory G-proteins inside the cell to instigate a cascade of signals within. The signal cascade can do several things to inhibit the neuron from firing, like stimulate potassium efflux, close voltage-gated calcium channels, and reduce cAMP production. The net result: the neuron is quieted.

4. With the neuron hushed by the opioid-bound μ-receptor, the neuron has a dampened ability to pass on a pain signal or block dopamine release. Thus, pain perception is lessened, and dopamine is allowed to flow freely.

Two important clarifications. First, many diverse neurons feature μ-receptors that make them sensitive to opioids. Depending on what system the neuron is a part of (pain processing, dopamine release, etc.) the effects of quieting that neuron will differ. Second, it may seem counterintuitive that an opioid quieting a neuron would result in more dopamine release. Dopamine, though, is controlled in a similar way to a dammed lake: the water (dopamine) is held back by the strong, continuous work of the flood gates (dopamine inhibitory neuron), but when the gates are weakened (the inhibitory neuron quieted), water can come rushing out.

In summary, by binding to μ-receptors found on neurons that control certain pathways, and inhibiting those neurons from firing, opioids can have different effects on the body. Two important effects are pain reduction and dopamine release. While these effects explain the painkiller applications of opioids and their unwanted side effect of addiction, they do not explain how opioids can cause death.

How do opioids cause overdose deaths?

In a similar mechanism to pain reduction and dopamine release, opioids also affect respiration. They depress it. Strong artificial opioids can depress it so much that breathing ceases altogether, and a person may die for want of oxygen. The mechanism for opioid control of respiration continues under investigation, but the following broad strokes appear likely.

There are neurons featuring crucial μ-receptors in the epithelial, submucosal, and muscular layers of the airway responsible for sensing lung intake and release. There are also μ-receptors on neurons in regions that help create breath rhythm by provoking inhalations. Opioids bind to and quiet these neurons in the same way they quiet neurons controlling pain and dopamine release. The result is skipped inhalations and an irregular breathing pattern. With enough opioid binding to μ-receptors, the disruption can become so great that breathing stops altogether, simply due to a lost impulse to do so. This is how opioid overdose deaths can occur.

> Strong artificial opioids can depress [respiration] so much that breathing ceases altogether, and a person may die for want of oxygen.

Be aware that if someone has been in contact with an opioid and starts to breathe infrequently and pass out, emergency support should be called. Luckily, it is possible to reverse the effects of an opioid and restart normal breathing.

How can an overdose be reversed?

The drug naloxone, sold under the brand name Narcan, can be introduced to the bloodstream through nasal spray or injection to completely reverse the effects of opioids. Naloxone is a competitive antagonist of μ-receptors. This means it can bind to the same μ-receptors that opioids do, but it doesn't have quite the right conformation to activate them and trigger the troublesome G-proteins. With no G-protein activation, there is no neuron inhibition. Thus, naloxone boxes the opioid out from μ-receptors and ends its effects. Without disruption from the opioid, the body is able to resume breathing like normal.

A noteworthy characteristic of naloxone is that its effectiveness depends on which opioid is causing the overdose, and how long that opioid stays bound to the μ-receptor. Naloxone is good at reversing overdoses because it has a higher affinity for μ-receptors than opioids do, so it wins the μ-receptor seat in competition. However, before it can compete, the opioids already bound to the μ-receptors must be released. Fentanyl, the artificial opioid responsible for an alarming number of opioid overdoses in the US, binds to μ-receptors very quickly and is released rapidly. An overdose on fentanyl can be reversed in seconds by just one application of naloxone. An opioid that binds to μ-receptors for a longer time, though, may require an extended application of naloxone for reversal. Multiple, longer naloxone applications may also be needed in cases of extremely high levels of opioid in the body. If an opioid overdose victim is not fully responsive to one application of naloxone after three to five minutes, administering another can help, though oftentimes, a single application will suffice.

Naloxone is available over the counter in Ohio, and can be purchased for around one hundred dollars for two doses at CVS pharmacies in over 40 states. In the case that naloxone is not quickly available, call emergency services. It is also critical to get oxygen to an opioid overdose victim as quickly as possible; rescue breaths, one every five seconds, should be given immediately. Since such oxygen delivery cannot sustain a person indefinitely, it is important to respond to an overdose with both naloxone and rescue breaths.

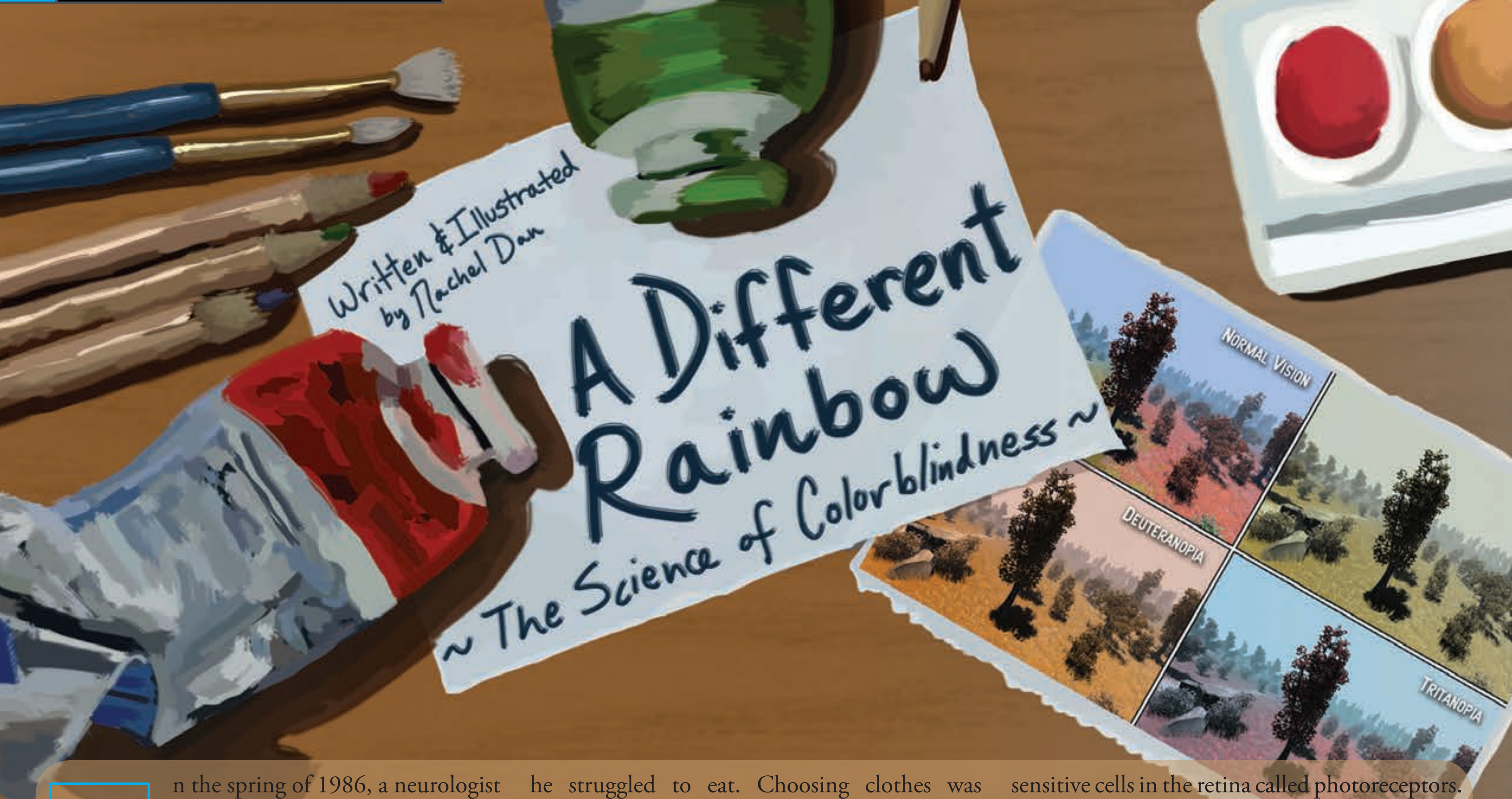
Preparing for what to do in the presence of an opioid emergency is grim business. However, armed with an understanding of how opioids function and how to reverse an overdose, it is possible to save lives and keep people safe.

And a crucial coda.

This article exhibits a firm understanding of the opioid crisis as a health concern. In the past, however, the United States has addressed such substance abuse not as a health concern, but as crime: in the 1980s, when a crack cocaine epidemic affected predominantly black communities, the United States passed laws criminalizing addiction and requiring longer sentencing. Thousands were incarcerated, and communities were torn apart. The opioid crisis originated in rural communities with predominantly white populations. The crisis is being treated, very much correctly, as a public health issue.

New York State Assembly member Diana Richardson outlined the injustice of this discrepancy in a powerful declaration at the state house: "There are racial disparities here. When there was a drug issue in the African American community we were prosecuted, we were put in jail, children were put in foster care.… But now, we have an opioid issue. It is affecting another demographic, and now it is a health issue.… What is missing is a restorative justice package for all those individuals…who have criminal records because they had addiction issues. More needs to be done here." It is good to begin understanding addiction and overdose as health problems; it was and is inexcusably unjust to treat addiction as crime.

With this disparity held in our minds, it is important to move towards compassionate policy changes to support every person struggling with addiction, in the past and present. ●



In the spring of 1986, a neurologist received an extraordinary letter. The writer, Mr. I., had been recently concussed in a car accident. Within days of the crash, his vision had become "that of an eagle" — he could see the smallest details from a city block away. "BUT," he wrote, "I AM ABSOLUTELY COLORBLIND."

Mr. I. did not notice this change until after leaving the hospital. Eager to return to work as an artist, he set out for his painting studio only to find the road shrouded in mist, despite the sunny weather. Alarmed, he rushed toward his studio and was ticketed for running two red lights that he could not see. At last he entered his workspace, seeking comfort in a room he expected to be filled with vibrant paintings. Instead, his artwork was gone. The painter's gaze darted over the slate-toned walls, trying to understand. Though the canvasses hung where he had left them, all their colors had drained away, leaving only black, white, and gray. He closed his eyes and tried to picture the studio as it should have been, but even his memory was void of color. As far as his brain was concerned, the world had always been shades of slate and lead.

Total colorblindness due to brain damage, a phenomenon known as acquired cerebral achromatopsia, is not only incredibly rare — it's irreversible. For people accustomed to the world of color, its effects can be devastating. Mr. I. was disgusted by his new reality. Without color, art and life felt meaningless. Profoundly disturbed by the altered appearance of food, he struggled to eat. Choosing clothes was impossible. Human skin, now rat-colored, was repulsive. He visited specialist after specialist to no avail and gradually sank into despair. That spring, while the world around him delighted at the sight of bluebells and roses, Mr. I. sat at his gray desk and wrote the letter that would lead him to neurologist Oliver Sacks.

> As far as his brain knew, the world had always been shades of slate and lead

Dr. Sacks and his team instantly recognized the importance of Mr. I. Uncovering the cause of his achromatopsia would yield valuable information on how the brain processes color. The task, then, was to determine which part of the painter's visual system had been altered in the crash. In a normal human visual system, light enters the eye and hits light-sensitive cells in the retina called photoreceptors. Activated photoreceptors send a signal back through the retina, down through the optic nerve pathway, and into the visual cortex of the brain. The brain then assembles the information to decide what it is seeing.

All photoreceptors are either rods or cones, both essential for normal vision. Rods are responsible for seeing in low light, providing night vision. Cones perceive color and function best in bright light, which is why it becomes hard to see color in the dark. Humans possess three types of cones, each sensitive to different wavelengths of light. Short cones show the most sensitivity to blue light, medium to green, and long to red. (Cone names do not reflect the sizes of the cones themselves, but rather the size of the wavelengths they receive.) If one type of cone is mutated but still present, a person may be able to perceive that color, albeit weakly. If a cone type is missing entirely, the corresponding color cannot be seen.

Most cases of colorblindness involve only type of one cone, usually red or green. Lack of either red or green cones restricts a person's vision to a blue-yellow spectrum. Due to their similar effects, both conditions are grouped together under the name red-green colorblind. Tritanopia, the loss of blue cones, is far rarer. Tritanopes confuse blue with green and yellow with violet, seeing the world as largely pink and turquoise.

Colorblindness occurs in one in twelve men and one in two hundred women. It is usually genetic, though not all types are

inherited the same way. Both red and green colorblindness are sex-linked, meaning the relevant genes are located on a sex chromosome — in this case, the X chromosome. People assigned as female at birth generally have two X chromosomes, so if one carries a defunct gene, the other can compensate, preventing expression of the abnormal trait. People assigned male at birth, however, have only one X chromosome; if those genes code for colorblindness, nothing can prevent it, which explains the higher prevalence of red-green colorblindness in assigned men relative to assigned women. Tritanopia, by contrast, has no association with sex chromosomes and thus appears with equal frequency in all sexes. It is a dominant trait, meaning one copy of the gene is enough to produce the condition in all cases.

Then there is achromatopsia. Here, it is crucial to distinguish between achromatopsia that is present from birth (congenital) and achromatopsia that has been acquired, such as that of Mr. I. In people born with achromatopsia, all types of cone cells are either nonfunctional or absent, resulting in complete loss of color vision. Unlike Mr. I., born achromats do not describe their world as gray. To them, the concept of gray is as foreign as any other color. At least four genes have been implicated in congenital achromatopsia, which affects approximately one in thirty-three thousand people and, like tritanopia, is not sex-linked.

But what could cause the total colorblindness of Mr. I.? The sudden onset of achromatopsia indicated degeneration of the eye was not to blame, since degeneration requires a longer timespan. Moreover, his cones were functioning perfectly, as evidenced by his ability to see clearly in daylight. If only his rod cells had remained, their inability to function in regular light would have caused Mr. I. to find

daylight unbearable, even painful. This extreme sensitivity to light, called photophobia, is often found in people born totally colorblind, but not in those whose total colorblindness is acquired, since their cones are intact. Our painter's problem, then, lay not within his eyes.

Thus, the only explanations not ruled out were damage to the signal pathway between Mr. I's eyes and brain, or the visual cortex itself. When a visual signal leaves an eye through the optic nerve it passes through the thalamus, a relay station within the brain that decides where the signal goes next. Damage to the thalamus can cause achromatopsia, but such damage is usually internal, such as a tumor, since the location of the thalamus protects it from external harm. The visual cortex rests at the back of the head, making it far more vulnerable; it is easy to imagine Mr. I. injuring this part of his brain when he was rammed by the force of an oncoming truck. In the case of our colorblind painter, all tests conducted by Dr. Sacks suggested damage to the part of the brain that specializes in understanding color, an area of the visual cortex called V4.

Though colorblindness is often viewed as a disability, it can be advantageous in some cases. People who exhibit red-green colorblindness are not easily fooled by camouflage, which made them valuable soldiers in the World War II. Though achromatopsia would not be useful in such a circumstance, Mr. I., whose story was chronicled by Dr. Sacks in the phenomenal book An Anthropologist on Mars, grew to accept and even relish his new way of life. He became, in his own words, a "night person," taking nocturnal walks through city streets and delighting in his superior night vision. He returned to painting, 15 to 18 hours each day, but only in black and white. That was all the color he needed.

Talking to Cli

A Road Map to

Written by
Illustrated by A

So, you're talking to someone close to you or you're talking to someone you barely know. It doesn't matter who they are to you. During the discussion, the conversation turns to climate change and you realize you're the only one in the room who is not a climate denier. It is now your responsibility to defend the scientific consensus that the climate is changing as a result of human greenhouse gas emissions. What do you do in this position?

In the middle of conversations like this, it is important to consider who you are talking to. Several researchers suggest focusing on understanding the involvement of sociology in the climate denier movement. While discussing climate denial, Michigan State sociologists refer to the Conservative White Male Effect: the idea that white males with conservative political opinions are more likely to accept high risks, have an affinity for social hierarchies (which they tend to benefit from), have greater trust for authorities, and oppose government-sanctioned risk management. A general dislike of any threat to the industrial capitalist economic system also exists among this social group. A study revealed that, when asked questions over a phone interview about climate change, they were the most likely to believe that the effects of climate change would never happen, that there is a lack of scientific consensus on climate change, that the media is exaggerating the effects of climate change, and that any increases in temperature are not caused by humans. Why is it that this group is most likely to hold these opinions?

Some argue that this is an effect of cognitive dissonance, in which a discussion of climate issues triggers a defensive reaction, especially in political conservatives, because it indicates that their actions are harmful. In response, they change their attitude to justify their behavior, stating that the media exaggerates the effects of human actions on our planet. Psychologists at University of California Berkeley discuss the Just-World-Theory: the belief that the world has to be just, that rewards will come to good people and punishments will come to bad people. Climate change affects everyone and, therefore, conflicts with the belief in a "just world". When descriptions of the effects of climate change take an apocalyptic turn, people with a "just world" perspective are less likely to heed factual content about climate change. Oberlin College Psychology professor Paul Thibodeau describes systems thinking in relation to climate denial as the consideration of the high risk increasing the likelihood of believing in scientific consensus on climate change and tying economic value to preserving the natural world. With this in mind, it is important to consider how to approach speaking to a person who system thinks, considering that it is very likely that they have heard arguments about anthropogenic climate change in the past, and that those were clearly ineffective in changing their mind.

When discussing climate change, arm yourself with the facts to refute the statements of climate-deniers. By avoiding an apocalyptic description of the future, and by being able to explain why it is we know the climate is changing, convincing a climate denier may be possible (unless they have already dug in their heels too deeply).

Climate change denial tends to take a variety of forms, but some arguments remain particularly common. Many of those looking to sway people towards a more skeptical stance on climate will try to create doubt in scientific consensus. However, among abstracts of scientific literature expressing an opinion on climate change, 97% endorse the position that climate change is happening and is human-caused. Scientific evidence, obtained through empirical research, indicates that if we continue to produce greenhouse gases at the current rate, our climate will become much warmer and affect the world's citizens.

> One of the most common strategies of a climate denier is to claim that they would be unaffected by this change in climate.

Other climate change deniers will try to sway opinions by misinterpreting factual information. A very common argument about climate change is that in 4.5 Billion years of Earth's history, the climate swayed rapidly several times, showing that the planet is following its natural patterns as the global temperatures increase. However, climate models indicate that our global temperatures are skyrocketing at a higher rate than ever before.

imate Deniers

Changing Minds

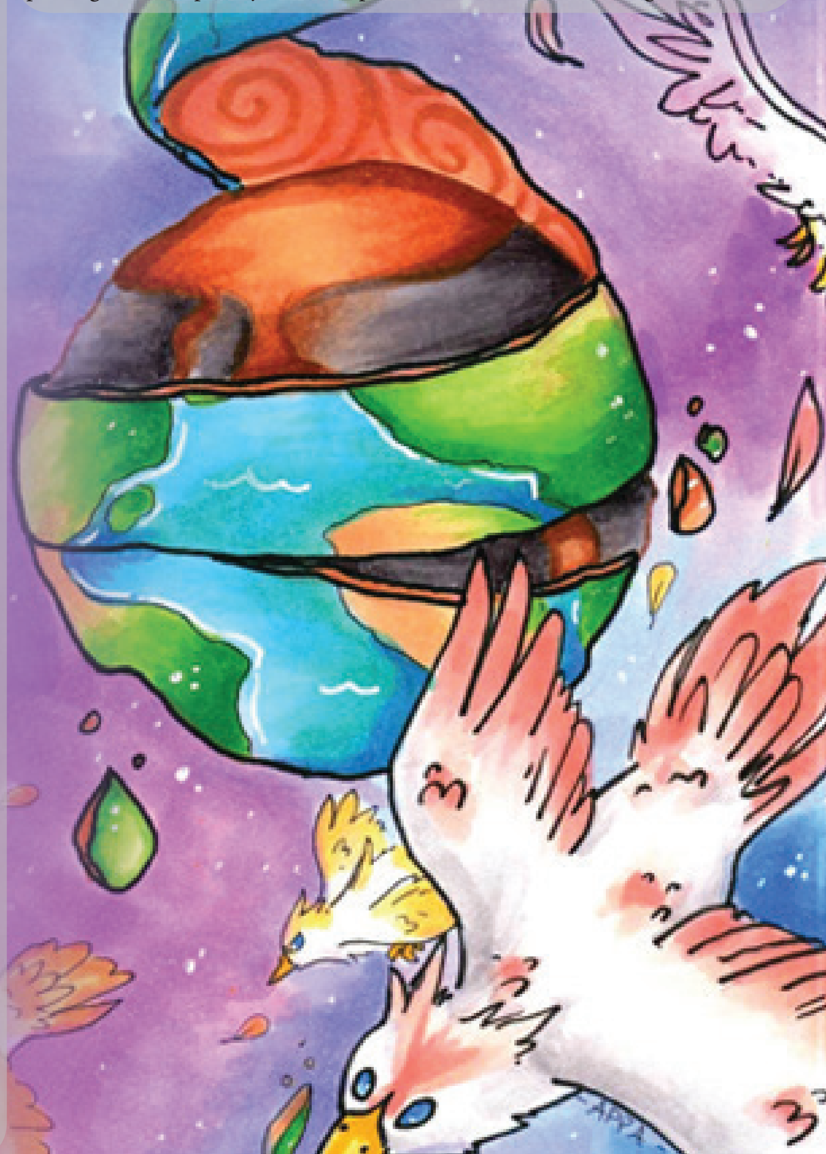
Anah Soble
thina Apazidis

One known analog to the speed at which our climate is changing is the Paleocene-Eocene Thermal Maximum (PETM), a rapid climate change event 56 million years ago during which average temperatures quickly increased by 6-8 degrees C. The root of the cause of this event is still undecided, but the direct cause was a rapid release of methane from the ocean. The planet took 200,000 years to recover from this rapid change in climate. In reality, natural history is simply further proof that human carbon emissions are negatively affecting the planet. Researchers are still trying to better understand the PETM and how it affected ecosystems. Because the fossil record on land is relatively sparse, scientists are looking at evidence from other climate events. All of the "Big Five" extinctions in history, from the death of the dinosaurs in the Cretaceous-Paleogene extinction to the wiping out of 95% of life on Earth in the Permo-triassic Extinction, were in some way related to major changes in the climate. Life on Earth depends on consistent and predictable climate patterns of which the effects of modern climate change will disrupt. If we are aiming for the predictability of climate that nature requires, we need to change our behaviors as a species.

One of the most common strategies of a climate denier is to claim that they would be unaffected by this change in climate. Unfortunately, this may be caused by our own discourse around climate change. Many advocates for change have made the mistake of associating climate change with the loss of certain animals, particularly polar bears. Unfortunately, many Americans seem to only superficially care about cute animals and it is only their own families that they really care about. Connecting climate to human health is an important step in recognizing the life-threatening effects of climate change. Climate change has caused an increase in heat waves, hurricanes, dangerous winds, forest fires, and droughts which have all had negative effects on human health and safety. Centers for Disease Control and Prevention claimed that there is a need for public health to prepare for the future. The apocalyptic approach to explaining how climate will affect Americans is obviously ineffective for those with "just world" beliefs. However, explaining the ways in which the changing climate will affect more than just polar bears and people on the other side of the world may help to contextualize the risks.

Many arguments are easy to refute and knowing the difference between climate and weather is an important step. Famously, Senator Jim Inhofe threw a snowball onto the Senate floor to indicate his disbelief of the warming climate in February of 2015. He is not alone. Many Americans do not understand that climate is related to patterns in weather over a long period of time, accounting for seasons and location, while weather describes day to day atmospheric changes. Other arguments are more difficult to approach. It is challenging to refute the argument that it is too late to mitigate climate change, and, therefore, there is no point in working to decrease admissions. Realistically, if we stopped carbon emissions today, we would still see the effects of climate change. However, it is not too late to limit some of the effects. By limiting the amount of carbon released into the atmosphere, we can hope to avoid some of the extreme effects. Furthermore, by preparing to adapt to higher sea levels and changes in global patterns we can protect the most vulnerable in our communities. Climate mitigation is not worthless.

Knowing the facts and avoiding scare tactics increases the possibility of effectively changing the minds of climate change deniers. Knowing how to handle the menagerie of logical fallacies, misuse of facts and the lies that climate deniers will use to defend their world view is one step in educating the public on climate. Timing is also important. Educating young people on the facts through clear communication and understanding early on is essential. Finding ways to make these conversations less awkward is important for the continuation of dialogue as well. Having an education in the sciences is a privilege and, hopefully, we can spread our education and do good work.



First Lab-Grown Human Eggs

A Beacon of Hope for Infertility

Written by Jayla Johnson
Illustrated by Zoe Cohen

February marked the beginning of immense new possibilities for fertility treatment. Researchers from the University of Edinburgh and New York's Center for Human Reproduction grew the first successful human eggs in a laboratory. This establishes the first-time human egg cells were removed and grown from ovary tissue at the cells' earliest stage of development. This scientific landmark both widens the potential of future fertility treatments and opens the possibility for further insight into the process of the development of human eggs, where a surprisingly large portion of the process still remains a scientific mystery.

In the human body, egg cells, or oocytes, usually develop in the follicles, which are small, fluid-containing sacs inside the ovaries. Produced in the pituitary gland, follicle stimulating hormone (FSH) and luteinizing hormone (LH) are responsible for signaling and causing immature oocytes (contained in follicles called primordial follicles) to develop into larger, more mature oocytes. Developing eggs outside the follicles of the ovary in the laboratory requires control of oxygen levels, hormones, growth stimulating proteins, and the medium culture in which the eggs grow. Dr. Evelyn Telfer and her colleagues at the University of Edinburgh carefully regulated these environmental conditions to bring the immature human eggs into maturity. The team began with ovarian tissue obtained from volunteers and primordial follicles from pieces of ovarian tissue. The individual oocytes were then removed from each follicle, and the researchers concentrated on growing the oocytes to a size typically seen at ovulation. There is a push for molecular characterization and chromosomal analysis testing to examine how the lab-matured egg cells compare to normal eggs. The human eggs grown to full maturity remain unfertilized, so the viability of the eggs has yet to be tested. Dr. Telfer and her team recently applied for a license to fertilize the lab-matured eggs with sperm, testing the lab-grown eggs' viability.

An abnormality that arose during the experiment is the unusually large "polar bodies" of the lab-matured eggs. An oocyte must shed half of its genetic material during development to reach the needed 23 unpaired chromosomes, and the excess genetic material is discarded into a tiny cell called a polar body. The development of oocytes is an incredibly controlled and timed process in the human body; if the egg cell does not shed some genetic material, too much DNA will be present when it is fertilized by a sperm. While abnormally large polar bodies might be harmless as polar bodies are normally discarded by the body, large polar bodies could mean the eggs are missing essential cytoplasm. Cytoplasm contains crucial energy-providing properties, so the eggs might develop adversely as a result of loss of cytoplasm to polar bodies. Dr. Telfer believes that by improving the technology, this abnormality can be prevented.

Prior to this scientific landmark, eggs had to be fully matured before they could be removed from a person's ovaries. To do so, individuals often underwent hormone treatments to trigger the ovaries' maturation process, causing the release of multiple eggs for collection and fertilization. The hormone treatment process is generally arduous, and comes with the risk of cancer, ovarian hyperstimulation syndrome, and long-term fertility effects. Now, the opportunity exists for individuals to forgo the hormone treatments needed for full egg maturity for in-vitro fertilization or storage. Growing human egg cells from the cells' earliest stage to full maturity means it could be possible to avoid hormonal treatments altogether.

The technique's potential of growing eggs to full maturity also offers new ways of preserving the fertility of children or young adults undergoing cancer treatment. Infertility remains a common complication for adults assigned female at birth who received treatment for cancer in their childhood. Treatments such as radiation, surgery, and chemotherapy often adversely affect parts of the hypothalamus, pituitary gland, and the gonads,

> Growing human eggs in the laboratory to full maturity could, in the future, be added to the list of accessible fertility preservation measures for childhood cancer survivors or people with ovarian fertility disorders.

jeopardizing cancer survivors' reproductive outcomes. The maturation of primordial follicles is connected to ovarian hormone production. Thus, particular agents of chemotherapy that indirectly deplete follicles may influence ovarian hormone production and fertility. Preservation fertility measures are subsequently often considered if an individual's cancer treatment is expected to create a risk of infertility. Currently, fertility preservation involves removing pieces of young children's ovaries before beginning chemotherapy or radiation treatments that might harm their egg supply, then reinserting the tissue when the patients are older and desire to start a family. The only problem is that the tissue could potentially contain residual cancer cells. However, with matured eggs developed from ovarian tissue in the laboratory, these eggs could be fertilized in vitro, where only the resulting embryos would be implanted. This would thus bypass the issue of replanting cancerous tissues.

Growing human eggs in the laboratory to full maturity could, in the future, be added to the list of accessible fertility preservation measures for childhood cancer survivors or people with ovarian fertility disorders. While a lot rests on the success of fertilization from the lab-matured egg, the results from the experiment will regardlessly pave the path for further research. The research has challenged our understanding of fertility and oocyte development, and has sparked greater hope for discoveries that lie on the horizon.

Fighting 50 Years of Failure

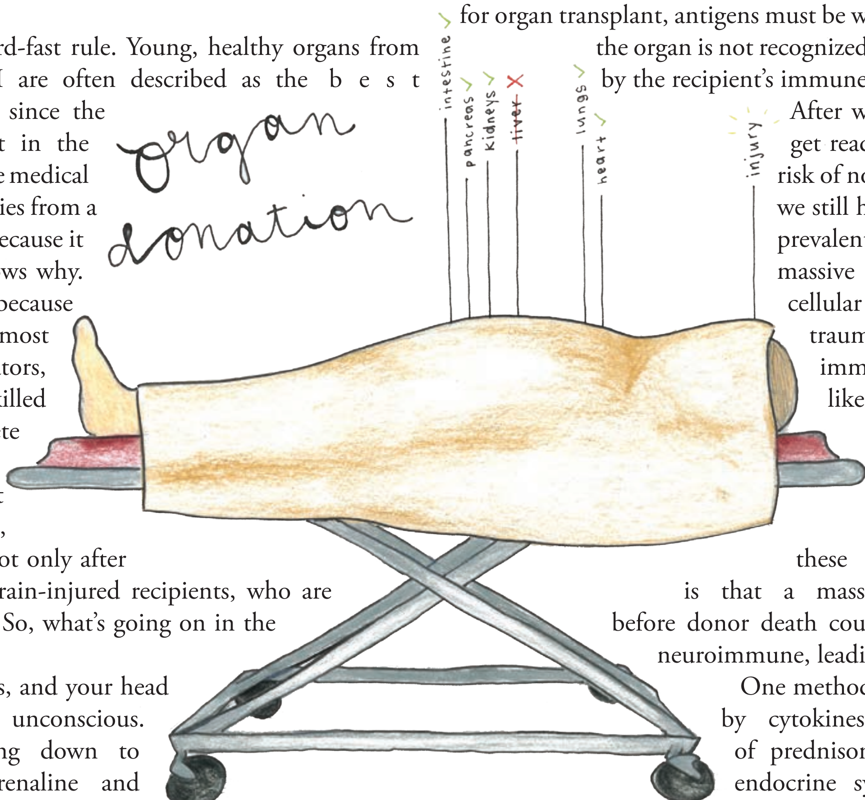
Liver Transplant Failure after Traumatic Brain Injury

Written by Zoe Swann
Illustrated by Claire Hoy

Every day, 30 people die before they can receive life-saving organs (i.e., 11,000 people every year), according to Donate Life America. Organ shortage is increasingly found to be one of the most urgent medical dilemmas of our generation.

Most organ donors die in car crashes. A third of all people who die from traumatic brain injuries (TBIs) die in car crashes. Therefore, TBI victims supply most organs viable for donation and transplant. Of these organs, the liver has posed a particular problem for the medical community. I am currently working on a project with the University of Arizona's College of Medicine to determine a long-unexplored question: why does liver transplant tend to fail if the donor has had a traumatic brain injury?

Now, this is not a hard-fast rule. Young, healthy organs from motorcyclists who die of TBI are often described as the best candidates for transplant. But since the first successful liver transplant in the 1960s, it has been a mantra in the medical community that if your donor dies from a TBI, you don't take their liver, because it will probably fail. Nobody knows why. This is especially worrisome because brain-dead donors make up most of the population of car-operators, motorcyclists, and pedestrians killed each year (not to mention athlete and veteran populations who often undergo severe, if not fatal, brain injuries). Even worse, liver transplant failure occurs not only after a donor's injury, but also in brain-injured recipients, who are already struggling to stay alive. So, what's going on in the body?



BAM! Your car crashes, and your head whips forward, knocking you unconscious. Your periphery starts shutting down to keep your brain alive. Adrenaline and norepinephrine, examples of hormones called catecholamines, upregulate when you walk onto a stage — or give yourself a head injury. Your heart starts pumping, your hands start sweating, you may even lose control of your bladder; your body starts to shut down to prioritize other systems. In severe head injuries, a "catecholamine storm" may occur, resulting in vasoconstriction, spinal cord paralysis, and lack of oxygen — all in an effort to maintain cerebral perfusion, the amount of blood and oxygen in your brain. Normally, your mere three-pound brain uses 20% of the body's oxygen. Now, your brain is starving, and your body does everything it can, even at the expense of the rest of you, to maintain those oxygen levels. This redirection of oxygen causes organ damage throughout the body, including viable livers.

> In the medical community, if your donor dies from a traumatic brain injury (TBI), you don't take their liver, because it will probably fail. Nobody knows why.

Transplant aggravates the recipient's immune system, which, detecting a foreign body, attacks the new organ. Cytokines, molecules that signal immune cells to respond to a disease or injury, can be pro-inflammatory or anti-inflammatory. Often the cytokines we see with brain injury (such as IL-6, TNFa, or IL1B) are pro-inflammatory. Pro-inflammatory responses increase swelling, giving immune cells more access to the injured area of the brain. However, these cytokines can also affect the donor's immune cells responsible for long-term response, called B cells and T cells. An individual has their own set of B and T cells that remember markers, called antigens, on immune cell surfaces. This is how B and T cells distinguish self from non-self (e.g., a virus or dead cell debris). During preparation for organ transplant, antigens must be washed from the organ's surface so the organ is not recognized as non-self and thereby attacked by the recipient's immune system.

After washing the organ of antigens to get ready for transplant and reduce the risk of non-self recognition and rejection, we still have a problem that is even more prevalent in the case of brain injury. The massive upregulation of cytokines and cellular damage we see after fatal head trauma may have affect peripheral immune cells. Certain cytokines, like TNFa, contribute to direct cell death and necrosis, causing liver damage and dysregulation.

Cytokines are at the heart of the problem in all three of these mechanisms. My hypothesis is that a massive cytokine increase shortly before donor death could result in the liver becoming neuroimmune, leading to recipient graft rejection.

One method to reduce inflammation caused by cytokines involves the administration of prednisone, a steroid that acts on the endocrine system to downregulate NFkB signaling, repressing pro-inflammatory responses. But prednisone treatment has proved to be complex. One study found that after prednisone administration in brain-dead rats, cytokines were favorably regulated in the kidney, but not in the liver. A major inflammatory cytokine, IL-6, was highly upregulated after brain death in the kidney and liver, but reduced after prednisone administration in only the kidney.

Another molecule responsible for programmed cell death is C-3, part of the complement system generated in the liver. The complement system serves to enhance the ability of antibodies to promote inflammation and attack foreign microbes. After prednisone administration, this molecule is downregulated in the kidney but significantly unregulated in the liver. Other studies have shown variable efficacy in prednisone and steroid administration both in the liver and in organs more generally.

Despite these efforts to understand the workings of TBI-related liver rejection, much remains unknown. The body is an incredibly complex machine whose systems interweave beyond imagination. Ethics, public knowledge, and family consent are other roadblocks in procuring lifesaving organs. But we might just discover the cure for this ongoing medical dilemma. So do not give up — donate to science, do research, and consider registering to be an organ donor.

Debating the Use of Public Lands

Conservation or Mining for the Boundary Water Canoe Area Wilderness

Written by Ally Fulton
Illustrated by Francesca Scola

Just north of Ely, MN lies a seemingly endless expanse of brilliant blue lakes and vibrant green islands. Noise from planes and vehicles cease, and signs of human activity are hard to come by. It's a place traversed by canoe where you can travel for two weeks without seeing another person.

This is the Boundary Waters Canoe Area Wilderness (BWCAW), a 1.1-million-acre national wilderness area in the Superior National Forest in northern Minnesota. The region has a century-long history of protections starting in the early 20th century. In 1926, it became a 640,000 square mile roadless wilderness area. In 1964, with the congressional passage of the Wilderness Act, the BWCAW became part of the National Wilderness Preservation System. A little over a decade later in 1978, Congress enacted the BWCAW Wilderness Act, which extended the bounds of the park to its current size, eliminated logging and snowmobiling, restricted mining permits, and allowed motorboats on a quarter of the wilderness area. Today, the wilderness area is one of the nation's most popular, receiving 150,000 annual national and international visitors.

While the area has a long history of conservation, northern Minnesota has an even longer history of mining. Iron ore mining has been the primary economic driver for generations. However, since the 1980s many northern Minnesota towns have seen significant population and job loss as mines close. In the past decade, two major mining conglomerates, PolyMet and Twin Metals (a subsidiary of the massive Chilean mining corporation Antofagasta), have poured millions of dollars into surveying mineral deposits in the Superior National Forest on the edge of the BWCAW. They have collected permits and submitted their projects for environmental review, all in an effort to build underground sulfide mines. In December 2016, the Obama administration, in their final weeks, refused to renew Twin Metals' mineral leases, which they would need to build a copper-nickel sulfide mine. In response, Twin Metals filed a lawsuit against the federal government, citing this decision as a "blow to [the] economic vitality" of the region.

> The conflicting claims made by the conservationists and the mining companies crease, "two Elys, two different realities, different visions".

In late December 2017, the Trump administration reversed the Obama-era decision claiming they did not have the discretion to deny Twin Metals leases for copper and nickel mining and reopened the possibility for mining in the region. The federal leases at the center of the conflict over the proposed mine were issued over fifty years ago before the passage of wilderness laws. The charge was led by Democratic Congressman Rick Nolan and Republican Congressman Tom Emmer's HR 3905 bill "Minnesota's Economic Rights in the Superior National Forest Act," which the House passed on November 30, 2017. Currently, Nolan and Emmer have Amendment 70 floating around to attempt to defund the United States Forest Service (USFS) study of the impacts of sulfide mining on the BWCAW ecosystem.

The nuanced debate stems from the long histories of mining and conservation in northern Minnesota and is only heightened by America's current fractured political state and the added dangerous environmental consequences of sulfide mining. Sulfide mining removes metals, such as copper, nickel, and platinum, from sulfur-bearing ores. These common metals fuel major consumption patterns around the globe, as they are used in vehicles, cell phones, and countless other products. While the negative environmental effects are many, the main pollutant comes from acid mine drainage (AMD). AMD is a process that occurs when sulfides in excavated mine rock are exposed to oxygen and water through weathering. Sulfuric acid is produced as a result and will continue to erode the rock for years or even decades until it is no longer exposed to air and water or the sulfides are removed.

Sulfuric acid drains pose a significant risk of polluting the interconnected waterways of the BWCAW because the acid from the site can spread by rainwater to surface water or can seep into groundwater and severely degrade water quality. The Twin Metals proposed underground mine targets four mineral deposits that lie largely on public land in the Rainy River watershed. The surface waters and any potential pollutants above the deposits — in Birch Lake, between Birch lake and the BWCAW, and along the south Kawishiwi River — will flow into the BWCAW. Because sulfide mining is the nation's most toxic production industry, according to the Environmental Protection Agency, the lakes and rivers of the BWCAW are particularly vulnerable. The potentially harmed area is 234,000 acres of the Superior National Forest, an area fifty times bigger than the leases held by Twin Metals.

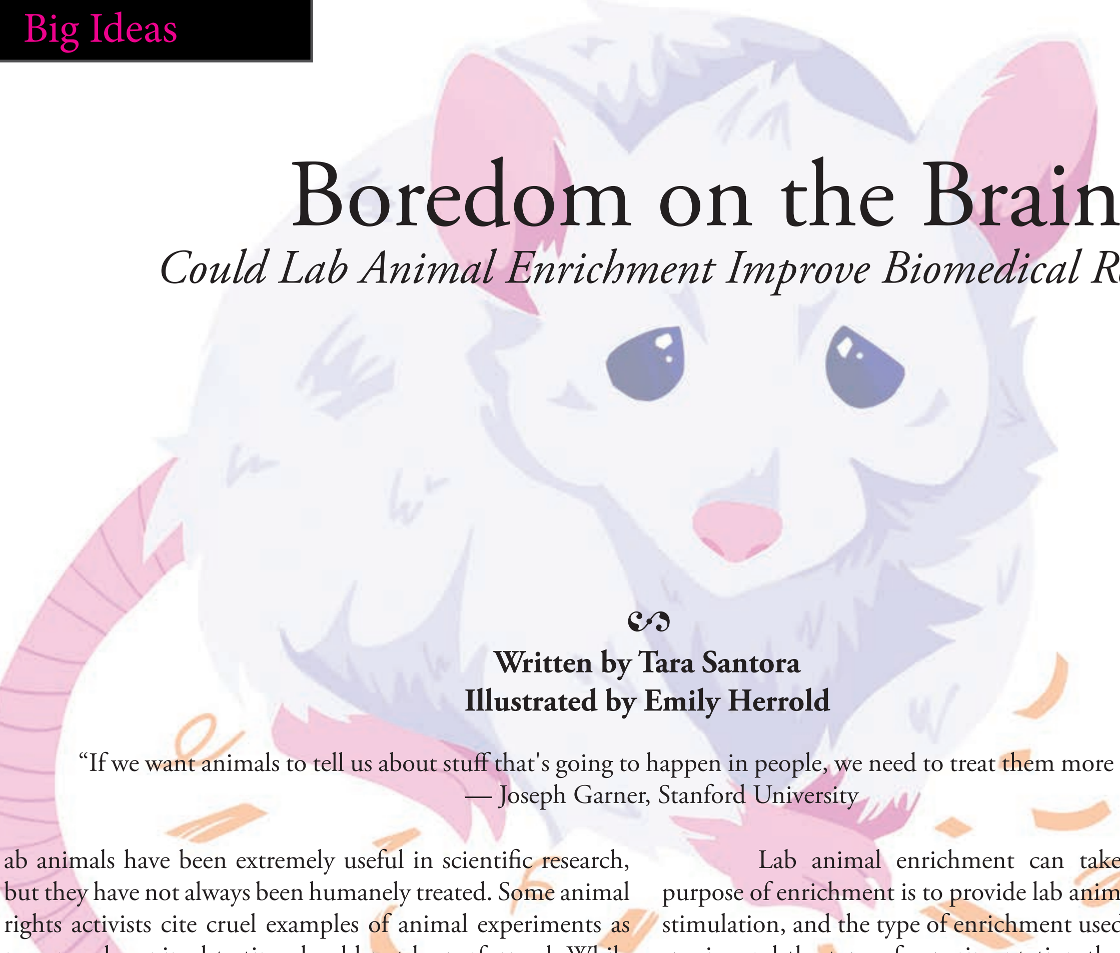
Twin Metals claims their testing indicates the leftover rock will be non-acid generating. However, as stated by a Friends of the Boundary Waters sponsored website: "Mining companies are unable to point to a sulfide mine that has ever been developed, operated and closed without producing polluted drainage from its operations." Moreover, it is common for mining companies to go bankrupt when mines close because they have no incentive to stay if the mine is completed or if mineral prices take a hit. When this happens, costs are often deferred to taxpayers, and the locally affected community ends up paying the environmental and monetary damages.

The conflicting claims made by the conservationists and the mining companies create,"two Elys, two different realities, different visions," says Tom Coombe, editor of the Ely Echo and fourth-generation Ely local. The other reality is shaped by a population of mining families who have made their livelihoods for generations from iron ore mining in the region. One such mining advocate is Dan Forman, a taconite miner whose family has been mining in Ely since the late 19th century. He is frustrated by the moral integrity exhibited by the generally white-collar conservationists who are against mining, pointing out their constant consumption of products that only function from the hard metals that Forman and other blue-collar workers mine on a daily basis. Also, he cites the economic security that comes with working in a mine, which pays more and with greater benefits than the more seasonal, lower-paying positions that tourist job positions pay. Without mining, he says, these small northern Minnesota towns wouldn't exist.

> So continues the national debate about the proper use of American public lands, and what kind of economy those lands will support.

So continues the national debate about the proper use of American public lands, and what kind of economy those lands will support. The divide runs deep, from the federal clash between lawmakers to the bitter arguments between local Minnesota residents. After the Trump administration's late 2017 decision, Twin Metals issued the statement: "This decision is an important first step to ensure the certainty of investments in U.S. mining projects and to reaffirm long-standing property rights and the rule of law." In stark contrast, Democratic Congresswoman Betty McCollum stated, "The bill will create an industrial wasteland. One of our nation's last wild places becomes collateral damage." Wild places should not suffer at the environmentally irresponsible hands of mining conglomerates, but it is important to keep in mind the economic vitality and well-being of a major sector of the population.

If you'd like to read more about the debate over the use of public lands, check out Reid Forgrave's *New York Times* article, "In Northern Minnesota, Two Economies Square Off: Mining vs. Wilderness".



Boredom on the Brain

Could Lab Animal Enrichment Improve Biomedical Research?

Written by Tara Santora
Illustrated by Emily Herrold

"If we want animals to tell us about stuff that's going to happen in people, we need to treat them more like people."
— Joseph Garner, Stanford University

Lab animals have been extremely useful in scientific research, but they have not always been humanely treated. Some animal rights activists cite cruel examples of animal experiments as reasons why animal testing should not be performed. While some experiments cause lab animals pain and discomfort, even the everyday housing for these animals can cause them undue stress. Often lab animals are kept in cages only a fraction of the size of their natural range, their exposure to other animals is limited, and the lighting they are exposed to does not match their biological clock. These conditions can cause lab animals to have weak immune systems and develop cancer before they even have time to be experimented on.

However, animal testing does play an important role in ensuring human safety. In 1937, a pharmaceutical company in the U.S. marketed an antibiotic dissolved in a solvent that was, unknowingly, poisonous. There were no federal regulations mandating animal testing of medicine at the time, so the company skipped this step and headed straight to market. More than a hundred people died as a result, but their deaths could have been prevented by lab animal testing. In 1938, the U.S. government passed the Federal Food, Drug, and Cosmetic Act, which requires animal testing for safety before products can be sold.

Federal regulations requiring animal testing eventually led to regulations on how animal testing is conducted. The Animal Welfare Act of 1966 set minimum safety requirements in handling lab animals, and the requirements are minimal indeed. The tone of the document is that of ensuring animal survival, not comfort or well-being. The Act focuses on ensuring that animals have adequate space, food, and water, and that their habitats have suitable light and temperature.

Researchers often keep lab animals in featureless housing to decrease environmental effects and variations from standardized lab animal care. Some scientists believe that lab animal enrichment should be added to the list of standard lab animal care procedure. On the other hand, many worry that adding variation to lab animal care by providing variable types of enrichment could have negative consequences on research results. However, the typical featureless environment can itself impact lab animals, and those impacts may negatively affect the quality of scientific research.

Lab animal enrichment can take many forms. The overall purpose of enrichment is to provide lab animals with mental and physical stimulation, and the type of enrichment used is dependent on the animal species and the type of experimentation the animal is undergoing. One form is social enrichment, in which members of the same species are allowed to interact in a common space. Another type of enrichment is when animals are provided toys like crawl balls or chew sticks. Enrichment can also be provided through sensory stimuli, such as music to listen to.
While not all labs provide their test animals with enrichment, Oberlin College does. Lab animals at Oberlin include rats, mice, opossums, and zebrafish. If experimental parameters allow for it, the rodents are housed communally, as a form of social enrichment, since they are social animals. Additionally, the cages are designed so that the rodents can climb them, and the rodents are sometimes given cardboard that they can use to build nests.

Some researchers are calling for lab animal enrichment as a way to improve biomedical trial results. Only one out of nine drugs that succeed in animal trials pass through human trials. Some scientists think this may be because people generally live very different lives from lab animals. Most people are not confined to small areas and limited social interaction. Most people have toys to play with, stories to read, or other ways to engage their mind and body. Most lab animals do not. If lab animals had similar stimulation to humans on a daily basis, would they be better models for human disease? Some research suggests this is the case, but more evidence is needed to make any definite conclusions.

From an animal rights perspective, if animals must be used for lab research, they should at least be treated well. They have a right to living conditions that allow for them to be happy and healthy. But caring for lab animals is expensive; cages, cleaning supplies, food costs, and personnel costs can be high and ongoing. Some labs require hundreds of animals, and enhancing living conditions often translates to increasing expenses. While some forms of enrichment are cheap, like cardboard for nesting, enrichment like running wheels can be more expensive. Toys require cleaning, and cleaning costs add up over time. Many scientists wonder, how can we afford to enrich the lives of lab animals? Others argue, how can we afford not to?

The Death of the Luminiferous Aether

The Evolution of Scientific Thought

Written by Miguel Botran **Illustrated by Zimeng Xiang**

Scientific knowledge can feel monolithic and unchanging; we forget that many scientific ideas have been abandoned. It is important to look at the dogma of the past, to see how old scientific knowledge has been superseded by new ideas. Examining superseded scientific theories reminds us of the ever-changing nature of scientific knowledge.

The luminiferous aether, the hypothetical medium through which light propagates, is one such superseded scientific theory. We now understand that light acts as both a wave and a particle through wave-particle duality. However, in the 19th century people thought light acted only as a wave, and that waves needed a medium through which to propagate. It therefore seemed natural that light would have to propagate through a medium. At the time, it was understood that sound propagated through air and other materials, water waves propagated through water, and, theoretically, light propagated through the luminiferous aether.

Today, we know that the luminiferous aether doesn't exist, and that light travels instead through empty space — but how did we come to know this? The theory of the luminiferous aether came to an unexpected halt due to the 1887 Michelson–Morley experiment, conducted by scientists Albert A. Michelson and Edward Morley, who had hoped to prove the existence of the luminiferous aether. However, before we delve into the 1887 Michelson–Morley experiment, let us first explore the status of the luminiferous aether in the scientific community up to that point.

Throughout history, light has been considered both a particle and a wave at various points in time. At the time of the 1887 Michelson-Morley experiment though, it was generally understood that light acted only as a wave. In 1704, Isaac Newton put forth in his book *Opticks* the theory that light was made of particles. Newton's theory still required an aether, but was, at the time, the most accurate theory of light in terms of predictions and experimental observations. Newton's theory of light didn't explain diffraction, the interference effect of light waves that creates repeating patterns of bright and dark bands, so he proposed an "Aethereal Medium" being responsible for the phenomenon. Newton's understanding of light was eventually overturned in the early 19th century due to experiments like those done by Thomas Young, who demonstrated light's wavelike nature in a double-slit experiment. This theory of light as a wave differed from older theories as these were proposed to be transverse waves, not longitudinal waves. This understanding of light as a transverse wave once again revived the need for a medium through which light can travel. However, instead of acting like a fluid, the medium had to act more as a solid because transverse waves only travel through solids.

The idea of a solid that solely interacted with light initially raised questions in the scientific community, but George Gabriel Stokes developed a model which acted as a solid when interacting with high frequencies and acted as a fluid at lower speeds, explaining why the earth and other planets could travel through this medium. In the 1860s, James Clerk Maxwell published his works, which successfully combined the electric and magnetic forces and also proposed that visible light was an electromagnetic phenomenon. Maxwell's equations described all electromagnetic waves propagating at a fixed speed.

Physicists in the 19th century were concerned whether the luminiferous aether was dragged by or entrained by the motion of the Earth. Some believed there was no relative motion between the Earth and the luminiferous aether, while others proposed that an aether wind was created by the motion of the earth through the luminiferous aether. Maxwell's equations were understood by many to mean that the luminiferous aether was the absolute frame of reference for the universe, such that it appeared universally still.

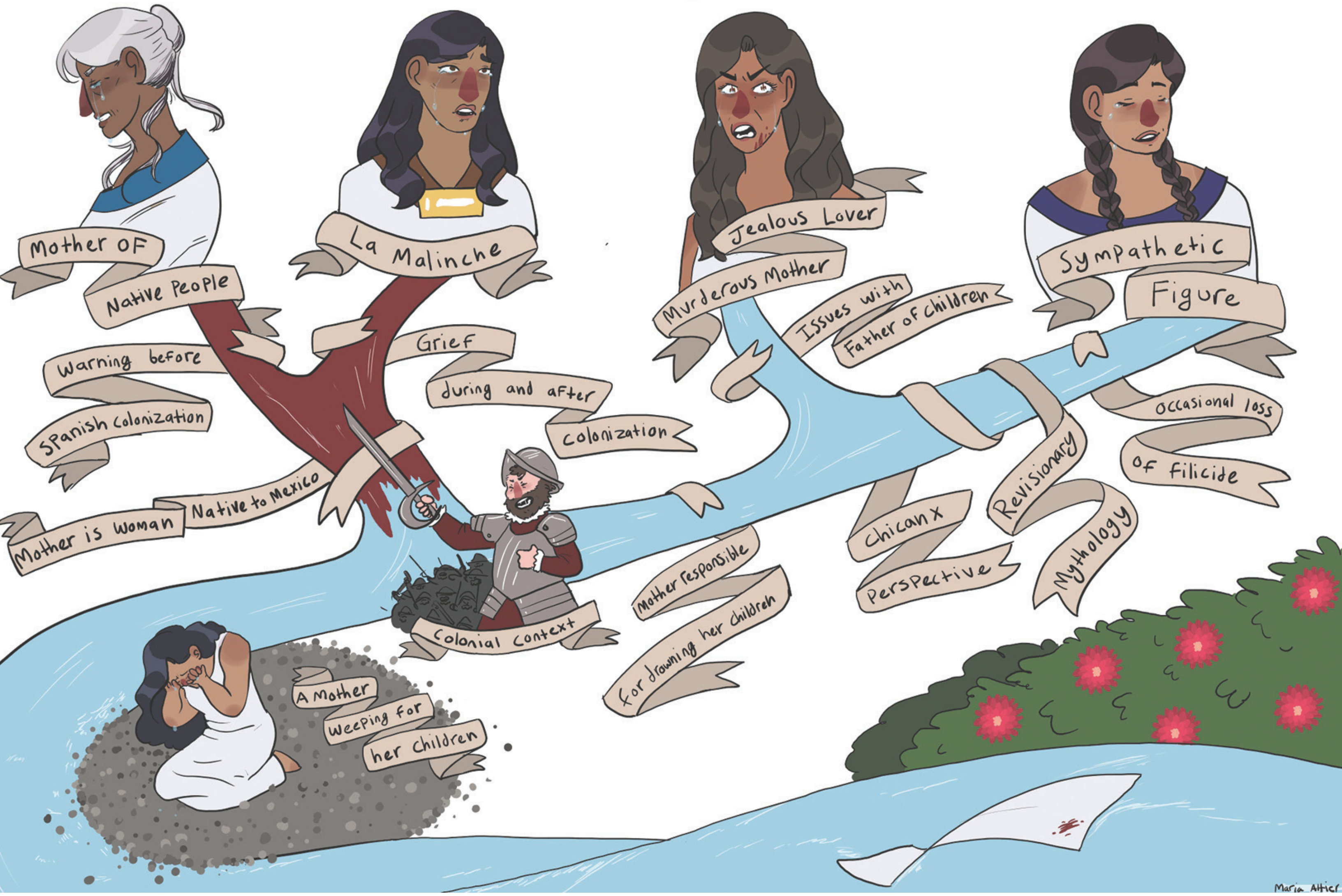
The idea behind the 1887 Michelson–Morley experiment was simple: if the luminiferous aether was the medium through which light propagates, then we must be moving through it as Earth orbits around the Sun. This meant that measuring the speed of two different perpendicular light rays would yield different results, as one of the light rays would "speed up" more due to extra velocity added by the luminiferous aether's motion relative to the Earth's orbit and rotation. However, Michelson and Morley instead noted that the speed of light never changed between the perpendicular light rays. Numerous other recreations of this experiment pointed to the same result: the luminiferous aether doesn't exist. Eighteen years later, Einstein proposed his Special Theory of Relativity, in which the speed of light was constant, regardless of reference frame, and in which light did not require a medium through which to propagate. Einstein's Special Theory of Relativity struck the death blow to the luminiferous aether theory, as the latter's presence was no longer required for a working theory of light.

The story of the luminiferous aether's birth and death is a perfect encapsulation of scientific progress. Experiments like the 1887 Michelson-Morley experiment remind us of the unexpected results that the scientific method often leads us to. Science history is full of superseded scientific theories like the luminiferous aether: spontaneous generation, caloric theory, phlogiston theory, contact tension, and, of course, the ptolemaic system. As expressed in the introduction of *Twenty-Five Years of Asymptotic Freedom* by theoretical physicist David Gross, "Science progresses in a much more muddled fashion than is often pictured in history books.... Consequently, historians of science often ignore the many alternate paths that people wandered down, the many false clues they followed, the many misconceptions they had. These alternate points of view are less clearly developed than the final theories, harder to understand and easier to forget, especially as these are viewed years later, when it all really does make sense. Thus reading history one rarely gets the feeling of the true nature of scientific development, in which the element of farce is as great as the element of triumph."

La Llorona

The Ecology of Folklore

Written by Cella Wright
Illustrated by Maria Altier



She is weeping, wailing, crazed, vengeful — she is La Llorona, the famous haunt of Latin American folklore. She is called "The Weeping Woman," but the cause of her crying varies substantially in different tellings. The folktale has an expansive history, is comprised of seemingly endless iterations, and plays a significant role in Latinx folk traditions, cultural identity, and diasporic communities. As in most folklore, her origin is almost impossible to pin down. It would appear that she emerged in oral tradition before the Spanish invasion, since she is mentioned in colonial texts of the 1500s chronicling the Mexican highlands. Folktales are generally multilayered due to the array of human experiences by which they are shaped. They are translated into different personal, social, political, and cultural contexts over the span of hundreds of years. In this way, they embody a sustained discourse.

Ecology examines how organisms interact with their environment and one another. It explores and honors the complexity within ecosystemic networks. This makes ecology an interesting perspective from which to view the folktale, which aptly participates in a complex web of communication. We can use an ecological approach with a small sampling of La Llorona variations to get a sense of how her narrative has adapted as it has been translated through storytellers, languages, places, and time. This kind of narrative ecology may shed light on the conditions that have influenced the story, such as those of gendered archetypes, colonization, and diaspora. Furthermore, La Llorona's history and variations can be imagined in the visual framework of phylogenetic trees, which are used in biology to illustrate the hypothesized evolutionary relationships among species.

The narrative of La Llorona can be considered as a form of DNA that encodes aspects of the culture it is a part of. This cultural DNA is stored, replicated, transcribed, translated, and inevitably mutated. La Llorona's variations result from mutations that change the narrative, however slightly, during the act of transmission. These mutations can contribute to its ability to adapt to its current environment. As a result, La Llorona remains relevant despite hundreds of years of shifting conditions.

The general template of this folktale is a woman who is crying for her children. In most iterations of the story, she is said to have drowned her kids in a river. The reasons for this atrocity vary. In some tales, she acts out of revenge against her cheating or negligent lover. In others, her children are illegitimate and there is an uneven power dynamic between La Llorona and the father, in which she takes the form of an indigenous woman of a lower socioeconomic class while he is an aristocrat of European descent. Her ghostly apparition is usually beautiful (though sometimes hag-ish), clothed in white, wailing for her children, and a serious threat to men and boys.

A divergent vein of the tale offers another explanation for her crying that is tied to colonization. In one of these stories, a woman weeps through the streets of Tenochtitlan, the Aztec capital, for the fate of her children before the Spanish invasion. Her children are the native people of México, faced with the violent erasure and injustice of Spanish colonization. Unlike her murderous equivalent, La Llorona is a maternal protector figure who suffers colonial exploitation here. In another, La Llorona is La Malinche, the indigenous woman who served as Hernán Cortés' translator, advisor, and mistress. She had a son, who was supposedly one of the first mestizos. Again, her ghost is also still weeping for her lost children, for the Mexican people.

> The role of the storyteller is inherently powerful: individuals make artistic and subconscious decisions in their retellings that inevitably reflect their beliefs.

We can imagine La Llorona's variations roughly in a phylogenetic tree (Fig. 1). There may have been a singular common ancestor or there may have been several origins (an issue mirrored in evolutionary biology). It could be hypothesized that the initial branching event took place during the time when the roles of La Llorona split between the pre-colonial and the murderous mother. Then the narrative continues to differentiate in response to changing conditions, further reproductive events, and accumulated mutations. The branching points, called nodes, represent the most recent common ancestor — the most recent common narrative in this context – and usually correspond with an event of adaptive divergence. Colonization, war, policy changes, and migration may all influence such branching.

Some versions are responding directly to the Spanish invasion and colonization of México, where La Llorona functions as a representative of the native people. Other variations of La Llorona's afterlife are suggestive in how they reflect social expectations of gender: when she takes the form of a beautiful seductress or a hag hunting her next male victim, it seems that environmental pressures, such as patriarchal norms, are shaping the narrative. These variations reinforce prejudices of the hysterical, sinful female and depict her sexuality as a dangerous threat to male victims.

Additionally, the loci on La Llorona's strand of cultural DNA, that correspond with why she is crying and how she is portrayed in her afterlife, seem to undergo quite a bit of mutation. The causes of La Llorona's tears in different tales determine her perceived credibility and relatability. Her afterlife variations reinforce the negative female archetypes prescribed to her and the eternal punishments she is thought to deserve. The variation we see at these loci correspond with how female and colonial subjects are characterized and treated in a greater social context.

The role of the storyteller is inherently powerful: individuals make artistic and subconscious decisions in their retellings that inevitably reflect their beliefs. Migration and diaspora influence central cultural narratives, including that of La Llorona. Chicanx voices have played an important role in re-representing her as a subject. "Revisionary mythography" and retellings of the tale by members of Chicanx communities have subverted the power dynamics of the story and allowed La Llorona to move beyond the terrible and the tragic. Monica Palacios' "La Llorona: The Other Side" queers the story and adds a casually playful tone to her retelling. Patricia Marina Trujillo's "Becoming La Llorona" taps into a collective suffering that offers a means of connecting with her mother and a newly discovered sympathy for La Llorona. Norma Elia Cantú's poem, "La Llorona Considers the State of Tortillas," describes La Llorona as weeping because of the appropriation and misuse of tortillas in a U.S. grocery store. In these adaptations, La Llorona is a mother figure who has been redeemed from her misunderstood murderous status and can connect with the children she has been weeping for since the Spanish invasion. This renovates the usual negative associations and makes her a wholly sympathetic character and cultural representative.

Looking at this sampling of folktales, we visualize only a mere segment of the network it belongs to, and the unfathomably complex, sensitive web of communication it is a part of. I imagine La Llorona in the middle of this expansive web constantly taking in vibrations and sending out signals. She is there, weeping. Or is she smiling?

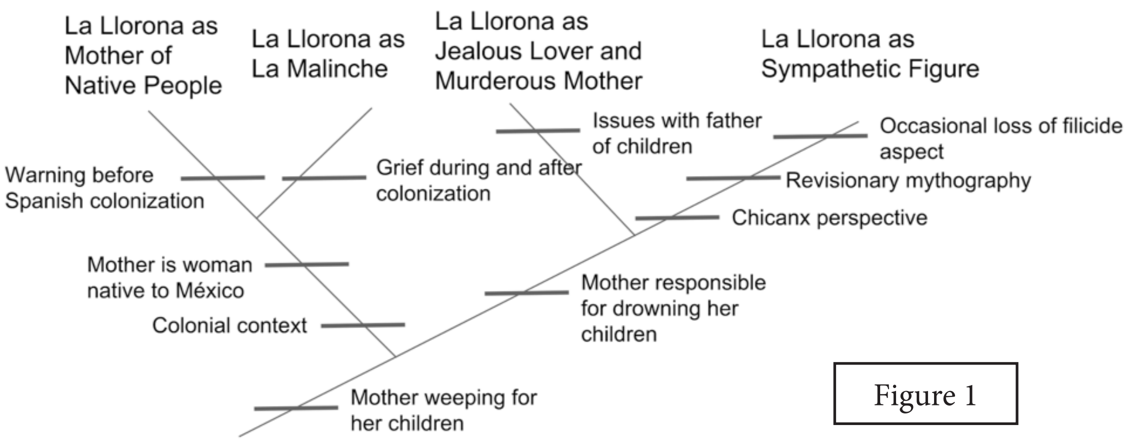


Figure 1

Brute Force Computing

Google's AlphaZero and the Consequences of Fast Thought

Written by Alexander Metz

Illustrated by Rin Liu

On the surface, the game of chess seems simple enough: thirty-two pieces, sixty-four squares. It's a very human game. It's a battle for territory, a clash of strategy, and, perhaps at the highest level, a game of intuition. The thing most people don't know, unless they have studied chess, is that the game is actually a mathematical pit. Even a three move game has 121 million possible permutations. Claude Shannon, a famous chess theorist and mathematician, estimates the lower bound for the number of possible (40 move) chess games to be 10120. In other words, there are more possible games of chess than there are atoms in the universe. Chess is an infinity of possibility packed into a eight by eight grid.

But how good is it possible to be? Chess is hard, and humans are often lazy, squishy pieces of meat. And, while our brains are exceptionally powerful organic processors, we often have better things to think about than which of 121 million openings might be the easiest path to victory. The obvious, and very human solution, is to have a machine figure it out for us.

Beginning in the 1800s, "chess automotons" began to capture the public's imagination. Perhaps the most famous of these is Wolfgang von Kempelen's "Turk," a supposed machine that could beat even the strongest human players (notably, Napoleon and Benjamin Franklin).Unfortunately, the Turk turned out to be nothing more than a puppet operated by a skilled human player. In the early 1900s, ideas for legitimate chess programs, including one written by "the father of modern computing," Alan Turing, began to emerge. Though Turing designed the protocols for a computer chess program, there were no computers powerful enough to run the protocols. It was not until the late 1950s that scientists developed the processing power required for a non-human to legitimately play a full game of chess.

The idea behind these computers was simple enough: use the raw computational power of the machine to outthink flesh opponents. If a human can think five, ten, fifteen moves ahead, surely a computer can think twenty, thirty, forty moves ahead. The problem, as mentioned before, is that even a computer cannot calculate all the billions or trillions of possible outcomes, and computers have no human intuition to guide their search. Human engineers had to find some way to narrow down the computer's purview. In other words, give a computer the human knowledge of chess that would allow it to make positional value judgments.

There are more possible games of chess than there are atoms in the universe. Chess is an infinity of possibility packed into an eight by eight grid.

For the last 50 years, this has largely been the direction of computer chess. In 1997, Gary Kasparov, the then World Chess Champion, was defeated by Deep Blue, IBM's then foremost computer intelligence. Though other human-computer matches followed, this defeat stood as a sort of turning point, after which it became clear that humans would no longer be able to compete with computers for chess dominance.

For fans of both chess and computer science, this was old hat. It does not seem surprising that a computer — with its cold, emotionless, calculating ability — would/should be able to beat a human. But humans still had one advantage over their silicone offspring. Computers needed to be taught what to value and what to ignore. A computer can churn out possibilities with relative ease. However, without human intervention the computers could not tell which of the possibilities was a masterstroke and which was a blunder. In short, computers didn't have the ability to learn.

That was, until a chess program called AlphaZero, a product of Google's AI skunk works, left its components — both human and computer — completely in the dust.

According to the research team's report, AlphaZero was able to beat Stockfish (the previous foremost chess engine) in 28 out of 100 games, drawing 72 and losing zero — an impressive feat in itself. But, what is more impressive, and really worth focusing on, is that AlphaZero taught itself to play.

What makes Alpha Zero such a good chess program is that it is not a chess program at all: it is a learning program. Unlike Deep Blue and others computers that are given human input concerning which moves are good and which are bad, AlphaZero is completely self-taught. Beyond being given the rules of the game, its chess mind is untouched by human hands. The only way it learned to play was by playing, over and over. In theory, the program could teach itself to be equally good at any game; all that it needs are the rules, and the time to figure out, by trial and error, the best way to play. This is known as machine learning, and it is at the forefront of modern computer science (see IBM's Watson for another, debatably more impressive, example).

What is both scary and cool about AlphaZero is that, for the first time, it seems like computers are starting to be able to do human things. They can learn from their mistakes.

A blank slate approach means that AlphaZero, unlike previous chess programs, has no knowledge of the chess theory that humans have spent hundreds of years developing. And yet, we see AlphaZero developing in hours what it took human players centuries to figure out. Whereas other chess computers traditionally play passively, entrenching themselves, waiting to leverage any minute positional advantage, AlphaZero plays aggressively. Its style of play is eerily humanlike.

If anyone reading this is getting chills, you're not alone. What is both scary and cool about AlphaZero is that, for the first time, it seems like computers are starting to be able to do human things. They can learn from their mistakes. They are beginning to think in a way that is not a parlor trick or a hoax. They are developing an intelligence, maybe even a sentience.

If you have seen any science fiction movies, you might also be slightly concerned that, as computers get more and more powerful, our ability to predict what they are going to do decreases. The fact that so much of our world is automated makes this worry doubly grounded. The New York Stock Exchange has already had to take steps to keep trading fair in the age of hyper-fast computers. It is not inconceivable that this technology may at some point grow beyond our ability to plausibly predict or control. Worse still, though these machines "learn"only what humans allow them to, they may develop a way to direct what it is they learn. It seems they could just as easily learn to break down bank firewalls and remove funds as they could learn how to detect early signs of cancer.

Admittedly, it is a far leap from chess to world domination — but not as large a leap as we might think. That is why it's nice to be informed on these computer intelligence issues. Ultimately, as all things are, this is a human directed technology. And it is up to us to direct that technology in a direction that we think is beneficial, not malevolent. ●

To learn more about this topic see "Mastering Chess and Shogi by Self-Play with a General Reinforcement Learning Algorithm" by David Silver of University College London.

Veronica De Pascuale

Questions by Jane Sedlak
Intervew by Victoria Albacete

Veronica De Pascuale (she/her) is a fourth year Biology major and Geology minor at Oberlin College who has curated her undergraduate degree for marine science. After graduating in May 2018, she plans to study for a Ph.D. in biological oceanography or marine biology in graduate school. Growing up in Gambier, OH, she attended Mount Vernon High School. In her four years at Oberlin, De Pascuale has participated in a diverse array of research experiences and presented her research at marine science conferences around the country, including the ASLO 2017 Aquatic Sciences Meeting and the 2018 Ocean Sciences Meeting. She currently works with Professor Denny Hubbard's coral reef laboratory, studying bioerosion rates on corals from St. John in the U.S. Virgin Islands.

This interview has been edited for length and clarity.

What first drew you to becoming a marine biologist?

Well, it's kind of funny when I tell this story, because I've always wanted to do marine biology — ever since I was basically a toddler. I signed up for this Undersea University Scholastic Book Club, where every month I'd receive a magazine on a specific marine science topic and an activity kit that came with it. So through that, as a child, I became very excited about science and marine biology in particular. From there on out, my heart has been set on becoming a marine biologist.

So what do you like about it? What is interesting about marine biology?

I think it has to do with the ocean being this vast, open space that has not been explored that much. I became really curious about what's out there — when I went scuba diving in Cozumel, I was descending down along a coral reef tower, and on one side I saw this beautiful coral structure with fish swimming all around it, and then I turned around and I saw this open blue. And I looked up and down and all I saw was blue and I saw the coral reef tower just continuing down into the depths of the ocean, and there's something about it that just drew me out towards the open blue.

You just presented your research from your summer 2017 research experience at Woods Hole Oceanographic Institution (WHOI) at the 2018 Ocean Sciences Meeting in Portland, OR. Do you like presenting at conferences? What was your research this past summer about?

I think I would say yes — at the beginning, it's extremely overwhelming and nerve-wracking because you're in this convention center with world-renowned scientists, and you're just an undergrad — you think you know what's going on, you think you know your research — and you get the schedule and there's so many sessions and so many oral presentations and workshops and poster sessions and you feel like you have to attend every little thing. But you have to take a step back and attend the sessions that you're interested in, within your own research interests and things you'd have never thought of or never heard about. Once you have that structure, the conference becomes more fun.

I actually really like doing poster sessions because I like that one-on-one communication; you're able to tell the story of your research and the person at your poster can ask you questions and then they can give you advice on how to continue your research, or they learn things from the research and take that home with them to apply to their research.

My research was on environmental epigenetics. I was looking at how hypoxia — which is a lack of oxygen — how that would affect DNA methylati on during early embryonic development in the Atlantic killifish. We exposed the embryos to hypoxia for 24 hours during a critical period where we believed the embryos were most susceptible to DNA methylation. We were looking at hypoxia because with climate change, the number of hypoxic regions, also called dead zones, are increasing worldwide — as global temperatures increase, dissolved oxygen in the water decreases because oxygen is less soluble in warmer waters. We can look at epigenetics to see how organisms are going to respond to this environmental stress, and then whether this will aid them or hurt them in the future.

Do you have a favorite research memory, having done so much of it?

I do! Two summers ago I was at Texas A&M, and through that research experience I was able to do my own individual project and then two weeks of participating in the overall project of my lab. My lab was part of the ADDOMEx Consortium, which stands for the Aggregation and Degradation of Dispersants and Oil by Microbial Exopolymers. The goal of the consortium is to understand the processes and mechanisms by which surface microbial EPS is triggered by oil, its overall role in the degradation of oil, and how Corexit affects those processes; my advisor focused on the bacteria and archaea aspect of that project. So we traveled to Texas A&M's campus at Galveston to conduct 100-liter mesocosm experiments testing oil and oil dispersant treatments.

So this meant that in the morning we collected the samples and ran our experiments, and then again at 10 p.m. we had to collect more samples and run the experiments again. We literally stayed up until 4 a.m. every night, and since we were the only ones in the building we would blast music and talk about our different talents and do magic tricks to keep ourselves awake and entertain ourselves while our samples were running! We barely slept that week, but while we were very tired, we collected so much data and had a really good time with it. I mean — who wouldn't want to stay up until 4 a.m. doing science?!

It was my favorite research experience because I felt like a true scientist — part of a team. I felt like I had a community in the ADDOMEx Consortium, and it was really cool being surrounded by scientists from different universities all collaborating in order to better understand a certain question! Our lab group throughout the entire two weeks in Galveston had this "In it together for science!" feeling, which I really liked. We kept on telling ourselves, "Think about how we'll feel once we have all the data!"

You've talked about forming communities with scientists and especially other undergraduate scientists across the past few research projects that you've done — what's it like having that community? Do you all meet up again?

Actually, that's one of my favorite parts about conferences! In Portland, I was able to meet up with friends from three summers ago and we didn't even know we were going to the same conference or be in the same program — we just ran into each other at the hotel! Through REUs we've been able to form our own marine science network, and through that we've been able to help each other move forward in our scientific careers. For example, I actually introduced one of my friends from WHOI to one of her role models in the "trace metals world" — because her role model was actually the mentor to one of my friends from Texas A&M! [. . .] You realize it's actually a small world and you know more people than you think you do.

[. . .] This past summer at WHOI I faced a lot of challenges — it was the first time I had to design my entire experiment. I had to design my own primers and ended up using Python [programming], which are things I've never done before. I felt completely alone in the process, but then I realized that I'm not alone! Because I was surrounded by peers who felt the exact same way. Your peers are actually a great resource; we helped each other tackle problems and find solutions. For example, I didn't know how to display my gene expression data and a friend taught me how to make a heat map in Python, and another friend showed me how she had designed primers in a research project two years ago. I think it's crucial that students understand that your peers are a great resource and you're in it together. It's not a competition — it's not! It's a community. Science moves forward with collaboration!

Tell me about your most memorable mentors!

One mentor I definitely want to talk about is my mentor from the University of Maryland Eastern Shore, from the research experience I did the summer after my freshman year. During freshman year, [Chemistry] Professor [Rebecca] Whelan told me about REUs and told me to apply. I got into this internship that was geared toward freshmen and sophomores and was an REU geared toward minorities, to introduce minority students into conducting research. My mentor was Dr. Ligia Da Silva, and she is a badass! She's a strong, independent woman who I aspire to be, and to this day we keep in touch. We send each other emails, she calls me, and I send her updates about the experiences that I've had. She's a fascinating person — she's from Guinea-Bissau and when she was eighteen, she studied in Uzbekistan for her Bachelor's and Masters degrees in a Russian-immersion university!

I remember weekends where I had to read all of these scientific articles and I had no idea what the articles were saying. I was struggling so hard trying to understand the background material, and she made me feel like I could do it. Something that's really cute that she did — she knew I had all of these articles that were highlighted and covered in post-it notes and she gave me this three-ring binder. And it felt like a gift into the sciences, like this is how you do it, you can organize the material into this binder — so I definitely got my organizational skills from her. She made me feel like a real scientist, she gave me a lab coat, she stayed with me until midnight conducting experiments with microbes. It was one of the best summers I've ever had.

Oberlin doesn't have a marine science program or any track particularly geared towards it. Do you think, despite that, Oberlin has prepared you to move on and study marine science in graduate school?

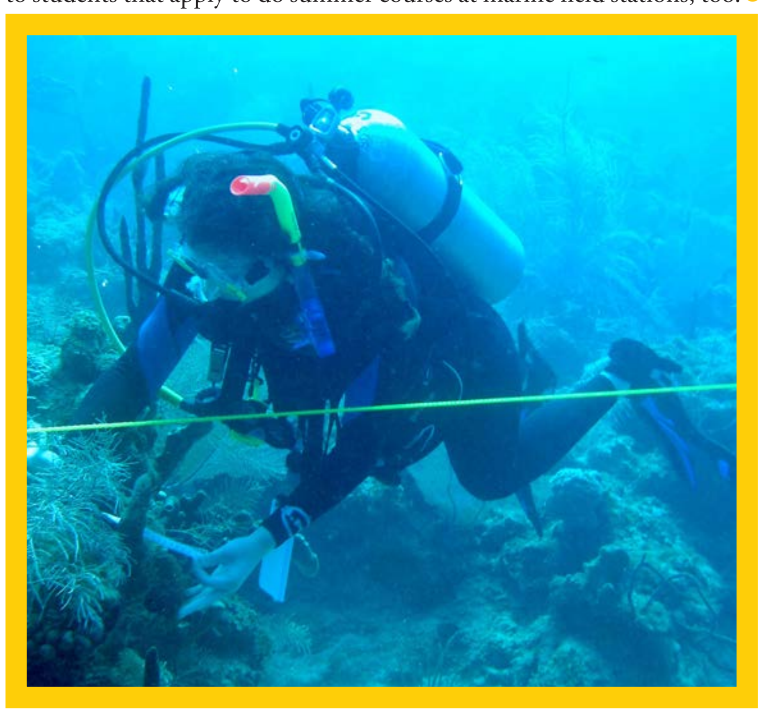
I think Oberlin could do a better job of talking about the different paths you can take and the different things you can apply your major towards. But I feel that Oberlin has prepared me to pursue a career in marine biology through the intensity of coursework and through lab experiences and experiments that we've done.

I've had the support to apply to summer research experiences particularly from Denny Hubbard in the Geology department. He has been a great mentor who has helped me figure out what I want to do in the marine science world and also talked to me about other opportunities out there. He was the one who exposed me to scientific diving. [. . .] In 2015, during Winter Term, 10 students plus Karla and Denny Hubbard went to St. Croix to characterize the change in the coral reef cover there since the previous data collection 37 years ago. It was a fantastic experience; I got to utilize scuba diving to conduct research and go out onto the reef every single day. That was an experience in marine science that was structured specifically through Oberlin.

Do you have advice for Obies interested in marine science?

I have a lot of advice! First — most people don't know this — at the Career Center, there is a marine science binder that an Oberlin alum who graduated in 2013 created. I had the opportunity to update and expand the binder a few years ago, so within this binder is useful information about what courses you should take at Oberlin, study abroad opportunities, information about conferences and internships, and also books to read and movies to see! That's the first thing I would check if you don't know what information is out there, or where to begin.

Second, I think that students should apply for REUs! REUs are an amazing experience — you get to carry out your own research, present it to the program, and make friends that you get to see at conferences! Sophomores should be on the lookout for the NOAA Hollings Scholarship, the application for which is due in January of your sophomore year, because if you get it you get two years of academic financial assistance and a research experience at a NOAA — National Oceanographic and Atmospheric Administration — facility during the summer between your junior and senior year. Juniors should apply for the internship that I did this past summer, which was at Woods Hole! [...] Oberlin actually offers scholarships to students that apply to do summer courses at marine field stations, too!



BY RACHEL DAN

Crossword Corner

ANSWERS TO PREVIOUS PUZZLE

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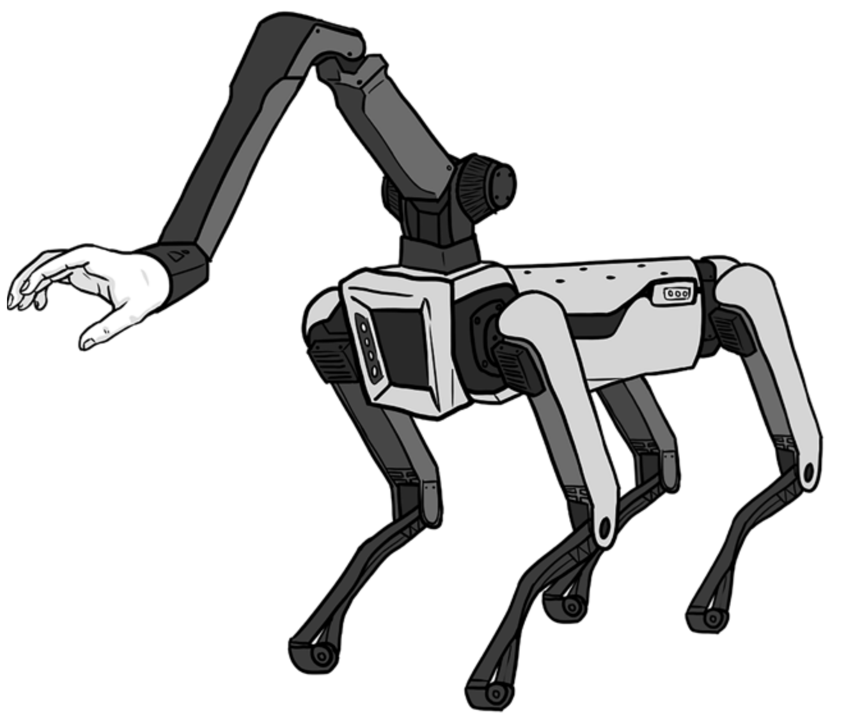

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THE WINNING CAPTION FOR THIS ISSUE'S CARTOON WILL APPEAR
IN THE NEXT ISSUE OF THE SYNAPSE.

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

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