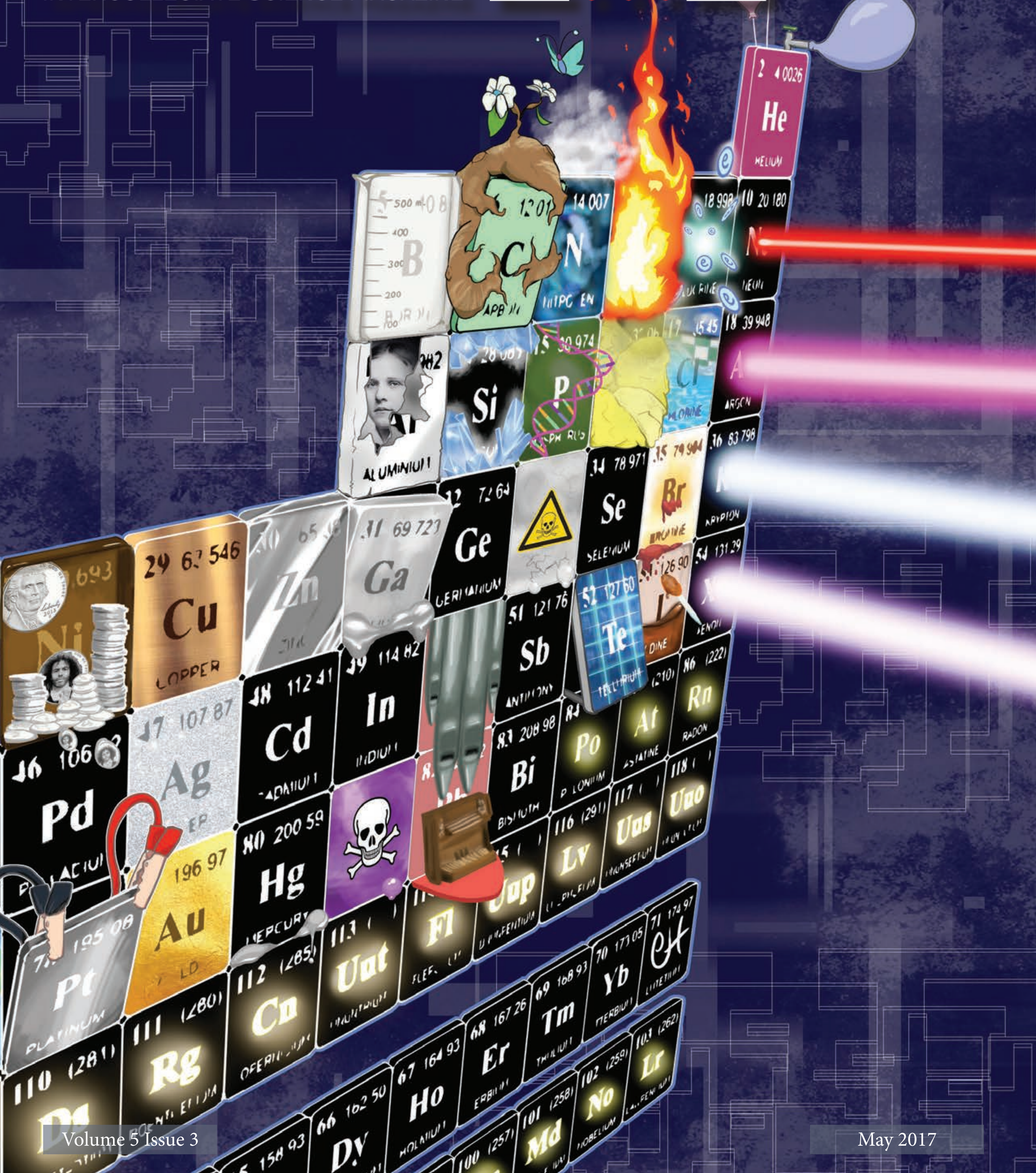
The Synapse

Intercollegiate Science Magazine



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Since its inception

in 2011, *The Synapse* has published articles discussing everything from the science of aging, to the chemistry of nail polish, to a brief history of the universe. As the incoming Editors-in-Chief of the magazine, we are proud to serve and support the scientific art and journalism community in Oberlin and across colleges. We are incredibly grateful and proud of our former Editor-in-Chief, Gabe Hitchcock (OC '17), who gave the magazine an intense overhaul in his sophomore year and has been an innovative leader throughout his tenure. We wish him all the best as he moves on to explore the world of science outside of Oberlin.

We, Victoria Albacete (OC '18) and Tara Santora (OC '19), are excited to serve as Editors-in-Chief for the 2017-18 year. Victoria has worked as an editor since fall 2015 and served as Outreach Coordinator for a year; she also works with *The Oberlin Review* as a production editor and dances with Movimiento. Tara led Denison to join *The Synapse*, has been Managing Editor since fall 2016, and teaches Biology 100 OWLS. Together, we aspire to continue *The Synapse's* legacy of increasing public interest in science, as well as add a bit of our own flair.

As Editors-in-Chief, we hope to maintain *The Synapse's* standard of excellence in science writing and delve further into the connections between science and social justice issues. We are pleased to announce that this issue will be our third published with contributions from Denison University writers, artists, and editors, and we are interested in reaching out to more colleges with students eager to explore the connections between scientific inquiry and artistic and literary pursuits. This issue features our "Big Ideas" section and focuses on ways to reconceptualize STEM, featuring articles such as *Can We Educate Better?* by Kepler Mears, *Making a Case for Citizen Science* by Ave Bisesi, and *Expanding the Job of a Scientist* by Ally Fulton.

Finally, we have several seniors who have worked with us as writers, artists, and editors over the past four years: Ave Bisesi, Brooke Ortel, Liv Scott, Lauren Rhodes, Emma Hahn, Gabe Hitchcock, Nat Pierson, Caroline Lawlor, Emilia Omerberg, Kepler Mears, Allison Murphy, and Katie Darrah. Thank you for all of your dedication and inspiring additions to the magazine; you will be missed!

We are excited to present this issue, the magazine's 12th, to you as the spring semester draws to a close. We hope you enjoy it — and don't forget to check out our cartoon caption contest on the last page!

Cheers!

Victoria Albacete & Tara Santora
Editors-in-Chief

Ally Fulton is a 2016 Oberlin graduate from Twin Cities, Minnesota, who double-majored in Biology and English. She has worked as both a writer and an editor in her three semesters with the magazine. Currently working as the Writing Associate Fellow for the Rhetoric and Composition department, Ally next plans to apply to graduate programs in English and R&C with an ecocritical focus. Highlights of her time as an undergraduate include captaining the ultimate Frisbee team, conducting research for Professor Keith Tarvin's Biology lab, and working as a tutor through America Reads. Don't miss her article in this issue: *Expanding the Job of a Scientist!*

Mikaila Hoffman, from Pittsburgh, Pennsylvania, is a third-year Chemistry major with a Cognitive Sciences concentration at Oberlin College. Besides making art for *The Synapse* for the past four semesters, she plays club soccer and works for the America Reads program at the Bonner Center, where she is also a member of the Education Leadership team. After Oberlin, Mikaila hopes to first work in a teaching/mentoring program for a year, and then attend graduate school for chemistry with a focus on research that intersects chemistry and neuroscience. Mikaila's favorite part about *The Synapse* is the challenge to create artwork inspired by the very specific scientific themes from the articles.

Monica Dix has been working with *The Synapse* as a writer and layout editor since starting her first semester at Oberlin in fall 2016. A double major in Politics and Geology from Shorewood, Wisconsin, she hopes to become a climate scientist and work in government as a climate policy advisor or elected official. In addition to her work with the magazine, Monica is a STRONG Scholar, the Community Outreach Coordinator for the Oberlin College Democrats, and works in Professor Amanda Schmidt's Geomorphology lab. Her article in this issue — *Thousands of Years in the Making* — studies the geological past of the nearby Great Lakes region.

Emily Herrold has been the Art Coordinator at Denison University and a contributing artist since fall 2016, when the magazine launched at Denison. She is a sophomore Geoscience and English double major with a creative writing concentration from Hinsdale, Illinois, who enjoys volunteering for America Reads in her spare time. After graduating from Denison, Emily plans to study geology at graduate school. Emily helped launch the artistic side of *The Synapse* at Denison because she enjoyed reading science magazines like *National Geographic* as a kid and had always hoped to be involved with something similar.

Contents

Mosquito Maladies

Genetic Manipulation of Mosquitoes Leads to Potential Solution to the Spread of Malaria

Written by Mariam Saied
Illustrated by Linnea Fraser

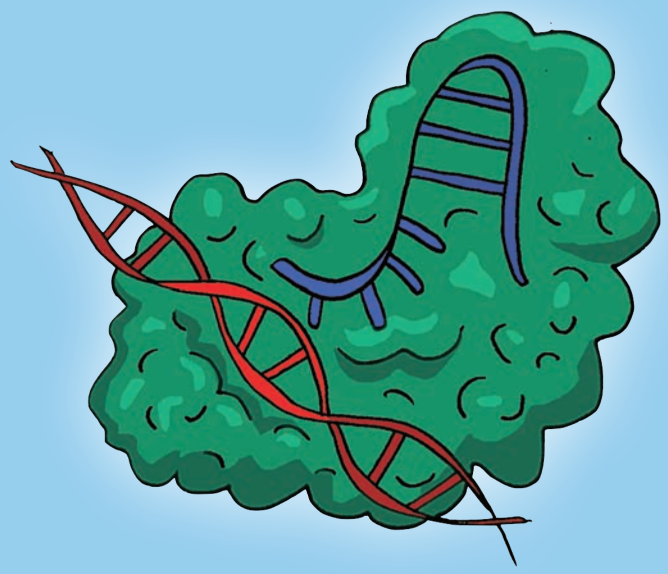
Twenty years ago, Anthony James, a molecular biologist and professor at the University of California Irvine, aimed to engineer a mosquito that could not transmit malaria. After years of failure, he succeeded in 2015 by inserting two anti-malaria genes in the mosquito genome that make it impossible for the malaria parasite Plasmodium falciparum to survive inside the insect. However, this discovery was only half of the battle; the other half was to discover a method that could get these anti-malaria genes added to the wild mosquito population.

Plan A was to breed 100,000 mosquitoes homozygous for the malaria-resistant allele and release them into a village that had 10,000 mosquitoes; this would cause the gene to be largely transmitted to future generations of the population via sexual reproduction. Introducing 100,000 extra mosquitoes was not a particularly popular idea among the village's inhabitants, so James opted for a Plan B instead. He contacted Ethan Bier, Professor of Cell and Developmental Biology at the University of California San Diego, who had previously developed a technique called mutagenic chain reaction (MCR), a procedure that utilizes and builds upon CRISPR/Cas9 gene editing, which James felt could be modified to become the crux of his Plan B.

Together, Bier and James used MCR to engineer two mosquitoes to be homozygous for the anti-malaria genes. It is important to note that the anti-malaria phenotype is only expressed when the recessive anti-malaria gene is homozygous, or present on both of two homologous chromosomes. When the anti-malaria genes are heterozygous, or present on only one homologous chromosome, the mosquitoes are still able to transmit malaria, just as if they were homozygous for not possessing the anti-malaria genes.

To test their MCR-based genetic manipulation, the researchers put two mutant (anti-malaria) mosquitoes in a box with thirty wild-type (non-mutated) mosquitoes, and allowed them to reproduce via random mating. Here is where the special effects of MCR really came to play. Usually when a mutant mosquito (homozygous recessive for the anti-malaria genes) mates with a wild-type mosquito (homozygous dominant for not having the anti-malaria genes) their offspring will be heterozygous and thus will still be able to transmit malaria. However, MCR works such that when this mating happens and a heterozygote baby mosquito is conceived, anti-malaria genes present in one of its homologous chromosomes will get duplicated onto its other homologous chromosome, making the offspring homozygous for the anti-malaria genes instead of heterozygous. Experimentally, this technique caused almost all of the 3,800 offspring to be homozygous for the malaria-resistant genes within two generations.

Thus, with this discovery Bier and James unlocked a potential



method to stopping malaria transmission forever. By inserting an anti-malarial gene in just 1% of a mosquito population, malaria could be eradicated in about a year. In a single year, dengue fever, chikungunya, yellow fever—diseases all carried by mosquitoes—could all also be eliminated if genes preventing these diseases were found and targeted by MCR.

Furthermore, the same gene manipulation techniques used in mosquitoes could get rid of invasive species, and hundreds of endangered or vulnerable native species that have been pushed to the brink of extinction could potentially be restored. For example, one of the most well known case studies of invasive species in North America is the Asian carp. Highly detrimental to the environment in the U.S., the invasive Asian carp could be removed by creating a gene drive that insured that all its offsprings would be male; therefore within a couple of generations, there would be no mating within the species, and it would become extinct in the U.S.

> Gene drives, if perfected, allow us to change an entire species. But should we?

However, using these gene drive techniques also poses some risks. Gene drives are when the inheritance of a specific gene is increased to promote the presence of that gene within a population. In theory, gene drives are so efficient that accidents, such as an experimental organism with MCR-modified genes escaping from a laboratory, could change an entire species. James bred his mosquitoes in a biocontainment lab, using a species that was not native to the U.S.; thus, in the case that some escaped, they and their modified genes would presumably die off for lack of mates. However, less careful experiments could pose a much larger ecological risk.

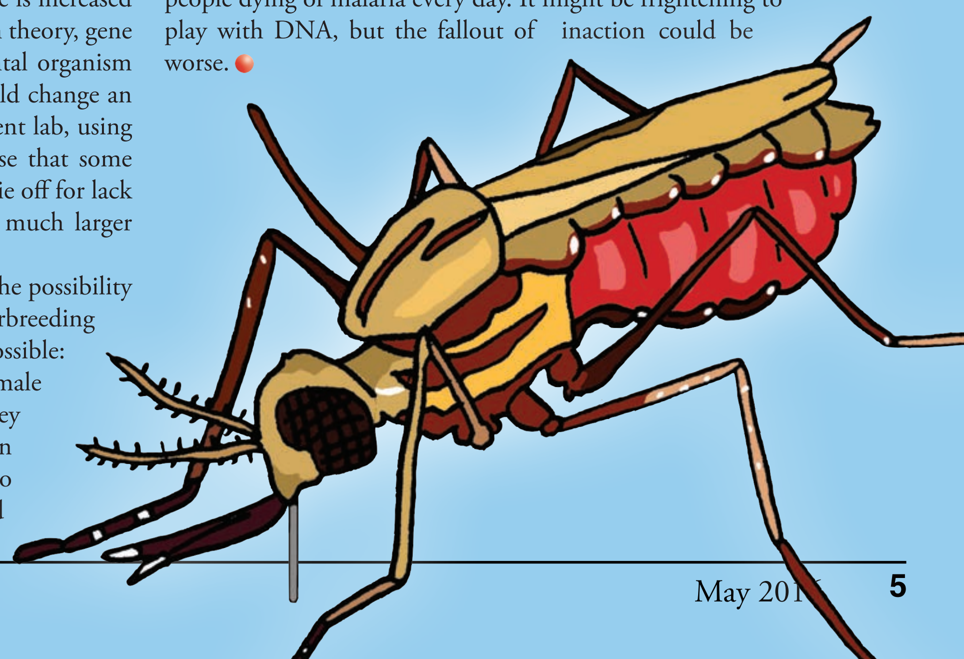
To understand why it is important to prepare for the possibility of a rampant gene drive, take an example where interbreeding between mutant escapees and wild-type individuals is possible: if a dozen Asian carp in the Great Lakes are given an all-male gene drive and then are accidentally carried back to Asia, they could potentially wipe out the native Asian carp population by making all of the native carps' offspring male. This scenario is not as unlikely as it may seem given how interconnected our world has become. In fact, this is exactly why there are invasive species problems around the globe. With organisms like mosquitoes and fruit flies that can travel undetectably, there is no way to contain them—and their genes—to specific environments.

Scientists up to this point have been allowed to play the mad genius; they could generally mess around with an organism's genes as much as they cared to do so. It was assumed that if any of their specimens were to escape, natural selection would take care of them. However, if an added trait is neutral or beneficial, the mutant could potentially spread the modified gene until, after many generations, every individual in the population possesses it. Gene drives don't work this effectively yet, but James and Bier think that they will soon. Because of gene flow, in which neighboring species occasionally interbreed and exchange genetic information, a gene drive can affect many populations, and thus the mutated gene could expand beyond the target species. This is not necessarily a bad situation if it promotes a trait beneficial to a vulnerable population (or to humans), but some gene drives could unintentionally harm populations or the ecosystems in which those populations live.

Gene drives do have limitations; they only work with sexually reproducing species, so they cannot be used to genetically engineer populations of viruses or bacteria. Additionally, the manipulated gene can only spread between generations; it is therefore only practical to work with species that have a fast reproductive cycle. With organisms such as humans, it would take centuries for a trait to spread widely. Additionally, the introduction of a mutant gene does not necessarily mean that the targeted trait will spread; how much it spreads will depend on how it affects fitness, the rate of gene flow, and on the strength of of genetic drift, which causes random fluctuations in allele and genotype frequencies and could lead to the disappearance of the introduced allele.

Where do gene drives leave us? It might be a bit of an exaggeration, but gene drives, if perfected, allow us to alter an entire species permanently. But is this something we should do? Some scientists are creating safeguards, where gene drives could self-regulate by replicating until a certain percentage of the population has the gene or where the gene drive stops completely after a few generations. Other scientists are debating who is allowed to use gene drives and for what purposes. Soon, if gene drives are perfected, governments will likely attempt to integrate them into health regulation programs, as countries that suffer greatly from malaria and other tropical diseases carried by mosquitoes would benefit significantly.

Altering DNA and using gene drives are not inherently evil. Currently, our solution to combat malaria is by spraying pesticides that hurt other species and pollute water supplies, yet this still leaves 1,000 people dying of malaria every day. It might be frightening to play with DNA, but the fallout of inaction could be worse.



My Grandmother's Memories

How Epigenetics Are Changing Our Understanding of Heritability

Written by Rachel Reardon
Illustrated by Maria Altier

There is a recipe card in my cupboard that is worn brown and thin at its edges. Looped, cursive font skims over creases that fray with soft edges after years of being folded in the same place. Some of the measurements are scribbled over and revised with new notes in the margins, or blurred by stains from melted chocolate and drops of milk. The card holds my grandmother's recipe for Babe Ruth bars, a family favorite that has made an appearance at every holiday in my memory. The marks on the card have been years in the making, documenting the countless times she's repeated and refined the process of making the treats. They are the little notes and symbols that enable me, her granddaughter, to make the bars exactly the way she does, using the unique touches that she's developed over years of experience.
Just like her recipe cards are a way for my grandmother to pass on her memories and experiences to me, biology has a special mechanism that allows her cells to pass their wisdom through the generations to my own. It is a process known as epigenetics, a field that scientists are just beginning to understand. Most people have some understanding of genetics, the study of DNA. These little molecules, coiled within the nucleus of every cell in your body, contain the instructions that tell your body how to perform the processes that enable you to live. Every little thing about you exists because your cells are constantly reading and re-reading your genetic code, fashioning the proteins that allow your body to contract muscles or fire an action potential in your brain.

> In 1942, Conrad Waddington first introduced the term "epigenetic" to describe how genes give rise to certain cell functions in early embryonic development.responsible for how a cell's genes are expressed.

However, it turns out that DNA doesn't carry all of this information on its own. The long strands of nucleic acids that comprise your DNA are wrapped around special scaffolding made up of histone proteins. For a long time, scientists understood that these proteins serve to provide structure to DNA, enabling it to condense into the X-shaped chromosomes that you may remember from high school biology. But in the 1990s, Dr. David Allis and his team began to discover just how vital these proteins are to the way that cells use their genes. They studied Tetrahymena, a microbe that showed different patterns of DNA coiling.

Sometimes, if DNA is tightly coiled around its histone proteins, it cannot be accessed by the cell. For DNA to be "read" and used by the cell, it needs to be able to bind to other proteins, known as transcription factors. These factors enable the cell to make a copy of the DNA that can be used in protein production outside of the nucleus. Allis noticed that in his microbe, the histone proteins looked different when the cell was uncoiled and accessible than when it was tightly condensed. By 2000, he and his team had identified a group of proteins that were able to modify the histones, as well as other molecules, like methyl groups. The groups could be attached and removed from histones as the cell used various genes.

If we compare the instructions in the cell's DNA to my grandmother's recipe card, we might think of these histone modifications and methyl groups as the notes in its margins. They are secondary additions to the main instructions that help me to better use and interpret the recipe itself. They are added through experience as my grandmother uses the recipe over and over and finds useful ways to improve her ability to follow it. Scientists now think that these changes might be heritable in much the same way as DNA itself.

In 1942, Conrad Waddington first introduced the term "epigenetic" to describe how genes give rise to certain cell functions in early embryonic development. What he described in his article largely dealt with cell differentiation. This is the process in which unspecialized cells in the body, known as stem cells, diverge to form the various types of cells that the body needs to survive. The cell does this by turning certain genes "on" and others "off" through processes much like the coiling and uncoiling of DNA sections using histone modifications and the addition of certain molecules, like methyl or acetyl groups.

Today, scientists generally understand epigenetic factors as molecules outside of DNA itself that are responsible for how a cell's genes are expressed. Epigenetic factors create the expression states, or activity levels, of the various genes in the cell — these are also the notes in the margins. They help the cell know which pathways might be important to use later on, and impact how it expresses various genes based on experiences it has had in the past. Excitingly, scientists now have reason to believe that these expression states could also be heritable.

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We know that individual cells are capable of activating and repressing various portions of their genome; this is what makes a blood cell different from a brain cell, even though both carry identical copies of DNA. Additionally, research has shown that certain behaviors and experiences can change the way that our cells use their DNA. A 1997 paper headed by neurobiologist Michael Meaney showed how maternal behaviors in rats influenced gene expression later on in the pups' adult life. The rats that received less grooming behavior from their mothers showed an increase in production of stress hormones, such as corticosterione, later in life. Dr. Moshe Szyf and biochemist Dr. Aharon Razin found the final piece in this puzzle. Through a series of follow-up experiments, they showed that neglected rats had much higher amounts of methylation in genes that regulate proteins involved in sensitivity to stress hormones. Essentially, the lack of maternal attention towards some rats caused changes on top of the genome that made them more likely to suffer higher stress levels throughout adulthood. These findings showed that individual experiences can have an effect on an organism's genes. While we generally expect genetics to determine an organism's behaviors, this research suggested that the process might also work in reverse, as behaviors help determine how genes are expressed.

However, the field of epigenetics suggests that we might have more of an impact on our genetic traits than we realize.

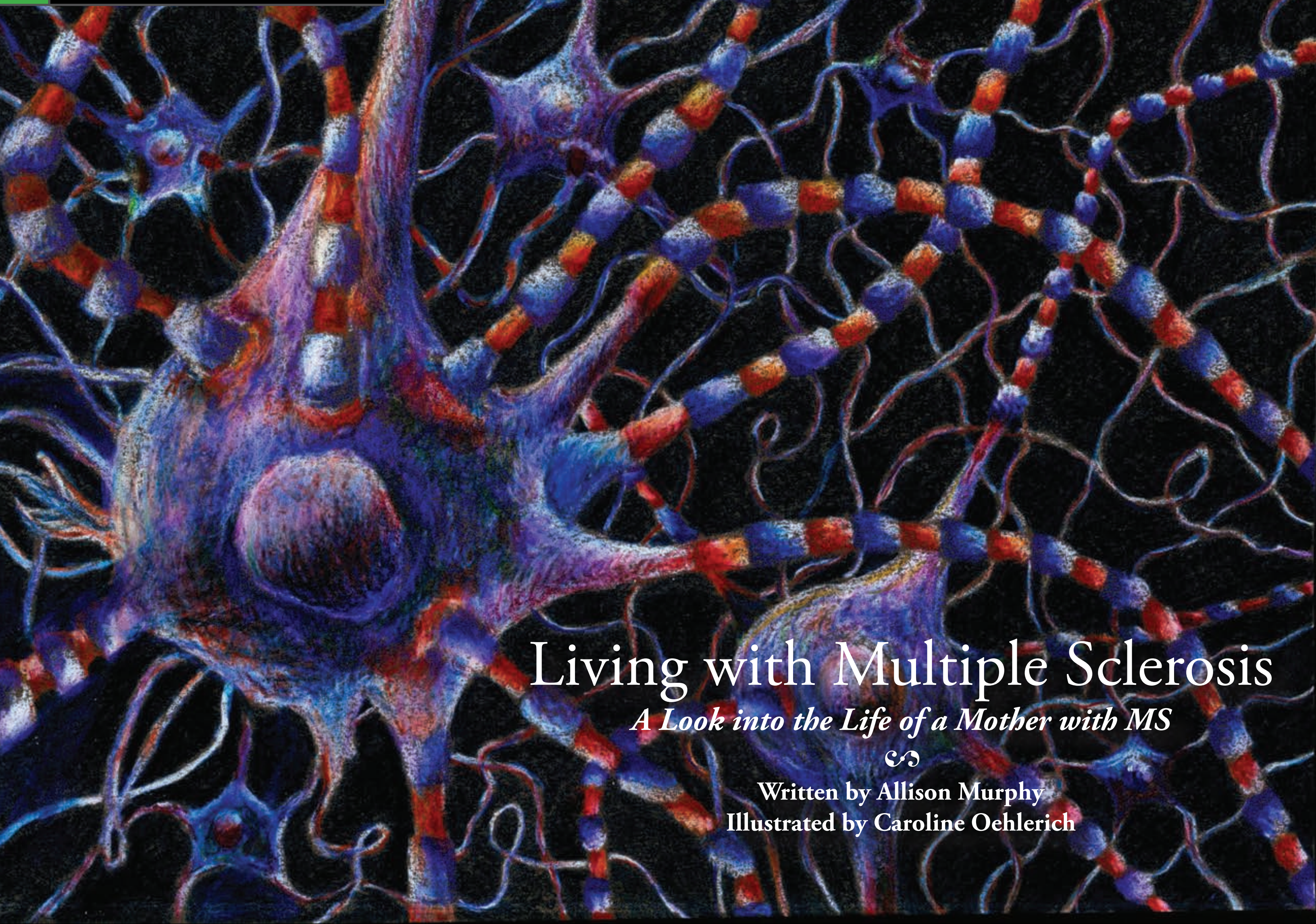
On a smaller scale, experiments done on yeast cells have shown that some environmental triggers could allow a cell to more easily access certain pathways in its DNA. Ultraviolet rays cause damage to DNA, but cells have repair pathways that allow them to remedy this damage. If a cell is exposed to a small amount of UV and given time to repair itself, it will be "primed" for subsequent exposures. Researchers at the University College of Swansea in the U.K. have found that pre-exposed cells are able to more efficiently repair DNA damage in particular gene locations than cells that have never experienced pre-exposure. This enhanced resilience suggests a sort of "memory" within the genome. This is as though the yeast cells recognize the UV damage, and are more prepared to access the repair pathways that they need in order to remedy it.

However, some types of damage are not so easily repaired. When Germany occupied the Netherlands during World War II, food became exceptionally scarce. Many people died of starvation, while survivors experienced severe malnourishment. Scientists later studied these survivors and their children, and found interesting trends. Children born to mothers who were pregnant during this period had higher rates of mental illness, diabetes, and obesity — and showed an increase in methylation of DNA that codes for proteins involved in growth and development. Their grandchildren also showed higher rates of various forms of illness.

Our society chalks so many things up to genetics, including propensity for certain diseases. However, the field of epigenetics suggests that we might have more of an impact on our genetic traits than we realize. Things like stress level, diet, exercise, and drug use can all impact the way our cells use their DNA. Since a female is born with egg cells that already contain DNA from her parents, the expression states of our DNA could be going directly into the cells that will eventually become our grandchildren. This area of research is unique because it combines so many factors of natural science and human interaction. Epigenetics is a direct link between our choices and behaviors and the inner workings of human biology. If we can better understand this link, we open up an incredible number of doors into preventative care, individualized treatment, and new ways of approaching genetic disorders and diseases.

Epigenetics is a direct link between our choices and behaviors and the inner workings of human biology.

Epigenetics offers us an even greater incentive to be intentional with decisions regarding our health. We now have evidence to believe that our choices have the power to not only impact our own DNA, but also that of our children and grandchildren. My grandmother passed down many things to me, from her deep brown eyes to her collection of recipe cards — things that I will likely pass down to my own children as well. The beauty of our genes, and our recipes, is that we each add our own special touches to them. Whether it's through histone modifications or notes in the margins, our personal experiences have the power to inform future generations and shape our heritage.



Living with Multiple Sclerosis

A Look into the Life of a Mother with MS

Written by Allison Murphy
Illustrated by Caroline Oehlerich

"The initial diagnosis was a long time coming (6 years of complaining to my doctors), because my symptoms are mild comparable to some patients and was attributed to being "all in my head" or a response to stress. It wasn't until I had trouble walking that I saw a neurologist and had an MRI. I have mild Multiple Sclerosis."

Think of the neurons in your nervous system as a complex circuit of interconnecting wires. The signals that these wires transmit and send are responsible for every aspect of your life: thinking, feeling, moving. Like any other part of your body, these wires are normally protected by your immune system. Multiple sclerosis (MS) manifests when the system meant to protect the nerves ends up destroying them instead. MS is a progressive, degenerative, autoimmune disease that affects around 2.3 million people worldwide, including Elizabeth Murphy, who is quoted above. In an autoimmune disease, the body's immune system attacks the very body it's meant to defend. During multiple sclerosis, the immune system creates inflammation that damages the central nervous system.

If neurons are wires, then you can compare myelin to the rubber insulation that covers them. It is a fatty substance manufactured by glial cells, which are just as or even more numerous as the signal-conducting neurons in your brain and body. This substance coats the axons of neurons, which helps make the electrical impulses traveling down those axons conduct to its neighbors more quickly and smoothly. Without it, the conduction slows down and communication is damaged or signals are lost. MS often damages the myelin coating, causing problems with signal transmission. It can also cause damage to the glial cells that create the myelin as well as the underlying neuron the myelin is trying to protect. The results of this damage can often be seen as lesions in the brain, which are detectable when the brain is imaged during an MRI.

> Multiple scleroisis (MS) manifests when the system meant to protect the nerves ends up destroying them instead.

The disease is progressive, and the course is different for every patient. Most patients have what is referred to as a "relapsing-remitting" course, which consists of "exacerbations" of heightened symptoms followed by periods of decreased disease activity. Others have a "progressive" course, consisting of continually worsening symptoms with a more sudden onset. In some rarer cases, there could be a combination of the two or a switch from one course to the other. It is sometimes referred to as a "snowflake disease" — no two people have the same history or severity of symptoms.

"If people find out about my MS it becomes an identifier — 'You know her, she's the one with MS.' People don't know that I have annoying

pain that doesn't go away. It wakes me up, it is worse at times, and I can't take anything for it. I have tried medications for nerve pain but they have proven ineffective. Some people think that it can't be that bad because I don't complain or have obvious symptoms; I am not in a wheelchair. I am truly thankful that it isn't "that bad," but it would give my MS symptoms more credibility when I am having a bad day and not showing it."

The damage for most patients occurs during relapses and can be temporary or permanent. There's no way to predict what the target of these attacks will be — what "wires" will be damaged — but there are some symptoms that are common in MS. The optic or auditory nerves, which help with vision and hearing, respectively, are common targets. Results can range from temporary sensory deficits to total blindness, which may or may not be permanent. Problems with muscle control, spasticity, and coordination can lead to changes in motor function. About half of patients will experience decline in memory and cognition. Clinical depression, whether as a result of damage to the brain or of other debilitating symptoms, is common as well.

Every patient's experience is different, however, and the effects of MS are varied and often unpredictable. For Elizabeth, many symptoms are sensory. She has peripheral neuropathy in her left leg, which causes numbness or pain that she cannot control or ease. Her right leg experiences "foot drop," a loss of muscle function when she walks. She occasionally experiences trigeminal neuralgia, leading to numbness and pain in nerves along her jaw. A phenomenon called the MS "hug" leads to a constricting sensation around her torso. She has tinnitus, a high-pitched ringing noise in her ears that many may experience after listening to a loud concert, but for her is incessant. Other symptoms include nausea, vertigo, and fatigue combined with an inability to sleep well.

Elizabeth recognizes that her case is comparatively mild; it is not uncommon for those with MS to lose motor function and use walking aids or a wheelchair. She is a full-time clinician in an intensive care unit, and without talking to her it would be nearly impossible to guess her condition. While MS can cause relapses leading to hospitalization, it can also present itself as an "invisible disease." This can be frustrating for many people with MS, who experience debilitating symptoms that aren't always apparent. Even medical professionals that Elizabeth knows well will seemingly disbelieve her diagnosis, saying that she looks "too well," pointing out that she is not one of the sufferers in a wheelchair, thinking that because she does not complain, there is nothing wrong. Although the course of the disease can vary, it would be misleading to say there is a "good" MS.

Elizabeth is seated with a syringe in her right hand. Staring at her bared thigh, she inhales, then plunges the needle into her muscle and quickly injects its contents. Before heading to bed, she swallows two ibuprofen to prevent the flu-like side effects to come. This has been a weekly routine for years.

Inside Elizabeth's needle is beta interferon, a protein that cells in the body and immune system use to signal to each other. It is also a substance that is released during illness, which means that Elizabeth experiences side effects such as fever, fatigue, and muscle aches. Taking it helps balance the overactive immune system, reducing inflammation that can cause neuronal damage. Many MS medications function in this way, intended to stop the immune system from causing further damaging attacks. There is no cure for MS, and so most treatments aim to alter the course of the disease, prevent relapses, and lessen damage over time. Other treatments work during a relapse period and involve an I.V. infusion of corticosteroids, which regulate the function of the immune system to reduce the length and damage of the relapse. Although these medications can limit damage and increase quality of life over a prolonged period, there is no cure for MS.

Furthermore, a patient with progressive MS may not be able to use these treatment options. Those who can use them sometimes find that the side effects, whether from the drug itself or from the complications of constant injections, are too severe and must try several different treatments. Other prescriptions given for MS intend to manage, rather than prevent, symptoms. Medications can help alleviate muscle spasticity, bladder problems, pain, emotional changes, or depression. In cases where symptoms make it difficult to walk, physical therapy can be useful. Stem cell therapy is one of the newest lines of research, hoping to use new, undifferentiated cells to repair a broken immune system and the damage it causes.

"As an ICU nurse I see patients with end stage MS. I see all of their losses in function and cognition…MS takes everything from its sufferers. Slowly, with teased moments of wellness, and then it comes back worse."

Although these medications can limit damage and increase quality of life over a prolonged period, there is no cure for MS.

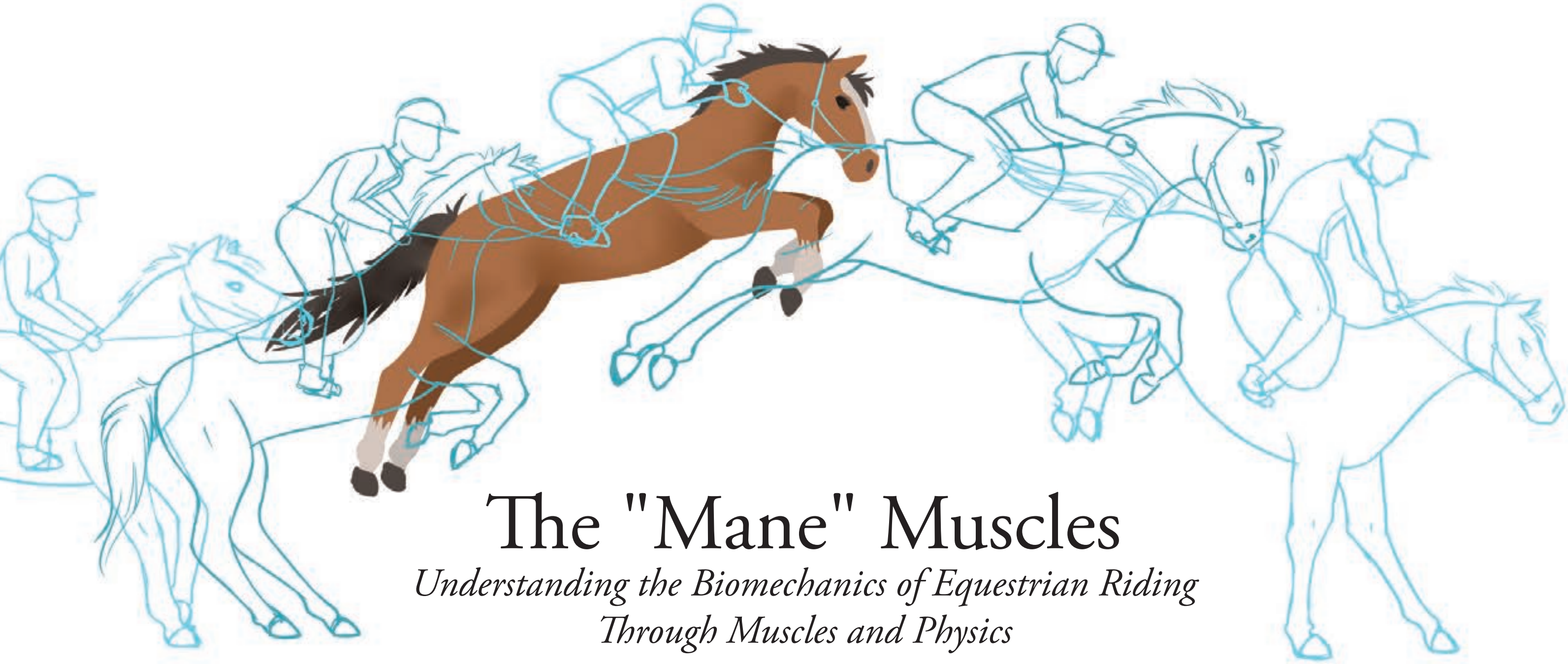
The prognosis for MS varies depending on an innumerable number of factors, including the age of onset, medications taken, and the course of the disease (progressive cases tend to have a poorer prognosis than relapsing-remitting). A majority of patients are able to walk, possibly with some assistance, throughout their lives. Life expectancy is, on average, about 30 years from onset or 5-10 years less than someone without the disease, but some cases progress rapidly and can quickly become fatal. For many long-term sufferers, complications from the disease can be a cause of death. However, with expanding research, a number of treatment options, and better care, the length and quality of life with an MS diagnosis has improved.

"I work to make sure that I work out and run to keep myself healthy," she states. Her Facebook timeline is littered with "check-ins" to a local running trail. She regularly logs 6-10 miles during these runs, occasionally training for a half marathon. Between runs, she pulls out an Insanity or P90X workout DVD from her growing collection.

Each MS story is different, and the one I chose to illustrate this disease — that of my own mom is an atypical one. Despite the fatigue, the dysfunction in her legs, and the side effects of her medications, she regularly performs physical feats that people without MS would struggle to do. The determination and athletic ability in the face of these challenges is incredible, and her above-average cardiovascular fitness and muscle strength likely helps lessen the effects of her diagnosis.

Not every experience looks like my mom's. While some of her challenges include making it to the finish line or the end of a set of jump squats, others may struggle with visual impairment or taking steps across the room. Those with a sudden onset of MS symptoms do not get the chance to build up their physical fitness before being confined to a wheelchair. But many may share similar obstacles: getting out of bed in the morning, managing a pain that can never go away, and experiencing chronic symptoms that are felt daily but go unseen by others. MS is progressive, and those diagnosed with it often live in uncertainty of what damage it will cause next.

"I do have a better appreciation of what I have, and it has given me a different perspective about what things are important, what I need to be worried about, and what moments I should treasure. I am thankful my MS is mild."



The "Mane" Muscles

Understanding the Biomechanics of Equestrian Riding Through Muscles and Physics

Written by Jayla Johnson
Illustrated by Jack Bens

Don't you just sit there?" "The horse does most of the work, though, right?" The specific mechanics that go into this sport and the coordination involved between horse and rider are perhaps the most misunderstood features of equestrian riding. The muscle movement of the lower back and legs of the rider and the muscles, tendons and bones that enable a horse to carry out the rider's commands all get lost in the awe of watching show jumping or dressage. The actions and physics required of both horse and rider are invisible, masking the complexity of the performance. To truly understand how a horse and rider jump over five foot fences, we must recognize and inspect the minuscule muscle interactions that occur in both the human body and in the horse.

Posture is vital for the rider and horse, keeping the rider on the horse and the horse balanced as he carries the rider over fences or around the arena. Strong abdominal muscles, including the linea alba, rectus abdominis, internal oblique, external oblique, transversus abdominis and tendinous intersection, are crucial for stabilizing the rider's midsection and spine while riding. The transversus abdominis, located right above the internal oblique and across from the rectus abdominis, provides stability between the rider's hips, ribs, and pelvis. For the rider to use seat aids correctly and remain in control over their arms, strong abdominal muscles are necessary. Engaging the abdominal muscles prevents the rider from losing their balance, and enables control over the hips to help them shift from side to side to cue and move the horse in specific directions.

The resilience and elasticity of the multifidus muscle, quadratus lumborum muscle, interspinales lumborum muscle, and other lower back muscles create a deeper seat and supple pelvis, both of which are crucial for good posture. These lower back muscles, in combination with the transverse abdominus, control the stability of the pelvis and must be strong enough to extend the rider's lower back in the canter so the rider can remain seated in the saddle as if they were "one" with the saddle. Specific positions in the saddle, such as the sitting trot, where the rider remains seated fully in the saddle with minimum bounce as the horse trots, are only possible with the use of these lower back muscles, which absorb the horse's movement. Stiffness of the rider's lower back muscles will cause the rider to bounce out of the saddle and make the horse less responsive to the rider's aids. The hip adductors, like the gracilis, adductor longus, sartorius, and pectineus muscles, provide riders with the ability for their thighs to grip. Given that the leg is constantly bent while riding, the grip of the rider's thigh provides stability for the bent leg.

The iliacus and psoas are muscles with roles that often overlap as the rider utilizes their lower muscles, together forming the iliopsoas or hip flexors. The psoas is involved with flexing the rider's hip and laterally rotating it, as well as flexing the spine sideways to extend and rotate it. The psoas attaches itself down the last thoracic vertebra, the lumbar vertebrae, and the discs between them, from the inside and top of the femur. Since the psoas manages the pelvis and controls the front to back motion, it has the power to restrict or release the rider's shock absorption of the horse's gait. When it is engaged with the rectus abdominis, it holds the rider in the center of the saddle so that the rider's seat bones are connected to the horse's back muscles on each side of the horse's spine. The iliacus begins at the iliac fossa on the interior side of the hipbone and releases the movement of horse below the rider. The psoas and iliacus muscles carry the torso vertically and prevent the rider from falling behind the line of gravity under the hip joints.

> The biomechanics of both horse and rider when jumping a fence occur in mere seconds, but determine rider and horse's clearance over the jump.

Riding would be nearly impossible without engagement of the quadriceps, muscles found in the upper leg, and the calf muscles. Equestrian riders can thank their vastus lateralis, vastus medialis, and rectus femoris which allow them to rise in the trot and to grip the saddle during the canter. These muscles are among the strongest muscle groups in riders, and are constantly conditioned and worked during riding. The tensor fasciae latae muscles are responsible for turning the rider's thighs inwards to grip the horse, opening the hips for the rider to sit more easily (and comfortably) on the horse. While riding, the calf muscles in the human body rest against the horse's sides and convey aids to the horse by applying or lessening pressure against the horse's sides. It is also not uncommon for equestrian coaches to shout, "heels down!" at their riders if they notice a rider lifting their heel and pointing their toes down. If this happens, the rider could lose the support of their stirrup, a support that is especially helpful when jumping because it absorbs the impact of landing. The rider uses their tibialis anterior muscle to hold the foot up and the heel down.

The biomechanics of both horse and rider when jumping a fence occur in mere seconds, but determine rider and horse's clearance over the jump. Equestrian jumping involves four phases: the approach, the takeoff, the flight, and the landing. In the approach, the horse gathers energy as he prepares to jump and raises his head to better view the jump. Since horses are prey animals, they have monocular and binocular vision, giving them far better peripheral vision than humans. When the horse is about four feet in front of a jump, the obstacle simply vanishes from its line of vision. The horse must not only measure the jump and its own takeoff point during the approach, but must place its faith in the rider to correctly guide them over the obstacle. At the base of the jump, the horse lengthens his frame and reaches forward and down with his neck to lower his front legs and his center of mass. The horse's front legs are propped out in front of his body, and a sudden brake-like motion allows his momentum to carry his hind legs further under his body. This brief stopping of the forward momentum of the horse allows the horse to gather enough energy to clear the fence.

> The horse must not only measure the jump and its own takeoff point during the approach, but must place its faith in the rider to correctly guide them over the obstacle.

During the takeoff, the horse's front and back ends undergo two shifts of energy. The first burst of energy comes during the takeoff, and is initiated by the forelimbs, using the stored kinetic energy released when the front leg muscles contract and straighten the fetlocks through the superficial and deep digital flexor tendons. The horse's trailing forelimb stretches out and propels the horse upward because it acts a slight braking force that converts forward movement into upward momentum, because the fetlock joints are briefly contracted by the muscles. As the horse lifts his head and neck, the front end is further pushed into the air by the contraction of the triceps brachii, biceps brachii, and supraspinatus muscles that straighten the shoulder and elbow joints. The horse's neck continues to shorten, stopping the normal forward movement of the canter. The thoracic sling, a system of muscles that lie deep against the skeleton under the shoulder blades, surrounds the thorax of the horse. The pectoral muscles of the front chest and between the front legs, and the ventral serratus that rests against the rib cage are the most vital muscles of the thoracic sling, because they lift the thorax of the horse between the shoulder blades. This movement is enabled by the structure of the scapulae of the horse, because they are attached to the horse's body through soft tissue structures and not through skeletal joints. The horse's withers rise relative to the top of the shoulder blades, providing crucial support as the horse's center of gravity shifts back and his front end lifts into the air. The back muscle, longissimus dorsi, runs from the sacrum along the back to the lower cervical vertebrae. When the horse's hind legs are stationed on the ground, the contraction of the longissimus dorsi creates a lever action on the horse's front end, allowing the horse to lift himself off the ground.

The flight of the jump begins with a rotation around the horse's center of mass. His front end tips upward at the takeoff, then becomes level with his haunches over the top of the obstacle before lowering the landing. The shape of a horse's trajectory through the air is the "bascule." The trapezius, brachiocephalic, and latissimus dorsi muscles contract to flex the horse's joints in the elbow and shoulder and lift the scapulae, lifting the forelimbs to clear the jump. The horse's folded forelegs bring his weight closer to his center of gravity, increasing his speed. Tension along the nuchal and supraspinous ligament helps further raise his center of gravity. After the bascule of the jump, the horse's head and neck begin to come up, shifting his center of gravity back. This action is a reflex to flex the hind limbs to clear the fence and to extend the forelimbs as the horse prepares to land. As the horse's forelimbs are extending for landing, the abdominal muscles are contracting to help lift the back while the gluteal and hip flexor muscles flex the hips, hock, and stifle to successfully clear the jump.

> The dynamic nature of riding requires the human body to move and flow with the horse, and requires the muscles to follow and absorb the impact of the horse's motions and gaits.

For the horse to land a jump, he must slow his forward momentum so that the force of impact is reduced by swinging his neck and head up as his forelegs touch the ground. The trailing is often perpendicular to the ground, landing first and absorbing much of the impact of the jump. The deep digital flexor tendon and suspensory ligament are stretched so much so that the horse's fetlock usually touches the ground. The navicular bone is strained through the deep digital flexor tendon when the horse lands on his heel. The thoracic sling and the forelimb muscles contract to brace the leg and support the horse's joints. As the forefeet reach the ground after clearing the obstacle, the hooves push the horse's body up into the next canter stride, reversing the rotation of the body axis, allowing the horse's hind legs to step under his body and continue forward to the next jump. This entire jump sequence happens in a matter of seconds, displaying not only fast thinking on the horse's part, but also on the rider's side, because the rider must adjust their body before and after the jump and brace their body.

It's easy to forget or misjudge equestrian riding as a "simple" pastime that requires little skill or effort. The ease and lack of apparent effort by the horse and the rider is a big part of impressing the judges and putting on a good performance, but cloaks the complexity of this sport. The dynamic nature of riding requires the human body to move and flow with the horse, with the rider's joints remaining static but not stiff, and requires the muscles to follow and absorb the impact of the horse's motions and gaits. While unseen and unacknowledged, the strength, ability, and endurance of the muscles in the rider's body and the horse's body affect every aspect of this sport, from the physics in show jumping to casual riding around an arena, establishing balance, stability, symmetry and coordination that create the imposing sight of equestrian riding.

Why Are You SAD?

The Science Behind Seasonal Affective Disorder

Written by Courtney Broady
Illustrated by Zimeng Xiang

After long nights in the deep freeze, you might wake up one morning to realize you hear birds chirping, see green grass, feel warm sunlight on your face, and know: spring is here! The lengthier exposure to sunlight associated with the changing seasons is critical for our bodies and minds to properly function. Even the smallest amounts of sunlight exposure from walking between buildings or running through the park program our brains by keeping chemicals in balance and stabilizing our bodies' natural circadian rhythm. But during fall and winter months, the decrease in natural light can lower the amount of serotonin in the brain, which is responsible for changes in mood balance that result in seasonal affective disorder.

Seasonal affective disorder, aptly nicknamed SAD, is a seasonal depression that affects roughly 5% of the United States population, with women nearly 4 times as likely to be affected by SAD than men. Naturally, many of us experience a longing for warmer days and some form of annoyance or grogginess during the early mornings before the sun rises, but those who suffer from SAD experience much more serious effects. Feelings of guilt, hopelessness, self-esteem crashes, lethargy, and sleep problems are a few of the telltale signs that you or someone else could have seasonal depression.

Overeating, specifically carbohydrate-rich foods, is a key giveaway of having SAD. When you eat a bite of pasta or a handful of chips, neurotransmitters like serotonin are fired off in the brain. This intake of carbohydrates increases the tryptophan levels in the bloodstream. Tryptophan is an essential amino acid, meaning that our bodies cannot create it, so it must be consumed through food. Serotonin and tryptophan are closely intertwined because serotonin is produced from tryptophan. A low level of serotonin in the brain can lead to feelings of sadness, insomnia, and the urge to overeat, so it is important to have enough tryptophan to make enough serotonin. It also means that when tryptophan levels increase as food is digested, it can give you a surge of happiness, which can develop into an unhealthy habit of excessive eating for happiness.

Eating a mixture of carbohydrates and proteins produces insulin, which diverts amino acids to the muscles and divides tryptophan between the muscles and brain to be converted into serotonin, ultimately producing a sense of happiness and peace. Eating protein alone, however, does not have the same effect of serotonin release that carbs provide. This is because protein is made up of thousands of strands of amino acids; if not enough carbs are consumed to increase insulin levels, it is harder for tryptophan to enter the brain because it must compete with many other amino acids in the bloodstream.

However, depression cannot only be treated with a change in dietary regimen. Sometimes the most effective way to treat seasonal affective disorder is to physically remove yourself from the low sunlight area. That's right, take a vacation! Going to a new location that provides plenty of sunlight, preferably near the equator, is a surefire way to boost spirits and realign the brain's natural processes. People who tend to live in regions further from the equator are more likely to be affected by SAD; for example, in Washington state, people are seven times more likely to develop SAD than residents of Florida. In the far north, Alaska suffers from a six-month period of very little sunlight in the winter, which makes the population more susceptible to developing SAD.

> Something as simple as sunshine plays a vital role in allowing the human brain to properly function.

Lethargy is another common symptom for people who deal with SAD and other forms of depression. The frequent inability to stay mentally alert and motivated throughout the day, coupled with the desire to go to sleep earlier and for longer, could result in a broken sleep schedule of waking up in the early hours of the morning and then oversleeping to compensate. This vicious cycle creates a pattern of long, blurred days and restless nights.

EEG (electroencephalogram) brain scans are used by psychologists to measure electrical activity in the brain. Those suffering from SAD have been shown with an excess of left frontal alpha activity compared to neurotypical patients. The result of this excess is not completely understood, but it could make the patient more inclined to suffer from depression sometime in their life. Additionally, levels of a serotonin transporter protein have been reported to be lower in those affected by SAD compared to neurotypical patients.

> Feelings of guilt, hopelessness, self-esteem crashes, lethargy, and sleep problems are a few of the telltale signs that you or someone else could have seasonal depression.

Many studies have been published on the effect of sunlight increasing the levels of serotonin within the brain and the wonderful benefits that accompanies this increase. Incorporating outdoor routines into a daily ritual can optimize the serotonin and other chemical levels in the brain. Besides going outside, bright light therapy is another popular option as treatment for seasonal and nonseasonal depression. In therapy, an artificial light is shined on the patient for 30 minutes a day over a period of a month or more to restore neurochemical balance and realign the patient's circadian rhythm. Results can be seen in as little as one week, but to reduce the chance of a decrease in serotonin, a month is recommended.

Patients could, however, need a longer treatment time if they have a problem physically absorbing light. Those diagnosed with SAD are 5.6 times more likely to have a mutation in their photopigment layer of the retina called melanopsin. Retinal ganglion cells, a type of neuron that collects visual information and sends electrical impulses to the brain, contain melanopsin and other proteins. These proteins work together by creating a network of nerves, called a dendritic plexus, to capture photic (light) stimuli. A mutation in the DNA that codes for these proteins decreases the amount of light captured and transmitted to the brain.

> Sometimes the most effective way to treat seasonal affective disorder is to physically remove yourself from the low sunlight area.

SAD and winter blues are commonly interchanged, but those with seasonal affective disorder experience the effects of depression, lethargy, mood changes, and appetite changes to a much larger degree. Something as simple and beautiful as sunshine even on negative degree days plays a vital role in allowing the human brain to properly function. So, if you are going outside to walk to the parking lot or the next building, walk a little slower and be thankful for spring arriving, because sunshine has powerful effects on the body and mind.

Note, however, that no guarantees are made for the curing of seasonal depression due to sunlight and natural remedies alone. Depression in all forms is a real disease that affects millions of people worldwide. Great strides have been taken in the past decade to combat depression through a combination of natural forms of treatment such as light therapy, psychological consultations, and pharmaceuticals. Raising awareness about all mental health issues is an important step for everyone to take and should be treated with the same urgency as a physical disease.

Too Sensitive?

The Science and Experience of Highly Sensitive People

Written by Lauren Rhodes
Illustrated by Lydia Newman-Heggie

Seemingly everyday experiences are too loud or too cold or too overwhelming. The light from my computer charger can keep me awake at night. As an adult, I have adapted my life to accommodate my sensitivity. I do not watch many violent movies. I try not to overbook my schedule. I venture into new things with extreme caution. I respond heavily to other people's emotions and to different kinds of stimuli in my environment, like sounds or bright lights. When I was a child, this came across as shyness. Now, my behavior may come across as introversion or being antisocial. It is none of these things. I am a Highly Sensitive Person (HSP), or someone who has Sensory Processing Sensitivity (SPS).

> The main parts of being a Highly Sensitive Person that manifest in daily life are being easily overwhelmed and being highly aware of subtleties.

Dr. Elaine Aron, the pioneering researcher of Highly Sensitive People, began studying Sensory Processing Sensitivity in 1991. Sensory Processing Sensitivity is the scientific term for high sensitivity, a widespread trait. According to Aron's research, out of the world's population, 15-20 percent of people are Highly Sensitive. However, this trait is not well known. My untested hypothesis for this lack of common familiarity with SPS is that it may not sound real to people who do not have it; opening up about the topic could lead to ridicule if it does not sound real; and that it is difficult to talk about, because of the nature of the people whom it affects. If a Highly Sensitive Person attempts to explain their experience to someone who does not believe them, this could potentially be an overwhelming and negative experience, because of their sensitivity.

Like the title of this article, Highly Sensitive People may be told that we are "too sensitive". The trait of Sensory Processing Sensitivity is specifically focused on experiences of four things: depth of processing, overstimulation, emotional intensity, and sensory sensitivity. I believe that sharing the scientific background of Sensory Processing Sensitivity is an important step in finding more recognition in the wider world. In a study, "Sensory Processing Sensitivity: A Review in the Light of the Evolution of Biological Responsivity," Aron et al. find that the neural regions relating to visual attention and visual processing are more highly stimulated in Highly Sensitive People. Sensory Processing Sensitivity has actually been found in over 100 different species, not just humans, because it is a survival mechanism in some situations. Broadly, it is good for a species to have a minority of organisms that are Highly Sensitive, so that the overall group benefits. The main benefit of sensitivity in organisms, especially social animals, is the ability to learn from one situation and make a better choice of how to react in another situation. If an entire species were Highly Sensitive, the biological costs would outweigh the benefits.

> According to Aron's research, out of the world's population, 15-20 percent of people are Highly Sensitive.

In a study by Acevedo et al. including Dr. Elaine Aron, "The highly sensitive brain: an fMRI study of sensory processing sensitivity and response to others' emotions," the researchers discovered that the brain areas responsible for awareness and responsiveness were activated in different situations, and activated more highly by people with Sensory Processing Sensitivity. These situations included seeing photos of strangers and of their romantic partners with facial expressions that were either neutral, happy, or sad. There is much other research backing that in general Sensory Processing Sensitivity is a trait that is associated with higher than average responsivity to stimuli, both environmental and social.

The main parts of being a Highly Sensitive Person that manifest in daily life are being easily overwhelmed and being highly aware of subtleties. A self-test available on Aron's website, which can help people determine if they are Highly Sensitive, includes checking boxes on statements with which the test-taker agrees. The trait can be misunderstood as introversion or shyness, because a Highly Sensitive Person often may avoid overstimulating situations and may be too overwhelmed to socialize. Highly Sensitive People tend to pick up on extra sensory input. It is easy to become overwhelmed by too much input. For example, I am sensitive to cold, light, sound, touch, smell, pain, and emotions. If I have done too many things in a day and have not had time to sit and do nothing, I am emotionally overwhelmed, even if none of the things have been upsetting. I am unable to function well if I am overwhelmed in a sensory way.

Being highly aware of subtleties is, in some ways, the inverse of being overwhelmed easily. Highly Sensitive People tend to notice subtle things in our environments, like quiet sounds or tiny lights or small interactions. Sometimes this can manifest in Highly Sensitive People enjoying subtle sensory input, but I think of this sensitivity to subtleties with more of a sense of annoyance. When I try to fall asleep, often times a very quiet but persistent sound, or a light coming under my door, will keep me awake (to which my previous roommates can attest). I understand that this could sound like some people are sensitive, and therefore other people are insensitive. This is not the case at all. As this is a trait, there does not need to be judgement attached to sensitivity, and it is more about a minority of people being Highly Sensitive rather than dividing people into sensitive and insensitive. Some Highly Sensitive People may feel judged for their sensitivity, and I am learning not to judge my own.

I am personally grateful to Dr. Elaine Aron for her research. This is a way in which I am able to understand my identity, and learning about the scientific basis for my experiences helps me accept myself. One of the important things I want to remember with this kind of science is that while the science is validating and crucial to conveying the reality of the trait, my experience is also valid by itself. That is, the science behind the trait helps explain and validate Sensory Processing Sensitivity, while the individual and collective experiences of Highly Sensitive People are also important to learn about. So: am I too sensitive? I am highly sensitive, but I do not need to judge myself for that.

Addressing One of Football's Greatest Issues: CTE

A Discussion on the Neurology Behind the Life-Changing Disease

Written by Carson McCann
Illustrated by Mikaila Hoffman

It is the fourth quarter; the score is tied with little time left. As the players explode off the line of scrimmage, a war erupts. A rushing linebacker sees his shot to give his offense the ball. He slides past the blockers and closes in on the quarterback. BAM! The linebacker, and accordingly, the defense, won this battle. However, the quarterback and linebacker stumble as they attempt to regain their footing. The quarterback loses consciousness and falls back to the turf. He is taken off the field. The linebacker does not last on the pitch much longer. The game continues as if nothing happened in the previous play. However, on the sidelines, each player's body is undergoing physiological changes. The trainers note that both players are in a daze. They seem to be in some type of purgatory of consciousness.

The players are developing a condition known as Chronic Traumatic Encephalopathy (CTE), which is caused by Traumatic Brain Injuries (TBIs) such as the concussion from which the quarterback and linebacker are both suffering. After taking on a severe TBI, a person's brain starts to undergo physiological changes. Even one TBI can lead to CTE, but it is usually the culmination of multiple brain injuries. CTE wreaks havoc in a player's life. The disease changes the brain at the cellular level, which ultimately affects behaviors at the social level. A beloved player can be changed forever because of the disease. In this article, I will discuss the effects of CTE at multiple levels as well as explore possible prevention tactics for this disease.

In order to understand CTE, one must first understand the most common TBI: a concussion, or a bruise within the brain as a result of an impact with the skull. The brain is not tightly packed in the skull. Instead, it is suspended in cerebrospinal fluid (CSF) inside the skull. When a player is tackled, their head launches in the corresponding direction of the hit; eventually, the head meets a force, like the ground, which stops all momentum. However, the inertia of the hit leaves the brain moving toward the stopped skull. The brain then hits the bone. The brain contuses, causing the unfortunate player to suffer from a TBI. This is why many concussions often result from the head hitting the ground rather than the initial hit while running the ball.

Once the player has sustained a TBI, changes at the cellular level occur. CTE is a neurodegenerative disease characterized by the hyper-phosphorylation of tau proteins. Tau proteins normally help the microtubules in the neuron maintain its shape. When a phosphate group is added to the proteins, they undergo a change in shape, which is natural and not deleterious when the phosphorylated protein is at low concentrations. But in diseases like CTE, the tau protein is over-phosphorylated, which causes inappropriate protein folding and entanglements known as neurofibrillary tangles (NFTs). A plaque forms and there is a block between neurons.

One way to visualize the effects of CTE is to imagine the neural pathways as electrical information highways in the brain. The normal tau proteins help stabilize the roads. When there is an overrepresentation of hyper-phosphorylated tau proteins, the resulting plaque is like a car crash on the highway, leading to major blockage.

Blocked neural circuits can significantly change a person depending upon which area of the brain is affected. Unfortunately, CTE affects the cerebral cortex, the most important and largest part of the brain. The cerebral cortex controls personality, higher thoughts, feelings, and holds some memories. The disease can also spread from one area of the brain to another. CTE might initially affect higher thought processes by plaguing the prefrontal cortex, but then affect memory later on by spreading to the hippocampus. Additionally, the NFTs often cause neuronal death, which is why many autopsies of patients suffering from CTE show patients with significantly shrunken brains.

Chronic Traumatic Encephalopathy is not the only disease characterized by misfoldings of tau proteins; Alzheimer's disease and Tangle-Only dementia also resemble the sports-related disease. All three diseases can change a person's behavior, decision-making, and memory. Alzheimer's disease and Tangle-Only dementia usually only affect people in the later years of their lives, typically afflicting individuals age 65 and older. However, CTE can affect a person's brain decades before the other diseases. Autopsy cases have shown the presence of CTE in people in their late 30s and early 40s who were in excellent physical condition. This is perhaps the most haunting aspect of Chronic Traumatic Encephalopathy: it can affect people at very young ages.

Unfortunately, the physiological changes can be tied to severe behavioral changes. One of the best football players of all time, Junior Seau, suffered from CTE. His wife reported that she noticed behavioral changes in her husband two decades before his eventual suicide. She said that he suffered from headaches, dizziness, and insomnia for quite a long time in his football career. After games, he would quietly return to his room at home and draw the blinds to sit in the darkness for hours. These are only some of the physical effects of CTE; the extremely troubling effects were ones that changed Seau as a person. Years before his passing, he reportedly developed new habits. He made rash financial decisions. He developed addictive habits, like drinking and gambling. Lastly, he suffered from severe fluctuations in emotions and correspondingly, behavior. These symptoms are linked to the physiological effects of CTE. The development of plaque in regions of the cerebral cortex can influence all of these behaviors. Junior Seau was a good man who passed away from a disease currently viewed as incurable.

So how can we decrease the number of people suffering from CTE in the future? The simplest answer is to avoid TBIs. This is a rather tall order, though, because people love the fast-paced, intense action of physical sports like football. It is human nature to enjoy these sports — playing them as well as watching them. However, the human body was not made to crash into other humans at top speed. Maybe we can learn from other animals in nature that are able to withstand such brutal impacts.

A woodpecker is estimated to bang its head against trees around 85 million times over the course of its lifetime. Woodpeckers are able to avoid brain injury because they have a special bone to protect their brain. This bone, the hyoid bone, starts at the top of the woodpecker's beak and then it wraps around the back of the head to become the tongue in the bottom of the beak. The hyoid bone acts as a seat belt for the woodpecker's brain as it flings its head into the bark of the tree and prevents the brain from hitting the back of the skull, the main cause of concussions.

> Both animals adapted to compensate for their repeated head banging while preventing brain injuries; the human boday has not developed these adaptations.

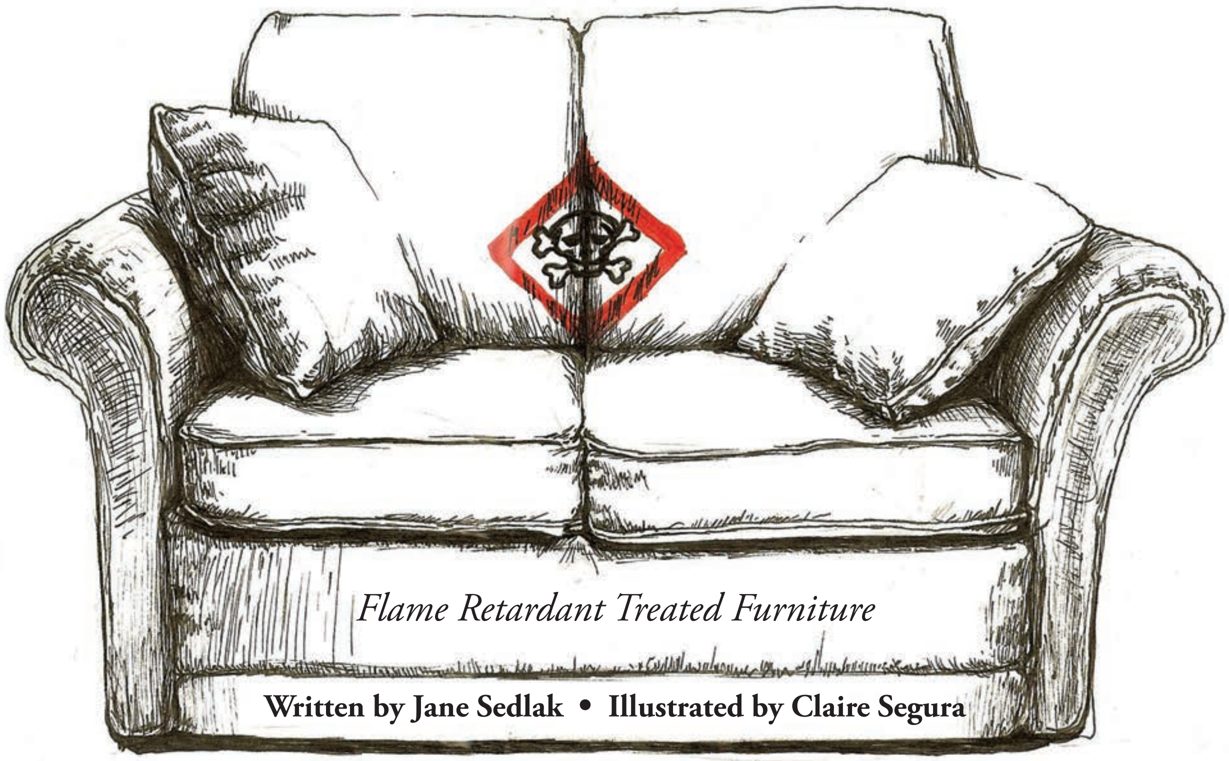
The bighorn sheep are another type of animal who live their lives by ramming heads. Male bighorn sheep are famous for ramming their heads with other males to establish dominance for mates and territory. The bighorn sheep can withstand the massive impacts from ramming heads because of the shape and structure of their horns. The curved horns displace some of the energy to the tips instead of the skull. Additionally, the trabecular internal structure — characterized by complex, porous spatial construction to maximize bone strength — of the horns allows the energy to dissipate. The segmented design of their horns allows the energy to dissipate further as it passes each partition.

Both animals adapted to compensate for their repeated head banging while preventing brain injuries; the human body has not developed these adaptations. Although sports are exciting and fun, one must keep health and safety in mind. Companies are currently searching ways to prevent concussions through the development of new helmets. A company called Vicis has created a flexible helmet named the Zero1. The flexible design in the helmet provides a cushion to help absorb the impact of a hit. Other companies are finding inspiration in porcupines, which fall out of trees quite often. To protect themselves, the porcupines tuck into a ball and allow their quills to brace the impact. Research is currently being undertaken to pursue the potential for quill-like structures in the shock-absorbent portion of a football helmet. There are plenty of companies seeking to innovate the helmet industry, but many are having trouble securing funding; they need a larger corporation to supply funds for their research.

The National Football League (NFL) is attempting to do exactly that. The organization is now recognizing the dangers of football, and designating a lot of money towards research to prevent concussions. The NFL announced a plan to pay $100 million for an initiative to seek safety for the players. $40 million dollars will be put toward medical research and the other $60 million will be applied to developing new technologies, such as helmets.

Preventing concussions seems like an impossible task in many sports that rely on brute force. Some could argue that changing the rules is the first step. The NFL has done that already — in fact, it has made over 40 rule changes in the past couple years. Some people argue the changes are needed, while others say they are ineffective and only ruining the sport. Either way, everyone can agree something needs to be done to prevent the players from developing Chronic Traumatic Encephalopathy.

The Monsters Lurking in Oberlin's Science Center's Couches



Flame Retardant Treated Furniture

Written by Jane Sedlak • Illustrated by Claire Segura

If you've ever misplaced your cell phone at Oberlin, your frantic search may have led you to the lost world underneath the Science Center's couch cushions. Although you may not have noticed them in your distraught state, there are a bunch of white tags among the loose coins, crumbs, and stray pencils. These tags tell you who built the couch, where it was made, and what it is made of. But the most interesting, and possibly the most unintelligible tag, is the one that tells you that your couch complies with TB117.

In an effort to prevent fire-related deaths, the California Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation created Technical Bulletin 117 (TB117) in 1975. To comply with the standard, furniture had to be able to withstand twelve seconds of exposure to a small flame without igniting. The only way for manufacturers of foam-containing couches to meet this standard was to add flame retardants to the foam. Flame retardants are chemicals that slow a fire's progress by interfering with the complex chemical reactions related to fire. The flame retardants used in furniture usually consist of a group of compounds that include organohalogens (i.e., compounds with multiple carbon-halogen bonds), and phosphate esters (also called organophosphates). Although these chemicals have properties that make them useful as flame retardants, they are also quite toxic. For example, some organophosphates, like VX, the compound used to assassinate Kim Jong-un's half-brother, can be deadly. Some organohalogenated flame retardants commonly added to furniture, like the polybrominated diphenyl ethers (PBDEs), are endocrine disruptors and potential carcinogens.

So what did TB117 mean for consumers? For a Californian like me, TB117 meant that the couch I grew up with in my living room contained about 100 grams of PBDEs. People who grew up in other states are usually surprised to learn that their couches often contained PBDEs too. When TB117 was enacted, most companies didn't want to run a separate production line just for couches to be sold in California, so they just made all of their couches TB117-compliant. To see if this also happened to the couches at Oberlin, I collected five foam samples from the Science Center's couches and sent them to researchers at Duke University's Superfund Research Center. After a few months, I got my answer: three of the couches contained flame retardants, including PentaBDE, a brominated diphenyl ether flame retardant that was phased out in the US in 2005 due to concerns about its potential health effects. The couches also contained tris (1,3-dichloro-2-propyl) phosphate (TDCPP), a compound with potential neurotoxic and carcinogenic effects that was introduced to replace PentaBDE, as well as something called V6 — a mixture of compounds with structural similarities to TDCPP.

These findings about Oberlin's couches are concerning for several reasons. For starters, flame retardants are only added to polyurethane foam; when someone sits on the couch and compresses the foam, flame retardant-containing dust can be released. The tendency for flame retardants to escape through this mechanism becomes more pronounced as the foam ages. The flame retardants released from an aging couch can collect in household dust, which occupants come into contact with on a daily basis. Pets and young children are especially at risk to exposure because they play on the floor, where dust often settles. A 2012 *PubMed* study found a linkage between cats with feline thyroid disease and high concentrations of PBDEs (endocrine disruptors) in household dust. I'm not saying that every time you sit on a couch you expose yourself to a chemical as potent as VX; however, long term exposure to chemicals with known and unknown toxicities cannot be good for us.

> Although these chemicals have properties that make them useful as flame retardants, they are also quite toxic.

It's important to note that flame retardants aren't just found in dust. If you've ever taken Professor Thompson's CHEM 341 Trace Analysis class, you've probably analyzed dryer lint for PBDEs using a halogen-sensitive electron capture detector. Over the past few years, his students have detected PBDE 99, 147, and 180 — compounds typically used in commercial flame retardant mixtures — at levels ranging from 180 to 1200 ng/g lint.

If this wasn't bad enough, some flame retardants are classified as persistent organic pollutants (POPs), which means that they are resistant to degradation by bacteria and sunlight and can travel long distances through the atmosphere and ocean. PBDEs have been found in polar bears' fatty tissues, in sea otters' livers, and in cephalopods, a deep-sea mollusk. Because these POP compounds are resistant to degradation, they could be in our environment for the next hundreds to thousands of years.

> The flame retardants released from an aging couch can collect in household dust, which occupants come into contact with on a daily basis.

But it's not all bad news. In 2013, California's legislature amended TB117. Now, furniture can comply with the standard if it can withstand a test exposure to smoldering embers instead of open flame. The new standard focuses on the fabric covering the foam, where the fire starts, as opposed to the interior foam, which usually isn't exposed to flames until a fire has already gotten out of control. As a result, manufacturers no longer add as much flame retardants to many of their products. It is even possible to find companies that sell flame retardant-free couches.

Maybe in a few years when you're digging through the couch cushions to find your phone, there will be one less tag you need to push aside. Although you might not find your phone, hopefully you can be confident that you won't find any monstrous organic compounds hiding in the couch cushions either.

Predator Free by 2050

Protecting New Zealand's Fauna

Written by Tara Santora
Illustrated by Elena Hartley

New Zealand, also known by the Maori name Aotearoa or the Land of the Long White Cloud, is a place of much record-breaking, and it's not giving up that reputation any time soon. On a musical note, the islands of New Zealand are home to more Scottish pipe bands per person than any other country. According to the Corruptions Perception Index, New Zealand is tied with Denmark for being the least corrupt nation in the world. And, slightly more frightening, New Zealand is the birthplace of the giant weta, the heaviest insect in the world. Now New Zealand is embarking on a journey to break a new record: to be the first country in the world to completely eradicate introduced predators with its project "Predator Free 2050".

New Zealand has a unique ecology that makes predator eradication vital for conservation. The country is home to only two native land mammals: the long-tailed bat and the lesser short-tailed bat. Most of the native species are either insects, reptiles, or birds. While the bats and some birds eat insects and a few bird species eat some reptiles, the birds themselves are only prey to other birds such as eagles, and these predatory birds are not common enough to be a significant threat to the prey birds. Since these birds do not have to evade any predators on the ground, many of them have evolved to conserve energy and have become flightless. This adaptation has led to endemic — only found in a certain area — flightless birds becoming a trademark of New Zealand's fauna.

The national icon of New Zealand, the kiwi, is an example of one of the flightless bird species that is endemic to New Zealand. Other examples of flightless New Zealand birds are the kakapo, a nocturnal parrot, and the weka, a chicken-sized bird known to steal shiny objects from tourists. Of course, we also can't forget the moa, a flightless 550 lb bird — once the world's largest — that was hunted to extinction by the Maori about 500 years ago.

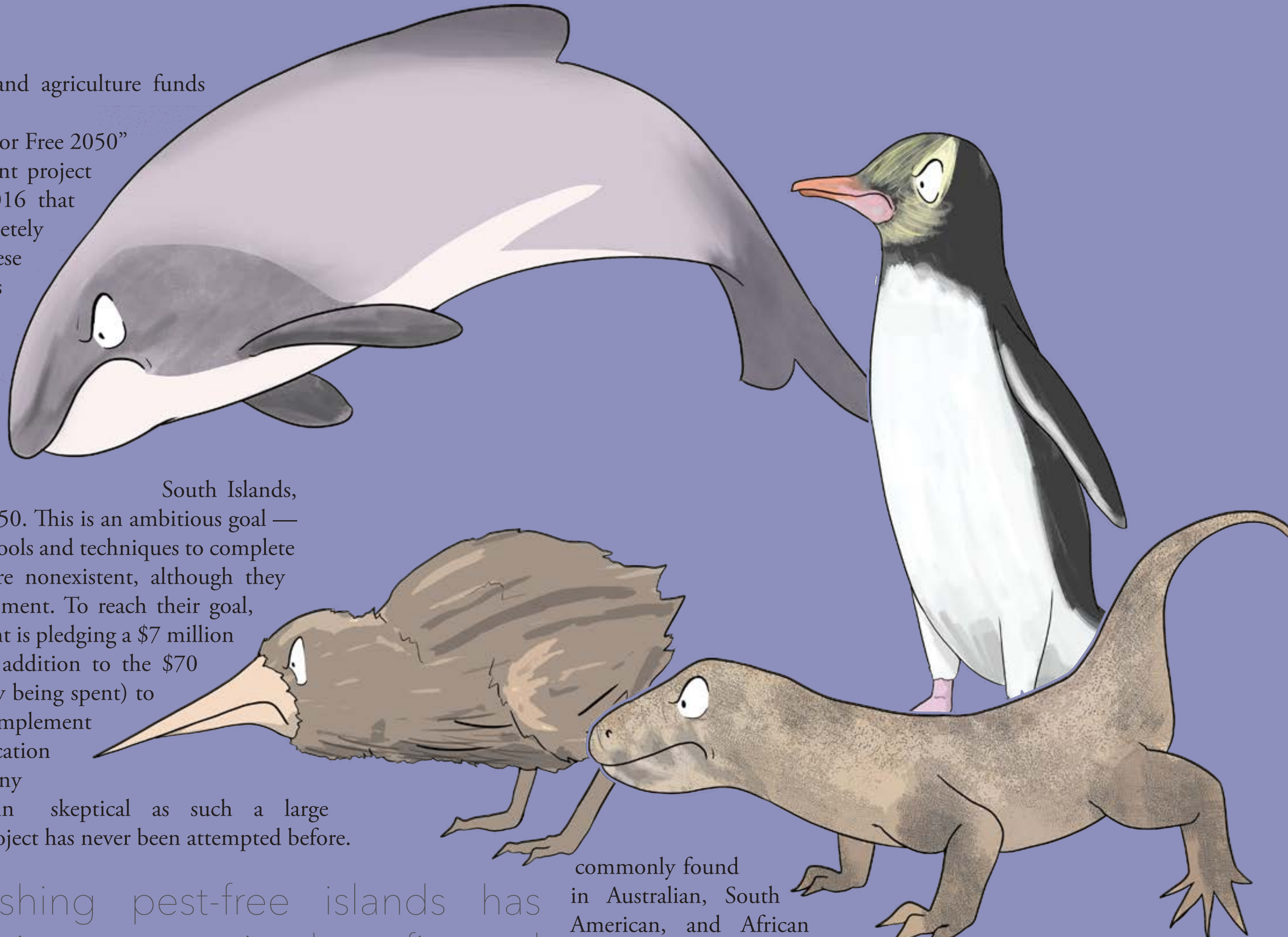
It's important to stress that because of New Zealand's long-term isolated geography and its unique lack of natural predators, these specific endemic flightless bird species cannot be found anywhere else in the world. In fact, 57% of New Zealand's birds are endemic! That is why conservation of these species is so important; if they are driven to extinction in New Zealand, they disappear from the earth forever.

The introduction of invasive predators to New Zealand began in the tenth century when Polynesian settlers, now referred to as the Maori, brought the Maori dog and kiore rat with them to Aotearoa (New Zealand). Later, sealers and whalers from Europe introduced European rats and mice. However, the largest and most impactful influx of predators came when European settlers began to colonize New Zealand in the 1840s.

In total, 32 mammal species have been introduced to New Zealand. A significant proportion of these invasives predate on endemic species, including endemic flightless birds; these species are easy targets because they have not evolved to be able to evade these new predators. Additionally, there were not predators native to New Zealand before the invasives arrived, so there existed an empty niche that predators were able to fill when they were introduced. Since obtaining food is so easy for these invasive predators, many of the species' population sizes have expanded rapidly, which in turn leads to the killing of more endemic wildlife. The three invasive predators that are considered the largest threat to conservation, and the three that are therefore targeted by New Zealand's pest eradication program, are the rat, stoat, and possum.

Rats are problematic because they eat everything from lizards to snails to insects to birds. They destroy agriculture and can carry disease. Possums, which were introduced from Australia, eat many native snails, beetles, and birds, as well as directly compete with flightless birds for resources. Possums also pose health and economic risks because they have been known to spread bovine tuberculosis to cattle and deer. Stoats, which are related to ferrets and weasels, were originally introduced to predate on the rampant rabbit population that has overrun the country. However, the stoats are a problem unto themselves and have already caused the extinction of several endemic bird species. They are famous for attacking defenseless young kiwi. Combined, these three predators alone kill millions of New Zealand's birds and cost the country $70 million in conservation and agriculture funds each year.

"Predator Free 2050" is a government project enacted in 2016 that aims to completely eradicate these three predators from all the islands of New Zealand, including the main North and South Islands, by the year 2050. This is an ambitious goal — currently the tools and techniques to complete this project are nonexistent, although they are in development. To reach their goal, the government is pledging a $7 million each year (in addition to the $70 million already being spent) to develop and implement predator eradication strategies. Many people remain skeptical as such a large eradication project has never been attempted before.



> Establishing pest-free islands has had major conservation benefits, and establishing a predator-free mainland would undoubtedly be a huge step forward in the effort to save New Zealand's threatened flightness bird.

However, New Zealand is not new to predator eradication. The country has secured and maintained over 100 of its offshore islands pest-free. To keep these islands pest-free, travellers are required to check their gear for rodents, insects, and skinks (an invasive lizard) that may be hitching a ride. People are also mandated to clean off any soils or seeds that may be on their shoes since they could potentially transport disease or weed seeds; this is often done by placing soft bristled shoe-scrapers next to the ferries that transport people to and from the islands. If you spot a pest while on an island, you are encouraged to call a hotline specifically set up for monitoring island invasives.

Establishing pest-free islands has had major conservation benefits, and establishing a predator-free mainland would undoubtedly be a huge step forward in the effort to save New Zealand's threatened flightless birds. But while saving the birds sounds great, there are a wide array of ethical questions that come with the predator eradication strategies being implemented. Sometimes traditional traps are used to capture and kill the predators, which in and of itself angers some animal rights activists. More controversial, however, is the current main strategy of killing the predators with the poison sodium fluoroacetate, commonly called 1080.

1080 is biodegradable, cost-effective, its active ingredient is commonly found in Australian, South American, and African plants, and it has not been found to pose a risk to water supplies. The poison is added to baits, and the baits are sometimes placed in marked locations but more often aerially dropped into designated areas. While the government believes that 1080 is not harmful, some people distrust the government-funded studies that have declared the poison to be safe to humans and the environment. The distrust has led to some pushback against the use of the poison by people who claim it is dangerous for the environment, as well as for native animals. Their arguments are supported by the fact that 1080 is banned in several countries, including in most parts of the United States.

1080 is directed specifically at possums and rats; the poisoned baits are dyed dark green and have cinnamon lures, which attract these two pests but deter most native animals. However, the government does admit that some bird species, including kea and weka, occasionally eat these baits and subsequently die. The Department of Conservation claims to use "less palatable baits" and avoid dropping these baits in open areas where the susceptible birds are known to inhabit. Additionally, they defend their choices with the fact that the number of birds saved by pest eradication via 1080 is more than the number of birds killed by the baits. Another argument supported by protesters is that because 1080 does not kill immediately, a pet such as a cat may eat a poisoned rat and die.

There are no easy answers for Predator Free 2050. There are many sides of the issue to consider and many opposing people to please. However, New Zealand has a long history of pioneering conservation efforts. Predator Free 2050 is the latest scheme to preserve the country's unique, endemic fauna. It is a lofty goal, but if the project succeeds, it will open new doors for invasive species management and wildlife conservation worldwide.

Salt Glaciers

What They Are and How They Form

Written and Illustrated by Cecilia Larson

Salt glaciers are huge surface masses of salts - halite, gypsum, and other minerals that form from evaporating seawater - that move and function in a similar way to ice glaciers.

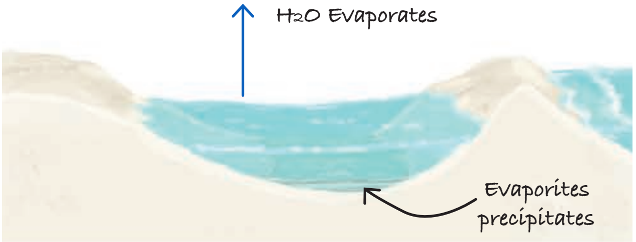
Technically, real glaciers have to be made of ice.

“Salt glaciers” is a nickname given because the way “salt glaciers” move is so similar to the movement of ice glaciers.

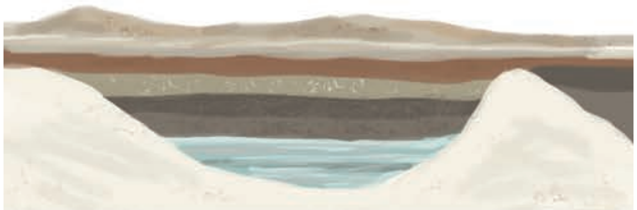
Check out these salt glaciers on Google Earth with these coordinates:

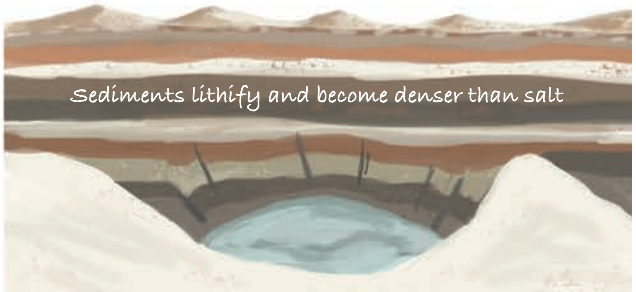
27°33'5.61"**N** 54°32'57.43"**E**

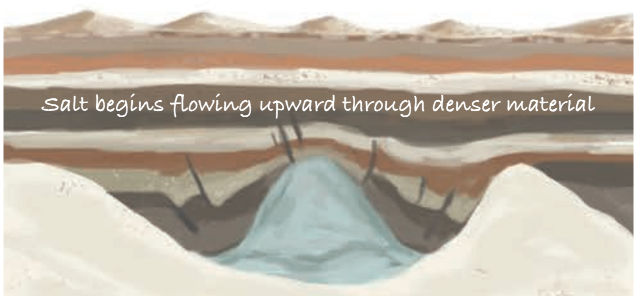
Zagros Mountains, Iran



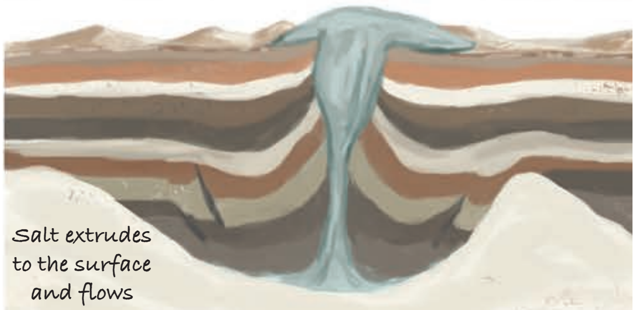
Sediments begin to accumulate







This teardrop shaped stage is called a diapir



How do they form?

First we need salt! Millions of years ago, shallow seas dried up and left behind evaporites in layers many kilometers thick. The term evaporite refers to the series of minerals that precipitate in a certain order from dissolved ions in seawater. The most abundant of these are gypsum, anhydrite, and halite. Halite's chemical formula is NaCl, the same mineral as ordinary table salt.

Sediments begin to gather on top of the layer of salt. As more and more sediment builds up, the increased weight compresses the lower layers. Over time the bottom layers lithify, or become rock (mud to shale, sand to sandstone), and increase in density.

Sediments like mud and sand can compact, but salts cannot. Halite has a fixed crystal structure with relatively constant bond lengths, so its density cannot change. Mud and sand have open pore spaces between mineral grains that shrink and force gases out as pressure increases. As the sediments above the salt turn to rock, they become more dense than the halite. This means that the salt is buoyant in comparison to the rocks above it.

Halite flows very easily since its crystal structure can accommodate bonds breaking and reforming in new places. If the pressure from overlying rock layers is uneven, it can cause the halite layer to flow laterally away from points of higher pressure and gather together. The mass of salt can bulge upward and begin to flow vertically, pushing rock layers aside and fracturing the crust above it. At this stage, the droplet-shaped salt structures are called diapirs. Once they break the surface, they are called salt glaciers.

Na^+ Cool Facts

(So-*DA-yum* Cool Facts)

Salt glaciers can be up to 2 miles long!

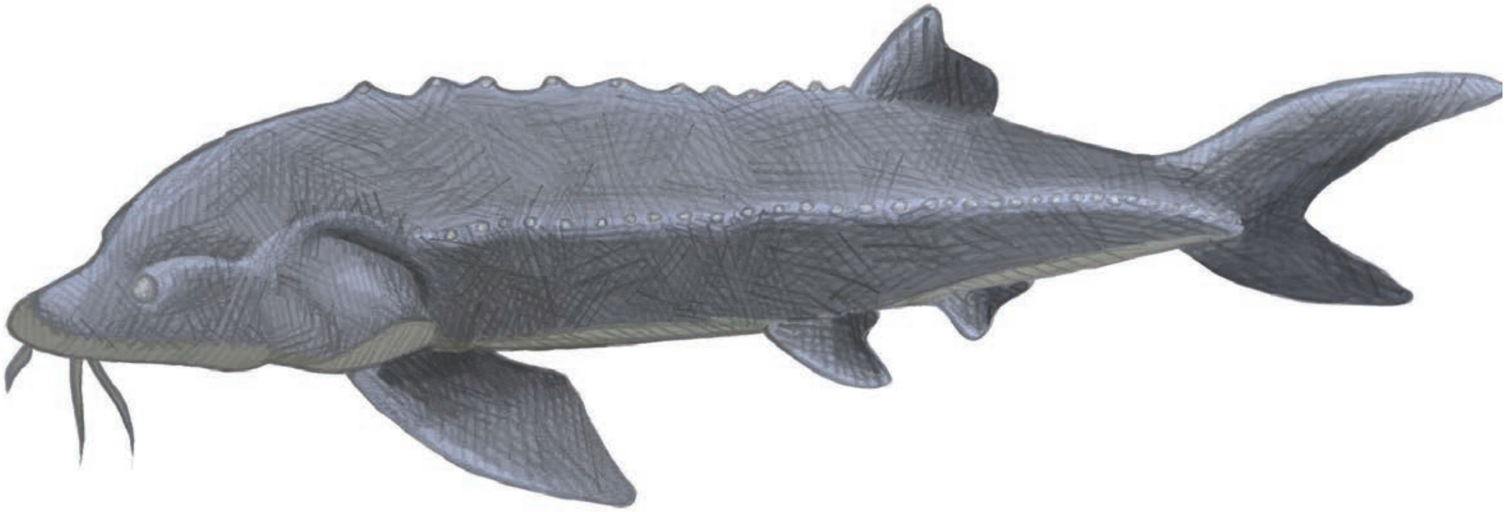
Because halite has a crystal structure that easily *flows*, it is impermeable to *liquids* and *gases*.
This causes salt diapirs to trap **OIL** and natural *gas*.

Salt glaciers pick up and move **sediment** just like ice glaciers.

Salt glaciers only exist at the surface in **DRY** environments, otherwise they dissolve away rapidly.

In the crust, salt diapirs form upside-down droplet shapes, **mushroom** clouds, or canopies.

Salt diapirs and glaciers are often **black** in color because of clay minerals they pick up as they move through the crust.



Thousands of Years in the Making

Insights into the Frozen Past Behind the Great Lakes

Written by Monica Dix
Illustrated by Emily Herrold

Picture a vast freshwater sea covering the entire continental United States. You may think that this water does not exist, but that is simply not true. All of that water, which amounts to 20% of the world's available surface freshwater, resides in the Great Lakes — a chain of five lakes that define the northern border of the United States and provide drinking water to nearly 40 million people.

How did they get there? The simple answer would be to say they are a product of glacial advance and retreat over thousands of years — but that doesn't do them justice.

The Great Lakes began to form as a product of constant advance and retreat during the Pleistocene Epoch, during which the earth experienced its last ice age. What we now consider the northeastern United States was covered in the Laurentide Ice Sheet. This massive ice sheet formed as small ice caps thickened and grew under snow as the temperature dropped. They eventually reached a thickness of three miles, inching centimeters further south each year under the force of their own weight.

This ice sheet underwent at least four major glacial advances and retreats, spanning from Cape Cod to Minnesota and along the entire modern-day US/Canada border. At its lowest, the Laurentide Ice Sheet even moved into Southern Ohio. Over this series of advances the glacier slowly worked away at the bedrock, leveling mountains and moving sediment across the Northeast.

As geologists know, despite the fact that this glacier was moving across continental crust, not all crust acts the same, as not all bedrock near the surface is the same. These differences caused weaker or softer bedrock to give way more quickly, and the glacier dug deeper into these areas, causing major depressions in the continental crust. What we know now as the Great Lakes began as depressed weaknesses in the continental crust.

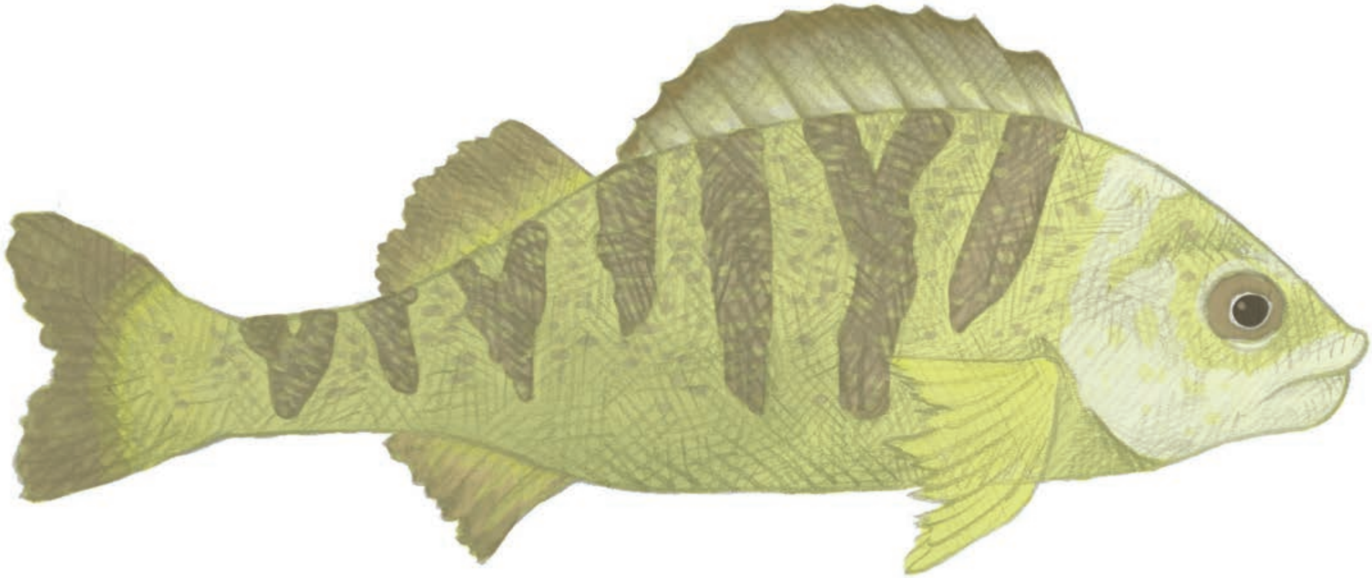
These formations were reinforced over the course of the advances and retreats, but as the earth began to warm, the glaciers made one final retreat. In their place they left a variety of landforms. Geologists can determine a glaciated landscape by looking for several features, all seen as the Laurentide retreated into Canada. The power of the glaciers can be seen on our landscapes today — a good example is Kelley's Island in Lake Erie, where dramatic lateral grooves can be seen in the bedrock. These were caused by the sheer force of glacial rocks and ice.

Another dramatic example of a formation made during glacial retreat is Long Island on the eastern coast of the United States. These features were produced initially as a terminal moraine, a large lateral deposit made of all the sediment that the glacier had been pushing in front of itself as it moved southward found at the end of the glacier. The glacier then melted for a while without retreating, continually depositing more and more sediment onto what is now present-day Long Island, Cape Cod, and Nantucket. These deposits were all made with rocks called 'glacial till'. This term is used for the deposits that a glacier makes, which are mixed in grain size — the size of the rocks and sediments — and also their type.

> As geologists know, despite the fact that this glacier was moving across continental crust, not all crust acts the same, as not all bedrock near the surface is the same.

Other, more subtle examples are numerous across Michigan and Wisconsin, called kettle lakes and moraines. While kettle lakes are also caused by glaciers, they are much smaller, formed as a block of ice left by the glacier depresses and then melts in the landscape. The ice creates a depression for itself to fill as it melts, creating a small, very circular lake. Moraines are another formation, essentially the same as terminal moraines, but more general and smaller. They are ridges caused by lateral glacial deposits, usually by a stream running through the bottom of a glacier, and are often found in junction with kettle lakes.

A more common yet much less subtle example of evidence of glaciation is found in the glacial erratic. True to its name, the erratic is a



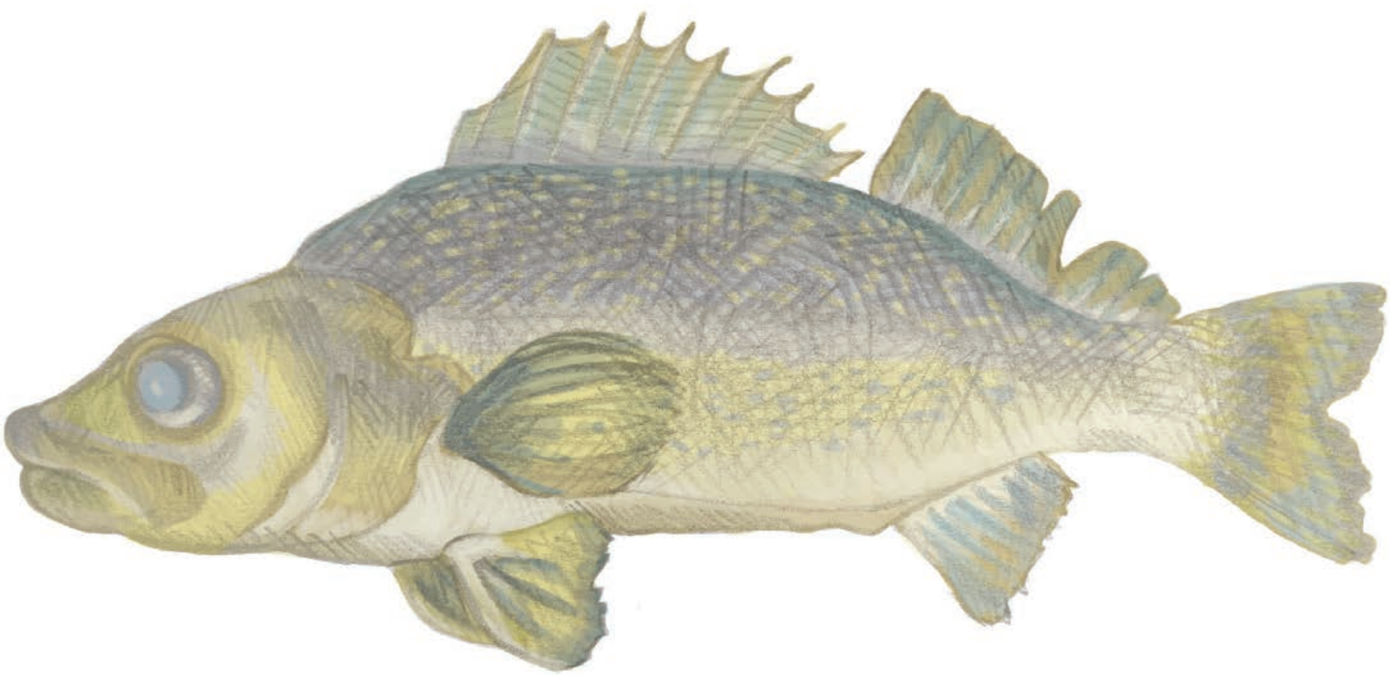
large rock which often appears out of place with its landscape. These are large rocks that were carried by the glacier but dropped out as it melted away. They are often incredibly dissimilar to the landscape in which they have been placed and can be as heavy as 16,500 tons, although they are typically more boulder-sized.

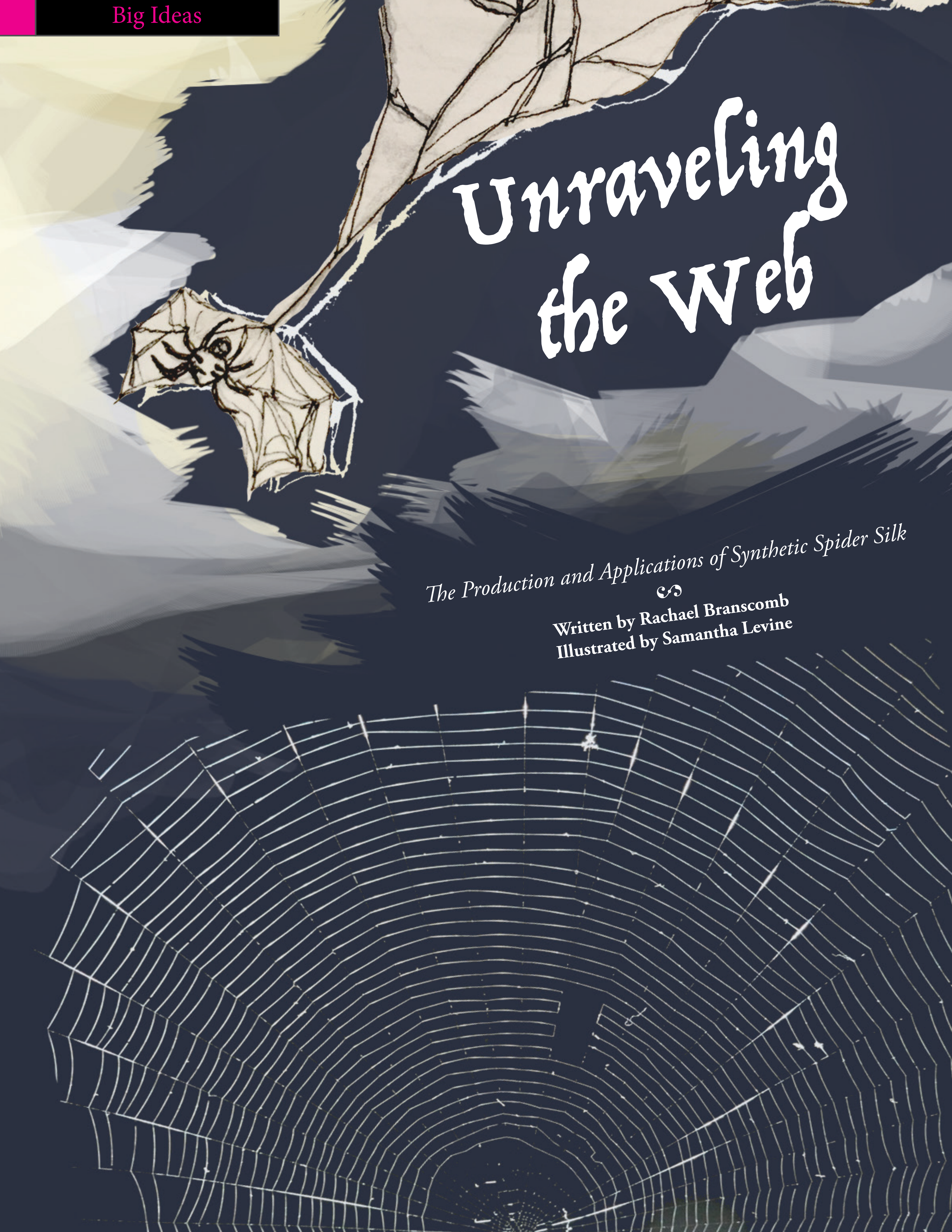
The Great Lakes were another piece of this puzzle, and their ground-out basins filled slowly with glacial meltwater as the glacier retreated across them. These basins overflowed onto the depressed land and spread gradually into the Great Lakes we know today. Their network of channels formed soon after, as the water in the lakes tried to find paths to reach the oceanic base level, initially traveling north and then traveling south.

This whole process took nearly 6,000 years, starting at the final retreat of the glaciers about 10,000 years ago and finishing up around 4,000 years ago.

However, like all geological systems, the process will continue to change. The continental crust on which the glaciers used to stand is still rising up in a process called isostatic rebound. This process operates on the premise that the crust compressed by the weight of the glaciers is now responding to the lack of weight by slowly rising up to its initial height, currently at a rate of eight inches every century. Isostatic rebound is actively changing the coasts of the Great Lakes, which are preventing uplift because they have replaced the weight of the glacier on the continental crust. This tension between the lifting land and the stationary lakebottom causes the incision of rivers, which can be seen across northeastern Ohio. This means that rivers are digging further and further into the crust as the crust rises, forming deeply cut valleys as the water travels towards the lake.

The Great Lakes are an essential resource to the people they support, providing flood control, natural water filtration and nutrient cycling, not to mention the water they supply to feed industry and agriculture across their coasts. While their system's geological changes cannot be seen on our human timescale, the evidence of glaciation reminds us of their long history and the need to protect them so they can continue to evolve into the future.





Unraveling the Web

The Production and Applications of Synthetic Spider Silk

Written by Rachael Branscomb
Illustrated by Samantha Levine

Most people's interactions with spider silk are limited to an accidental panicked run-in with a web or the comic icon Spiderman. However, the incredible tensile strength and elasticity of spider silk could be a game changer in the production of everything from bulletproof clothing to synthetic skin. When size is taken into account, spider silk has greater tensile strength than high-density steel and is five times tougher than Kevlar. It is also biocompatible with the human body, biodegradable, antimicrobial, and hypoallergenic. Its usefulness in the medical world has already been widely recognized, but the synthetic silks generated up to this point have not been able to exhibit the same properties of natural silk. Scientists have also been unable to produce artificial silk proteins or spinning processes that would allow for the large-scale production of biomimetic silk.

Previous work in 2015 by Randy Lewis, a biochemist at Utah State University, led to the development of a method to generate synthetic fibers. Their artificial silk was much lower in protein level than the silk produced by a spider, resulting in weaker strength in the synthetic silk. Recently, a team of scientists led by Anna Rising from the Swedish University of Agricultural Sciences and the Karolinska Institute have developed a process to produce synthetic spider silk, nearly identical to a spider's own silk, by constructing recombinant DNA from two species of spiders. If the mass-production of silk from Rising's lab is possible, this discovery could revolutionize our industrial capabilities.

Spider silk is composed of a long chain of proteins, each with three main sections. The main body of the protein is made of repeating segments of amino acids called "repeats" that make up more than 90% of the whole protein. Lewis describes this repeating section as looking like towers of stacked Lego blocks connected by springs; the towers provide the strength, and the springs allow for elasticity. At each end of the main domain exists a non-repeating segment of amino acids that links to the next silk protein. This allows the proteins to attach to each other and produce fibers as the silk is spun.

Spiders store silk proteins as a water-based solution in their silk glands before it is shot out of spinnerets and spun into a continuous fiber. Thus, researches needed to find a similar starting protein that mimicked these watery proteins. Rising paired up with another biochemist, Jan Johansson, also from the Swedish University of Agricultural Sciences and the Karolinska Institute. Together, the two began to research how to artificially recreate the spider's silk proteins and the mechanisms by which silk is naturally produced.

Rising and Johansson's interdisciplinary team began the research process by collecting South African spiders and studying their genomes to determine which genes encoded the silk proteins. They then extracted these genes and used a polymerase chain reaction to make many copies of this particular sequence of DNA. These small segments of DNA were then inserted into E. coli bacteria, which implanted the silk genes into their own DNA and produced small amounts of natural silk proteins. However, the silk proteins that the bacteria were producing could not be dissolved in water, so the researchers were unable to make a protein solution like the one that spiders store in their silk glands.

Luckily, at the same time that Rising and Johansson were performing research with the African spiders, Chinese researchers were also tackling this project with Asian spiders. Working together, the two teams of researchers were able to select specific soluble parts of the two different spider species' genes and splice them together to create hybrid genes. These genes were then again inserted into bacteria, which produced a new chimeric protein. This new protein had a beginning section from the African spider's genes, a middle section composed of two repeats also from the African spider, and a terminating segment drawn from the genome of the Asian spider. The research put into splicing the spider's

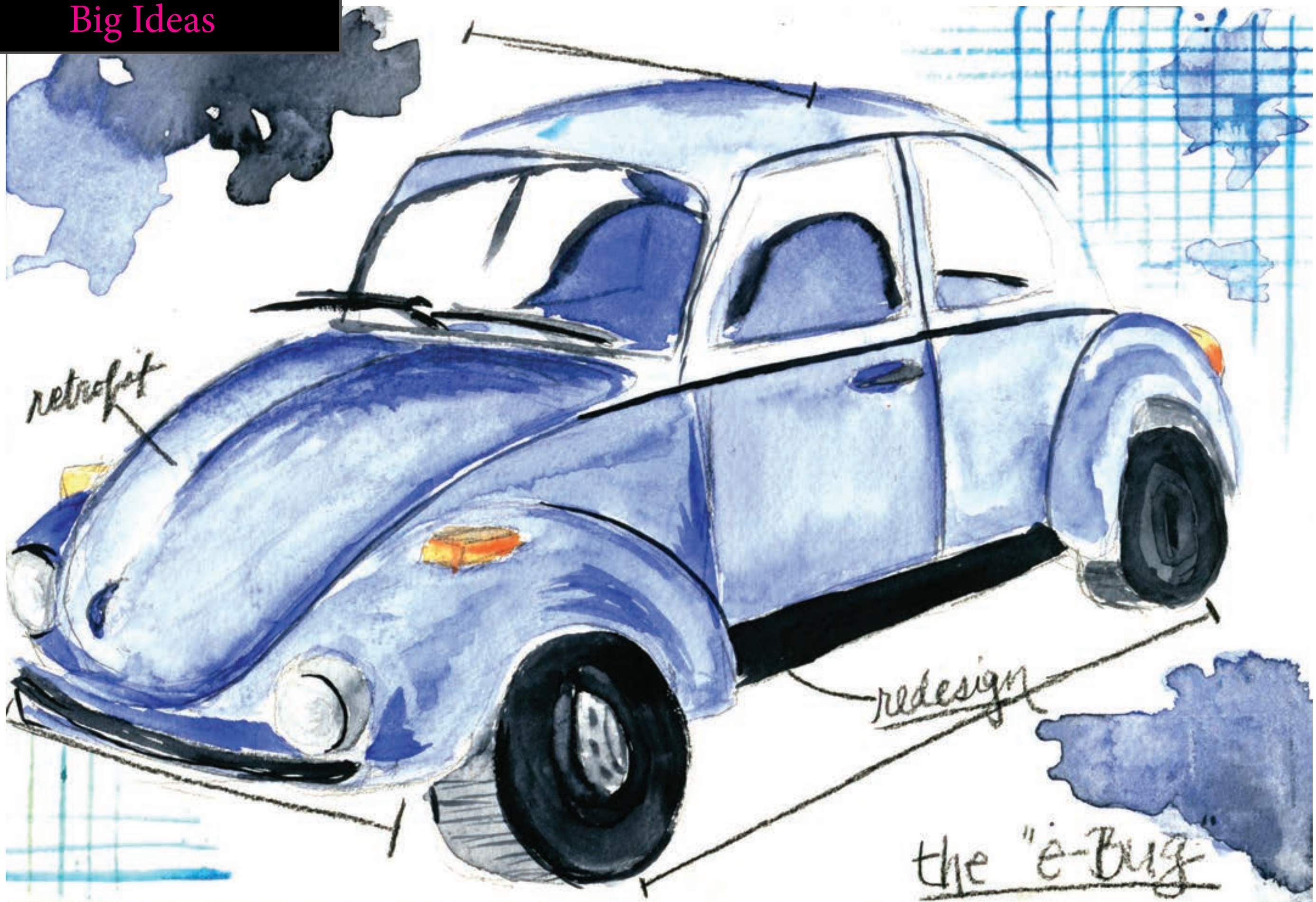
genes to produce a new kind of protein paid off: the chimeric protein was found to be soluble in water! Rising's team had found a way to create a silk protein solution that was similar to that found in a spider's natural silk glands.

The next step was to figure out a mechanism to turn the newly formulated protein solution into actual fibers. Previous research by Rising and Johansson's team had determined that the pH of the silk gland solution decreased as it was drawn from the gland into strands. The lab developed a setup where the protein solution was pumped through a thin tube that narrowed at the tip and propelled the solution into a beaker of acidic solution via a jet stream of air. At the lower pH, the proteins linked up into chains to form spider silk threads. The lab was able to produce strands that were a kilometer long! These strands could then be pulled out of the solution and wound onto spools.

There is still room for improvement in this silk fiber production process. Further research is currently being done to determine how to increase the tensile strength of the artificial silk. Lewis and Johansson agree that the strength of spider silk likely stems from the number of repeats that the proteins have in their core domain. This makes this artificially created silk even more impressive because it is about a third the strength of naturally produced spider silk, but only has two percent of the number of repeats of the African spider's silk. Further research may need to be completed in this area to further test the possibilities of increasing the strength of artificial silk.

> It is only a matter of time before we should be expecting to see its integration into many aspects of our lives.

Now that the basic ability to produce synthetic spider silk has been understood and developed, it is only a matter of time before we should be expecting to see its integration into many aspects of our lives. Rising and Johansson are now mainly focused on bringing the silk's unique abilities into the medical world. Their team is working on using spider silk for nerve regeneration associated with injuries to the spinal cord. With the incredible properties of artificial silk, it's possible that in the upcoming years we could see aircraft parts, tendons, protective gear, and possibly nerves all partly or completely comprised of spider silk. Though we may never be able to shoot web out of our wrists or swing around skyscrapers like the Amazing Spiderman, the applications for synthetic spider silk are still amazing in their own right!



Making the Bug Great Again

An Electric Future for a Vintage Car

Written by Brooke Ortel
Illustrated by Mikaila Hoffman

At age 15, my brother Wade bought a rusty 1973 Volkswagen Bug, a purchase that marked the beginning of an extraordinary journey. His dream? To build an electric car all on his own, using salvaged laptop batteries. Two years and countless hours of work later, the "e-Bug" is a reality. In front of our family's home on Block Island, Rhode Island, sits a little blue Bug with an extension cord running from its gas cap to an outlet in the kitchen. It is likely the first homebrew electric car powered entirely by repurposed laptop batteries in the world. On a tiny island 13 miles off the coast of mainland Rhode Island, one remarkable kid has quietly led the way in developing environmentally sound transportation using materials that otherwise would have ended up in a landfill. By April 2017, the e-Bug will not only be gasoline-free, it will also be powered by electricity generated by the first offshore wind farm in the U.S.

Hopping into the e-Bug presents a curious two-way time warp. On the one hand, you are catapulted into the past in the small, narrow car, with its lone side mirror, manual windows, and lack of heat and airbags. On the other hand, the car is a futuristic vehicle. A digital gauge mounted on the dashboard displays the voltage of the battery pack and how much current is being drawn from it in real time; behind the front seat rests the handmade battery pack, comprised of 18 smaller packs of lithium ion cells known as 18650s. These cells were painstakingly extracted from dead laptop batteries and hand-soldered into place in a configuration Wade designed himself.

When you pull out of the driveway in the e-Bug, it is nearly silent, save for a quiet whirring and an occasion creak from the 44-year-old chassis. The battery pack, bristling with brightly-colored wires, is at odds with the worn vinyl seats stuffed with coconut fiber. The e-Bug launches quietly and elegantly, unaccompanied by the roar of an engine or spew of exhaust.

Although the manual gearshift was retained during the electric conversion and the car still possesses four forward speeds, it is now clutchless. There are two voltage systems in the e-Bug: the 72-volt battery pack and a "legacy system" from the original car, which powers things like the headlights and turn signals. When the key is turned in the ignition, a relay flips and turns on the 12-volt DC-to-DC converter, which is equivalent to the alternator in a vehicle with an internal combustion engine. Wade has always embraced the "reduce, reuse, recycle" creed; this relay was salvaged from a broken furnace control panel and is housed in a plastic box that was once packaging for a watch. When the e-Bug's gas pedal is depressed, a loud click signals that the contactor, a high-voltage switch, has received a signal from the controller, which allows the car to move forward.

The e-Bug has a range of approximately 25 miles, which more than fulfills the needs of most island drivers. Wade estimates that the e-Bug could probably reach 50-55 mph maximum, though he hasn't pushed it beyond 45 mph. Either way, it's perfectly adequate for Block Island, which has universal speed limits of 25 mph on its paved roads and no stoplights.

Wade Ortel did not set out to save the world one electric Bug conversion at a time. Originally, he merely wanted to tackle a project that would occupy him for more than a single weekend. He wasn't motivated by the recognition he might garner by building the first vehicle powered entirely by repurposed lithium ion laptop batteries; he just wanted to challenge himself. In the process, he has shown that using old laptop batteries to convert a 40-year-old car from gasoline-powered to electric doesn't require an advanced degree or a lot of money.

Wade is perhaps best described as the ultimate autodidact. He's always been fascinated by taking things apart and putting them back together to learn how they work. In middle school, he secured an internship with a local computer shop, and each week, he came home bearing a stack of rescued computers from the discard pile. At age 12, it wasn't unusual to see him hunched over my mom's sewing table, wearing a headlamp and de-soldering components of discarded computer parts so that he could reuse them in new projects. He happily filled his room with an eclectic jumble of computer parts and miscellaneous electronics that the rest of the world labeled as junk. He repaired a marine radio that washed up on the beach, built a capacitor out of recycled beer bottles, and conducted arcing experiments in the bathroom. His unyielding commitment to repurposing so-called junk would fuel the success of his electric car project and allowed him to accomplish extraordinary ends with limited funds.

As he tinkered with used computers, Wade began thinking about just how many batteries were going to waste — batteries that could be used for something. Even when a laptop battery is dead, it often still contains usable cells, so he started testing individual cell voltages. Around the same time, he encountered an article about converting a Geo Metro to an electric vehicle. He was fascinated.

While he played Frisbee with my dad on the weekends, he tossed out the idea of building his own electric car. Jim Ortel didn't brush off his son's dream as ridiculous, though he did have a suggestion: why not use a VW Bug? They were cheap, lightweight economy cars that could be found with a manual transmission. Besides, vintage Beetles were just plain cool. So began the quest for a Bug, which culminated in June 2014, at the end of my brother's sophomore year of high school.

But buying the '73 Bug was only the very beginning of the journey. Not only did my brother successfully devise a way to transform an antiquated Super Beetle into a vehicle of the future, he also taught himself everything he needed to know about auto mechanics and electrical systems as he went. Most kids don't teach themselves how to weld and dissemble a car by watching YouTube videos and reading online forums, but Wade did — and he did it successfully. He'd look up the relevant videos needed for the day's work, commit to memory the necessary techniques or visuals, and head up to my grandparents' modest garage space to work without Internet access, sometimes for eight to ten hours at a time.

Unlike most people, he didn't need to constantly reference the resources he found online. He explains matter-of-factly that, "for welding, you have to absorb key concepts. For things like heater channels [a key structural feature of the car], you have to memorize how the panels go together." Although Wade is singularly gifted with an ability to teach himself, he also learned a tremendous amount from his mentor, Lionel "Chopper" Butterfield, who helped him configure the battery packs, install the electric motor, and navigate various crises along the way.

Wade's first major objective was to restore the Bug's structural integrity, doing battle with what he calls "the most evil and conniving property of steel": rust. He painstakingly cut pieces from the old car, then welded in new patches of sheet metal, learning as he went. He used Bondo to smooth the edges of the welded patches and painted over the repaired surfaces. The Bug now sports a neat black "hood" towards its rear, as well as a much sturdier floor, and is freed from its dreaded "death foam." Volkswagen once used the foam for insulation purposes, but unfortunately, it also catalyzes the rusting process and has since been dubbed "death foam" by air-cooled VW enthusiasts. Before he began the project, Wade says, "I had absolutely no idea what rust repair involved. I had never done bodywork before; I had never welded." Now he works for a local mechanic.

When he wasn't engaged in rust repair, Wade was working on the electrical component of the project. He recruited fellow students at the Block Island School, as well as his mother, to help "husk" the dead laptop batteries he ordered from eBay and collected from local computer stores. The husking process involved prying open laptop batteries with a screwdriver to harvest the individual cells inside, then disconnecting the nickel tabs that connected the cells. A typical laptop battery contains six to nine cells, which Wade tested individually to determine their resting voltage. To meet Wade's criteria, the cell had to have a resting voltage of greater than two volts. If the cell had sufficient resting voltage, it was then charged and discharged, so that its capacity, measured in milliamp-hours, could be tested and recorded. Wade's battery pack currently contains 1530 cells, each of which he tested individually, and he estimates that he tested nearly as many that were unusable and had to be discarded.

> Using old laptop batteries to convert a 40-year-old car from gas-powered to electric doesn't require an advanced degree or a lot of money.

When he had finally amassed enough usable cells, he organized them by their capacity, laying them out in long colorful lines on the living room floor. Since some cells had a higher capacity than others, he determined how many of each needed to be included in each 85-cell pack in order to construct packs with the same overall capacity. To make fuses for the positive ends of the batteries, he removed wires from eight-watt resistors, since these melt at the desired current threshold. For safety purposes, Wade soldered a fuse to each of the 1530 cells individually. If one cell shorts, its fuse melts and it is removed from the circuit, leaving the rest of the battery pack unaffected and preventing an explosion.

In Wade's car, each 85-cell pack within the larger battery pack is connected by a latticework of nickel strips. None of the individual strips carry much current, but they connect to thick copper bars on either edge of each pack, which conduct the combined current of all 85 cells. The packs are connected with shorter copper bars bolted between the copper bus bars so that electricity can flow between them. Thick copper cables connect the battery pack to the contactor and the controller for the electric motor, allowing electricity to flow from the battery to the motor.

Converting a vehicle that is more than four decades old to electric and using discarded laptop batteries to supply it with energy storage enabled Wade to create a zero-emissions car with a minute carbon footprint. When Block Island completes its transition from diesel-powered generators to offshore wind turbines, his vehicle will truly be emission free. Now home to the first offshore wind farm in the U.S. as well as the first electric car powered entirely by discarded laptop batteries, tiny, isolated Block Island has unexpectedly emerged as a testing ground for innovative renewable technologies.

Cruising around the island in the e-Bug, Wade says he's satisfied with his project. He doesn't have huge ambitions for the Bug's future; for him, it's enough to enjoy driving the little car around the island, listening to the quiet hum of its electric motor.

Expanding the Job of a Scientist

A Call for Explicit Writing Instruction in Undergraduate STEM Education

Written by Ally Fulton
Illustrated by Sulan Wu

When Joshua Schimel was an Assistant Professor at the University of Alaska, the oil tanker *Exxon Valdez* crashed into Bligh Reef, spilling 10.8 million gallons of crude oil into the sea. Schimel, along with most Alaskan scientists, became part of the damage assessment crew. He was told by lawyers that his job was not to gather data, but to gather evidence. By putting himself in the shoes of lawyers and politicians dealing with the disaster, Schimel came to understand the different set of pressures these executives were under: "Effecting change means working in their world, not expecting them to work in ours."

While it is unrealistic for every scientist to learn the intricate ropes of America's elite political and corporate circles, it is essential for scientists to both see the outcome of their research from the point of view of those implicated by the findings and communicate to them in such a way as to enact change. As the 2016 election made blatantly clear, scientific issues such as climate change are absent from the main concerns of politicians and the general public. Does this mean science communication has failed to convince most Americans of the truths enmeshed in the data?

Not necessarily, for the fabric of American culture is threaded with science-fiction books and movies, science and natural history museums, and countless camps and school programs that highlight the thrills of science. Yet somehow this love for science cannot find a footing in national politics. Why is our science communication failing us?

The roadblocks that inhibit effective scientific communication are twofold. As Schimel speaks to, one reason is that scientists often get caught up writing and speaking only to other scientists; they are stuck in an unpoppable bubble of scientific expertise. The job of the scientist has been established as one that is limited to grant writing, publishing journal articles, getting cited, advising graduate students, and running research labs, condemns Dr. Jonathan Foley, the director of the California Academy of Sciences, in a letter written to fellow scientists. Second, scientists, clouded in an air of expertise, lack an awareness of the needs of the American populace. They beat data over the public's head to convince them of the truth, and the need to enact societal change. Yet scientists do not situate the data within the emotional, needs-based framework that drives the daily life choices of the general public.

The Guardian's Robert P. Grant questions such a move when he asks how many scientists are "willing to step outside their cozy little bubbles and make an effort to reach people where they are, where they are confused and hurting; where they *need*?" And this is our entry point: to learn to attend to the emotions of the people who will be affected and influenced by these scientific discoveries by *listening* to their concerns. It's in these instances where, as difficult as it may be, the facts and the truths must be set aside to allow for a space to understand the compassionate human dimension of science. With this in mind, we can expand the job of the scientist laid out by Dr. Foley to include communicating science to the public in a manner that bridges their interests, commitments, and needs to the facts of the data.

Not only is this part of our "social compact" as scientists, as Dr. Foley suggests, but becoming better communicators actually makes us better scientists because it promotes big picture thinking. With big picture thinking we are better able to understand how each specialized science sector fits into the whole. In effect, we become more creative problem solvers and critical thinkers. Effective communication skills must be recognized as an essential component of the core professional skills for science students. While a few science communication courses are slowly being layered into the curriculum as electives at universities and colleges across the country, a gaping hole in the curriculum remains that needs renewed attention, particularly at the undergraduate level.

One of the biggest hurdles in science education is getting students to root their thinking in concepts, rather than in a pile of facts to be memorized. This becomes a challenge when science communication is absent from the core curriculum. This approach, described in a paper published in "Life Science Education" as *learning-to-write*, should take the back seat to the *writing-to-learn* approach, which uses writing as a tool to develop students' comprehension of broad concepts and to engage students in the transfer of knowledge from one context to another by drawing out core principles and applying them to different situations.

To patch this gaping hole in the curriculum, institutions and science departments must begin to attend to science rhetorically. To do this, all writing and speaking assignments need to be situated in definitive contexts, with an identified audience, purpose, and, most importantly, an objective. Students must also work toward becoming self-regulated learners, meaning they must frequently reflect on their own writing and learning process. To foster this sort of thinking in the classroom, students need to engage in assignments that call for reflection on their beliefs about knowledge and its production and application.

Stanford University is actively working toward incorporating this sort of explicit writing instruction into their science

curriculum. The Immunology Program in the School of Medicine at the University implemented a neuroimmunology course for undergraduate and graduate students that gave students the opportunity to develop skills for writing to a general audience. The course asked students to attend expert-taught lectures in the field of neuroimmunology, read primary scientific papers that described critical advances in the field, and write *New York Times* "Science Tuesday" styled articles directed at a general audience that would summarize key aspects of the primary source and the implications of its findings. All assignments were subject to feedback from teaching assistants, peers, and "general audience" members (students who hadn't taken college level biology), and revision was mandatory to normalize the reflexive process of writing.

Like Stanford, the University of Wisconsin Madison (UWM) is committed to making writing a primary focus in the science curriculum, though through an outside avenue: a strong partnership with the University's Writing Center. The Writing Center is uniquely positioned to access the student body through multiple levels, from workshops to individual sessions, so they train their staff on how to work with scientific writing. While there are many stories of fruitful writing center sessions, one partnership stands out. Described in a blog post by UWM Writing Center tutor Amber Meneses-Hall, the partnership was between Zachary Marshall, a Writing Center tutor, and Tara Davenport, an Environmental Studies graduate student working on her dissertation. When Tara thought about her science education, she came to the conclusion that "Often in science, the emphasis is on the presentation and analysis of the data rather than making sure the document itself is structured and written in a way that makes sense." With her dissertation, she appreciated the Writing Center's help in organizing her ideas so that they flowed logically, what she deemed "science with structure".

As these examples highlight, there are many avenues to incorporating writing into the science curriculum at the undergraduate level. Though both of these initiatives are from large research universities, liberal arts colleges like Oberlin and Denison are uniquely situated to adopt a writing attentive curriculum in the sciences. The curriculum needs to do two things. The first is that communication must be taught in the context of introductory science courses. Second, it needs to be impressed upon students that practice will not make for "perfect" writing, but it will develop their writing and revision skills. Moreover, it will allow students to grapple with complex ideas from primary literature or course lectures for longer periods of times, which deepens understanding and increases opportunities for the transfer of knowledge to occur.

In addition, faculty must implement written and oral communication assignments with real-world applications to inspire student creativity. For written work, this could take the form of *New York Times* style articles (to mimic the assignment at Stanford), but could be adopted to an Oberlin or Denison setting: establishing a science section for *The Oberlin Review* or *The Denisonian*, submitting creative nonfiction pieces to *The Wilder Voice* or *Exile*, crafting a class blog or newsletter, or partnering with *The Synapse* itself, potentially to create smaller offshoot publications or zines. Lastly, oral communication needs to be recognized as an essential component of science communication. This requirement should extend beyond formal research presentations into the realm of authentic communication experiences, such as devising a minute-long presentation that answers the question: *Why do you love what you study and why is it important?* Encompassing these curricular requirements should be a renewed attention to peer feedback and support, specifically in the form of collaboration between the Oberlin Writing Associates Program and the CLEAR center. If we foster stronger relationships between these three departments, we will provide science students with non-scientific readers to offer advice on the effectiveness of their communication. This will forge and strengthen connections between science and non-science students with the goal of making science topics important to the campus community.

> Often, emphasis is on the presentation and analysis of the data rather than making sure the document itself is structured and written in a way that makes sense.

These sorts of curricular revisions are necessary to implement because if we are to solve nation-wide science issues, we need to tackle them as a national community. Margaret Wertheim, the director of the Institute for Figuring in Los Angeles, is dedicated to crafting new methods for captivating public interest in science and technology by situating communities at the core of issues. Wertheim's Crochet Coral Reef project, which encompasses math, science, craft, and community art practice, allows millions of people worldwide to visualize complex mathematics and science in beautifully colorful, dynamic crocheted coral forms. This project literally embodies ideas so that communities can play with them, and hopefully come to understand them. What makes Wertheim's project so special is that she has the foresight to see that communities flourish when they care about and act around similar principles. Thus, as young scientists, we need to not only learn to explain our answers, but to embody them. To do so, we need to go back to the beginning and hone in on our initial questions and why those questions matter. We are obliged to become empathetic communicators if we want the public to find worth in caring about the complex scientific and technological issues presently at hand.

Can We Educate Better?

Active Learning and Underrepresentation in STEM

Written by Kepler Mears
Illustrated by Emilia Omerberg

Science, Technology, Engineering and Mathematics (STEM) fields are currently facing a problem with underrepresentation. Out of the 24,547 STEM PhDs awarded to U.S. permanent residents in 2015, only 12.5% were awarded to Underrepresented Minorities (URMs, normally referring to Black, Latinx and Native American students) and 42.4% to women (the author acknowledges other gender identities; however, the literature is limited to male/female). These numbers are disproportionately low considering the overall population of the U.S. is 32.3% URM and 50.8% female. What makes this problem more troubling are the retention rates. URMs and women are significantly more likely to enter undergrad intending to major in STEM but drop out over the course of their education. Oberlin College similarly struggles with representation in the sciences. From 2014-2015 Oberlin graduated 358 STEM majors of which 11.5% were URMs and 48.9% were women compared to a campus population of 14.7% and 56.8% respectively.

Why exactly is this a problem? Dr. Manuel A. Pérez-Quiñones visited Oberlin last year to talk about underrepresentation in programming, stating "a lack of diversity in software development teams can have serious consequences for a fair society." These consequences range from facial recognition software that was unable to track black faces to lack of character options like the "é" and "ñ" in Dr. Pérez-Quiñones' own name — problems that would have been easily solved in a diverse team go unnoticed otherwise. This problem extends across disciplines and is most notable in medicine. Several popular drugs, such as the insomnia medication Ambien, have been discovered to have severely different effects depending on sex. Ambien is metabolized differently in females, leading to a 45% increase in blood concentration of the drug compared to male counter parts with the same dose. However, for twenty years all patients were prescribed the same dose. Why? Because the original studies on Ambien were done only on men, by men. Overdosing on prescribed medication because women were excluded from clinical trials is a serious problem. If programmers, engineers, and scientists are going to be designing products, services, and treatments for the greater society, there must be input from people of all backgrounds.

Oberlin College recognizes the problem of underrepresentation and has launched several programs in response. This includes the Science and Technology Research Opportunities for a New Generation (STRONG) program which gives non-male, POC, and first generation students interested in STEM early research experience along with support and workshops. Qualified students are attending regular conferences such as the Annual Biomedical Research Conference for Minority Students and the Nebraska Conference for Undergraduate Women in Math. These programs are modeled off those at other institutions (like the Meyerhoff Scholars

Program at University of Maryland, Baltimore County) that have been effective at reducing attrition in STEM for URMs and women [Summers 2006, Alvarado 2010]. However, these programs are reliant on funding and are only able to succeed so long as money is available. Additionally, they do not inspire any change in the climate of STEM fields. At Oberlin, fewer URMs and women graduate in STEM that proportionally should. If only certain students, namely white males, can succeed in STEM, then there is something fundamentally wrong with how we educate.

Active learning has been postulated as a better way to educate STEM, but may also be an ally for programs like STRONG in increasing representation in STEM. Since the introduction of the Center for Learning, Education, and Research in the Sciences (CLEAR) Center at Oberlin, which organizes the Oberlin Workshop and Learning Sessions (OWLS) program to provide supplemental active learning, there has been an increase in participation in STEM from URMs at Oberlin (Figure 1). This has been especially prominent the past few years, and with the introduction of STRONG, the trend is expected to continue.

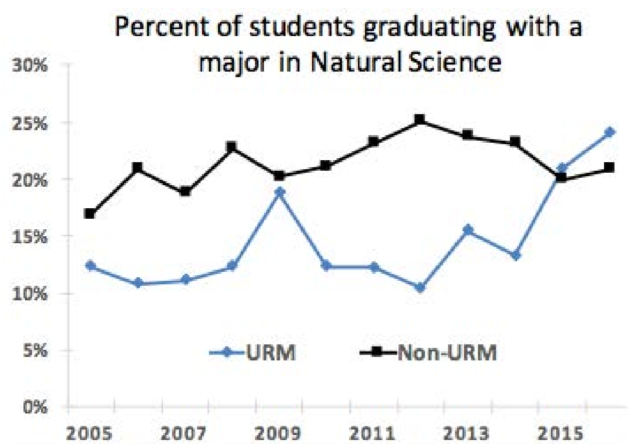


Figure 1. Percent of URM and non-URM students graduating with a STEM major since 2005. Adapted from the CLEAR HHMI narrative.

What exactly is active learning? At Oberlin, many active learning techniques have been used in the classroom. Clicker questions are a popular technique in the literature and have been used in computer science, physics, and astronomy classes. The teacher will explain a concept from the reading, then pose a multiple-choice question. Students think alone and answer the questions via clickers before the teacher displays a histogram of the answers. The students then break up into pairs to discuss the questions and re-answer, at which point the teacher displays another histogram, and then either explains the correct answer or moves onto the next topic. Clicker questions are an example of Think-Pair-Share activities that involve students pairing up to discuss a topic, then sharing the results. Activities like these are popular in OWLS sessions as well.

Mary Pat Wenderoth authored an extensive review of active learning in 2013 and visited Oberlin to discuss her group's findings. The group analyzed 225 studies that reported examination scores and failure rates when comparing active learning in undergraduate STEM classes. Wenderoth's group found an average increase in exam scores of 0.06 GPA points and a decrease in failure rates from 30% to 20% (Figure 2) when active learning was used, noting that low income students, who tend to be URM, are more likely to fail. Active learning has a double effect of increasing performance overall, so even majority students benefit, while also reducing failure rates, benefitting low income and URM students.

Members of the Wenderoth group took a closer look at active

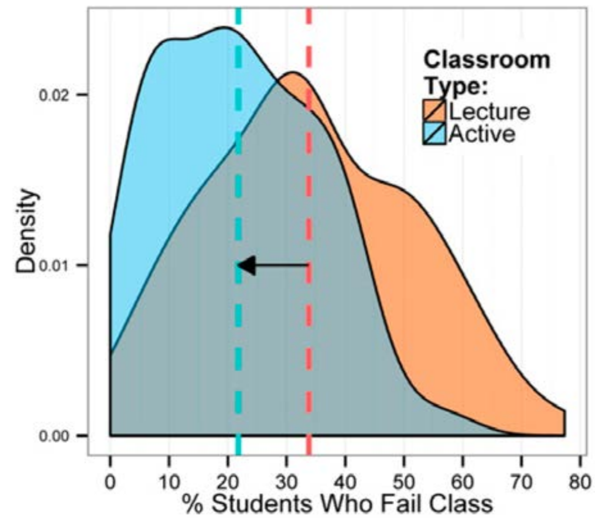


Figure 2. The density of students who fail science courses with and without active learning. With active learning the density is shifted closer to 0, indicating less student fail. Adapted from Freeman 2013.

learning effects for URM students taking introductory biology courses at the University of Washington. Active learning classes that had clicker questions, reading quizzes, and group problem solving were compared to traditional lecture courses. Achievement was measured by traditional final exams given to both classes that did not vary in difficulty. In traditional classes, there was a 0.8 GPA achievement gap between URM and non-URM students. However, in active learning classes the achievement gap was nearly halved to 0.45 GPA points. Overall student scores increased, demonstrating the simultaneous effect of increasing scores while disproportionately benefiting URM students. While this report was only examining URM students, it noted that the effects could be generalized to women.

Similar studies have been carried out at other large institutions. University of Maryland Baltimore County (UMBC) has revamped their introductory chemistry courses to include group problem solving. Pass rates have increased from 70% to 85%, and the amount of chemistry majors has since doubled. Introductory courses at large universities sometimes contain more than 500 students. If the benefits can be seen in such massive lecture classes, small class sizes like those at Oberlin should have a significant advantage in implementing active learning techniques. Harvey Mudd, a very small school, has re-designed their introductory computer science course to provide a more broad and interdisciplinary scope that has increased participation of women in the computer science major 15% over in only three years.

The reasons why active learning works are tricky to determine, though there are a few tested theories. Active learning incentivizes participation in classroom activities, and many studies find increased attendance when active learning is incorporated. Researchers have found that when using clicker questions, the act of talking with fellow peers is crucial to increasing understanding. Answering questions alone or getting explanations from more experienced students is not enough [Blunt 2014]. Active learning techniques often focus on recalling information rather than copying it down, which has been demonstrated to cause an increase in test scores.

Why active learning specifically improves achievement for URM and women students is poorly understood. However, it may have to do with a sense of belonging. URM and women students face a serious stereotype threat in STEM; they often feel that they are judged based on negative stereotypes and not personal merit and are perceived as outsiders in fields that consist primarily of white men.

Outsider groups may face a large, though unintentional, implicit bias. A pair of studies found that sending out identical resumes, but with different names to imply women or URM applicants, resulted in different ratings of an individual's achievement. Women and URM names were viewed as less qualified by employers [Milkman 2015, Moss-Racusin 2012]. These implicit biases begin early. In 2016 a Washington University in St. Louis group asked introductory biology students to rate the intelligence of their peers throughout the semester. Males consistently overestimated the GPA of other male peers while they underestimated those of their female counterparts. This effect is not unique to STEM, but it is more pronounced within STEM fields. Similar trends are seen with URM students as well. Megan Urry wrote a beautiful piece "Are photons gendered?" about her personal experience as a woman in physics documenting the feeling of moving through the male-dominated physics world and seeing fellow female colleges drop out as the discomfort became too stressful.

> Oberlin has a huge advantage in fixing this problem. As a small school with motivated and caring professors, Oberlin can be flexible and experiment with pedagogy.

STEM tends to value independence and inherent intellect. The more a discipline values these notions, the less participation is seen from URM and women [Leslie 2015]. This mindset of independence does not help URM and women students who already feel isolated in STEM. Instead, values of interdependence and collective problem solving are much more appealing to URM students, similarly URM and women students tend to do better in an environment that stresses acceptance rather than individuality [Bennett 2014]. Active learning focuses communal problem solving and interaction, creating an environment where anyone can achieve and be part of STEM. At Oberlin, many OWLS leaders can tell you that students who work together during sessions and form study groups are more successful in class. Forcing students to interact and work together goes against the notion of independence and creates community. When this environment is created, the achievement gap starts to disappear.

It is important to note that many institutions that have looked at URM and women in relation to active learning have also introduced additional programs to fix the problem of underrepresentation. UMBC in addition to active learning has introduced the Meyerhoff Scholars Program. Like STRONG, the Meyerhoff Scholars Program is dedicated to creating a supportive environment for URM students. Harvey Mudd has been offering early research experiences and mentorship for women in computer science in tandem with changing their computer science courses. The University of Texas Austin has designed smaller chemistry courses for URM students to help foster a science community, which has resulted in URM students graduating with chemistry majors at the same rate as the rest of the school. These programs try to create a community that URM and women students feel accepted in and that helps them to succeed, just as active learning does.

As scientists, it is our duty to identify and solve problems and implement evidence-based approaches. This is not limited to the lab. We teach and learn in a system that is not working for everyone: URM and women students are not graduating with STEM degrees at the rates that they should be, which leads to imbalanced products and treatments. Active learning has the potential to help fix underrepresentation by fostering a caring STEM community that allows all students to succeed. Oberlin has a huge advantage in fixing this problem. As a small school with motivated students and caring professors, Oberlin can be flexible and experiment with pedagogy. Oberlin has the drive to create the caring STEM communities that are needed and is on the cutting edge of STEM education, bringing relevant speakers and taking active learning techniques to the classroom. We hope to encourage students to experiment with their education, to look and ask for the approaches that will help their peers, especially those who are underrepresented and underappreciated in STEM. Moreover, we encourage students to embrace the changes that will make Oberlin the best STEM education institution that it can be and is becoming.

Making a Case for Citizen Science

All People Can Share in the Experience of Discovery

Written by Ave Bisesi
Illustrated by Steven Mentzer

Hey, kiddo." My father's soft voice startled me out of my sleep, his hand on my shoulder. I rolled over, peering up at him through gummed eyes. Moonlight filtered through my white opaque curtains, casting a shadow on the left side of his face and reflecting in the lenses of his glasses. On my nightstand, the clock blinked 12:06 AM in red block letters. "It's time."

When he left, keeping the door cracked so that a single shaft of yellow light from the hallway crisscrossed my room, I got up slowly and stumbled, still half-asleep, into my closet. I pulled on a hooded sweatshirt and a jean jacket over that. Before I headed downstairs, I tucked my stuffed rabbit under my arm, buttoning the jacket around him so he stayed pressed against my chest.

Downstairs, my dad was waiting by the front door, wearing his winter coat along with his striped pajama bottoms. He handed me a mug of hot cocoa without a word, beckoning me to follow as he moved outside. The concrete of our driveway was frigid, so cold it burned the soles of my feet, but I didn't complain. Instead, I settled on the curb next to my father, following his gaze up to the stars.

"That's Orion," he pointed, without preamble. "You can see his belt, there—look." For many years now that has been the first constellation I pick out of the dark winter sky. "And there," he added, "that's Mercury. It's bright right now. And there's the Big Dipper and the North Star. See? It's called Polaris."

I can't recall how long we sat outside watching the stars. Finally, as I felt myself getting sleepy, transfixed by the vastness of the speckled sky above me, I remember asking him, "How are we ever going to know how many stars there are? There aren't enough astronauts to count them all."

My dad laughed at that, wrapping an arm around my slim, bony shoulders. "That's probably true. But I bet there are lots of fathers around the world doing this with their kids right now, like we are. Maybe we can help the astronauts out."

> Today, if you have a few spare minutes, you can help NASA scientists classify galaxies based on morphology through Galaxy Zoo or identify stellar wind bubbles in the Milky Way via The Milky Way Project.

Now, ten years later, as it turns out, my dad wasn't too far off. Today, if you have a few spare minutes, you can help NASA scientists classify galaxies based on morphology through Galaxy Zoo or identify stellar-wind bubbles in the Milky Way via The Milky Way Project. If outer space isn't your thing, you can spend time folding proteins into their lowest energy conformations in a game called Foldit, created by the University of Washington, or join nearly 200,000 players from around the world in the online puzzle game EyeWire in order to aid researchers at the Massachusetts Institute of Technology as they work to map neurons in the retina. This is all thanks to the recent explosion in citizen science projects.

A term coined in the 1990s, 'citizen science' has two widely accepted definitions. The first, accepted into the Oxford English Dictionary in 2014, was adopted by the Cornell Lab of Ornithology in 1995 after researchers began searching for a name to refer to their projects that depended on large numbers of participants—the majority of them non-scientists—collecting data on birds. The definition equated citizen science with participation of the general public in scientific research, where citizens collaborate with professional scientists to collect or analyze vast quantities of data.

> All around the world over the past 20 years, several thousand citizen science projects have engaged millions of participants in gathering and processing data.

The second definition of the term arose from the 1995 publication of a book by Alan Irwin, a professor of organization at Copenhagen Business School. The book, Citizen Science: A Study of People, Expertise, and Sustainable Development, discusses citizen science as an avenue for democratizing science. By building an active "scientific citizenship," the public can be more meaningfully educated and involved in the policy-making and discourse surrounding scientific topics, especially those regarding human and environmental health. Irwin's call for a democratization of science centers is based upon his belief that the troubling rise of climate change should be tackled with vigor by both scientists and citizens alike.

All around the world over the past 20 years, several thousand citizen science projects have engaged millions of participants in gathering and processing data. These projects tend to center on answering particular scientific questions, in line with the Cornell Lab's conception of citizen science. However, at least in the United States, a significant portion of funding for these projects typically comes from the Advancement in Informal STEM Learning program of the National Science Foundation. As such, science education and science accessibility have become important goals of many projects, much as Irwin anticipated.

Particularly in the current political atmosphere—one in which the survival of the Environmental Protection Agency is under siege, as just one of many examples—science, technology, engineering, and math (STEM) accessibility and public engagement in the sciences are more crucial than ever. Citizen science has an important role to play in engaging communities to demand policy that improves human and environmental well-being, as well as encouraging folk to take an active and meaningful interest in the ways in which the world works. It carries the potential to change public attitudes and opinions of science through empowering individuals without formal STEM training to better understand and more critically evaluate the scientific claims they may be confronted with over the course of their daily lives. Citizen science provides a unique opportunity to transform the institutional, exclusionary, and bureaucratic scientific process into a participatory, deliberative, and human one.

Of course, many questions arise for professional scientists in pursuit of these types of projects: what are the most effective ways to genuinely engage the general public in citizen science without compromising scientific rigor and accuracy? What are the best implementations of citizen science in terms of furthering both scientific research and science education and accessibility? What are the challenges that may arise in the pursuit of a more globally collaborative scientific process?

True to scientific form, an open access journal called Citizen Science: Theory and Practice was started by the Citizen Science Association and Ubiquity Press in May 2016. It is dedicated to answering these and other questions regarding the assumptions, practices, outcomes, costs, benefits, challenges, and overall impact of citizen science within both the scientific community and society at large. The journal has taken on a variety of topics, ranging from strategies for increasing the credibility and scientific rigor of data gathered through citizen science to the evaluation of best practices for enlisting and retaining citizen participants. Continued engagement by the scientific community with these and other issues surrounding the practice and goals of citizen science are crucial, since citizen science, despite obvious power as both a research method and a tool for communication, is not without its limitations.

For example, in 2012, Graber and Graber published an article in the Journal of Medical Ethics in response to the success of the protein-folding game Foldit. They made a case for the potential ethical concerns of citizen science, especially in projects that reward players with scores and social capital, motivations which they suggest pose risks for the economic, social, or mental health status of participants. Graber and Graber argue that citizen science projects are, by definition, experiments involving human subjects. In that vein, many of these individuals may not fully understand the methods, goals, and ramifications of the projects in which they are participating, which breaks with the value of informed consent in medical and research ethics. As such, the authors recommend that all citizen science projects be run past an institutional review board (IRB). IRBs, committees dedicated to approving and monitoring any kind of research involving humans, are standard practice in the US and could be used to offset the potential harm done to participants involved in citizen science projects.

Nevertheless, as it stands, the potential of citizen science for bridging gaps and forging connections between the scientific community and the general public outweighs the drawbacks. Citizen science cultivates the possibility of engagement with members of diverse communities who might otherwise be excluded from such collaboration due to institutional inequality and oppression. Improved scientific literacy and accessibility are critical for shaping sound public policy and encouraging folk to take a genuine and well-informed interest in their own health, the wellbeing of their environment, and the general stitching of the universe. To the average person, the physics of protein-folding may seem like a niche interest even for a scientist, but understanding that games like Foldit could lead to medical breakthroughs or drug discovery may contextualize for folk the importance of the game they play as they ride to work each morning on the Metro.

Simultaneously, members of the scientific community must constantly interrogate their own motives and the efficacy of their practices, moving to cultivate more inclusive and accessible approaches to scientific dialogue and deliberation as they design and implement citizen science projects. Project developers must make a serious effort to contextualize their investigations by integrating both general knowledge and scientific expertise, empowering citizen participants to become engaged members in the process of creating and executing projects. In order for citizen science to be successful, there must be space for unconventional scientific practice. Scientific institutions ought to be pushed to reevaluate their conceptions of

"expert knowledge," challenged to question whose knowledge is viewed as valid and respected within the scientific community and the historical and structural reasons for that. Academia and industry prize years of rigorous scientific training that are simply not obtainable for low-income folk, as well as are systematically denied to women, queer and trans people, and people of color. As such, a sustainable model of citizen science will depend

as are systematically denied to women, queer and trans people, and people of color. As such, a sustainable model of citizen science will depend on serious considerations of trust and equity, as the community of trained science professionals learns to accept the validity of scientific work that comes from beyond the ivory tower. Citizen science has incredible potential to further scientific research and innovation, but with its application comes great responsibility.

Since that night under the stars with my father, my scientific interests have moved away from the interstellar. Still, I have never forgotten my dad's reminder that this planet and the ones beyond — and the forces that govern it all — belong to each of us. Professional scientists or not, we all have a role to play in uncovering their mysteries.

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Torn paper border courtesy of freegreatpicture.com

Can We Educate Better?

Figure 1 courtesy of Oberlin CLEAR.

Figure 2 courtesy of Freeman 2013.

Crossword Corner

By Rachel Dan

The crossword will return in fall 2017.

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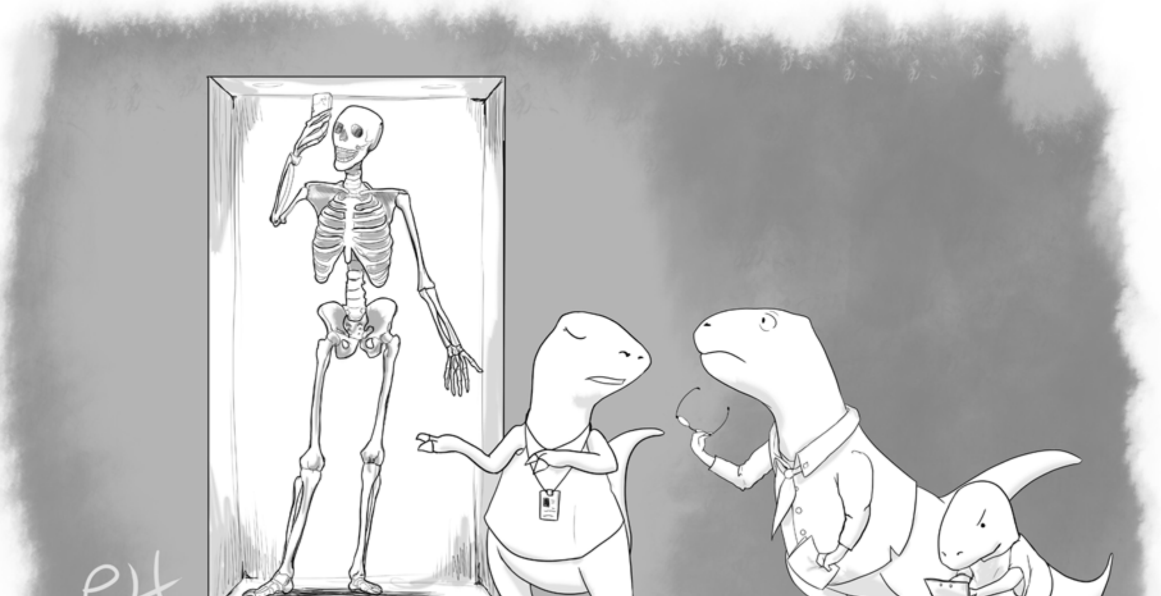
By Elena Hartley



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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

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