LAByrinth

2021

The Science Journal of Manhattan High School for Girls

Artwork by Cherri Citron

Cover Art by **CHERRI CITRON, GRADE 11**

LABYRINTH 2021

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We are pleased to grant this year's

HARRY KAPLAN SCHOLARSHIP AWARD
FOR EXCELLENCE IN SCIENCE WRITING

to

GOLDA SCHUSTER

for her essay

Shaking Hands in Foreign Lands:
Can Microorganisms Survive in Space

and to

YEHUDIS KUNDIN

for her essay

Genetic Susceptibility to Infectious Diseases

We gratefully acknowledge Dr. Tuckel and family
for their generous sponsorship.

LABYRINTH 2021: FOREWORD

Mrs. Brenda From, Chair, Department of Science

Not surprisingly, many of the submissions centered on the virus—detection, transmission, symptom manifestation, and recovery—and the vaccine—development, mode of action, and efficacy.

Ok, let's get real and name the elephant in the room: COVID 19. This has been less than a stellar year for science education. I don't think Queen Elizabeth would mind if I borrow a phrase from her speech on the 40th anniversary of her accession to the throne. 2020 ….." is not a year which I shall look back on with undiluted pleasure. In fact, it has turned out to be an 'Annus Horribilis'. I suspect that I am not alone in thinking it so. Indeed, I suspect that there are very few people or institutions unaffected by these last months of worldwide turmoil and uncertainty"….Between zoom classes, cancelled classes, and raging absences, it is no small wonder that this publication sees the light of day.

And yet, here it is, a testament to the resilience and perseverance of our student body and the uncompromising dedication of the administration and science faculty of Manhattan High School for Girls. Thank you to Mrs. Yanofsky and Mrs. Friedman-Stefansky for their unflagging support of this project. Thank you to Dr. Abigail Haka (Chemistry 10, Human Anatomy & Physiology) and Mrs. Sarah Tendler (Genetics) for the gentle but firm guidance/prodding they provided our students in this demanding effort. This journal bears the unmistakable stamp of Mrs. Dena Szpilzinger and her desktop publishing wizardry. Mrs. Russi Leiter-Itzkowitz's professional proofreading touch is evident on every page.

Not surprisingly, many of the submissions centered on the virus—detection, transmission, symptom manifestation, and recovery—and the vaccine—development, mode of action, and efficacy. Read Yehudis Kundin's tour-de-force on the interplay between genetics and susceptibility; Dassi Hakimi's piece "A Glowing Antibody Test;" Chavi Weiner on the dangers of wood instruments during the pandemic; and Yehudis Ginsberg on the Race to the COVID Vaccine. However, in a dazzling display of the wide-ranging insatiable curiosity of our students, the selections incorporated here demonstrate a cornucopia of interests and passions. Ranging from Astronomy, Biology, Chemistry, Genetics, Human Anatomy & Physiology, Psychology and Technology, there is something here for every demanding palette. This is the first year where we have charged the freshmen with writing research papers and they have produced magnificently, surpassing all our expectations. They have proudly joined the cadre of exceptional science writers at MHS together with the 10th grade Chemistry, and upper class advanced electives.

A word about our cover. Produced by Cherri Citron of Ms. Klapper's AP Art Class, it depicts our vision and hope for a world cleared of the detritus of this year's scourge and the greener fields that lay beyond.

May Hashem grant that next year be an annus mirabilis with the coming of Moshiach.

ACKNOWLEDGEMENTS

Mrs. Estee Friedman-Stefansky, Principal, General Studies

I am so proud of our student contributors who found joy in their studies and elected to expand their knowledge independently.

Early this Fall, we applauded Emmanuelle Charpentier and Jennifer Doudna, recipients of the Nobel Prize in Chemistry. In collaboration, Ms. Charpentier and Ms. Doudna developed CRISPR-Cas9 genetic scissors which can be used to change animal, plant and microorganism DNA, and to edit genes that could one day cure genetic diseases.

While the Nobel Prize in Science has already been awarded to 185 individuals since 1901, only seven of the awarded have been women. This statistic makes us wonder about the representation of both women and minorities nominated for Nobel Prizes, and inspires greater allocation of funds toward STEM education for "girls."

I am so proud of our student contributors who found joy in their studies and elected to expand their knowledge independently.

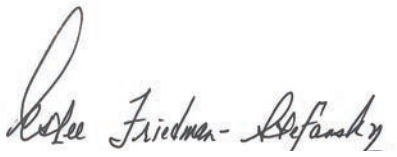
Our Science department, under the capable leadership of Mrs. Brenda From, is dedicated toward the mission of encouraging our girls to contribute to the conversation of research and discovery and for them to continue to be more attentive to their own questions and observations, to the ongoing challenges in science and medicine, and to the emerging literature.

In the words of the poet, David Whyte,

"Put down the weight of your aloneness and ease into the
conversation. The kettle is singing
even as it pours you a drink, the cooking pots
have left their arrogant aloofness and
seen the good in you at last. All the birds
and creatures of the world are unutterably
themselves. Everything is waiting for you."

We do not know which one of our school's science lovers will be the one to help solve some of our world's toughest challenges. Let us continue to encourage our girls to work hard, think big, and move forward.

With appreciation to our Science Teachers: Mrs. From, Dr. Haka, and Mrs. Tendler, best wishes for a beautiful happy summer.



HOMEOSTATICALLY CONTROLLED COUCH POTATOES

Ariella Bennet, 12th Grade

What if I told you there was a way to lose weight without diet or exercise? Seriously. Most people dream of such a scenario, shedding pounds by doing absolutely nothing at all.

What if I told you there was a way to lose weight without diet or exercise? Seriously. Most people dream of such a scenario, shedding pounds by doing absolutely nothing at all. Recent studies have shown that our bodies do everything in their power to maintain homeostasis, by tricking our body into thinking we weigh more than we actually do, our body is more likely to let go of that stubborn fat. This phenomenon is one that works both to our advantage and our disadvantage.

In her article, *"The Lightness of Being a Couch Potato May Work to Keep Us Fat,"* Gretchen Reynolds discusses how simply by and being a couch potato one can gain weight without actually changing their eating habits. Reynolds presents a clear scientific explanation for this. He explains that a body has a set point of homeostasis, in other words, an ideal point of stability.

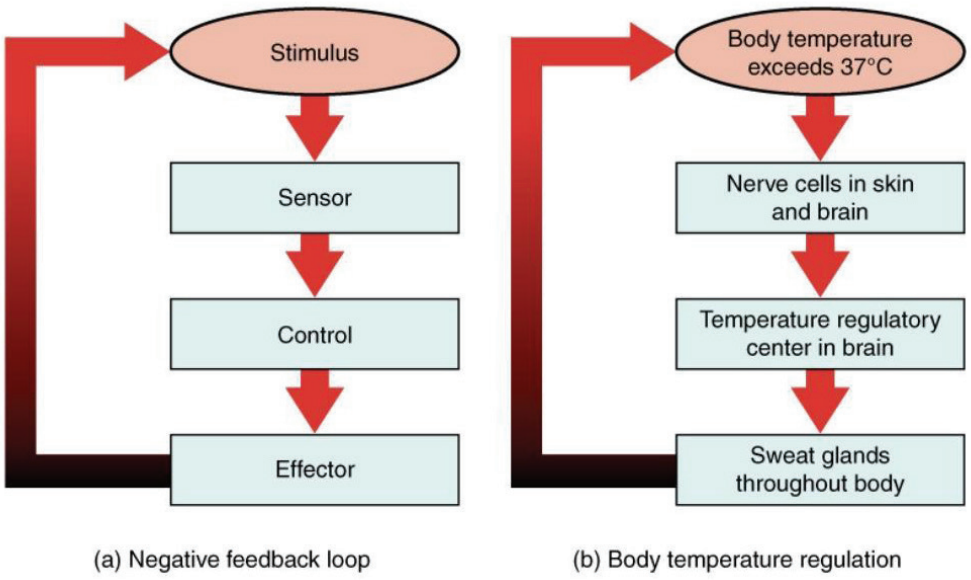


Figure 1: An explanation of homeostasis

As we go throughout our day, our body is constantly trying to maintain its ideal homeostasis. It is why we sweat when we are hot and why we shiver when we are cold. This is why a heavy coat will help speed up weight loss, and sitting on the couch or sitting at an office desk will actually be counteractive.

According to Nick Fuller, obesity researcher and writer, not only does our body have a stable temperature, it also has a stable weight and it can sense when we begin to move away from that desired

range. When we sit down for an extended period of time, our bodies feel that the homeostasis has been disrupted since the body can only identify the weight at the top half of our bodies. The body begins to feel unstable since our bodies need stability, they begin to conserve fat and put on extra weight as a form of compensation.

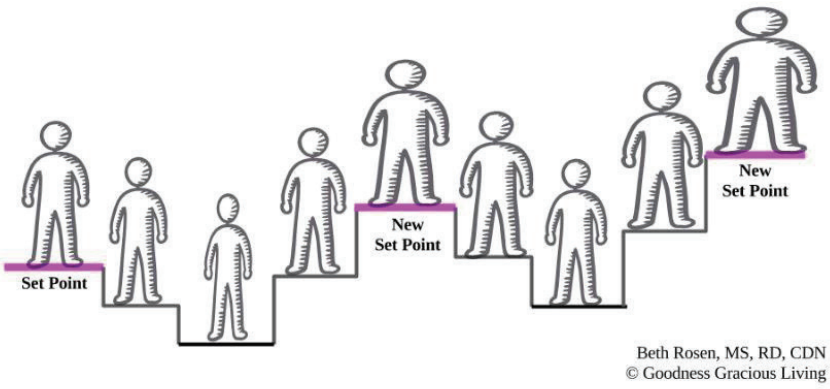


Figure 2: The Set Point Theory-every person has homeostatic controlled weight gain or loss

However, Anna Monette Roberts claims that homeostasis does not allow our bodies to lose weight. The scientific reasoning behind this is because the body tends to store extra fat just in case of an emergency. This prevents our body from losing weight and this is the main cause behind the stubborn fat that we just cannot seem to shake.

In order to prove his theory, Reynolds conducted an experiment using mice and humans. He stuffed half of the mice with heavy pellets and he gave half of the humans weighted vests. The group's weight was recorded and tracked over a set period of time and the results showed that the group wearing the extra vests ended up losing more weight than those who did not. This experiment proved the theory that weight gain is homeostatically dependent. When the body feels underweight it gains more weight and when it feels overweight it loses weight without any exercise or dieting. By relying on the body's natural response to environmental changes and its homeostatic nature, we can trick our bodies into dropping or gaining more weight as desired.

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CRISPR: READY OR NOT, HERE IT COMES

Tova Berger, 10th Grade

The use of CRISPR technology in humans in this stage of its development is not even remotely ethical. We have no way of knowing what will go wrong and we have too little information about it to minimize any risks.

Emmanuelle Charpentier and Jennifer Doudna recently won the 2020 Nobel Prize in chemistry for developing CRISPR, a method for editing genomes. CRISPR, Clustered Regularly Interspaced Palindromic Repeats, is the process that prokaryotic cells use to protect themselves against infectious viruses. It essentially takes pictures of the virus using RNA. When the virus is encountered, bacteria and archaea use CRISPR/Cas9 to make double-stranded cuts in the viral DNA, disabling the function of that section of the genome, thereby hindering viral function (figure 1).

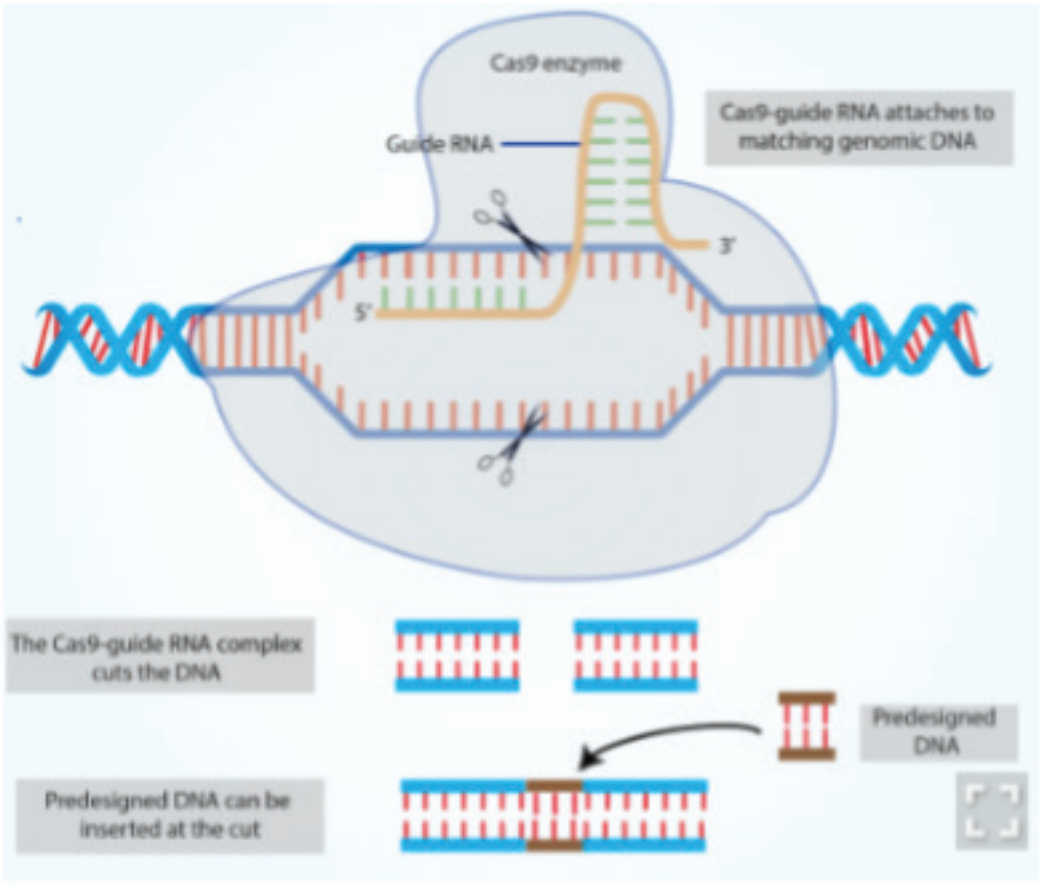

Figure 1. The guide RNA binds with one strand of DNA so that the Cas9 enzyme can cut the other strand, disabling or altering its function. Sampath, Vanitha. Using CRISPR Technolgy for Allergy and Asthma, May 2018. Stanford Medicine.

Doudna and Charpentier analyzed this method to create a way to target and edit sections of the mammalian rather than the viral genome. They succeeded in creating a method to make the RNA recognize a specific gene as opposed to a virus, enabling Cas9 to cut any gene they wanted. Because of the relative simplicity of CRISPR technology, only eight years after its development it is already being widely used in research labs across the world. Scientists are trying to use it to cure diseases that occur from a mutation, a misspelling of DNA. The ethics of the use of CRISPR in human or animal populations is controversial, but clinical trials employing CRISPR technology to cure cancer, sickle cell anemia, and other inherited diseases are already underway. Many scientists believe it can solve problems we have been struggling with for centuries, changing the future of the human race (Saey).

CRISPR works differently than the way gene editing is often imagined. It is commonly believed that scientists somehow physically cut out a piece of DNA and replace it. Contrarily, researchers actually program the RNA to do that itself. Furthermore, the significance of gene editing is also often underestimated. Gene editing is popularly introduced as a method for creating GMOs, usually food, and clones. CRISPR introduces an entirely new concept: gene editing can be used to cure genetic diseases that previously seemed incurable, making the future of CRISPR in the field of medicine bright.

That being said, use of CRISPR technology in humans in this stage of its development is not even remotely ethical. We have no way of knowing what will go wrong and we have too little information about it to minimize any risks. For all we know, Cas9 could accidentally cut out many vital genes on a chromosome! Using anti-CRISPR proteins, scientists are working to reduce the risk of CRISPR targeting complementary sites (segments of the genome that could be affected because they have a similar DNA sequence to the one being targeted), but this method is not entirely effective (figure 2).

Whereas CRISPR/Cas9 actually cuts the DNA, there is a safer method that simply replaces one amino acid in a base pair. This base editing system uses Cas12a instead of Cas9, and is often referred to as CRISPR 2.0 (Tang et alia). It's slightly more complicated and will take a lot more research before it can be used in animals. Eventually, for the sake of creating healthy people, if the chance of CRISPR causing damage is lower than the chance of a disease affecting someone, employing CRISPR 2.0 would be proper, but using CRISPR in humans either too early or to change a standard genetic trait that does not affect one's health, such as eye color, is completely unethical and should never be done.

Assuming enough research is done to create a version of CRISPR that can be used in humans, gene editing would likely need to happen in every affected cell. In the case of sickle cell anemia, targeting specific red blood cells would probably be sufficient, but in the case of Tay Sachs, every cell in the body would need to be targeted to cure the disease. If gene editing is done in an embryo, it wouldn't be too difficult to mutate the genome in every cell, protecting the child and all their descendents from the disease. In contrast, in an adult, the task of editing the DNA in every cell individually seems impossible. In 2017, Chinese oncologist Lu You began experimenting with cancer patients by extracting some cells, modifying them, and multiplying them, and the method proved to be inefficient (Cyranoski). The developers and researchers of CRISPR technology are working on finding a solution, though it may take years until CRISPR is safe to use in humans and proper studies can be conducted. I trust that our scientific and medical fields won't do anything foolish and are capable of turning CRISPR into a life-saving device. If that is not yet done by the time I start medical research, perhaps I will join their team and discover something life-changing.

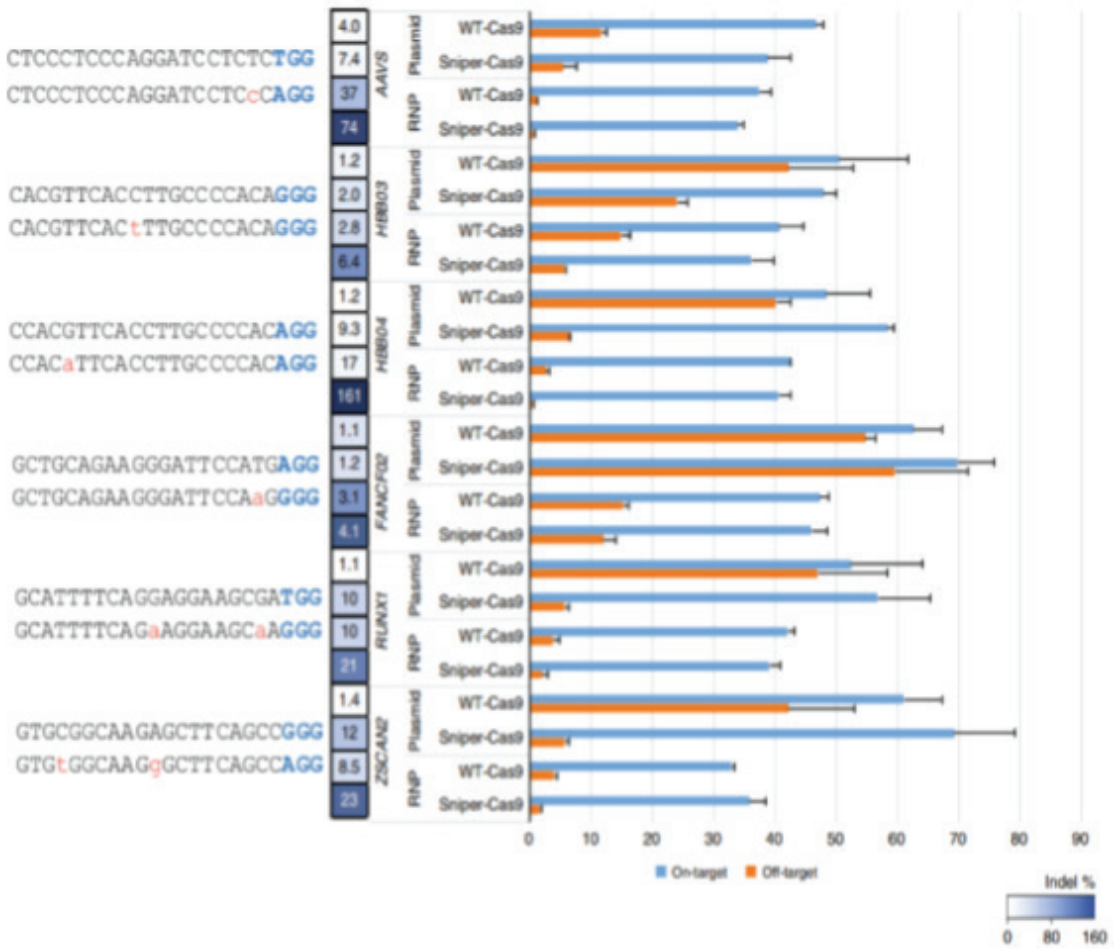

Figure 2. The orange bars indicate off-target effects, and while they are generally shorter when the Sniper-Cas9 inhibitor is employed, they aren't nearly short enough. Lee, Joonsun, Min-Hee Jung, Euihwan Jeong, Jungioon K. Lee. Using Sniper-Cas9 to Minimize Off-target Effects of CRISPR-Cas9 Without the Loss of On-target Activity Via Directed Evolution, Feb, 2019. JoVE Journal.

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SKIN ON STRESS

Cherri Citron, 11th Grade

Chronic stress, from issues either in our personal lives, or even larger global ones like a pandemic or political unrest, takes a serious toll on our bodies. Most of this is due to an overproduction of cortisol, the primary stress hormone.

Our stress is spelled out on our skin. It is exhibited in the form of acne, or even eczema or psoriasis breakouts. Chronic stress, from issues either in our personal lives, or even larger global ones like a pandemic or political unrest, takes a serious toll on our bodies. Most of this is due to an overproduction of cortisol, the primary stress hormone. The barrier that usually protects our skin and keeps out irritants relies on oil, water, and the microbiome. Cortisol decreases the production of oils, taking the protective layer it gives us, that is supposed to trap in hydration. This makes our skin drier. It also causes an overproduction of sebum, which causes acne. This alters the acid mantle, and makes the environment inhospitable to the microbiome on the skin barrier. Usually, these microorganisms take care of our skin and protect us. Stress can also make our bodies produce free radicals, which can lead to skin cancer, wrinkles, fine lines, dehydration, damage to the skin barrier, and acne (DeFino). Most skin care products aren't effective when our skin barrier is unhealthy. The best way to address acne is to deal with the stress in our life. Even if there's not much you can do to fight a pandemic or climate change, you can decrease your stress level through meditation. Working on breathing techniques can also be beneficial. Eating more antioxidants and exercising is also effective. Even crying can decrease cortisol levels.

We often try to treat the symptoms of stress rather than the actual problem. Most teenage girls, like myself, are quite familiar with the idea of a skincare routine. Instead of dealing with the stressors in our lives that cause our skin to break out, we try to treat these blemishes with countless products. This might seem like an easier answer than trying to solve all the world's issues, but most of the products we use are unproven and ineffective. When our stress levels are low, the microbiome takes care of most things we assign to skincare products. Most skincare products only work when the skin barrier is healthy, but most acne is due to weakness in the skin barrier due to stress. Some products might cause even more harm to our skin if they contain ingredients like glycolic acid, salicylic acid, benzoyl peroxide, or retinol, which break down the skin barrier even further (DeFino). The skincare industry was estimated at a value of around $300 million in 2015 (Caulfield). Rather than proof and science, this multi-billion dollar industry is driven by advertising and celebrity endorsements. There is rarely any actual proof for the efficacy of products advertised to improve our skin. Instead of wasting our money on ineffective products, we should be putting more time and effort into researching what we use on our skin. Even better would be to deal with the stressors in our lives that degrade our skin barrier and make acne an issue for us. Even if it is not so easy to rid ourselves of the problems that cause our stress, we can still incorporate certain practices into our lifestyle to decrease the effects on our body. Besides just our skin, stress can wreak havoc on our body in many different ways, such as heart disease, inflammation, and dampening the immune system (O'Connor). Incorporating exercise can help us, so can taking a break from phones and social media. It might be hard to acknowledge as a sixteen-year-old girl myself, but I have bigger issues to handle than the pimple on my forehead.

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HOW HIGH IS YOUR PLANT'S IQ?

Anaelle Cohen, 9th Grade

Snap! Another bug is trapped by a hungry Venus flytrap. Venus flytraps are carnivorous plants…How is the hinge mechanism of Venus flytrap's triggered to ensnare its prey, and what does this indicate about plants and their supposed simplicity?

Figure 1: Leaves of Venus Flytrap

Snap! Another bug is trapped by a hungry Venus flytrap. Venus flytraps are carnivorous plants. In other words, they get their nutrients from both the soil as well as from digesting prey, mostly bugs. Venus flytraps resort to this un-plant-like behavior because they live in environments that contain few nitrates in the soil. Venus flytraps get the nitrogen necessary for amino acid synthesis even in the boggy soil they inhabit through carnivorous nutrition. How is the hinge mechanism of Venus flytrap's triggered to ensnare its prey, and what does this indicate about plants and their supposed simplicity? Additionally, they have the surprising ability to remember the articles that touch their sensitive hairs once so that when these articles touch the Venus flytrap a second time, it can determine if they are worthy enough prey for the Venus flytrap to expend its energy.

A new study by Mitsuyasu Hasebe, a biologist at the National Institute for Basic Biology, suggests that Venus flytraps have short-term memory. If an insect touches one of the Venus flytraps sensitive hairs once, the plant won't swallow it. Only once the insect has tapped the Venus flytrap two times, the plant swallows the insect. These two touches of the insect are required so that the Venus flytrap can distinguish between prey and other things like rain and won't waste its resources swallowing anything other than its prey.

The question is how does the Venus flytrap remember the initial touch of the insect so it can decide to swallow it after the second touch? A new study teaches that the Venus flytrap's memory is based upon the waxing and waning concentration of calcium in the leaf cells. When the insect initially touches the Venus flytrap, it signals to the plant to release a certain amount of calcium. When the insect touches it again the concentration of calcium reaches a certain threshold and the Venus flytrap closes and swallows the insect (Segarra, 2020).

This theory was proven using genetic engineering. Hasebe and his colleagues made the plant glow green by inserting the gene for a protein that emits green light when exposed to calcium. They touched the Venus flytrap's sensitive hairs causing it to glow green. This established the touch/calcium connection. When the glow started to fade, they tapped it a second time and the plant glowed even more brightly, opened its leaves, and swallowed the insect. This experiment showed how the short-term memory of the Venus flytrap is influenced by the calcium concentration in the plant. The experiment proved that when one taps a Venus flytrap, it releases a certain threshold of calcium as seen by the glow emitted by the Venus flytrap. After the second tap, the plant reaches a certain threshold of calcium fast-

er, causing the Venus flytrap to ensnare the insect. This was seen in the experiment as after the second tap, the Venus flytrap glowed brighter demonstrating how calcium concentration causes short-term memory in the plant (Segarra, 2020).

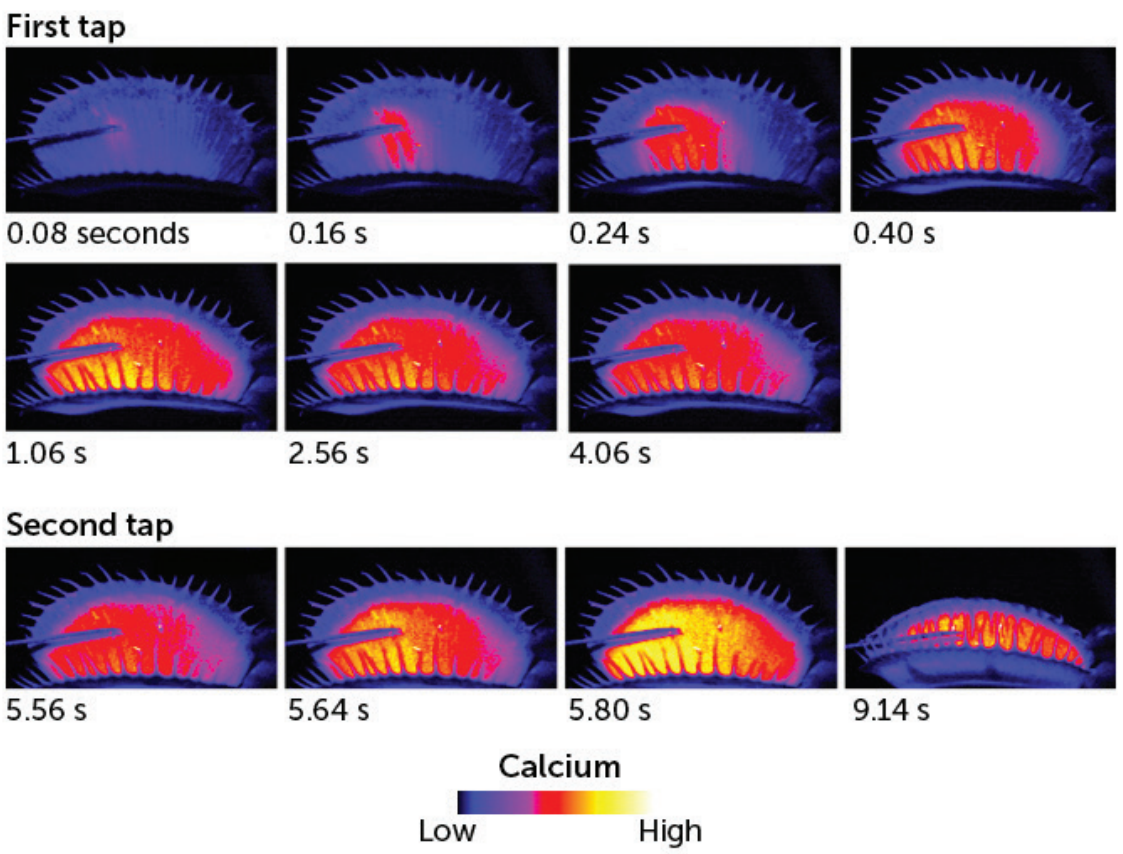

Figure 2: The diagram above shows a genetically modified Venus flytrap which demonstrates the use of calcium who ch causes the short-term memory of the plant. When prey touches the sensitive hairs of the Venus flytrap the first time, the plant releases a certain amount of calcium which is characterized by the glow. When the prey touches for the second time, the Venus flytrap reaches a certain threshold of calcium faster and the glow is brighter. This causes the leaves of the Venus flytrap to snap shut and ensnare its prey.

The Venus flytrap also uses an electrical network to turn the movements of the insect into electrical signals causing the motor cells in the leaves snapping the plant shut. The two systems in the plant, one which utilizes calcium for short-term memory and the electrical network, work together to cause the snap of the Venus flytrap when it swallows its prey. The phenomenon of calcium and electrical signals working together is present in many other plants, such as in the Mimosa pudica (sci-news.com), leading researchers to hypothesize that it is present in Venus flytraps too (Volkov, 2008)).

An electrical stimulus is a big part of the process in which Venus flytraps snap shut and ensnare their prey. A Venus flytrap generally has 5 to 7 leaves. Each leaf is composed of two parts. The upper part has lobes that are held together by a midrib, an important vein in the plant. These lobes contain three or more trigger hairs that contain a pigment that attracts bugs. The lower part of the leaf is known as a footstalk. The sensory hairs in the upper part of the leaf act as mechanosensors. When prey touches

the sensitive hairs of the Venus flytrap, the mechanosensors send out an electrical impulse. This impulse causes the motor cells in the leaf to snap the leaves of the Venus flytrap shut and swallow the prey. These mechanosensors in the leaves cell pick up even the smallest tap of an article and amplify it, so an electrical signal will be sent out. Plants can respond quickly to stimuli in their surrounding environments because of this network of electrical impulses located in the plant. So too the Venus flytrap uses its electrical stimulus pathway in order to respond to environmental factors, such as signaling whether to trap its prey or to let it go free (Volkov, 2008).

Researchers have found that calcium causes the short-term memory of the Venus flytrap which allows it to distinguish between potential prey and other substances, but there is still much to research and discover (Segarra, 2020). The Venus flytrap ensnares its prey using both its calcium memory system as well as its electrical stimulus system, but researchers are not confident in their knowledge of how the two systems work together. Plants in general are not as simple as one may think. The Venus flytrap helps prove this theory by demonstrating short-term memory as well as an electrical stimulus system (Volkov, 2008). The concept of plant intelligence, as well as plants' ability to exhibit complex functions such as memory, is evident in many plants.

A study done in 2014 sparked a completely new way of viewing plant sentience (Funk, 2019). Monica Gagliano and her research team at the University of Western Australia experimented with the previously referenced Mimosa pudica, a plant that folds up its leaves when threatened. The team dropped the Mimosa pudica once and it folded up its leaves in defense. When they dropped it many times, it stopped folding up its leaves. When the team switched to shaking the Mimosa pudica, the plant folded up its leaves again. A month later when the team dropped the plant it did not fold up its leaves in defense. This experiment proved the theory that plants can remember, as well as learn, what is a real threat to the plant. In 2016, Gagliano and her team did another experiment in which they caused pea plants to respond to a breeze from a fan. Gagliano concluded that this means plants can learn in addition to remembering. However, when the experiment was retested by Kasey Markel, a graduate student, he did not get the same results (Funk, 2019).

This experiment completely spun the concept of plant sentience—the ability to feel sensations as well as having an awareness of outside environments—on its head. Many plant biologists strongly disagree with Gagliano's results. They specifically argue that this area of science should not be referred to as "plant neurobiology" because plants don't have brains or neurons. Although there is no real evidence that plants are actually thinking, plants can react to their environments, exhibit short-term memory as seen in the Venus flytrap, and even learn. More evidence of plant sentience can be seen through plants' ability to keep information about their environments up to date as well as their ability to determine dangers in their environment (Marder, 2012). This evidence brings a new perspective on plants and their supposed simplicity and totally redefines the concept of plant sentience (Funk, 2019).

Researchers have found that Venus flytraps contain secondary metabolites but more investigations of the Venus flytrap must be done before these metabolites can be used to fight off foreign bacteria and cancer. Venus flytraps were not so heavily investigated, therefore future studies of the Venus flytrap hold the promising potential of preventing cancer, curing cancer, and other medicinal uses. Further study of the Venus flytrap holds much promise (Gaascht, et al. 2013).

It's interesting to note that King Shlomo, the wisest of all men, was blessed with so much wisdom including knowledge about the natural world. "He discoursed about trees, from the cedar in Lebanon to the hyssop that grows out of the wall"(I Kings 5:13). Rashi explains that Shlomo spoke not only about each plant, and its function, but also the medicinal purposes it contains. Shlomo knew about all plants and their functions which means that Shlomo knew about the Venus flytraps calcium-based memory and electrical network. He also knew exactly how the Venus flytrap can be utilized to cure

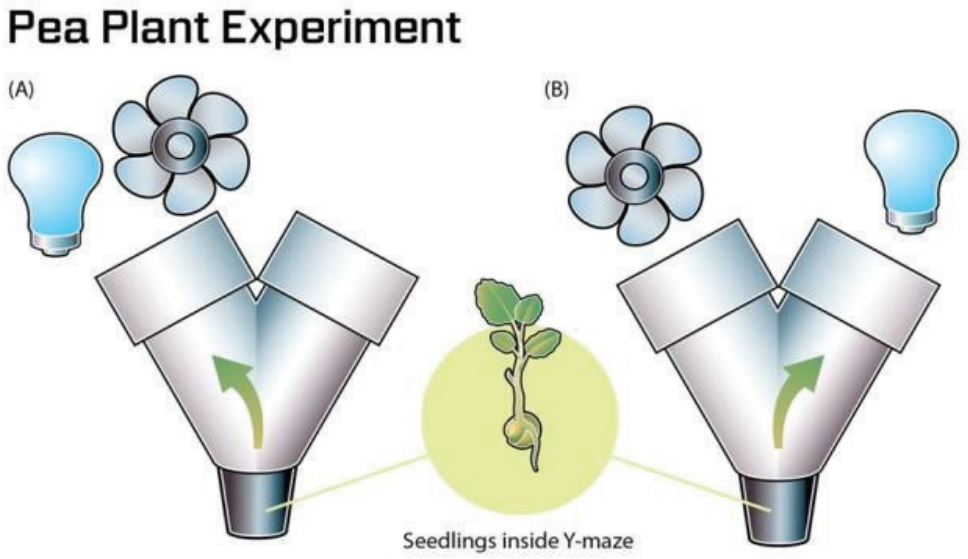

Figure 3: The diagram above depicts Gagilano's experiment with the pea plants. She put week-old pea plants in a Y–shaped pipe so that when the pea plants reached the junction it would have to choose which direction to continue to grow in. The plants were kept in the dark for three days. One hour a day half of the plants were exposed to light on one side, and the fan on the other side. The fan and light would switch places every day. The other half of the plants always have a light and fan on. The results were that the plants that weren't exposed to the light continued to grow in the same direction, but the group that was exposed to the fan grew opposite where the light was last. This experiment concluded that plants can remember, and learn.

illnesses such as cancer. This invaluable knowledge that King Shlomo had will hopefully be researched and confirmed by scientists soon so that it can be used in future medication and drugs that will save lives.

In conclusion, Venus flytraps have short-term memory using calcium that allows the plant to determine whether or not to trap its prey. It also has an electrical network that turns the movement of the prey into electrical signals that notify the plant through an electrical stimulus that causes the motor cells to close the leaves. The collaboration of the two systems is still unclear and more research is needed in that area. The Venus flytrap also shows complex functions such as calcium memory and electrical stimulus. These functions help give new insights into the concept of plant sentience. Venus flytraps also hold potential medicinal uses that are further being investigated. The Venus flytrap is a complex carnivorous plant with much future potential for the betterment of medicine, health, and the understanding of plant intelligence.

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A LIGHT TOUCH OF TECHNOLOGY

Nechama Friedman, 9th Grade

The area of technology in science has fundamentally changed our world, from the seemingly simple calculators to the endless discoveries now possible because of the work computers can do. The evolution of technology over the past decades has truly proven that virtually anything is possible.

"Technology is the campfire around which we tell our stories," says musician Laurie Anderson. Screens have evolved from being a passive technological accessory to a conduit for human touch. The digital world has impacted our world so much in recent years, especially technology relating to touch. Screens that react to our touch have helped us connect and accomplish unimaginable things.

The first finger-controlled touch screen was created in 1965 by E.A Johnson. His invention consisted of an insulator, such as the glass we find on the surface of an iPhone, and a transparent conductor, commonly indium tin oxide. Something touching the screen, such as a finger, acts as an electrical conductor (acante.co.uk). Johnson's original invention could only process one touch at a time, but in the 1990's to early 2000's researchers advanced touch technology to acknowledge multiple points of touch at a time (loc.gov).

The main components of a touch screen are the touch sensor, the controller, and the software. The touch sensor processes touch by registering a change in the electrical current. Most sensors are made to process fingers, but some can process styluses as well. The controller's job is to determine the location of touch based on the information given from the touch sensor, which then enables the software to react to the touch (Kim. 2020). In the recent 2000s companies have aimed to advance tech as much as possible by turning everyday surfaces into computer interfaces. They put together a screen that was able to recognize numerous points of contact (loc.gov).

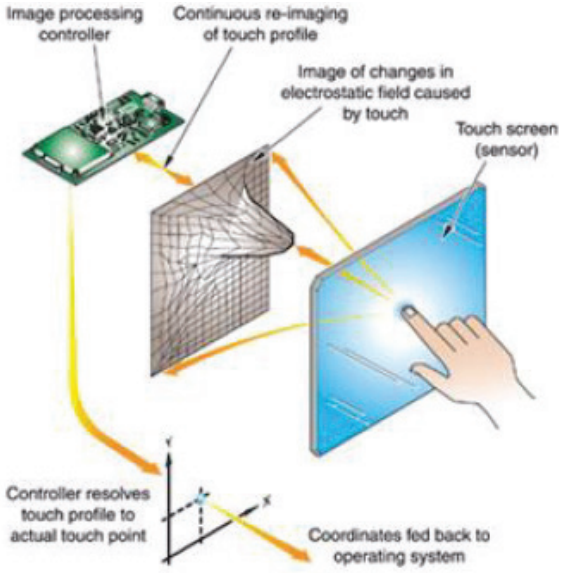

Figure 1: The energy flows at the point that the finger touches the screen as the finger closes off a circuit. The screen can then process and acknowledge the location of touch because of the disruption of energy and respond to it.

One recent movement in Purdue University has contributed to the making of a unique advancement in the science of technology; a device that allows for digital communication through human touch. Many devices use Bluetooth signals to send information to one another using a method called "near-field communication", but this can create problems in the stability of security because the digital information radiates around the device performing the action, and can potentially be accessible to someone wishing to hack it who is near this physical space. This new prototype transfers information through different means that enable a more precise and selective range of space for data to be sent to. Through much experimentation, researchers discovered how to get data to transfer through a person's body and then be transmitted to computers only when direct contact of a finger is made to the sensor (Wiles, 2020).

Figure 2: The image above displays one of our world's earliest touch screens. When touching a screen, the body acts as an electrical conductor and completes a circuit. This disrupts the flow of electricity at the point that has been touched and the computer is able to register the location of touch on the screen.

Figure 3: The picture above shows a moment during Purdue University's experimentation. Information from a chip in the man's watch is being transferred to the computer as the man touches the receiving sensor. The body behaves as an invisible wire that allows the information to flow from the watch to the computer.

For this experiment, a watch designed to be a "human body communication transmitter" was worn by a subject. The subject touched a specially crafted sensor that passed on the information to the computer to which it was connected to. This sensor would only pick up on the information provided with a direct touch from the human body that the watch was on, and would not register anything otherwise, even when the finger hovered as close as a centimeter away. This prevents any unwanted predator from intercepting personal credentials and can therefore make payment transactions safer (Wiles, 2020).

This development could simplify so much of our world's regular lifestyle. Everything could potentially be accessible through the touch of a finger, such as making a payment, perhaps unlocking your door, all with a single touch of your finger. It wouldn't be necessary to take anything out, as long as you

had the device on your body or in your pocket so it could be easily touched. The complication is that in all of these transmission scenarios all receiving machines would require the hardware that is needed to process your finger's touch, as well as the necessary software running through the device worn by the person in order to transmit the data. These devices must also have a way to shut off so that the data would only go to the place it's intended to go, and wouldn't transmit at every surface with a sensor (Wiles, 2020).

The area of technology in science has fundamentally changed our world, from the seemingly simple calculators to the endless discoveries now possible because of the work computers can do. The evolution of technology over the past decades has truly proven that virtually anything is possible. The regularity of people's everyday lives has been completely remodeled as a result of having so many things come easier through the help of technology. An example of this is an extraordinary device that tracks heart rate. Although it requires immense energy, a touch screen panel sensing system is capable of monitoring human heart rate through direct human contact (Kim, 2020).

Despite the vital assistance to which technology aids us with, it can be a dangerous domain as well, because it makes our machines smarter than we are. Is it bad that we're now doing less work and allowing machines to take over? Are we giving up too much power? Some might not want to continue advancing discovery in technology because of concerns like these, for technology has the potential to create and solve great things. In the medical field, for example, so many devices now help scientists explore the complexities of diseases and find cures and vaccines. Many types of machines run medical tests and there are also vital machines responsible for keeping patients alive. Technology is a leading factor in the wellness of our economy as well, in that so many things that would otherwise be inaccessible are available online, keeping businesses in shape despite the unprecedented circumstances in which we currently find ourselves.

There is still so much unexplored terrain in the matter of technology. Technology will likely continue to improve our lives, but there are still many consequences to its use. While many exploit its exciting possibilities, technology may simultaneously be hurting our health. There are endless discoveries yet to be made on this matter, and they will doubtlessly be found through the help of technology as well. How fantastic are the stories we can now tell around the campfire!

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VAX FACTS

Yehudis Ginsburg, 10th Grade

Many people question the long term effects of mRNA technology since it is fairly new, so I asked Dr. Graham if he had anything that I could share with my peers in high school about such possible long term effects.

On January 9th, 2020, the Worth Health Organization announced that there was a new mysterious pneumonia in Wuhan, China, stemming from a novel coronavirus. A little over one year later, there have been more than 109 million cases and 2.4 million deaths worldwide due to SARS COV-2 infections. Besides illness and death, the pandemic has caused unprecedented disruption of everyday life for billions of people and staggering economic instability.

Almost immediately, a race began to create a vaccine to provide acquired immunity. By April 2020, over 90 Covid-19 vaccines were in development by scientific teams in both universities and companies, some using established vaccine methodologies and others using new techniques. The goal of a vaccine is to provide immunity to a virus without having to fight the disease itself. It does this by training the immune system to recognize a virus before an infection can occur. The immune system can then aggressively fight the virus should it ever enter the body.

For many years there were three main techniques used to create vaccines for viruses. They are whole virus vaccines, subunit vaccines, and viral vector vaccines. Inactivated vaccines are the most traditional type of vaccine, having been used to inoculate against smallpox over 200 years ago. Inactivated whole virus vaccines utilize dead viruses to elicit an immune response. In the 1950s, new technology led to the creation of live attenuated vaccines, in which a whole virus is weakened or altered so as to not cause illness - yet still generating immunity. Subunit vaccines, on the other hand, do not utilize whole viruses, but rather viral components such as proteins to generate an immune response. Lastly, viral vector vaccines, such as the Hepatitis B vaccine, use a harmless virus to deliver instructions in the form of messenger RNA (mRNA) to the receiver's cells. The cells' factories read these instructions and produce the antigens, which in turn induces an immune response.

For a long time, researchers have been trying to develop easier ways to make vaccines. Since it is fairly easy to make large amounts of mRNA in a laboratory, scientists wondered if mRNA itself could be injected into the body, where it would then make its way into the cells. The cell would go on to produce the agents needed to trigger an immune response. This technique is as complex as it sounds and took many years of research to develop. Firstly, when just the mRNA was injected, it created a violent immune response. They also had to figure out how to get the cell to devour the mRNA. Next, how could the researchers get the cells to make enough of the antigens once the mRNA entered the cells? Lastly, how could the researchers protect the mRNA so that the chemicals in the body did not destroy it. After many years and the breakthroughs of many scientists, mRNA vaccines (also referred to as nucleic acid vaccines) were created.

Two of the main scientists whose research led to this discovery, were Dr. Barney Graham and Dr. Jason McLellan. In 2000, Dr. Barney Graham was hired by the National Institutes of Health (NIH) to create a vaccine evaluation clinic. His lab focused on vaccines for respiratory viruses such as influenza, coronaviruses, but particularly respiratory syncytial virus, or RSV. According to the University of Oxford's *Vaccine Knowledge Report*, RSV is the second largest cause of death in infants under one year

of age worldwide. It sends more children to the hospital every year than any other illness. What might surprise many people is how many older adults it affects: *Respiratory Syncytial Virus in Older Adults: A Hidden Annual Epidemic: A Report by the National Foundation for Infectious Diseases* states that RSV causes approximately 177,000 hospitalizations and 14,000 annual deaths in the US. A vaccine for RSV would be a tremendous breakthrough and would save many lives.

In 2008, Dr. Jason McLellan, who was conducting HIV research, fortuitously came to be working in the lab next to Dr. Barney Graham at the Vaccine Research Center at the NIH. They realized that they could combine their knowledge to further the development of a RSV vaccine. Their focus was on the neutralization of a protein on the surface of the virus called the fusion protein (F protein). In "The Plague Year" in *The New Yorker*, McLellan said, "From the structure, we can determine function—it's similar to how seeing a car, with four wheels and doors, implies something about its function to transport people." What made the creation of a vaccine for RSV so difficult was the frequent transformation of this protein. One of the main imaging tools used to visualize viruses is x-ray crystallography. Only recently did x-ray crystallography become powerful enough to capture images of the F protein. Once McLellan and Graham were able to visualize the protein, they figured out how to stabilize it. In 2013, their discovery was published in the journal *Science*. Their article "Structure-Based Design of a Fusion Glycoprotein Vaccine for Respiratory Syncytial Virus," explained how they were able to stabilize the F protein so it could be used as an antigen which would in turn enable antibodies to attack the F protein and kill the virus.

In 2014 there was an outbreak of a new coronavirus named MERS. Graham and McLellan knew that coronaviruses have spike proteins that are similar to the F proteins in RSV. They used their important breakthroughs regarding RSV to create a vaccine for MERS. One similarity that the F protein and the spike protein have is that they are both shape shifters. Through the use of another imaging tool, cryogenic electron microscopy, or cryo-EM, McLellan and Graham discovered that by adding two prolines (rigid amino acids) they could prevent the MERS spike protein from changing shape. This was a key getting to the immune system to fight the virus. The last piece of the puzzle was how to deliver these modified proteins. Graham knew that a startup company called Moderna had encoded a modified protein on strips of mRNA. It uses lipid nanoparticles that encapsulate the mRNA so it can get to the cells without the mRNA deteriorating.

MERS, despite being more deadly than COVID-19, petered out quickly so the need for a vaccine became less urgent. When the COVID-19 outbeak occurred, Graham and McLellan were then able to transfer the knowledge from the MERS coronavirus to the COVID-19 coronavirus. They discovered what an article in Science in August of 2019 called "clinical proof of concept for structure-based vaccine design." It also said that this discovery brought an "era of precision vaccinology." They were able to discover a basic technology where a vaccine can be customized to a specific virus very quickly. Their lifetime of work and knowledge in virology enabled them to customize a vaccine for the COVID-19 virus in only two weeks.

As my research on vaccines progressed, I became very curious as to how this new vaccine mechanism can be taught in a relatable way to high school students such as myself. On a whim, I decided to email Dr. Barney Graham at the National Institutes of Health some questions, and I was pleasantly surprised when he answered. The first thing I asked him was what he would tell high school students to convince them to take the COVID vaccine. He answered that taking the vaccine is a choice that everyone has to make, but immunity for the entire populations is inevitable either way: "We are all going to have immunity to SARS-CoV-2 eventually either through infection (1-2% mortality and up to 20% chance of long term symptoms) or vaccination (2-3 per million chance of severe allergic reaction)."

Many people question the long term effects of mRNA technology since it is fairly new, so I asked

Dr. Graham if he had anything that I could share with my peers in high school about such possible long term effects. Dr. Graham said that the mRNA in the vaccine is "very transient and cannot be detected after about 72 hours" and that mRNA, in general, is "one of the fundamental elements of every cell and is required for our survival." Next, I asked him if there was anything he would mention to women in particular, since I attend an all-girls high school and there are unsubstantiated myths that the vaccine could affect fertility. Dr. Graham answered very clearly that the mRNA spike proteins and mRNA are expressed primarily in lymph nodes and muscle and are not widely distributed. mRNA stays in the cytoplasm and has no contact with the chromosomal DNA in the nucleus of a cell.

I went on to explain to Dr. Graham that my school was at the forefront of the COVID-19 outbreak and how we were one of the first schools to be affected and shut down due to COVID. Since a good number of students have antibodies, many are resistant to getting the vaccine. I asked what information he could share that will help convince people with antibodies to get the vaccine. Dr. Graham answered by saying that the mRNA vaccines are establishing better immunity than infection itself and he concluded by saying that "It is recommended that people who have had COVID-19 should also be vaccinated to protect against reinfection. You will also be helping to protect your grandparents."

Scientists often start out researching one area and use that information and knowledge for discoveries in other areas. It took knowledge from Graham and McLellan's research in HIV, RSV, and MERS to be able to create a vaccine for COVID-19. Another important detail is that while the knowledge and understanding of how to do something might be there, the technology might not be. Graham and McLellan needed more advanced imaging than was not available at the time. As they progressed in their research, more imaging was available which facilitated the creation of the vaccine.

So what makes this discovery so exciting? First, producing an mRNA vaccine can be faster and cheaper than traditional vaccines, which means scientists can respond more rapidly to emerging outbreaks. To create a new mRNA vaccine, scientists only need to identify and target one part of the virus. Scientists just need to synthesize the specific sequence of the protein they want the mRNA to duplicate. The mRNA is easier to produce in a lab than the actual proteins, like the spike protein in COVID. They also seem to provide better immunity than many other vaccines, by not only facilitating the creation of antibodies but natural killer cells as well. The Moderna vaccine is 94.1% effective in preventing cases of COVID. It is also safer than traditional vaccines because it does not contain any parts of viruses, so it cannot cause infection. It also does not impact DNA and degrades very fast. With new coronavirus outbreaks becoming more and more frequent, this new technology will hopefully allow for quick, inexpensive vaccine development and, in turn, help save many lives.

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A GLOWING NEW ANTIBODY TEST

Dassi Hakimi, 9th Grade

There is still much we do not know about antibodies and there is much room for more research. For example, how long are antibodies effective in fighting each disease in our bodies? With respect to this new method, how sensitive and effective is it?

Like sentinels at the parapets, our bodies are constantly on the lookout for foreign invaders. Antibodies are the key component of our immune system and the warriors inside our bodies, constantly helping to fight off various invading particles. Antibodies are a type of protein, known as immunoglobulins that are created by our immune system. Antibodies are produced to protect us and fight off antigens, which are chemicals, viruses, and bacteria that enter our body and can cause us to get sick. When antibodies recognize a foreign substance that can cause harm, their role is to locate these antigens and bind to them in order to attack them and render them ineffective. (Perkins, 2020)

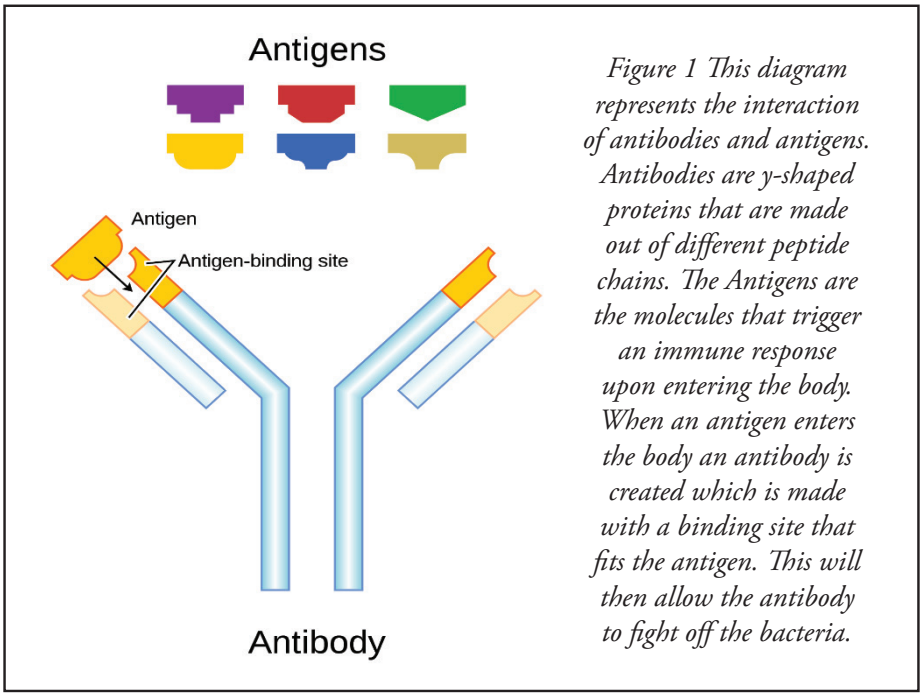

Figure 1 This diagram represents the interaction of antibodies and antigens. Antibodies are y-shaped proteins that are made out of different peptide chains. The Antigens are the molecules that trigger an immune response upon entering the body. When an antigen enters the body an antibody is created which is made with a binding site that fits the antigen. This will then allow the antibody to fight off the bacteria.

When this response happens, the body responds by making memory B cells. When a reinfection occurs, these memory B cells that are specific to the antigen will respond and proliferate into plasma cells. Those plasma cells secrete large quantities of antibodies that will neutralize the antigen threat. (Perkins, 2020)

Antibodies are disease-specific, which means they only protect you from the disease that they were created to fight, thus preventing you from getting it if exposed. For instance, although COVID-19 is a fairly new virus, we have a basic knowledge that COVID-19 antibodies will only protect you from getting corona if you were to be exposed to that specific virus again. However, antibodies are

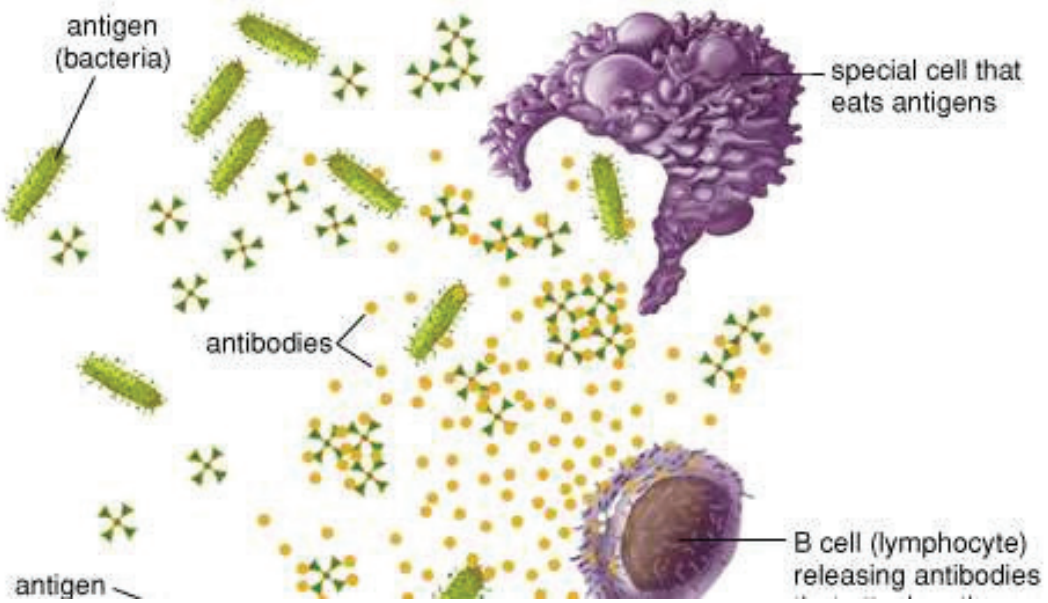

Figure 2: This diagram depicts what happens when your body recognizes antigens. Memory B-cells that were formed, are now producing many antibodies to fight off the infection in order to prevent your body from getting the illness. The antibodies that are produced by B-cells are capable of fighting off specific bacteria or bad substances that enter your body when a reinfection occurs.

not formed in your body immediately after you get the disease, your body may take several weeks to produce them (Hurt, 2020) The most common way that we test to see if someone has antibodies is through blood tests. The blood is drawn and then taken to a laboratory to be tested to see if it contains antibodies to a virus. These tests typically take at least 24 hours to get results, and can take even longer depending on the laboratory and many different circumstances.

Recently, a team of researchers discovered a simple and efficient way to measure if a person has antibodies in their body towards a number of different diseases. (Perkins, 2020) Most antibody tests today must be processed in a lab and require expensive equipment. These antibody tests must usually be performed by a trained technician, in a laboratory, which is costly. In addition, these tests require at minimum, a vial of blood. These factors led these researchers to search for a simpler method to detect and identify antibodies.

The team adapted a system that they developed 2 years prior that requires only a drop of blood. It is put onto a test strip that contains two types of glowing substances, luciferin and luminescent. Luciferin is a substance that glows when combined with oxygen. Fireflies utilize luciferin to produce their mesmerizing glow. Luciferase is an enzyme that speeds up the reaction between luciferin and oxygen. Luminescent is a specific antibody-sensing protein also known as LASP protein. Together with GFP (green fluorescent protein) Luciferin and luciferase are incorporated into Luminescent. To do this test they use two strands of thread. Luciferin is put on one strand and LASP is put on the other strand. Both these strands get wrapped around each other and when adding blood, the chemicals mix. The color of the glow determines if there are antibodies present in the blood or not. If there are none of the antibodies being tested for in the blood the chemicals produce a bluish-greenish glow. If the blood does contain those specific antibodies it causes a more bluish glow since it interferes with the GFP from the LASP protein. These results take about 5 minutes and only need a drop of blood, which is a huge advantage.

In addition, their new test was designed to detect up to three different virus or infection antibodies at once.(2) This glowing new way to measure antibodies is a practical upgrade, a huge advancement, and opens the door to more easy antibody testing.

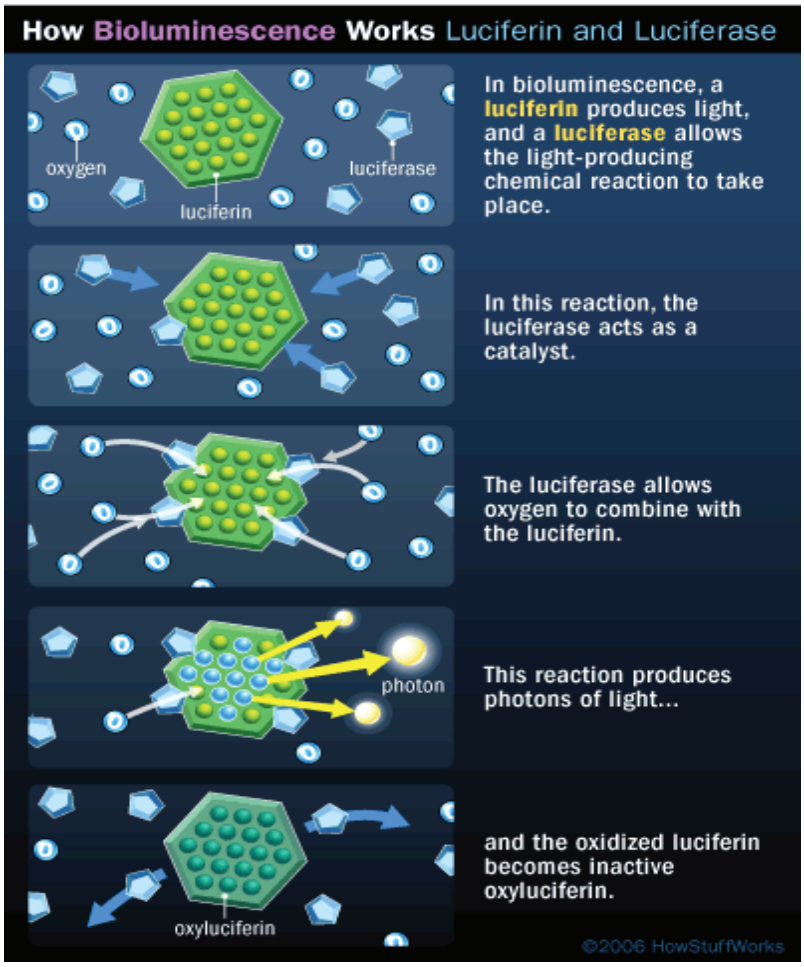

Figure 3 illustrates how bioluminescence works. Luciferase is the enzyme that allows this light producing reaction to take place. Luciferase is a catalyst and allows the luciferin to combine with oxygen and produce a glow. This process is deeply involved in the quick, new way of testing for antibodies and is what allows the light/ glow to be given off and indicates if the certain antibody is present.

This new way of measuring antibodies is important in many ways and can be beneficial to many people. Change in antibody levels over time can be very crucial to guiding us in an infected or diagnosed patient's progress. Data and details concluded from these tests can help doctors figure out the severity of one's disease or virus. This may help doctors to have a clear view on the right precautions and next step for them to take in order to prevent further harm to the patient. It is important for medical and health care workers to be able to speedily measure a patient's level of antibodies to determine their course of treatment. This topic provides knowledge on a convenient new way to test for antibodies

which can be very helpful to us as we are now provided with the necessary tools to make antibody testing more practical.

There is still much we do not know about antibodies and there is much room for more research. For example, how long are antibodies effective in fighting each disease in our bodies? With respect to this new method, how sensitive and effective is it? Can it distinguish between new and old antibodies? Also, is there a way to find out when the exposure to any given disease occurred based on an antibody test? All these questions, and more, have yet to be explored. In the future, this new method could open more doors and help scientists make more discoveries involving antibodies. The idea that testing for antibodies can be expanded is important and can help doctors to understand more about diseases and their treatments.

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TURN BACK TIME: REPROGRAMMING EPIGENETICS TO RESTORE VISION

Zippora Harris, 9th Grade

Throughout history, there have been many failed attempts to reverse aging, such as the search for the Fountain of Youth (Ledford 209).

Throughout history, there have been many failed attempts to reverse aging, such as the search for the Fountain of Youth (Ledford 209). Legend has it that Ponce de Leon discovered Florida while seeking this mythical fountain that would reverse aging, although this story is probably not historically accurate (Peck 1). New research published in the journal Nature is not the proverbial fountain, but it does come tantalizingly close to promising the restoration of youth.

One way of thinking about aging biologically is that it reflects an accumulation of epigenetic changes to cellular DNA. Epigenetics are when chemical substances (such as methyl groups, CH3) are added to DNA and change its function without changing the actual DNA sequence. Epigenetic changes can occur as part of development. For example, every cell has a pattern of epigenetic changes called methylation patterns that determine its particular type and function. They can also occur as a result of environmental influences, such as injury or stress. Over time, these cellular methylation patterns change in a way that reflect aging (Horvath 1). Some researchers believe that these changes actually cause aging (Yang 6).

One example of age-related damage is loss of vision, either due to glaucoma (age-associated pressure in the eye that damages eye nerve cells) or direct damage to eye nerve cells for which there is no treatment (Roska and Sahel 359). However, do epigenetic changes actually cause these visual diseases? One way to demonstrate their role is to reverse the epigenetic changes and examine what happens to vision.

Dr. David A. Sinclair and his colleagues hypothesized that if they reversed the age-induced epigenetic changes, they could reverse damage to eye nerve cells and restore vision (Lu *et al.* 124). There are four specific proteins that regulate the process of transcribing DNA to RNA known as Yamanaka transcription factors (OCT4, SOX2, KLF4 and MYC). It was previously known that artificially expressing the Yamanaka transcription factors erases the epigenetic patterns that give a cell its unique identity (Lu *et al.* 124). The team tried to use these Yamanaka transcription factors to erase the epigenetic patterns that result in aging. They excluded one of the four transcription factors, MYC, because it is known to cause cancer and reduce mouse lifespan (Lu *et al.* 125). They individually tested in vitro (in glass [petri dishes]) the remaining three by expressing them in fibroblasts (connective tissue cells) and found that KLF4 (OSK) restored the youthful methylation pattern without erasing cell identity or causing any sign of cancer (Lu *et al.* 125). Next, they infected young and old mice with a virus that expressed KLF4 (OSK) and monitored the mice for up to 18 months to make sure that it did not cause health problems (Lu *et al.* 125). The infected mice did not develop tumors or other health problems. These experiments demonstrated that KLF4 (OSK) can work *in vivo*.

To see if reversing these epigenetic patterns can reverse the effects of aging, the authors studied retinal ganglion cells (the nerve cells of the eye). Young retinal ganglion cells can regenerate if injured, but old ones cannot. The authors expressed KLF4 (OSK) in old retinal ganglion cells and found that they regenerated in response to injury by reversing DNA methylation patterns (Lu *et al.* 125). Finally,

they restored vision in two mouse models of vision loss. The first was a model of glaucoma which was induced by injecting polystyrene microbeads into the eyeball. This increased pressure in the eye and caused vision loss. The second model was natural loss of vision seen in old (12-month-old) mice. In both models, expressing KLF4 (OSK) with a virus restored eyesight (Lu *et al.* 127).

The findings of this research greatly affect how people view age-related illness. Many aspects of aging which have previously been thought to be irreversible, such as brain damage after a stroke, may one day be treated with this approach (Huberman 36). However, there will have to be more research before this can be done. First, this needs to be replicated by another group of scientists to make sure it is really true. Second, it needs to be tested in humans to see if the principles seen in the mice also work in people. Finally, since this treatment has never been done with other diseases, it needs to be applied and tested in other cell types and illnesses. Hopefully, this paper will inspire other researchers to carry this important work forward.

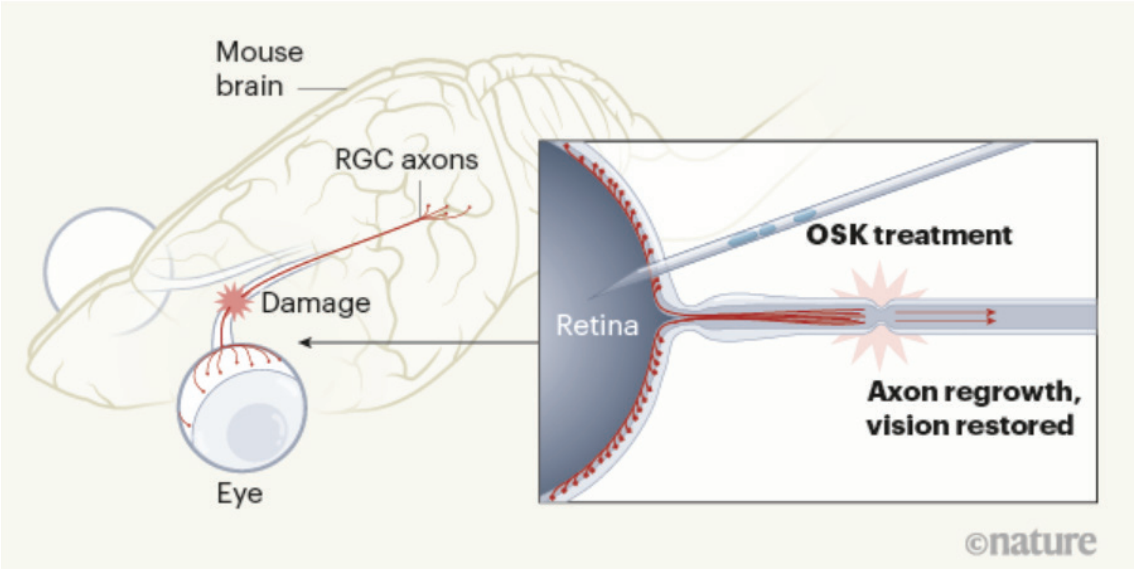

Figure 1. Injecting the Yamanaka factor, OSK, into the eyes of mice with damaged retinal ganglion cells (RGC) repaired the damaged nerves and restored the ability of the mice to see (Huberman 36).

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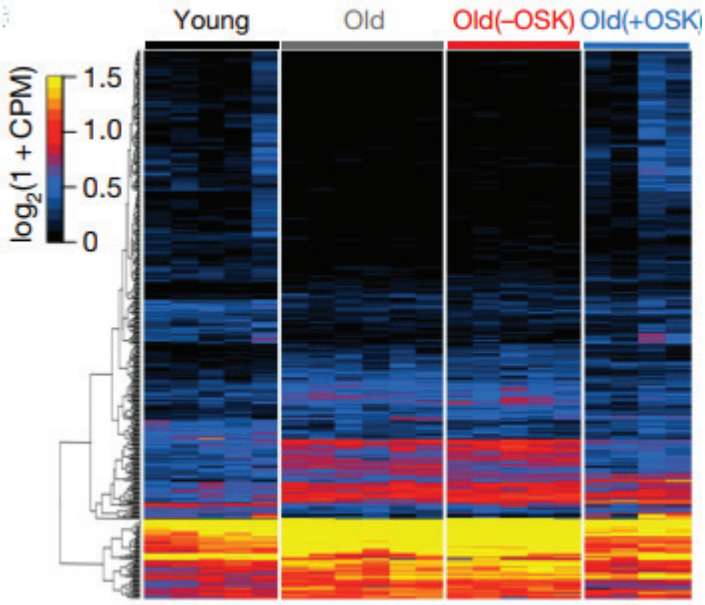

Figure 2. Epigenetic profiles for 464 genes that differed between young (1st column) and old (2nd column) retinal ganglion cells (notice the absence of light colored squares in the second column). Retinal ganglion cells from mice in which OSK was not induced (3rd column) showed the expected old epigenetic pattern. However, inducing OSK (4th column) caused old retinal ganglion cells to have a young epigenetic pattern (Lu et al. 127).

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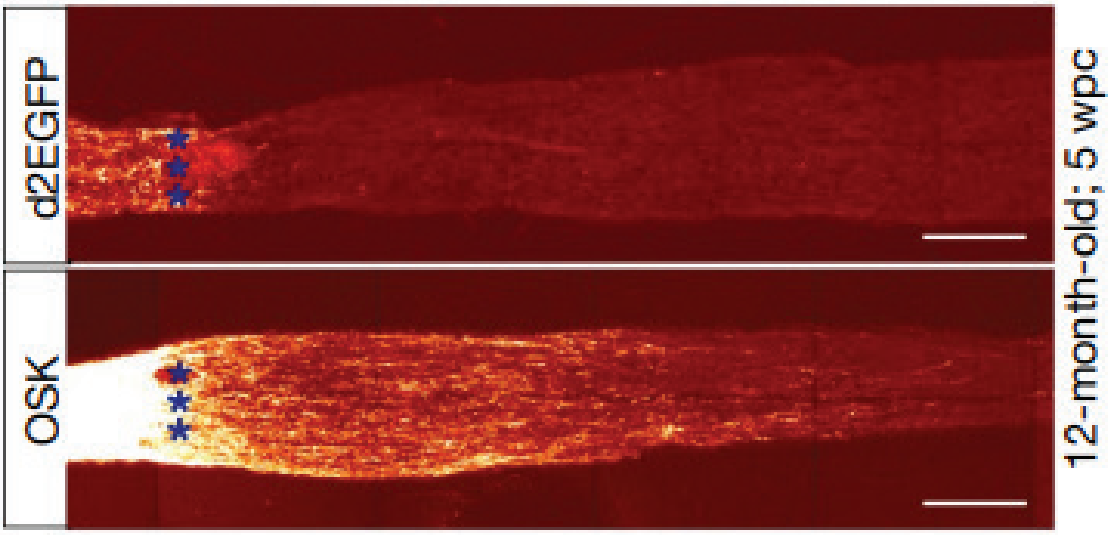

Figure 3. Top. An example of damaged optic nerves axons without OSK injections. The blue stars indicate where the nerve was injured. Red background represents the nerve sheath and white represents the nerve axons. Very few axons can be seen past the site of nerve injury. Bottom. An example of restored optic nerves axons after OSK injection. White axons can be seen protruding past the site of nerve injury, indicating regeneration (Lu et al. 125).

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OIL-INFUSED PLASTIC: A GLIMPSE INTO A MORE CONVENIENT FUTURE

Ayelet Hirsch, 10th Grade

In the coming years, it can be expected that the developers of oil-infused plastic will come up with a plethora of ingenious uses for this invention...that will hopefully play key roles in the future and help save lives around the world.

The recent discovery of oil-infused plastic and its practical uses in today's world are fascinating. Originally developed in 2011, the technology used in the invention is referred to by the acronym SLIPS, which stands for "slippery liquid-infused porous surfaces". This relatively new science allows a slippery liquid, in this case oil, to be injected into a porous material and act as a lubricant to ensure that substances making contact with the surface do not stick to it. One successful research project, performed in Jonathan Boreyko's lab at Virginia Tech, focused on infusing vegetable oil into food-grade hydrocarbon plastics such as polyethylene and polypropylene, which are often used in the production of condiment bottles.

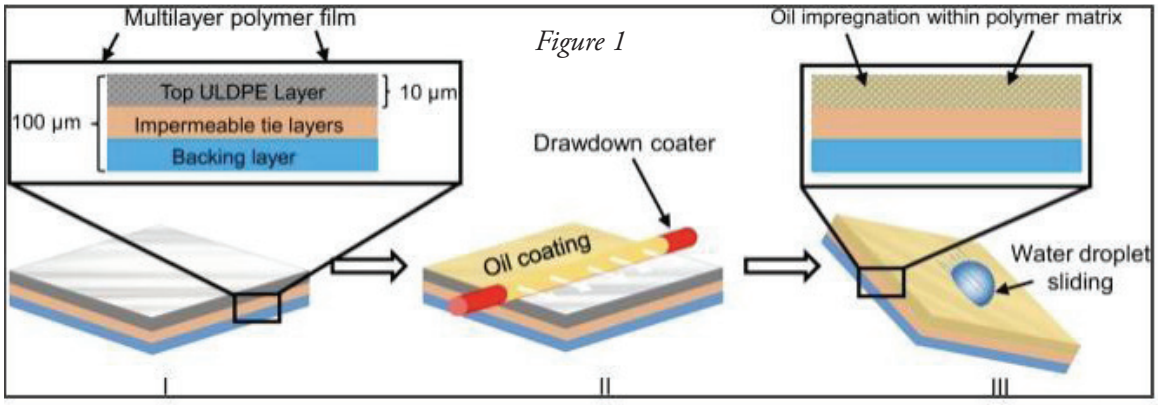

Figure 1

In contrast to scientific experiments whose results don't often have a direct effect on the general population, the discovery of oil-infused plastic will likely have a lasting impact on day-to-day life. For instance, as mentioned in Urquhart's article, the innovation will likely be applied to condiment bottles and other food containers to decrease food waste as well as the general frustration that comes from that last bit of sauce that is so unwilling to be separated from its container. Furthermore, the article presented the idea of utilizing this technology as "anti-fouling" surfaces in hospitals and other medical centers, something that is especially relevant amid the current pandemic. Applying the discovery to surfaces in science laboratories and medical centers can help decrease the transmission of bacteria due to the fact that, according to Ranit Mukherjee, "bacteria...has a hard time adhering to a lubricated surface". The microbes would likely slip off the surface before they could contaminate anyone or anything, effectively preventing the spread of harmful bacteria. Another implementation of "oil-infused plastic" could be for entertainment purposes. As a departure from traditional ice or roller skating, a company in the industry could potentially design a rink using the oil-infused plastic as the floor and a layer of liquid on the bottom of a specially made shoe. Once on the rink, people could "skate" around, and perhaps the NHL would even use the rinks for a new sport: "slide hockey".

Figure 2

In the coming years, it can be expected that the developers of oil-infused plastic will come up with a plethora of ingenious uses for this invention. Although they may seem unimportant, such as ensuring that the last drop of a condiment will slip out of a bottle, the concept of "anti-fouling surfaces" and other similarly useful inventions will hopefully play key roles in the future and help save lives around the world.

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RAPID AGING DISEASE - HUTCHINSON-GILFORD PROGERIA SYNDROME

Mikaella Inzlicht, 9th Grade

Progeria is very rare but the cause of it is not very complicated or a rare occurrence.

As people get older, men and women alike try to stop the aging process by any means possible. Many dye their hair, exercise, or even undergo plastic surgery. In typical aging, people live a full life before they face these challenges. Unfortunately, there is a condition in which a person can age, from baby to old person all in a fraction of the normal time. Progeria is a rapid aging disease. There are many manifestations of this disease, for example, Hutchinson-Gilford Progeria Syndrome (HGPS) which happens in early childhood and teenage years. Werner Syndrome is slightly different; it is adult progeria and the aging starts later than HGPS. Hallerman-Streiff-François Syndrome is a combination of progeria and dwarfism in addition to other features of abnormal growth. They are all severe but begin and worsen at different times. (britannica.com)

Progeria is very rare but the cause of it is not very complicated or a rare occurrence. One in every 4 to 8 million babies have Hutchinson-Gilford Progeria Syndrome which means less than 400 children in the world have it. The disease happens when there is a single autosomal dominant mutation, in the genetic code of the cell. This means that if one parent has this copy of the gene mutation, even if the other parent does not, the child has a 50% chance to have that mutation and consequently, the disease. The mutation interferes with the gene that makes the protein Lamin A. Lamin A is a protein that helps hold the cell's nucleus together. Children with Progeria end up with too much faulty protein called Progerin which is similar to Lamin A but with an additional piece. Progerin gets stuck in the cell membrane and can't get new proteins from outside the cell. The cells of HGPS patients age early making the blood vessels and connective tissue stiffer. Everyone makes Progerin, and as they start to age they make more. Children with HGPS have too much Progerin and that's what makes their body age prematurely. (britannica.com)

In the first year of life, babies show no signs that they have HGPS but symptoms start to appear soon after that. There is absolutely no indication until they reach about age one or two that they might have a life-threatening disease. Children never grow bigger than the size of a five-year-old but by age 10 they look to be 60 years old. Symptoms for HGPS include baldness, loss of body fat, skin thinning, joint abnormalities, and prominence of blood vessels on the scalp. (medlineplus.gov) Very few are mentally disabled, most are very smart at a young age. Arteriosclerosis, heart disease, and other vascular disease develop and those are the causes of death for most HGPS patients. Progeria is not transmissible to the next generation because the mutation is in a somatic (body) cell. Unfortunately, life expectancy is only to age 15, but some, yet rarely do they reach age 20. (britannica.com)

There is currently only one treatment for Progeria. Before its release, there was no way to properly treat and extend life expectancy. On November 20, 2020, the FDA approved a treatment for Hutchinson-Gilford Progeria Syndrome. Zokinvy is the first and only treatment approved for Progeria. Zokinvy

Figure 1: In this picture, the progression of Progeria from age three to age nine is shown. The physical differences are evident but besides the differences from each other, just imagine a healthy child of those ages. There are immense and tragic differences.

was created by Eiger BioPharmaceuticals of Palo Alto, California. It blocks some of the Progerin being made and does not let the Progerin accumulate in the cell. It is an oral drug that has side effects like vomiting, diarrhea, and fatigue. Because of the side effects, the dosage is limited. During the clinical trial after three years of taking this drug, they saw that life was lengthened by three months but after taking it for 11 years it was lengthened by two and a half years. Because Zokinvy is a new drug and the only treatment for Progeria, the future is still a big unknown. There is not much doctors can do but they have given HGPS patients an additional two and a half years, which is huge. It is a small step and it's not enough but it will bring bigger discoveries. It is not a cure but hopefully, with more research, it will come. (Wilke, 2020)

There are other therapies that seem promising but they are still testing them out on mice. David Liu, a Harvard Chemist tried to use the standard form of CRISPR but it caused problems for the healthy genes. CRISPR cuts DNA with the Cas9 protein and stops the mutated genes. The issue is that at the same time it disables the mutated genes it frequently disables the healthy genes as well. Liu and his team modified the Cas9 protein so that instead of cutting DNA it only cuts one letter of DNA, known as base editing. Liu and his team used CRISPR base editor to make single-letter changes that caused most of the causes of Progeria. They first used it on skin cells taken from a person with HGPS then in mice with a human version of the lamin A gene. Liu thinks that with this DNA base editing, once ready for human use, and Zokinvy, the medicine mentioned above, this will be the best course of treatment. (Page, 2021)

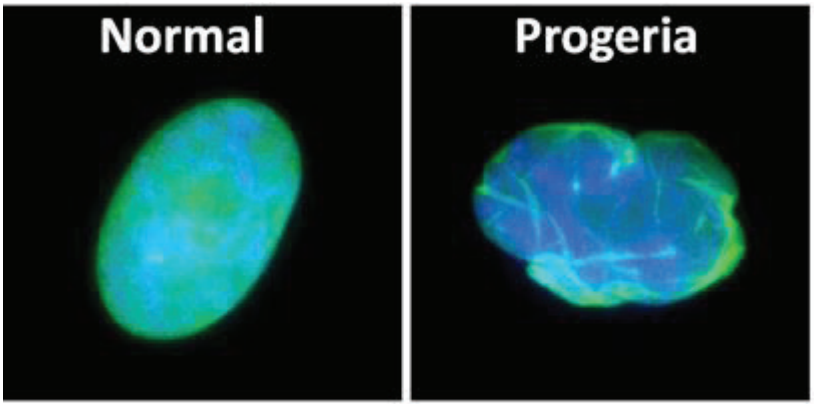

Figure 2: The first picture is what a healthy cell would look like under a microscope with a dye. Its shape has not deformed. It is in an oval shape, unlike the cell that has Progeria. The cell that has Progeria, is more circular and it has ridges. It is unclear from the picture but the nucleus and other organelles are affected too, not just the shape.

In another study on mice, it showed that mice that have Progeria have a much higher chance of dying because of starvation, malnutrition, and cachexia. What is cachexia? than actually dying because of the disease. Cachexia means weakness and wasting away of one's body due to chronic illness. They also die much faster than they are supposed to with the illness. Scientists have also figured out that if mice who have Progeria go on a high-fat diet (HFD) their lifespan could be doubled. To make sure that the HFD actually worked they split the mice into three groups: RC (Regular Chow, meaning a regular diet), HPD (high protein diet), and HFD. After monitoring the mice, it was clear that the RC and HPD did not do anything to help the mice grow bigger and live longer. They only grew to a mass of 18.2 and 17.8 grams and they would decline after it would reach the peak. The mice that were fed a HFD grew to 20.3 grams, 14% larger than the RC-fed mice. This indicated that the HFD increased both the size of the mouse and its life span. The effect of the HFD on life span was pronounced. RC-fed and HPD-fed mice lived to at most 120 days. The HFD fed mice on the other hand lived to nearly 200 days, 193 days on average. This is not a cure but it is a more natural way to try to help prolong the lives of people with Progeria without the harmful side effects that usually come with pharmaceuticals (Kreienkamp, 2019).

Researching Hutchison-Gulifrod Progeria syndrome may seem pointless but in fact, it is very important. Even though there are less than 400 children in the world who are suffering from Progeria, it is still vital to find a cure. Just because they are a minority does not mean we can forget about them and let them suffer. Besides, even though it is very rare there could be a major increase in cases of Progeria and we need to be prepared. Learning about it might lead to inadvertent discovery and could help more of the population and other conditions. By looking into the roots of this disease which is gene mutation scientists might be able to find a way to stop genes from mutating and therefore preventing diseases like Down Syndrome, Cystic Fibrosis, and Sickle Cell Anemia. So many diseases including Progeria are caused by single-gene mutations and if there is a way to stop or prevent that it will save so many lives. By doing research you may save more lives than people first imagined. (britannica.com)

COVID-19 and Progeria seem like they don't have anything in common. But they actually have similarities that teach us very important lessons and open our eyes to things that we might not think about. Because of COVID I now have an appreciation for people's faces even more than before. Since everyone has to wear a mask it is harder to see people's facial expressions making it harder to fully understand what people are saying. You hear their voice even though it could be muffled but you don't see what they are feeling or saying because half their face is hidden. It is hard to truly get to know a person behind a mask because a very prominent component is being blocked. Children who have HGPS are masked by their condition. The external old age and internal aging of their internal organs mask these victims' true age and feelings. It was hard to see young children looking older than their grandparents. These children are trapped in a body the size of a five-year-old but they look like they are 80. As much progeria is hurting the body it is also hurting the heart.

Progeria is a horrible disease that people need to be aware of. Perhaps learning about aging abnormalities will help us to understand normal aging processes, and help people live longer, healthier, and active lives.

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GENETIC SUSCEPTIBILITY TO INFECTIOUS DISEASES

Yehudis Kundin, 9th Grade

A new theory that evolved after the germ theory was the ecological theory. This theory explains that the variability in symptoms caused by infectious diseases is due to the conditions and place a person is in (Casanova & Abel, 2021).

Infectious diseases have been killing approximately half of the human population under the age of 15 for around 200,000 years up until the late 19th century (Casanova & Abel, 2021). The course of infectious disease as it travels through the population, and the variation in symptoms and outcomes, has always been a big mystery. Pre-modern superstitious explanations included divine retribution, an imbalance of Hippocrates' four humours, or noxious miasmas (poisonous emanations from putrefying dead plant and animal matter) (Singh, 2016). In the late 19th century, several more theories were proposed to understand this enigma and create a cure.

In around 1868, the first scientific theory, the germ theory, was proposed (Genet, 2016). It attributed infections to microbes that can spread. Following the establishment of this theory, hygiene improved tremendously, increasing the average life expectancy from 20 to 80 years (Casanova & Abel, 2021). Although hygiene, vaccines, and drugs decreased total deaths from infectious diseases, deaths from these diseases continue worldwide. The germ theory was a start, but still more had to be discovered. Vaccines reduce a large number of diseases in the population, but there are still some problems concerning their effectiveness. They have been unsuccessful in a variety of diseases such as tuberculosis and malaria (Casanova & Abel). In addition, drugs naturally kill the weaker microbes and leave the more resistant ones (natural selection), thus causing drug-resistant diseases such as Mycobacterium Tuberculosis to increase.

Furthermore, new infections are constantly emerging. This is plainly seen by recent pandemics such as Coronavirus, the Ebola virus, and the constantly evolving influenza virus (Casanova & Abel, 2021). Although death from infectious diseases is rare in developed countries, globally it is more common, and it is therefore still of great importance to find the root cause and restore health.

A new theory that evolved after the germ theory was the ecological theory. This theory explains that the variability in symptoms caused by infectious diseases is due to the conditions and place a person is in (Casanova & Abel, 2021). For example, there are diseases known as vector-borne diseases which are transmitted by blood-feeding arthropods such as mosquitos. Living in an environment with many of such insects can lead to vector-borne diseases such as malaria, Dengue fever, and Lyme disease. This is an analogy to the seed/soil conundrum, where the microbe is the "seed" and the environment is the "soil." Two identical seeds can be planted but one will grow and thrive and the other will wither and die. The difference in outcome is due to the environment.

In 1882, a third theory, the immunological theory, was created, explaining that individuals who were previously infected with less virulent or smaller amounts of the same microbe, will be immunized to this microbe that can kill other individuals when infected (Genet, 2016). This is the idea behind vaccines; giving a small dose of the microbe immunizes the individual to a certain infectious disease. This was an important discovery, but more work on the topic showed that despite how virulent the microbes are, there is still great variability in reactions to the disease. Several individuals die while oth-

ers are completely asymptomatic (Genet). This theory can account for the reactivation of diseases and secondary infections, which occur during or after treatment for a different infection, but it still cannot fully account for interindividual variability within primary infections.

The fourth theory is the genetic theory of infectious diseases that was put forward in 1920. This most recent theory explains that the clinical variability of infectious diseases can be partly due to the genetic background of the host (Casanova & Abel, 2021). This is a novel concept because infectious diseases were always thought of as diseases that are passed from person to person, and not heritable. There are certainly some genetic diseases, such as sickle cell anemia, which are heritable and not contagious, but this theory suggests that infectious diseases, which are generally passed from person to person, also have a genetic and heritable component. Inherited mutations and defects in genes can confer susceptibility or resistance to certain infectious diseases (Hill, 2012). Although other factors can confer predisposition, such as acquired immunodeficiencies (by immunosuppressive drugs or by the actual microbe) or severe conditions (like malnutrition), these are rare cases in the developed world and are not usually seen in patients with infectious diseases (Casanova & Abel).

Louis Pasteur, a chemist and microbiologist in the 1800s, proved this concept of genetic susceptibility with silkworms. He found that flacherie, a disease silkworms get when eating infected or contaminated mulberry leaves, was "inherited" from parent to offspring in the sense that the predisposition was passed down and not the actual disease itself. An example of how genetics impacts susceptibility or resistance to infectious diseases in humans is the discovery of the heterozygous genotype for sickle cell anemia (which is a heritable, loss-of-function mutation, and a non-infectious disease) possessing resistance to malaria (a non-heritable infectious disease). Although malaria is infectious, there is a gene that can account for a level of susceptibility. In another example, a deletion in the CCR5 Co-receptor gene showed a reduced risk for HIV infection, which is an infectious disease. In addition to such discoveries, twin studies were performed, aiming to compare the infection rate between fraternal and identical twins. More similar rates of infection were found in identical twins when comparing diseases such as

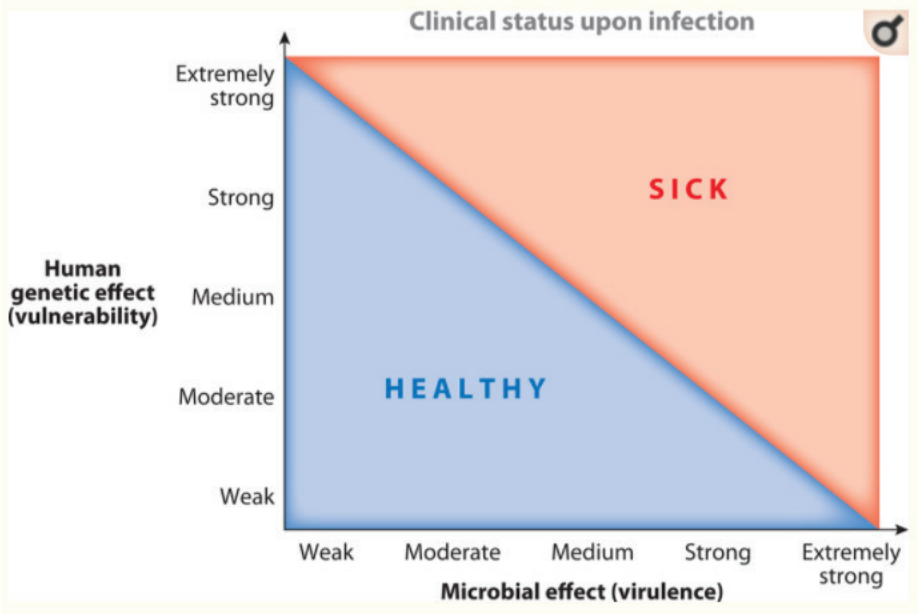

Figure 1: This graphic illustrates interplay between microbial virulence and genetics, and its effect on the health outcome.

tuberculosis, chronic hepatitis B, leprosy, and others, thus confirming that susceptibility and resistance to infectious diseases indeed has a genetic component (Hill, 2012).

Once the genetic theory was firmly established, many methods were used to find the genetic locus of a given variation that is causing susceptibility to a given infectious disease. In animal studies, researchers would create and breed knock-out mouse strains. They methodically "knocked out'' certain genes in the mouse by purposefully mutating that gene so it doesn't carry out its function. Through this, they were able to determine which genes affected the susceptibility of the mouse to specific infectious diseases. However, once researchers found out which genes in the mouse were responsible for susceptibility to a specific disease, it was very difficult to extrapolate those findings to humans. Despite the similarity between mice and humans, oftentimes the genes do not correlate. After receiving disappointing results, researchers started comparing genetic mapping of families with multiple cases. They compared the genes of family members who all had a particular infectious disease to identify the gene they all had in common that was the cause of their susceptibility to that disease. Although this seems like an intelligent path to take, due to the fact that there is indeed a heritable component to infectious diseases according to the genetic theory, the inheritance pattern for susceptibility to infectious diseases isn't so strong, unlike autoimmune diseases (diseases of the immune system) where the inheritance pattern is very clear (Hill, 2012).

With the advancement of technology, genome-wide association studies (GWAS) and next-generation sequencing techniques came down in cost and ease. Therefore, these methods started being used to try to solve the puzzle of the genetic architecture of infectious diseases. GWAS looks at an entire genome, as opposed to studying every single nucleotide, to try to find the genetic variation that is behind susceptibility to a certain disease and its locus. Because GWAS looks at the whole genome, large groups of the population can be tested quickly and easily. However, although it can identify common variants that are seen often in genomes, it cannot identify the exact loci of the mutations. In addition, it can not detect smaller and rare mutations because of its broad overlook of the genome and its lack of detecting specific detail. Next-generation sequencing, also a technological technique, is very similar to GWAS, except that it looks at genes more closely and is able to identify smaller mutations. It can also locate the exact genetic loci of mutations so those mutations can then be characterized and sequenced, offering a greater opportunity for therapeutic intervention (Hill, 2012). Phenome-wide association studies (PheWAS) aimed to study genes and look for associations with many phenotypes, as opposed to looking for just the effect on one disease (Genet, 2020). Whole-exome sequencing (WES), a technique used to sequence protein-coding regions of genes in a genome known as an exome, studies the effects of rare, large-effect variants in individuals' genes (Genet).

Life-threatening primary infections were found to be caused by monogenic (single-gene) inborn errors of immunity, or by multiple mutations. The many views on the cause of genetic susceptibility to infectious diseases were categorized into three competing hypotheses. The first hypothesis states that the predisposition to these diseases is caused by a common variant in the gene; a variant that's prevalent in the population. The second hypothesis proposes that rare, monogenic variants in the genome with high penetrance (expressed strongly among the population) account for the susceptibility. The third hypothesis claims that the susceptibility can be attributed to several rare mutations of low penetrance. GWASs done to identify the genes responsible for susceptibility and their loci are based on the first hypothesis, as they can only detect common variants that can be clearly seen; they can't detect the rare mutations that are said to be the cause for susceptibility by the second and third hypotheses. Although this first hypothesis has its competitors, it must be noted that GWAS has had some, albeit limited, success. Probably one of their most important discoveries was the discovery of the gene underlying susceptibility to leprosy. Next-generation sequencing, which has the ability to identify these small, rare variants, is a technique that can be used to find genes based on the second and third hypotheses,

which both attribute susceptibility to rare mutations (Hill, 2012).

In addition to finding a correlation between genes and predisposition to diseases, geneticists have found that genetics also affect vaccine responses. It has been shown that inborn errors of immunity can result in life-threatening disease following live weakened vaccines such as poliovirus vaccine, while defects in immunity can result in severe illness succeeding the yellow fever vaccine (Genet, 2020).

Finding mutations such as gain-of-function mutations (GOF) or loss-of-function mutations (LOF) leading to infectious disease predisposition gives an opportunity for more precise medications. A GOF mutation is a mutation where the gene gains a function, whereas an LOF mutation is a mutation where a gene loses a function (Genet, 2020). WES found that LOF variants in IFIH1 affect susceptibility to common respiratory viruses (Genet). (Patients with heterozygous GOF mutations in a certain gene who have a fungal and viral infection can be treated with therapeutic suppression of that gene by a specific medicine. Influenza virus pneumonia may arise due to inborn errors of immunity involving the genes IRF9 and TLR3 deficiencies, while some alleles were found to protect against norovirus and HIV (Genet). Knowing which genes confer the susceptibility to certain infectious diseases and their exact location allows for the development of drugs and vaccines to prevent that disease (Genet). In addition, by the use of various screening techniques, people's genes can be sequenced. Knowing which gene gives

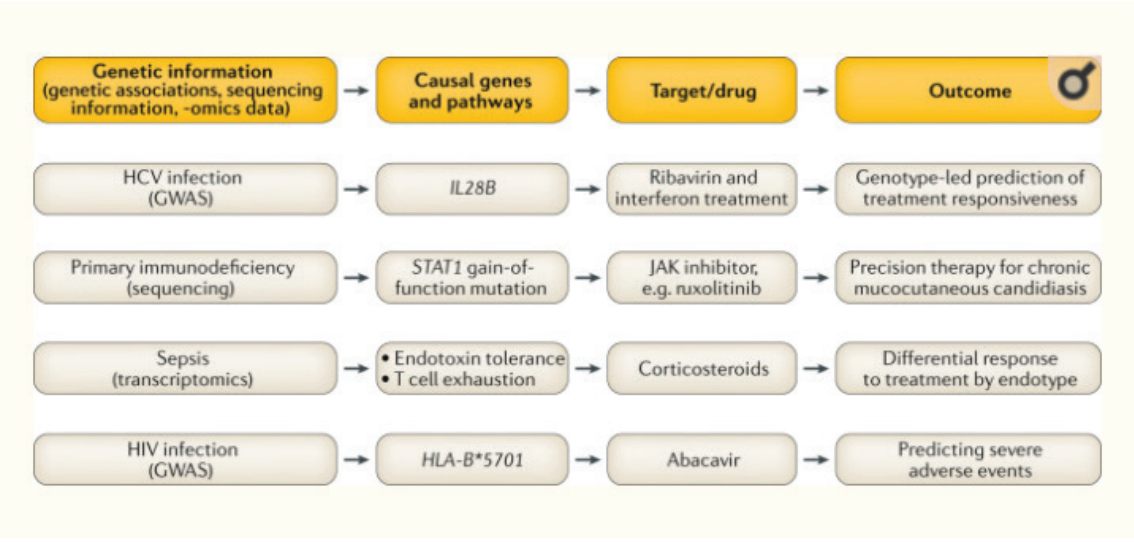

Figure 2: As science progresses and more technology is available for scientific use, more predisposing genes are being found for different infectious diseases. This opens up a bright future in the genetic and microbiological fields. Knowing the genes that confer susceptibility to a certain infectious disease highlights what type of medication must be used and who it should be given to. Above are examples of some causal genes for certain diseases and the drug that can be given to target that disease.

susceptibility to a specific infectious disease can identify the individuals who are more susceptible to that disease. Then, therapeutic intervention can be targeted specifically towards these high-risk individuals, as opposed to attempting to cover the entire population (Hill, 2012).

Currently, the world is dealing with a major global pandemic: SARS-CoV-2. Just like many other infectious diseases, a large variety in clinical outcomes from the disease is seen. Many people have gotten it and remained completely asymptomatic and healthy, while others have died from it. The cause

of this variability can certainly be due to genetic susceptibility. The COVID Human Genetic Effort found that inborn errors of type 1 interferon immunity increased the risk of respiratory diseases (Genet, 2020). Interferons are proteins that trigger immune cells to fight off invading cells. Type 1 interferons were found to be of great importance in protection against COVID-19, so this error would correlate to severe symptoms of this disease (Immunol, 2020). Interestingly, it has been found that the severity of respiratory diseases, including COVID-19, varies depending on the expression of inflammation following infection with a respiratory virus. Therefore, it may be due to susceptibility to inflammation that causes such a high risk of death in certain individuals. This, of course, is most likely due to mutations in their genes. Knowing this, these high-risk patients can be treated with targeted anti-inflammatory treatments to prevent further sickness post-infection (Immunol, 2020). This example clearly shows how crucial this field can be when trying to find cures for deadly infectious diseases, especially for global pandemics which affect so much of the human population.

While much has been discovered lately about the effect genetics have on how people respond to infectious diseases, further work is necessary. Many more infectious diseases have to be studied to find the causal gene for susceptibility. In addition, an important unanswered question has arisen: if susceptibility depends on genetics, why specifically do children and young adults usually remain asymptomatic to COVID-19? It was reported that the death rate from the novel coronavirus is <0.01% for children ages 0 to 9 to >20% for those over 80. This can be due to high virulence, environmental conditions, or even somatic transformations that can occur in cells because of the patient's infectious history (Immunol, 2020). However, genetic theory seems to be the most logical answer. Variability in the reactions to COVID-19 can be caused by monogenic disorders that confer susceptibility to it (Immunol, 2020). If so, however, why isn't there a similar fatality rate in adults, who can also possibly have these disorders? Perhaps this can be attributed to the fact that as a person ages, random mutations accumulate in the genes that confer a predisposition to the disease. This is one hypothesis; however, this area still needs investigation.

With all the information geneticists have now, the next step is to bring it all together and start gene-sequencing many people's DNA (Genet, 2020). After that, different technology-based techniques can be used to figure out the mutations that are causing a specific disease, and with that, therapeutic intervention can be targeted specifically to treat their condition (Hill, 2012). Bringing light to this topic can decrease the rate of death from infectious diseases tremendously in the near future, and improve the lives of many people worldwide.

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SNAKE VENOM

Tzivya Mendelovitz, 9th Grade

Giving a patient an unnecessary antivenom can cause death. Deciding which of the many antivenoms to use can also be extremely time-consuming because the antivenom has to match its venom target almost perfectly.

Figure 1: This gruesome picture is the leg of an African farmer who was bitten by a poisonous rattlesnake. He sold his whole farm, and property just to get medical treatment, and still couldn't afford the proper antivenom treatment that would have cured him. His leg will probably have to be amputated in the near future if it doesn't quickly heal properly. As the breadwinner of his family this is extremely detrimental to his family's already poor finance. This same situation is happening to people around the world (especially in third world countries) and here's why.

Every year about 2.7 million people throughout the world are bitten by venomous snakes. Snakebites are a neglected disease that is majorly affecting the abandoned segments of society. In the western world, snakebites are very rare and seldom fatal, this is true even in Australia which is a country known for its venomous snakes. But in places like sub-Saharan Africa and India snakebite victims are many. About 27,000 people are bitten yearly in sub-Saharan Africa resulting in 12,300 deaths. And while snake bites won't always result in death it has resulted in over 55,000 cases of PTSD (post-traumatic stress disorder) and 14,700 amputations. In India (and other snake bite hot spots) there are about 2 million snakebites a year that need clinical treatment. The reason snakebites are so horrible (besides the obvious effects of death, amputation, paralysis, bruising, and more) they have especially horrible effects because the victims are usually the breadwinners of the house. In countries like Africa where the poverty level is extremely high, the money makers of the families must be functional so they can at least earn a bit of money for their families but snakebites can stop this and not just hurt the bite victim but his family too. So what is being done to solve this problem? (Wilcox, 2020)

The most common solution to the "snakebite disease" is antivenoms. Antivenoms are considered the gold standard of care because if a victim is treated with them the survival chances are very, very high. Antivenoms are made from the venom of snakes themselves by scientists who breed snakes. When they deem the snakes useful, the snakes' glands will be milked for venom and then stored and cooled for a while below -20°C. Take note that the snakes only produce a certain amount of venom from this milking process and it can take 69,000 milkings to produce one pint of venom. Next, the venom is diluted with water or another solution so the animal that is injected in can survive it. After this, the venom is injected into an animal (almost always a horse because they thrive in many environments and have a large body mass). The horse will then (hopefully) fight off the venom and produce antibodies to the venom in its blood. After about 8 to 10 weeks the antibodies are made in the horse and about 3 to 6 liters of blood are taken out of it. Next, the ejected blood is purified so there are no unnecessary

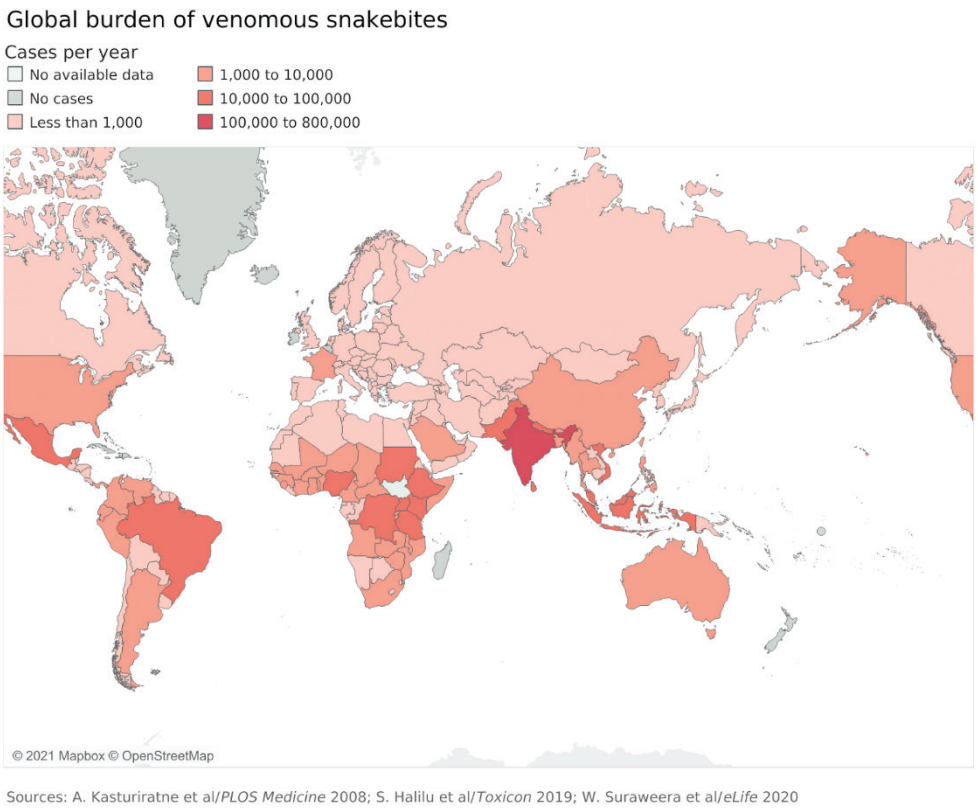

Figure 2: This map shows the snake bite cases per year. Countries like Mexico, India, and the democratic Republic of Congo in the darker red areas are redder because they have many more cases a year, and countries like the U.S., Canada, and the United Kingdom are in lighter areas because they are affected much less by snakebites yearly. You can clearly see how the worst affected countries are the poorer ones, which adds to the problem.

proteins inside of it, and then finally the active elements of the blood that will work against the venom will be filtered out so they are ready for use. This process is not an easy one, and while it's a detailed and cared for process this "gold standard" of care has many problems. (Puiu, 2021)

With antivenoms, you can truly say time is of the essence for a few reasons. There are about 600 venomous snake species that have been discovered (there may be more) and each one venom is its cocktail of ingredients. This means that quite a few antivenoms will have to be injected into the body until one or more are effective against that specific group of venoms but this is a big problem. As the snake venom runs through the body, its mix of proteins and other molecules that make up the venom will ruin the body. As time goes on the venom will destroy more and more tissue throughout the body and by the time antibodies are produced by the immune system it may be too late (If the venom gets too enough tissue it can cause physical damage such as intense bruising, swelling, tearing, bleeding and more, and it can also cause internal damage like severe paralysis). The same with antivenoms, if they don't get there on time the body can be destroyed. (Wilcox, 2020)

But fast delivery doesn't always happen for several reasons. As mentioned before the most affected areas by snakebites are often low-income places such as third world countries. Therefore the medical centers and hospitals don't always have the money and resources to store antivenoms because they must be refrigerated. They might also not have the medical experience in staff who know how to administer

Figure 3: Here the first step of antivenom making is shown; the snake is being milked for its venom, which will then be injected into the designated animal (usually a horse) for the next steps of this complex process.

the drugs and monitor the patient for side effects (which antivenoms can cause). Therefore snakebite victims will have to be sent to hospitals far away with the right resources to administer the antivenom which can take a lot of time. If the patient survives the trip to the correct medical center there are then further complications that mess with the timing there. The doctors must wait until they're completely certain a patient needs antivenom before giving it to them because a lot of snakebites are dry and don't have venom in them. (Wilcox, 2020)

Giving a patient an unnecessary antivenom can cause death. Deciding which of the many antivenoms to use can also be extremely time-consuming because the antivenom has to match its venom target almost perfectly. Because each venom is its mix of proteins and molecules a specific mix of antivenom is needed for that toxin so it can be neutralized. Because injecting patients with unnecessary antivenom can just worsen a patient's condition, the doctors have to wait for clear signs in the injury of which specific venom was injected because patients rarely know what snake species they were bitten by. Waiting for these symptoms to emerge and defining them can take time which as said before is a very big issue. (Wilcox, 2020)

Besides the timing issue, there's another big problem with antivenoms. The process of creating antivenoms is a detailed and grueling process which makes them extremely expensive. One vial can cost anywhere between 1,500 to 22,000 dollars for just one vial! And because the venom is a mix of proteins sometimes there are at least 25 vials of antivenom needed. Now that equals a lot of money! Besides the obvious fact that a lot of money is needed to acquire the antivenoms, the places that are most affected by snake venoms are some of the poorest countries in the world. Farmers have had to sell their land, herds, and sometimes their entire income just to get antivenom. Most times snakebites will just go untreated because the people affected are just too poor to pay for treatment. Besides having to pay for the actual antivenom there's also the added payment to the hospitals, other drugs, and doctors that just add to the already large bill. (Wilcox, 2020)

Because there are many problems with antivenoms, other options are being made to substitute them. One highly recommended option is replacing the animal antivenoms with human ones. Scientists are experimenting with human antibody genes. They are putting them in bacteria-infected viruses which the antibodies fight and build up into shells. Quite a few human antibody genes are already known so all these antibodies can be put in different viruses to be tested to see which ones can actually be bound to toxins to neutralize them. After testing scientists discovered an antibody that protected human cells from over 12 toxin mixes of 3 cobra species. Having one antibody that kills a dozen toxins can be super helpful because it can neutralize more toxins at once, which helps with the time issue, and it also helps with the money issue because a person won't have to pay as much for several vials of antivenoms because there's a human antibody that can cure several of them at once. The actual antivenom is also cheaper to produce because it's produced like insulin in large fermentation tanks en masse which makes it cheaper because it's produced in bulk and takes less time. (Wilcox, 2020)

Another approach to the antivenom crisis is a pill for snake bites. The aim of this pill isn't to completely neutralize the venom, rather it solves the time issue of antivenoms by slowing down the harsher venom effects until the patient can get proper treatment. Currently, the focus of this project

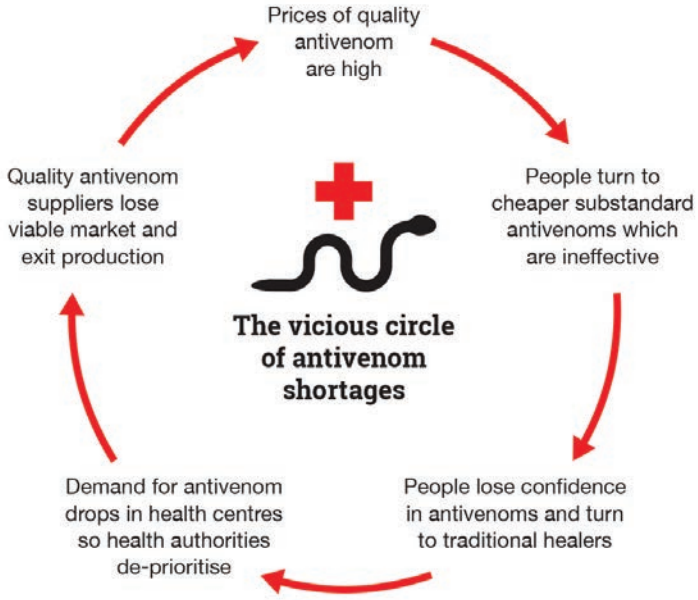

Figure 4: This flowchart shows the "vicious circle of antivenom shortages". All these reasons are why obtaining antivenom is so hard even though plenty of people throughout the world need it. Because of the problems shown above (and more), scientists are trying to find alternative ways to cure the snakebites to avoid these problems.

is on metalloproteinases which are toxins that destroy proteins in the venom which are major players in destroying the tissue. Some drugs (like heavy metal poisoning drugs) that are currently on the market are being bound to the metal ions the proteinases need to slow the venoms spreading. When this was tested by combining heavy metal poisoning drugs and a drug with toxins that destroys fats the drug produced proved to be extremely successful when tested on animals. When combined the drug neutralized venoms of 5 snake species from all around the world. Another combination of drugs (PLA2 inhibitor varespladib and metalloproteinase) saved mice from 5 different cobra species venom and it even worked 15 minutes after the mouse was bitten! Although this pill can't fully replace antivenoms it helps with the major factor in the antivenom problem concerning time. It also may lead to the solution of geographic fragmentation (each venom needs its antivenom) because one small pill showed it can cure 5 snake species venom at once. As bonus pills don't have to be refrigerated so once this study is concluded and the pills are fully formed it will be very helpful to poor countries that don't have the resources for refrigeration. The pill hasn't been fully developed yet but hopefully, it will be soon because it will solve a lot of issues. (Wilcox, 2020))

This next approach to replacing antivenoms is definitely unique. Professors Shih-Hui Lee and Kenneth Shea have come up with the idea of designing carbon polymers (essentially plastic nanoparticles) to bind to certain proteins in toxins that could act as antibodies. This idea first started when Shea injected mice with lethal doses of melittin (bee venom). He then gave an injection with a polymer he previously created to some mice. After observing, Shea saw that when the polymer got close enough to a toxin it was able to bind up most of the toxin which saved the mice. When he published this idea he was able to recruit Lee to his project as well as (snake expert) Jose Maria Gutierrez. Together they were able to create polymers that neutralized phospholipase A2s (a protein found in many snake toxins). This polymer proved extremely effective and was able to save mice from cobra venom by preventing skin tissue death. Although it has been proven to be effective on animals the polymer still has to be able to be transferred into injectable devices (like EpiPens) so it can be used on humans. Currently, the polymer particles are too big to be put in these devices, so they must be a smaller size to fit into injection. They also have to be downsized so they can travel from they were injected to the muscle surrounding the affected body part. But there's another problem with this idea. Because it's so out of the box and unheard to use plastic as a drug (even though it's been tested on animals and proved positive) it's hard to believe something like this could work. Therefore it's been extremely hard to find the necessary funds for this project. (Wilcox, 2020)

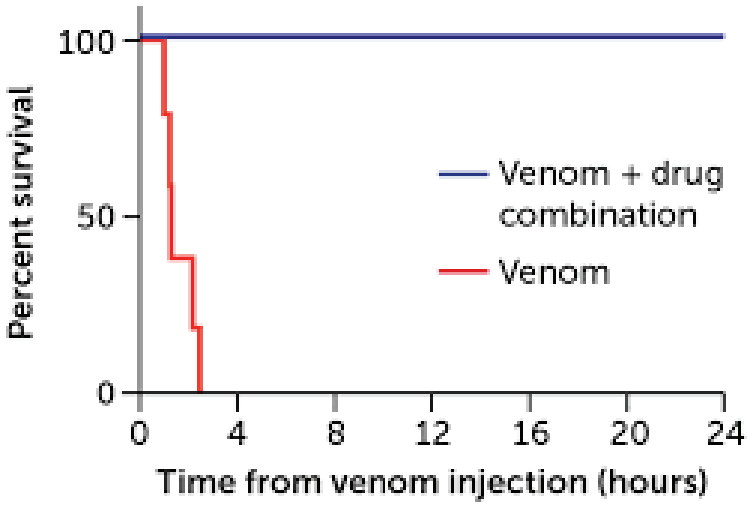

Figure 5: This graph shows the survival rate of the mice injected with the PLA2 inhibitor varespladib and metalloproteinase pill after being injected with venom (blue line) and the survival rate of the mice injected only with venom (red line). The red line quickly drops as the mice did not survive for long. On the other hand the blue line keeps at a steady rate of a 100% survival rate even after 24 minutes!

Besides for these approaches, there have been other approaches that scientists are currently working on to help lower or maybe even eradicate the antivenom problem. One example is a lab hoping to create DNA molecules that act as aptamers, this needs defining. mimicking antibodies. Another (pretty unconventional) approach is turned to opossums. Because opossums are naturally immune to spider venom, scientists are studying that immunity and what causes it. They believe once they find a solution to this they can translate the immunity into other drugs that can neutralize toxins in humans as well. This idea (and others) are unique and can maybe be proven successful but of course, they all need the necessary funding first. (Wilcox, 2020)

Science is working harder and harder to fight the "neglected disease" of snakebites every day, and maybe soon a cure-all solution can replace antivenoms and their dangers.

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MAKING UP YOUR MIND

Ariella Paneth, 9th Grade

Theories show that sets of emotions exist universally, like sadness, happiness, fear, anger, disgust, etc. But as people mature, they develop more complex emotions like shame, embarrassment, guilt, or contempt. The hypothesis shows that these single emotions can be rated on a scale to either a definable extent or absent.

Subliminal Advertising is a way of transmitting messages below the threshold of consciousness, to create emotions or mood changes without the knowledge of the subject of their source. Subliminal advertising first went into use in 1943, embedded in an animated short film called Daffy Duck. The words "BUY BONDS" would flash on the screen for a fraction of a second. In the year 1957, a market researcher by the name of James Vicary claimed that sales of popcorn and Coca-Cola would increase by briefly flashing the words "Eat Popcorn" and "Drink Coca-Cola" in a movie theater. He later on admitted that he faked the study, but by that time the public grew extremely concerned about the manipulative power of these messages. In the early 2000s, researchers claimed that subliminal advertisements are effective, just a lot subtler than what was previously thought. Between the years 2010 and 2015 it was discovered that subliminal messages do have a large effect on the way people think and behave (Stern,

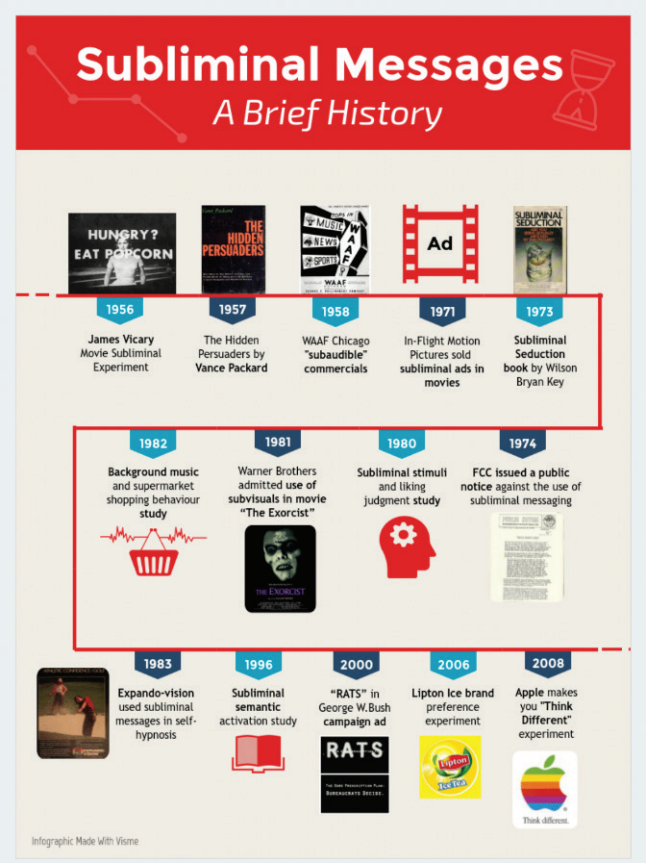

Figure 1: This figure illustrates the history of subliminal advertising, from 1956 to 2008. We can see the evolution of subliminal advertising, and how it has been integrated into our daily lives from planting messages in books, the kinds of music played in the background of supermarkets, to the slogans of certain companies such as Apple's "Think Different".

Figure 2: words that flashed in a movie theater in 1957, a fake study that was done by James Vicary.

2015).

When an advertisement successfully appeals to a viewer, activity of a brain structure called the nucleus accumbens accelerates. This small portion of the brain is specifically a center for self-reward and pleasure. For example, when seeing appealing foods or luxurious cars, our bodies will release a signaling molecule called dopamine and endogenous opiates which are caused by pleasure and lust. Accelerated activity in the nucleus accumbens usually occurs when viewing something necessary for survival, so why would activity accelerate from viewing luxury? Smart marketing makes viewers have a strong desire for the advertised item, which is translated by our brains as a necessity for survival. Sales will substantially increase because people will think they cannot live without the item. (Schäfer, 2005)

An optimal way to measure the effectiveness of the subliminal aspect of advertisements is to rate the ad using a single number that describes its general performance. However, this is quite impractical because no number would be able to include all aspects of the emotions triggered by the advertisement. The emotion evoked through the advertisement is very important because it can influence many aspects of our lives such as perception, memory, decision making, beliefs and values, and attention. All of this is highly impactful on how the consumers communicate. But no single method can capture every aspect of the emotional responses.

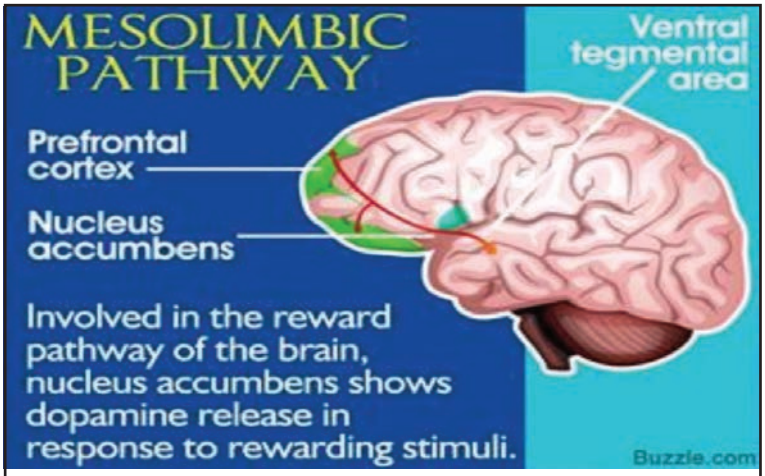

Figure 3: This figure shows the location of nucleus accumbens the part of our brains that process subliminal messages.

Theories show that sets of emotions exist universally, like sadness, happiness, fear, anger, disgust, etc. But as people mature, they develop more complex emotions like shame, embarrassment, guilt, or contempt. The hypothesis shows that these single emotions can be rated on a scale to either a definable extent or absent. They are put into two categories: valence, which according to Merriam

Webster's dictionary is defined as "relative capacity to unite, react, or interact (as with antigens or a biological substrate)" and arousal, which means "a state of physiological and psychological excitation" - either pleasure or displeasure and to what extent. It's also important that the emotion is subjective and has a personal quality, while still being observable by others.

To measure the emotions of the subject involves asking the subject how they feel explicitly after watching or listening to an advertisement, and rating it on a scale. One example of rating scales is PANAS- Positive and Negative Affect Schedule- where the subject is told to write down 10 positive and 10 negative emotions they had. But there are problems with methods like these. First, the rating could be biased, based on what the subject thought of the experiment before they saw the ad. Also, the subject could have faked the answers to seem impressive. There is also a problem with not being able to introspect on the emotions accurately, or not being able to locate the feelings of the subject on an absolute scale. Arguably, better methods may be to capture physical reactions such as breathing rate and heart rate. However, this method does not show a specific pattern of emotion for each physical reaction.

The most optimal method to rate valence and arousal is with Automatic evaluations. These emotions usually occur subconsciously, and plant seeds of emotional responses that are dependent on the subject's strength, motivation, duration, and many similar factors. IMPULSE is a test that measures specific bipolar emotions or feelings, such as joy vs. sadness. The automaticity of an evaluation can reflect on its biological importance, and social importance. Automatic evaluations can provide insight into the effectiveness of an advertising campaign in terms of how it is perceived for the positive, how memorable it ends up being, and how it takes an effect on the behavior of the viewer with their decisions in making purchases.

The experiment: The test consists of two phases--the control phase, and the experimental phase. During the control phase, the reaction time task was presented with an emotionally neutral film, and in the experimental phase, the movie was presented. In both phases, 30 words were presented and needed to be rated as either one feeling or its opposite. Words were sent out one every two seconds. The hypothesis was that the words congruent with the emotion of the clip would be detected more quickly than the incoherent words.

The first experiment was designed to detect simple emotions. 4 IMPULSE tests were created according to the 4 64-second video clips prepared- one for each bipolar emotion. One joy, a second fear, a third measuring disgust, and the fourth surprise. If the hypothesis was true, IMPULSE should provide accurate measures in response to the highly emotionally charged stimulus. 190 participants were chosen who were over 18, natively spoken English, and had normal vision.

The clip to evoke joy was called *'The Best Surprise Military Homecomings: Part Three'* and consisted of military personnel returning home to their loved ones (3). The scene chosen to evoke disgust was *'Trainspotting.'* The scene chosen to evoke fear was a scene from the movie *Silent Hill* (4). The scene chosen to evoke surprise was a commercial for the launch of a TV channel in which there was a surprise when a man pressed a button on a quiet street called 'push to add drama' (5). For the tests, they devised long lists of emotion words and asked a panel of 12 non-psychologists to mark off the words which they associated with each emotion (and their opposites). They selected the best eight words (and their opposites) for each emotion.

The results showed that overall 3 out of the 4 clips had an expected reaction. They felt joy at the joy clip, fear at the fear clip, and disgust at the disgusting clip. However, the subjects did not feel surprised at the surprise clip. Theories of why the surprise film might not have elicited surprise are either that the film wasn't a good choice for this category, or the word choice was not the best or the emotion of surprise is fleeting, and it was hard to capture. Further research would be needed to determine this

hypothesis.

The second experiment consisted of participants viewing either a sad ad or a happy ad. 140 participants from the age 18 to 65 viewed either a positive clip called 'I am part of the world' or a negative clip called 'cruelty to children must stop' (70 participants viewed each). The results were as follows: IMPULSE detected a continuous negative reaction to the negative clip and a positive reaction to the positive clip.

In both experiments, IMPULSE proved its ability to detect subliminal reactions to advertisements on TV, and the radio. Automatic evaluations can provide insight into the effectiveness of an advertising campaign in terms of how it is perceived for the positive, how memorable it ends up being, and how it takes an effect on the behavior of the viewer with their decisions in making purchases. It has been proven as a reliable way to rate the creativity and effectiveness of advertisements and will be useful for marketers all over the world.

It would be interesting to see if the IMPULSE rating scale of subliminal advertising could be applied to the education arena. Imagine if a teacher could immediately gauge if the lesson was received and internalized by the students. Pedagogy could be uniquely tailored for each individual student.

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WALKING ON PINS AND NEEDLES

Bailey Schuckman, 11th Grade

Since I was a little girl, I've always been a very worried person. Any time I got overwhelmed with anxiety or worry the roof of my mouth would quiver and I didn't have an explanation as to why this happened. Upon research I began to recognize that this is a form of paresthesia resulting from high stress levels.

We've all experienced the feeling that sitting in an awkward position for a long period of time renders us too lazy to move. When we finally do make a sudden movement we get shooting pains up our hands or legs, which seems like "pins and needles". When this occurs all feeling disappears from that part of the body making it very difficult to put pressure on it. If you've ever attempted to walk with pins in needles in your foot like I have, you'll realize that it's close to impossible. Who knew that being able to feel your foot was so important? Pins and needles is scientifically known as Paresthesia. There are various circumstances under which Paresthesia can occur, many temporary and harmless while others can be symptomatic of severe illness. Paresthesia is a reaction that occurs in the Nervous System when an awkward position cuts off the nerve impulses that are trying to circulate.

The simple anatomy of the Nervous System, consists of the Central and Peripheral Nervous Systems. The Central Nervous System (CNS) focuses on interpreting, storing and transmitting information through the spinal cord and into the brain as well as instructing muscle movement. The Peripheral Nervous System (PNS) consists of sending information into the nerves throughout the body. When Paresthesia occurs, it is developed through the distribution of nerve impulses in the CNS creating a "traffic jam" and causing the nerves to squeeze and by extension to cut off the blood flow of the arteries in that area. Arteries have difficulty functioning when there's a shortage of the oxygen needed. This causes the limb to fall asleep, reducing the feeling in that area. The Nervous System then tries to compensate when it begins to wake up by becoming hyperactive and forcing extra impulses through the spinal cord when not necessarily needed. This then results in an uncomfortable sensation in the joints of that area leaving a tingling sensation known as Paresthesia. This describes the basic level of this cycle which can happen to any human being and is completely harmless. Although this is a commonality that transpires amongst healthy people, Paresthesia can also be caused by other factors in the environment or based on specific situations one may experience.

Sensory symptoms like Paresthesia increase at night time with extreme change in temperature. It is common to have shooting pains similar to what one may feel when suffering from pins and needles. The way to solve these issues is to warm one's feet if they're cold or cool them down if they're hot. In addition to a change in temperature, paresthesia can also be a symptom of high stress levels. When one is overwhelmed or extremely anxious he or she can be overtaken by tingling sensations making it difficult to manage the anxiety he or she may be feeling. In order to avoid this it is crucial to take breaks and do something that will calm you before getting to that point.

Since I was a little girl, I've always been a very worried person. Any time I got overwhelmed with anxiety or worry the roof of my mouth would quiver and I didn't have an explanation as to why this happened. Upon research I began to recognize that this is a form of paresthesia resulting from high stress levels. Another way nerves tend to compress leading to paresthesia is with a lack of movement. This is because lack of movement halts the blood flow. Someone who is constantly in a wheelchair is

likely to have constant feelings of pins and needles due to little movement. Therefor,e it is important to be active and constantly allow the blood to flow properly. If one does experience paresthesia, it will likely be a common sensation that a majority of the population feels rather than a fatal illness.

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SHAKING HANDS IN FOREIGN LANDS: CAN MICROORGANISMS SURVIVE IN SPACE

Golda Schuster, 11th Grade

While the survivability of microorganisms in space has been tested numerous times, a lot of research still needs to be done before a conclusion can be reached. The experiments with tardigrades and D. Radiodurans are just scratching the surface of all there is to learn about life in space

The very mention of space often brings to mind absurd things like shaking hands with wiggly seven armed twenty four eyed creatures with a goofy grin. Shockingly, research has been establishing the possibility that cosmic life forms may actually be more similar to humanoids than previously believed possible (yeah, these creatures can actually be like you and me. How cool!) . Microorganisms such as bacteria and fungi, are very much alive, and research has been proving that they can survive in space. While it may not be possible to "shake their hands," the very fact that they can exist in space gives insight into the numerous hypotheses of compatibility of life in space.

So, what is a microorganism? Microorganisms are organisms that are so small that they cannot be seen without the aid of a microscope. Until the invention of the microscope in the mid 16th century, people didn't even know that bacteria and viruses exist! The magnifying properties of the microscope introduced to the world the existence of tiny living things and the realization that these microscopic beings can have a big impact on humanity.

It is understood that human beings cannot survive in space without the aid of a space suit and oxygen. Yet researchers have been consistently searching for proof that life can exist within the airless vacuum of space. My hypothesis is that under specific conditions, select species of microorganisms are able to withstand the harsh environment in space, such as varying levels of radiation, temperatures, and lack of oxygen.

Imagine what would happen if you would take a stroll through the Arctic planes on a sub-freezing December day. In those conditions, a person will likely suffer from severe hypothermia, or even freeze to death. Now, picture running back and forth as fast as you can in these sub-zero temperatures. These exercises will likely warm you up and you may even break a sweat while running even though the temperature is below freezing. Why is that? The Lithopanspermia Hypothesis explains this phenomenon in astronomical terms. Outer space is freezing, colder than any temperature one would find on Earth. So how would it be possible for life to survive there? If everything in space would move at a slow pace there would be no opportunity for living things to find a home as they would quickly freeze and die. However, as we know, things like meteoroids move through space at incredible speeds and thus have higher temperatures, making the cold less formidable. So while space itself is freezing and uninhabitable, a rock speeding through space contains enough heat to theoretically transport and host life. The protective confines of the meteoroid protect the microbes from some of the harsh radiation and temperatures that are found in space, thus making it possible for these microbes to survive.

We have just established the possibility that organisms can actually survive in the vacuum of space even if they require Earth - like conditions. But that isn't the only way through which microbes can survive. On planet Earth, there are life forms called extremophiles. These organisms have the dura-

bility to live in seemingly uninhabitable habitats, such as boiling hot geysers, low oxygen altitudes and high acidity. Some extremophiles actually reside in these conditions while others can withstand these conditions although it is not the ideal environment for their continued growth.

If organisms can survive under such extreme conditions, and in some cases thrive in those extraordinary habitats, then it seems logical that life would be compatible with the environment in space? There are still many undiscovered microbes and organisms. It may be possible that there are organisms that would thrive in the freezing temperatures in the severe dryness, and intense radiation found in space. If there are no organisms that like the conditions in space there may be organisms that can at least survive it. The goal should be to find these organisms and study their methods of survival, to further learn if and how we can survive the harshness of space.

Meet the Tardigrade. These fascinating extremophiles can withstand tremendous amounts of radiation, an immense range of temperatures, and starvation, among many other things. How do these incredible creatures survive? Tardigrades survive by becoming a tun. A tun is a state in which the organismal metabolism slows to .01% of it's usual rate and the tardigrade produces proteins that protect their DNA from radiation. The tun appears dead and dry. How cool is that? But wait! When the tun enters a more habitable environment it revitalizes itself and after a few hours is back to normal. Researchers were curious to see how these extremophiles (among others) would react under space conditions. Can the tardigrade survive?

Due to the tremendous versatility of the tardigrade, researchers have sent them into space to see how they would react under the harsh conditions. In one experiment researchers sent 3 groups of tardigrades to space and left a control group in the lab. The groups were made of a mixture of two species M. tardigradum and R. Coronifer. Each of the 3 groups had different quantitative exposures to UV rays in space in addition to a constant exposure to the space vacuum. The first group was exposed to the space vacuum but was protected from the harsh UV rays. The second group was exposed to the same level of the space vacuum but some of the protective measures against UV rays were removed. The third group was exposed to the same level of the space vacuum; it had no protection against the UV rays. The graph above illustrates the results from the experiment. The harsh space vacuum dehydrates the tardigrades but does not cause them to die because of their tun state abilities. In all the experimental groups, the two species of tardigrades were able to survive as well as reproduce once they were rehydrated.

However, UV light is much harsher on the tardigrade and the survival rate after exposure is sharply decreased. Take a look at this graph. Of the 2 species sent to space, R. Coronifer was unable to survive full UV exposure and so it's not even included in the graph. After moderate UV exposure, R. Coronifer had very few surviving tardigrades. If we take a look at this next graph, we notice that the M. Tardigradum species had a lower mortality rate after exposure to moderate and high levels of UV rays. Notice that while the M. Tardigradum had higher survival rates; it was also heavily impacted when faced with UV rays. Overall, while Tardigrades are clearly impacted from exposure to the brutal rays of UV light, surviving the space vacuum posed few challenges to their ability to survive. This proves that there are in fact species of life that are equipped to survive the harsh elements of outer space.

The bacteria Deinococcus Radiodurans, D. Radiodurans for short is an extremophile. Like the tardigrade, D. radiodurans can withstand dehydration, extreme cold, acidic environments, and high levels of radiation. As they did with the tardigrade, scientists wanted to observe how the bacteria reacts when placed under space conditions. After placing the bacteria under simulated space conditions in a laboratory with positive results, scientists sent samples to be tested in space. Different sized dried pellets of D. Radiodurans were sent to reside aboard the international space station. The bacteria were placed outside the space station and were observed over a period of 3 years. Scientists discovered that the cells with higher mass had a greater likelihood of surviving the conditions in space. Interestingly, once the

cells reached 1,000 m thick their ability to survive was equivalent to that of the control bacteria on earth.

How do the D. Radiodurans survive? Why does the thickness affect its survival?

Consider this analogy- when knights used to go out to war they would wear thick hardy armor to protect themselves. The armor would take the full brunt of the beating, possibly getting dented or rendered unusable, but the knight survived. Similarly, when the bacteria is exposed to the space environment it gets bombarded from all directions with harsh UV rays, dryness, and cold. With all this hitting them, they need something that can resist the impact and the damage so they can survive. The thicker they are, the more they are able to withstand and still live. Their cores remain unharmed and they can continue their replication process.

It is clearly possible that life can be sustained in outer space.

Is there a contradiction between believing that life exists in space and believing in the Torah? Should we even be testing if life is possible in space? Most chachamim agree that even if life existed in space it would not consist of intelligent creatures. But what is intelligence actually comprised of? According to the Torah, intelligence is the ability to have free will, which is unique to all people who have the Torah and the sheva mitzvos bnei Noach.

Some philosophers argue that because extraterrestrial life was not given the torah, they lack the free will that defines intelligent creatures and therefore can't exist. R' Yosef Albo, a 14th century Jewish philosopher, held that extraterrestrial life is impossible because beings without free will have no purpose and therefore would not be created. If you try to argue that a spider also doesn't have free will, so what is its purpose, remember that everything on earth is here to serve mankind. Extraterrestrial beings don't even have that secondary role because they are not near human civilization, so they seemingly have no function at all.

Other philosophers argue the opposite. They say that we have to believe there is life in space, otherwise it would be like placing limits on Hashem's capabilities (c'vs), or like we are trying to understand His motives. If we do not believe in extraterrestrial life we are saying that Hashem is incapable of creating life that is able to survive in space, which in essence is apikorsus. Contrary to what R' Albo held, it is incorrect to say that there is no purpose to any of Hashem's creations. Stating that there's no purpose to them is like trying to understand the intentions of Hashem and the function of His creations. Microorganisms may not have free will but are very much alive and are a creation of Hashem. With these perspectives in mind there is absolutely no reason why there can't be microorganisms living in space.

There are many places in the Torah that allude to there being life in space. The pasuk in Yeshayahu says (pasuk on slide), "For thus said Hashem, Creator of the heavens: He is the G-d, the One Who fashioned the earth and He is its Maker; He established it; He did not create it for waste; He fashioned it to be inhabited; I am Hashem and there is no other." The navi is saying that Hashem created the world for habitation specifically with living things. The world fulfills its function because it is filled with living things.

If Hashem doesn't create worlds and planets "for waste", then it must mean that the concept of living things helping fulfill a world's function can also be applied here. All the worlds that could support life likely have life even if that life can not be seen. The Navi is teaching that as evidence increases for the existence of planets with potentially habitable conditions, it can be presumed that they contain life. These planets must be inhabited, for otherwise they would not be fulfilling their function. The inhabitants however, do not need to be humans or something resembling a human. Microorganisms can inhabit these other worlds and enable the worlds to still fulfill their function.

Dr. Velvl Greene, a Jewish microbiologist, was part of NASA's planetary quarantine division which hoped to determine whether life on Mars is possible. Dr. Greene received a lot of criticism from the Jewish community for looking for extraterrestrial life which it was thought goes against Torah values. Dr. Greene posed a question to the Lubavitcher Rebbe to determine whether there was anything wrong with his research. (quote on slide). The Rebbe emphatically responded that not only should Dr. Greene keep looking for life on Mars, if he does not find life on Mars he should keep looking elsewhere - don't stop looking. The Rebbe was a huge supporter of Dr. Greene's research and even read and commented on his papers! The Lubavitcher Rebbe truly believed that microorganismal life was possible in space and was not willing to 'limit' Hashem.

While the survivability of microorganisms in space has been tested numerous times, a lot of research still needs to be done before a conclusion can be reached. The experiments with tardigrades and D. Radiodurans are just scratching the surface of all there is to learn about life in space. In the meantime, we can only imagine the possibilities of how extraterrestrial life presents itself, be it wiggly, multi eyed aliens, microscopic creatures, or anywhere in between.

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NUTRACEUTICALS

Zahava Schwartz, 11th Grade

The idea that natural substances can relieve pain and aid health has been around for thousands of years. Hipporities, an ancient Greek physician and the father of modern medicine, was the first to introduce the idea that certain foods can have therapeutic benefits.

We know that "we are what we eat'' and we feel different when we consume different foods. Processed foods and sugar can cause sluggish behavior and tiredness but eating healthy and natural foods can contribute to creating a healthy and fit body, improve digestion, prevent diseases and boost your mood.

Over the past few years, because of new scientific advances in medicine and nutrition, people have sought out nutraceuticals as a form of medical therapy and treatment to improve their health instead of taking pharmacy prescribed drugs, or pharmaceuticals. Nutraceuticals are nutrient rich or medicinally active food products derived from natural sources which can have medical and health benefits and are used to prevent and treat diseases (DeFelice, 1994). Nutraceutical products can be found in forms such as isolated nutrients, dietary supplements, herbal products, and genetically engineered "designer" foods (Prabu, et al. 2012). Although many scientists have produced many intricate and advanced medicines in the pharmaceutical world, there are many benefits to using nutraceuticals over the pharmaceutical alternative.

The idea that natural substances can relieve pain and aid health has been around for thousands of years. Hipporities, an ancient Greek physician and the father of modern medicine, was the first to introduce the idea that certain foods can have therapeutic benefits. He believed that, "food be thy medicine and medicine be thy food" and discovered that the leaves and bark from willow trees had the ability to relieve pain and fevers (Prabu, et al. 2012). Additionally in Ancient China, thousands of years ago, wolfberry fruits have been used to improve vision, protect the liver and promote longevity. However, although natural sources have been used to cure disease for centuries, the term "nutraceutical" was coined much later in 1979 by Stephan DeFelice, the founder and chairman of the Foundation for Innovation in Medicine. He provided a very specific definition as to what nutraceuticals truly are which is mentioned above and clarifies that nutraceuticals are "foods, or parts of foods, that provide medical or health benefits, including the prevention and treatment of disease" (Bull, et al., 2021)).

Nutraceuticals have many benefits over a pharmaceutical alternative. Firstly, for pharmaceuticals, patients almost always need a prescription from doctors for treatments but nutraceuticals don't always require prescriptions or medical supervision (Ricciardi, 2021). Nutraceuticals are also better for creating a healthier lifestyle. Not only do they treat the specific illness you may be suffering from, but they can prevent it from happening in the first place by boosting your overall immune health and energy levels. By implementing these lifestyle changes and eating healthily, one can reduce their trips to the doctor because their body will be healthier overall (Kim, 2021). Furthermore, our bodies are created to consume fruits, vegetables, and other natural foods so taking nutraceuticals can be more effective as they are closer to the substances our bodies were designed to intake, digest and extract nutrients from (paiwellnessgroup.com).

Nutraceuticals can also be seen as a better option to treat illnesses as they provide little to no side effects. For example, Fosamax is a medication used to promote bone health. It has side effects such as

gas, constipation, heartburn, overall stomach pain, joint pain and swelling. Melatonin is a nutraceutical treatment that can also be used to promote bone health as well as promote sleep enhancement and skin health. Although the use of melatonin may have side effects such as mild headaches, dizziness or drowsiness, they are much less serious than the pharmaceutical alternative (Bauer, 2020).

Additionally, pharmaceutical medications take a long time to get through all their requirements in order to be available for patients to use for treatments. They require many years of expensive testing on both animals and humans to ensure that the FDA, the Federal Drug Association, approves the medication as a safe and effective treatment. Only 1 in 10 drugs that are given to the FDA for approval are passed and permitted to be used by the public and it can take up to ten years for the drug to go from its development phase to being approved for prescription (Loria, 2016). Overall there are 12 steps to the FDA drug approval process. First the drug arrives at its preclinical screening phase where it is animal tested. Then it is moved to the clinical phase where the drug is analyzed and tested for potential side effects, effectiveness and how the drug reacts in combination with other drugs. Lastly, the drug arrives at the New Drug Application (NDA) phase, where it is labeled, reviewed and finally approved (fda.gov). Because of this excruciatingly long process, it is easier and may be more worth it to invest in and research nutraceutical medicines as they are not required to go through FDA screening. Additionally, since they have existed in the natural world for thousands of years, they are proven to be more tolerable than modern medicines (Kim, 2021).

A prime example of how nutraceuticals have specifically been used in disease is Familial Dysautonomia (FD), a rare genetic autosomal recessive disorder that impacts the development and survival of certain nerve cells and is present in the Ashkenazi Jewish community. Doctors estimate that one out of every 30 Ashkenazi Jews are carriers of FD and those who are affected have symptoms such as troubles with perceiving pain and heat, poor weight gain, inability to produce tears, indigestion, scoliosis and repeated vomiting (rarediseases.org). The disease has a 25% chance of being expressed if both parents are carriers of the recessive disorder (eugenelabs.com).

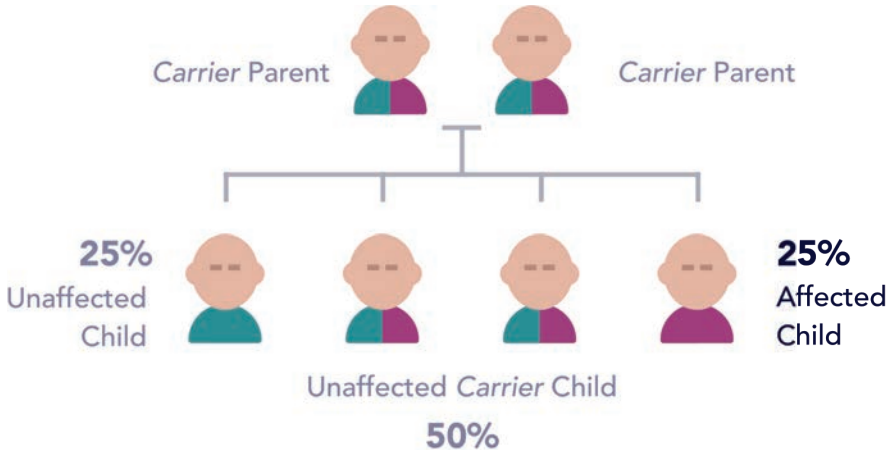

Figure 2: This chart depicts the chances of inheritance of Familial Dysautonomia, FD, a autosomal recessive disease present in the Jewish Askenazi community. It shows that when both parents are carriers of FD, there's a one in four chance that their children could be affected.

In the summer of 2000, Dr. Sylvia Anderson and Dr. Berish Rubin took it upon themselves to discover the source for the FD mutation. Within three months they had successfully identified the dis-

ease-causing mutation in the gene known as IKBKAP. After successfully discovering the source of FD, they began researching to find a treatment for the horrifying disease. Their goal was to uncover a treatment that would cause no harm to the patient, a treatment with very few side effects and to discover the treatment as quickly as possible. They chose to research nutraceutical treatments over pharmaceutical treatments as nutraceutical treatments don't need to go through the FDA approval process: a process that can take a very long time as mentioned above. Their first discovery, published in 2003, showed that vitamin E, tocotrienols, present in foods like brown rice increases IKBKAP production. They noticed while studying potential treatments that the gene of FD is present in the Chinese population, but symptoms are rarely if never expressed. The doctors hypothesized that this phenomenon was due to the fact that most Chinese mothers' consume brown rice while pregnant. After experimenting further they discovered that the consumption of vitamin E in foods like in brown rice drastically reduces symptoms of FD (fdnow.org).

Additionally after further study, Dr. Anderson and Dr. Rubin found that epigallocatechin gallate (EGCG), a compound present in green tea, and Vitamin A both increase the production of the functional IKBKAP gene product. These remarkable studies of nutraceutical therapies have significantly improved the lives of those with FD making the disease more manageable (fdnow.org). Before 1960, around 50 percent of all FD patients died before they reached age 5 but because of these revolutionary findings, approximately 50 percent of patients make it to age 30 allowing them to live life, make memories and reach important life milestones (childlifesociety.org).

In conclusion, nutraceuticals overall have many nutrition and therapeutic benefits that can improve our overall health. As we research further, hopefully scientists will be able to explore more benefits of nutraceuticals and how they can improve our overall health, helping us create a healthier lifestyle and allowing us to cure and prevent more illnesses.

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THE SCIENCE OF HAPPINESS

Yocheved Stein, 10th Grade

Happiness is a survival instinct, not at all a luxury. It's something that we need. Our states of happiness can affect our physical health and immune responses against disease. Research shows that people who have more negative emotions, have weaker immune systems compared to those who have more positive feelings (Tyson, 2021).

Happiness has been a human pursuit since ancient history. However, since the founding of psychology as a science in the 1800's, emphasis was on studying negative emotions. Psychologists investigated how to deal with worst case scenarios, mental illness, and trauma. The field of positive psychology, launched in the 1980's, finally began focusing on scientifically researching how humans could elevate their happiness and find meaning in their lives (Hudgends, 2020). The Science of Happiness, the scientific study of "what makes happy people happy," was started by Mihaly Czikszentmihalyi in the late 1980's. In 2002, Martin Seligman popularized Positive Psychology, which is the science of what makes life worth living, through his influential work, *Authentic Happiness*. Since then, studies on the science of happiness have exploded, and have been pursued by scientists and celebrities in popular culture.

There are many academic definitions of happiness. Researchers often use "happiness" interchangeably with the term "subjective well-being," which they measure by asking people to report how satisfied they feel with their own lives and how much positive and negative emotion they're experiencing. Positive psychology researcher Sonja Lyubomirsky describes happiness as "the experience of joy, contentment, or positive well-being, combined with a sense that one's life is good, meaningful, and worthwhile" (Lyubomirsky, 2021).

According to current research, genetics is responsible for about 50 percent of our happiness. Circumstances such as age, marital status, income, health, and religious affiliation, are responsible for about 10-20 percent, and our behaviors and thoughts account for the rest (Rubin, 2019). Therefore, while we clearly have genetic set points for happiness, we have the ability to offset our genes and take control of our happiness. Over time, we can build lasting habits that improve our resilience and increase our happiness levels (www.happify.com).

Happiness is a survival instinct, not at all a luxury. It's something that we need. Our states of happiness can affect our physical health and immune responses against disease. Research shows that people who have more negative emotions, have weaker immune systems compared to those who have more positive feelings (Tyson, 2021). Additionally, optimistic people have reduced risks of heart and lung disease and lower possibilities of cancer, lengthening their life spans (Toper, 2019).

There have been many studies done on how human beings can increase their state of happiness. Some of the suggested ways are performing acts of kindness, forming relationships, exercising regularly, challenging our intellect, using our strengths, and practicing mindfulness and gratitude for the good things we have (Tyson, 2021; Hackney, 2019).

One of the most studied methods of increasing happiness is to be a grateful person. Studies show that people who are consistently grateful, tend to be happier and more content with their lives.

Additionally, having more gratitude is one of the methods of inducing long term happiness, not just brief or momentary joy. We often compare ourselves to others who might have more than us, invoking jealousy and abolishing any happiness we previously had. Being thankful for what we have, allows us to not look at others' lives, but rather, focus on ourselves (Tyson, 2021).

Another way to improve happiness is by performing acts of kindness. A 2008 study by Harvard Business School professor Michael Norton and colleagues, found that although the participants of the study predicted that spending money on themselves would increase their happiness, in fact, giving money to someone else made them happier than spending money on themselves. These good feelings are rooted in our biology. In a 2006 study, Jorge Moll and colleagues at the National Institutes of Health, found that when people give to charities, it actually activates parts of the brain linked to pleasure, social connection, and trust. In addition, scientists believe that giving, releases endorphins in the brain, produces the "helper's high" (Suttie, 2021). This is one of the reasons that religious commitment increases happiness. People who are more involved with religion tend to be more compassionate and provide emotional support to others and are therefore more likely to be happy (Kraus, et al., 2021).

Surrounding ourselves with positive people can also influence our own happiness. Laurie Santos, Professor of Psychology at Yale University, explains that emotions can spread through Emotional contagion. This is the phenomenon of feelings and moods being "contagious", meaning that one person's mood can impact other peoples' happiness states. This happens because people subconsciously mimic facial expressions, postures, and movements of people around them and then come to experience those same emotions (Tyson, 2021).

There are many lifestyle habits that we can adapt to increase our happiness. Getting enough sleep is directly correlated to happiness. Exercising releases endorphins, serotonin, and dopamine which boost well being and decrease stress levels (Hackney, 2019). Taking walks outside can also boost happiness. In 2014, two scientists - Zelenski and Nisbet - conducted a study on the relationship between nature and happiness. The results of their research indicate that "nature relatedness has a distinct happiness benefit" (Price-Mitchel, 2014).

A big misconception within the public is that wealth brings happiness. However, this is usually untrue. Celebrities and other extremely wealthy people, usually have less positive emotions than the average person and report feeling empty and lonely inside (Tyson, 2021). While they may possess one type of happiness - happiness in their lives - they're lacking happiness with their lives, satisfaction and purpose. Princeton University conducted a study in 2010 and found that there is a connection between happiness and wealth, to a point of about $75,000 per year. People who make more than $75,000 per year don't have an increase in their state of happiness, despite their surge in income (Steig, 2019). There are many things that evoke happiness in this world that can't be replaced by money and wealth. Family, friends, and health, give certain joys that just don't come with a price tag (Tyson).

Happiness is about living in the moment, and not letting those precious seconds pass by. It can't be bought through money and technology. Our states of happiness affect our day-to-day lives, as well as our futures. In order to attain complete happiness, one has to be happy in his life, and happy with his life. Our moods and feelings influence our physical bodies and our minds. Perhaps having positive emotions is something we should focus more on, because we have the power to change not just our state of being, but the people around us as well (Tyson, 2021).

WHAT IS HAPPINESS, ANYWAY?

We all have deeply personal (and different!) definitions of happiness.
But here's how scientists see it:

Happiness is a combination of

How satisfied you are with your life

+

How good you feel on a day-to-day basis

40%

of your happiness is controlled by your thoughts, actions, and behaviors

It varies from person to person, but approximately ...

50%

is genetically determined

10%

is determined by your circumstances

Contrary to popular belief, we get used to our circumstances over time, so they don't play as large of a role in our happiness level as we might think!

Happiness is a skill that you can build with consistent practice.
You have the ability to control how fulfilling your life is!

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THE SCIENCE BEHIND BEING "HANGRY"

Ellie Trapedo, 9th Grade

The average person has trillions of bacteria in their body that make up their gut microbiome: a miniature colony that best supports your body's functioning when balanced and in harmony. From birth, each person has their own microbiome fingerprint, a diverse group of healthy bacteria that lives in their gut.

Have you ever had butterflies in your stomach before giving a speech? Ever felt nauseous while watching a virtual live surgery in school? Have you ever guessed the correct number of jelly beans in a jar and won them all because you had a 'gut feeling' about the number 947? That 'gut feeling' you've experienced isn't just a myth. It's science.

Making choices involves gathering and processing information, discerning its relevance, making a decision, and committing to it. To better understand how people make decisions, scientists used goggles that track a person's pupil and corneal activity to study the visual data individuals pull from their environment. Monitoring visual input taught researchers alot about how people make decisions (like choosing what to buy, what to eat, and even who to trust). Not surprisingly, they found that making eye contact and looking at someone's eyes was a strong predictor of social behavior choices. However, this tendency to make eye contact with people and acquire information about them based on visual input is flawed in people who have 'neurodevelopmental and neuropsychiatric disorders,' like schizophrenia and autism. (Platt) Recent research has shown that the gut microbiome plays an important role in neurodevelopmental and neuropsychiatric disorders.

While most believe that all human decisions are made in the brain, and our gut is only for digesting food and removing waste, scientists have discovered that your gut plays an important role in your feelings, preferences, and behaviors. The gut and the brain are connected through circulator chemicals, such as hormones and neurotransmitters that carry messages. Living in every person's gut is a "gut microbiome," a colony of many different types of bacteria and fungi in the digestive tract that aid digestion, regulate a person's immune system, and protect the body from other bad bacteria that can cause diseases.

The average person has trillions of bacteria in their body that make up their gut microbiome: a miniature colony that best supports your body's functioning when balanced and in harmony. From birth, each person has their own microbiome fingerprint, a diverse group of healthy bacteria that lives in their gut. While the gut microbiome is responsible for digestion, fighting infectious bacteria and diseases, it also influences a person's mood, emotions, and energy. Although scientists don't yet know much about the gut microbiome, they do know that it is incredibly critical to our health. The gut microbiome must be in a balanced state otherwise a person can get sick and not be capable of fighting off chronic diseases. An imbalanced microbiome is also the cause of neurodevelopmental and neuropsychiatric disorders like depression, schizophrenia, and autism.

Many scientists are conducting original research on the relationship between microbiomes and behavior. Most people commonly mistakenly think that neural processes only happen in the brain; in truth, every part of the body has some neural activity. However, the gut is similar to the brain because the gut has entire nerve cells in it. The gut has about the same number of neurons as the spinal cord.

What happens in your stomach and intestines affects your whole being, physically, emotionally, and mentally. The contemporary term "hangry," used to describe someone whose feelings of hunger causes them to act angry and annoyed, isn't just slang. It is really the gut telling the body it doesn't have enough food for energy, which negatively impacts a person's mood. This is similar to a baby crying when it is hungry, tired, or overwhelmed (Veilleux).

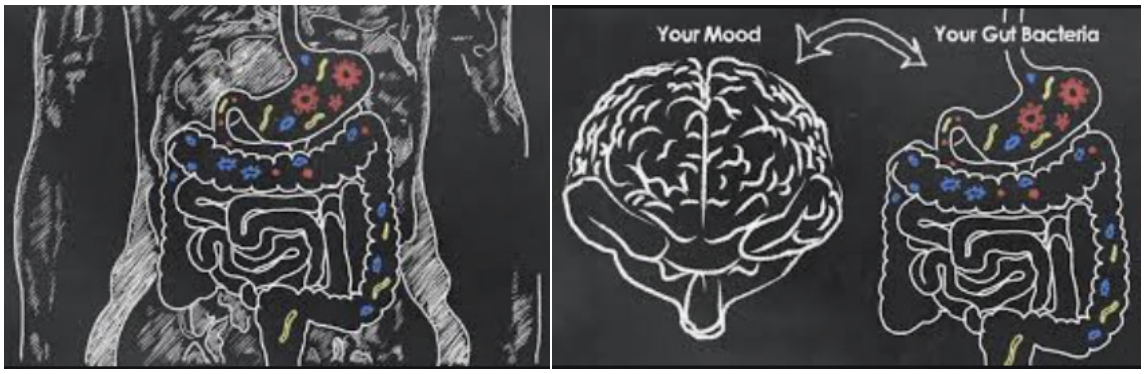

Figure 1: These images demonstrate how the gut-brain connection affects your mood through its microbiome. Because the gut microbiome has so many nerve cells, it is able to send 'feeling' messages such as pain, nervousness, joy, or anxiety to the brain. The gut microbiome is an ecosystem made up of over one hundred trillion good bacteria that not only send messages to the brain but also digest your food which gives you the energy necessary for living as well. Because the gut microbiome has the greatest concentration of good bacteria in a person's body, it is able to act as a second mini-brain that allows a person to experience feelings, emotions, and moods.

In 1765, Scottish doctor Robert Whytt came up with the concept of 'nervous sympathy' which was used to describe the mechanisms that he believed connected the inner organs. He learned that the gut had a plethora of nerve endings (millions of points on the inside and outside of a person's body that send messages to the brain when a person feels hot, cold, or pain) that disbursed 'nervous energy' throughout the body. As a consequence of his research, the gut and stomach became popular topics to study and many books have been published about the gut and stomach. In these books, the stomach was described as, "the great nervous centre," the "sensorium of organic life," and "the great abdominal brain" (Miller). In the nineteenth century, the stomach was believed to be the most important organ because of its strong influence on physical and emotional wellbeing.

More recently in 1996, the gut was referred to as a "second brain". Scientists have recently also discovered that an irregular gut can cause mental illnesses like anxiety, depression, or schizophrenia, which makes people see reality abnormally. A group of researchers found that the faecal microbiota in people with schizophrenia, bipolar disorder or major depression were different from that of the control group of healthy people. Specifically, "lower counts of Bifidobacterium and Lactobacillus, two bacteria that are thought to have a beneficial effect on the stress response, [were] reported in patients with major depression when compared to healthy subjects" (Bioque). This research is just the beginning of a better understanding of the relationship between mental health issues and gut health.

Although scientists don't yet know just yet how to determine whether a person will develop mental illness from the gut microbiome samples, it's possible that in the future doctors will be able to identify people who may be at risk. Moreover, by examining the bacteria that are more abundant in patients with active major depression, scientists might be able to develop more effective treatments and cures for

mental illnesses like schizophrenia, depression, or anxiety before they worsen or become out of hand.

With over ten trillion bacteria to examine in every person's gut, I imagine scientists will be busy for quite some time as they continue to discover cures for depression, anxiety, and "hanger."

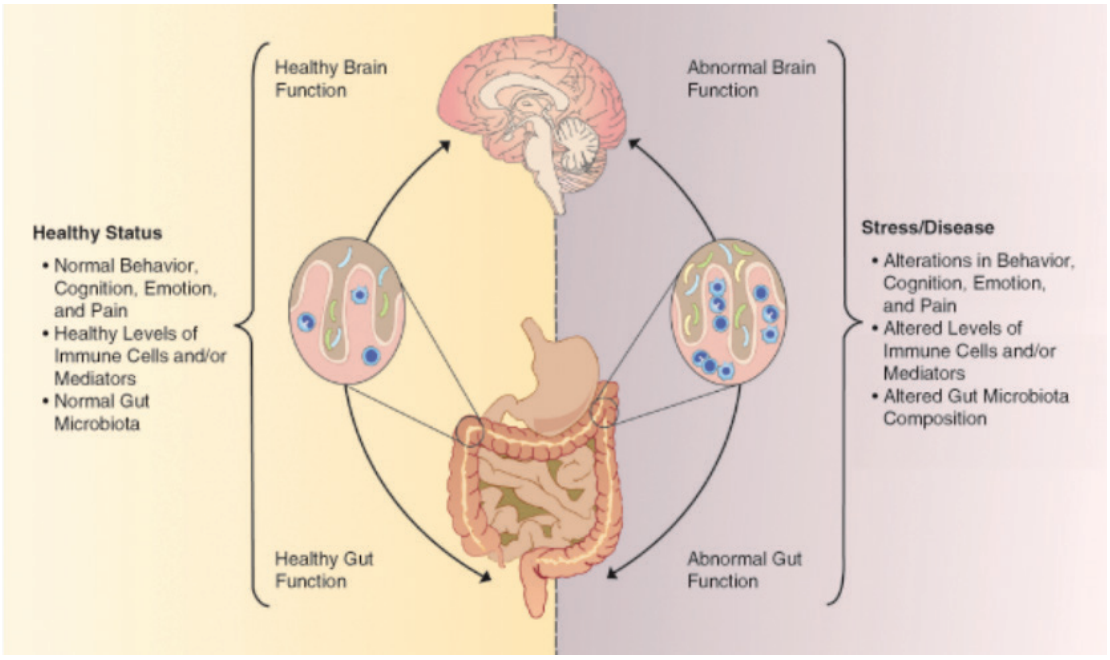

Figure 2: This image shows the comparison between a healthy gut and a gut that has a mental disease or sickness; it depicts how the abnormal gut microbiome causes mental illnesses (seen through the arrows), is imbalanced, and has 'altered levels of immune cells and/or mediators'. The diagram also shows how the healthy gut is balanced and has healthy emotions, behavior, and cognition. Both the healthy and unhealthy gut have different effects on the brain.

Figure 3: This cartoon illustrates the gut and brain communicating during a chess match. When playing a game or sport, we use our brain to process the logical pros and cons of an action as well as our instincts or feelings before making a decision. Here, the gut, which is responsible for impulses and feelings instead of logic, comments on the brain's apparent risky and brave move that isn't usually based on reason. When we follow that 'gut feeling' we are usually listening to our emotions emitted from our gut microbiome rather than thinking about all of the potential outcomes of our actions calculated in the brain. This role reversal is represented in the comic is what makes it funny.

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