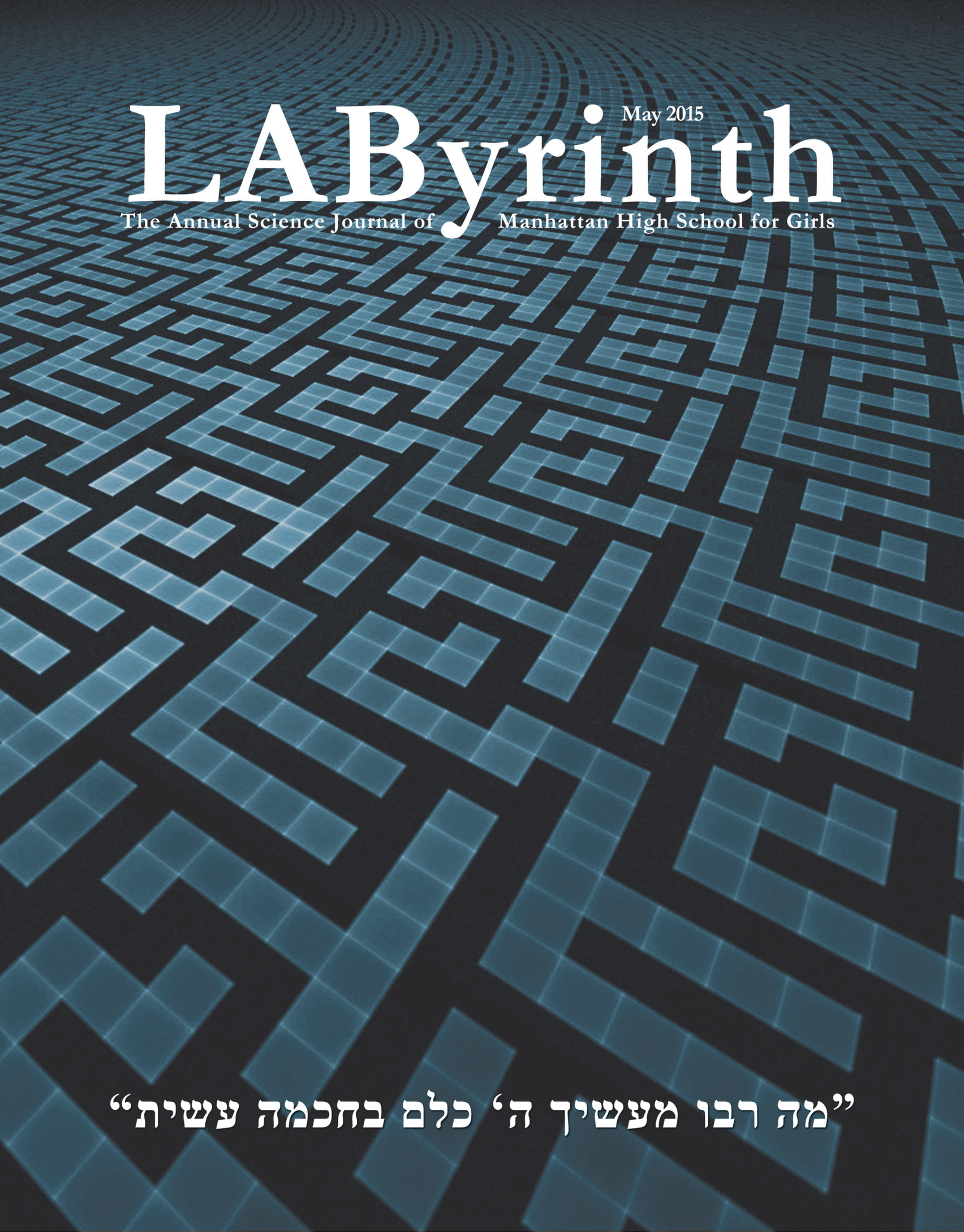

LAByrinth

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The Annual Science Journal of Manhattan High School for Girls

"מה רבו מעשיך ה' כלם בחכמה עשית"

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FOREWORD

Brenda From- Faculty Advisor

Every time I drive on the Van Wyck past the Flushing Meadows Corona Park and view the rusting hulk of the Unisphere, I am transported back in time to my twelve year old self. This was the site of the 1964 World's Fair (it's OK to do the math), whose theme was "Peace Through Understanding." The shining twelve-story high stainless steel Unisphere dominated the exhibition and was the symbol of that unabashed exuberant display of optimism that so typified the early 60's. The Space Age had just been born, the State of Israel had been established sixteen years earlier and Vietnam was some far off land, not yet penetrating our consciousness; you had to have lived through it to relate.

Hand in hand with my beloved grandfather, we visited the pavilions, mesmerized and enthralled by the exotic sights and sounds. Technological advance was celebrated: computers, with their dazzling array of blinking lights, covered entire walls; tethered telephones actually allowed you to see who was at the other end of the cord. In retrospect, I am bemused by my naiveté. My favorite was the DuPont pavilion with their repeating refrain "The Wonderful World of Chemistry." I was hooked and the rest is history.

You hold in your hands the 2015 edition of the annual Manhattan High School for Girls Science Journal, LAByrinth. It is the progeny of the seed that was planted then in the fertile soil of my adolescent brain. That nascent seed was lovingly tended over the ensuing years; it germinated, flowered, and ripened, giving rise to the next generation.

This publication is a testament to our students and their thirst to extend their education above and beyond the limitations of the classroom. They have no countenance for mediocrity. Each article is a product of intensive, independent self-study and a culmination of their findings. Some were initiated by national science competitions, such as the Dupont Challenge, Jerusalem Science Contest, DNA Essay Contest or the tenth grade chemistry class project, "The Substance of the Matter." While each article is as unique as its author, I found a recurring theme. Each entry expressed confidence in our ability to find future solutions together to solve problems that plague humanity, while maintaining a steadfast commitment to Yiddishkeit. They see no demarcation between the worlds of Torah and *derech ha'teva* and effortlessly bridge the two.

I am indebted to all my students as I learned from and together with them and expanded my own repertoire of scientific knowledge. Their zeal and infectious enthusiasm lends purpose to my time well spent here at MHS. *Hakarat hatov* to Ms. Estee Friedman, Principal General Studies, for her professionalism, continuing support and encouragement, and fellow faculty member, Ms. Larissa Dzegar, for her painstaking and meticulous editing. *Acharona acharona chaviva*, this journal would never have seen the light of day, with its sophisticated polish and lustrous gleam, had it not been for the technological expertise of Ms. Chani Schwartz. Kudos to you all.

ABOARD THE NEUTROPHIL FERRY

Malki Rubin '17

Third grade is too young to come face to face with the tragedy of a brain tumor. One of my closest friends was diagnosed with one and over time, it not only affected her sight, but also her personality. I loved her bubbly, vibrant and energetic personality, but chemotherapy drugs changed all that. It affected her physically and emotionally. In third grade, I was not able to understand these changes in my friend. At times, I wondered whether the drugs she took were worse than the original sickness. Chemotherapy, radiation, and surgery all cause harmful side effects to a person with a brain tumor, so it is crucial to investigate new drug treatment without devastating physical effects on the body and personality. The changes that I saw in my friend's personality upset me and I wanted to investigate innovations in the cancer treatment pipeline that simultaneously limited side effects.

"The function of the BBB is to protect neural tissue from variations in blood composition and toxins."

Current methods of treating brain cancer are moderately effective, but they can all damage healthy cells to a greater or lesser degree. Surgery, used to diagnose, determine stage of advance of the disease, and treat the cancer can be combined with chemotherapy and/or radiation therapy (1). The problem with surgical removal of brain tumors is that depending on location, damage to adjoining tissue cannot be avoided. The use of anticancer drugs to slow or stop growth of rapidly dividing cancer cells, shrink a tumor, destroy cancer cells, and relieve symptoms of advanced cancer are insufficiently selective to target only cancer cells while leaving healthy tissue unharmed (6). Finally, the last option is intraoperative radiation therapy (IORT). This delivers concentrated doses of radiation therapy to a tumor during surgery. IORT also helps kill microscopic disease and reduce length of traditional radiation treatment. However, radiation kills the greatest number of healthy cells, which is why it is the least ideal choice (8).

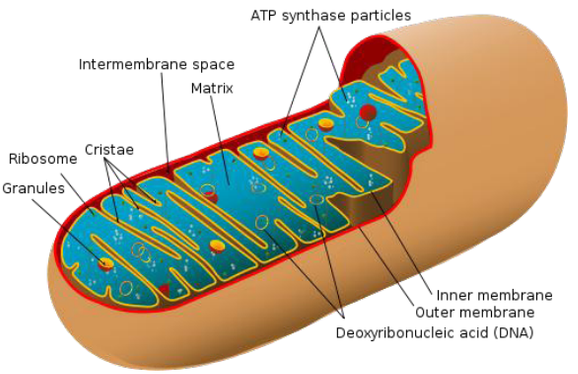

Figure 1: Inner structure of a mitochondrion

Recent innovations target how cancer cells uniquely acquire and use energy to divide and grow. Normal cells utilize mitochondria to perform aerobic cellular respiration, which is more efficient at generating cellular energy than glycolysis, which occurs in the cytoplasm. When normal cells are starved of food, their mitochondria (see figure 1) release apoptosis (programmed cell suicide) signals, which initiate a cascade of events which end with the death of the cell. These signals are also released to alert immune cells which then proceed to destroy the starved cell to make the sure the job is done. Cancer cells are ingenious at finding and scavenging other sources of energy; they substitute less efficient glycolysis, allowing them to bypass the apoptosis mechanism (9).

A promising drug to treat brain and many other forms of cancer is called mitochondrial dichloroacetate (Mito-DCA), which addresses this feature of normal vs. cancerous cells. Dichlorace-

tate targets only cancer cells, while previous treatments target both healthy and cancerous cells. Results from experiments show that it switched glycolysis metabolism of cancer cells back to mitochondrial aerobic oxidation allowing for the destruction of cancer cells by the body's own immune system via the apoptosis pathway. Mito-DCA allows cancer cells to be better detected by the immune system and eradicated; however, this drug is not without complications. Clinical trial of DCA caused side effects that affected the nervous system. Further clinical trials of DCA are needed to determine its efficacy compared to current cancer therapies that kill healthy cells along with the cancerous cells (13).

A major roadblock to the use of chemotherapy and other drugs to treat and diagnose brain disorders is that they must cross over the blood brain barrier (BBB) to reach the specific location of the tumor (11). The function of the BBB is to protect neural tissue from variations in blood composition and toxins. Cancer cells are creative chameleons and can hide behind this protective barrier to evade detection by immune system white cells (12). Endothelial cells forming the BBB selectively allow only certain substances to enter and leave the brain. Brain endothelial cells have continuous tight junctions that make them a cohesive unit and limit diffusion of molecules across it (figure 2). Drugs with high lipid solubility readily diffuse through the BBB and do not require protein carriers. Drugs with low lipid solubility can be transported across the BBB via a specific protein carrier. Some drugs used to treat brain tumors cannot enter the brain because of low lipid solubility and lack of specific transporters. Hence, the importance of understanding the transport process cannot be overestimated (9).

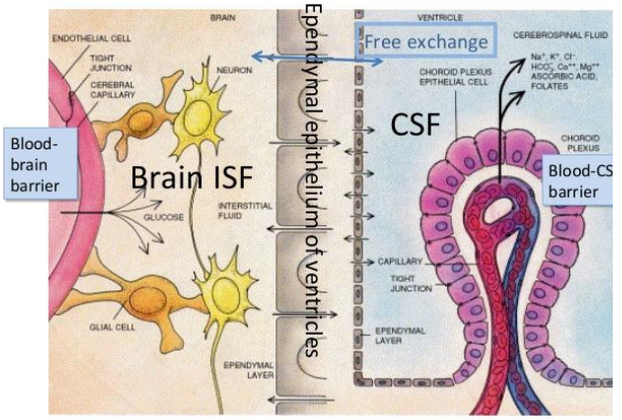

Figure 2: The Blood Brain Barrier

Bypassing the BBB to deliver drugs is a major problem that has propelled researchers to develop original drug delivery methods. A new cell-based therapy uses neutrophils, a type of white blood cell that normally traverses the BBB, to ferry apoptosis-inducing drugs past the brain's BBB and destroy malignant tumors. Drugs such as Mito-DCA can reach the tumor and only kill tumor cells without destroying healthy cells. In previous attempts, the drug leaked prematurely before reaching the desired tumor, killing the transport cell instead. To solve this problem, researchers are developing PPCL's (protease activatable polymer liposomes), which will function as artificial bubbles around the drug to prevent premature release within the neutrophil, and activate only when it reaches the desired destination. Healthy cells can avoid being destroyed, and there is no rejection of the transport cell since it is recognized by the patient's immune system. Some problems with this new type of therapy are that neutrophils are rarely seen in brain cancers, so it crucial to create a condition to attract white blood cells. This treatment needs more development and testing, but if it works, it would be a major breakthrough (14).

These newer treatments have great potential to treat cancer without devastating effects on the personality. Unfortunately for my friend, these advances are 4 years too late. She suffered through the standard treatments at the time and I was forced to watch as her personality progressively deteriorated. Today's new technology gives hope to cancer combatants to retain their personality and dignity as they persevere through the battle of their lives.

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AVOIDING THE ZOMBIE APOCALYPSE

Draisy Friedman '16

It's a plot all too commonly seen in science fiction movies; humanity succumbs to a rampaging illness, with symptoms ranging from insanity to death and zombification. Most people past the age of ten naively assume that this will always remain the stuff of a Hollywood screenwriter's overactive imagination, safely confined to the realm of fiction. After all, whenever they get sick, they pop a few pills and recovery is assured. Or is it?

Global pandemic has recently entered everyone's consciousness. Not only are new diseases constantly popping up over the horizon, but older diseases are rearing their ugly heads once again and are quickly becoming more and more resistant to commonly used antibiotics (1). The seemingly simple solution to this problem, developing new drugs, has become increasingly more difficult over the years (2). Thankfully, scientists may have discovered a way to solve this pressing issue by turning to the common solution for most of our problems today: technology.

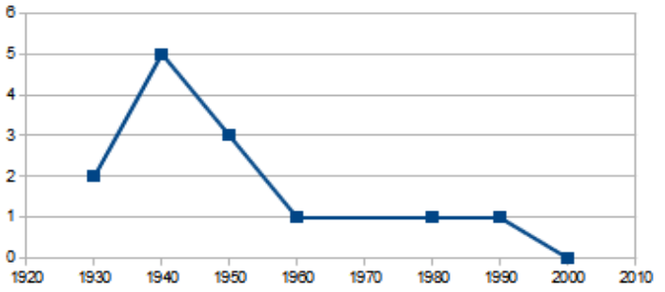

Figure 1: Antibiotic Class Discoveries per Decade: In 2000, no new classes of antibiotics were discovered.

In the first four decades after the first antibiotic, penicillin, was discovered by Alexander Fleming in 1928 and subsequently commercially developed, the antibiotics market grew into a flourishing industry, with more than half the drugs commonly used today produced during that time frame. However, around 1962, it all suddenly came to a grinding halt. In the past 40 years, only two new novel classes of antibiotics, the oxazolidinones and the cyclic lipopeptides, have been developed (See figure 1). The reason behind this is far from complex; they have simply run out of new sources. Like the gold for which miners are eternally searching, the first few novel classes of antibiotics were easily discoverable, buried just a few inches below the proverbial dirt, easily obtainable and, most importantly, profitable. After a couple of years passed, new sources became increasingly more difficult to find and the subsequent rise in the cost of production meant the support for them quickly declined (3).

"Combining biological sciences with its younger sibling: computer science."

However, even if the cost of production is prohibitive, the natural active agents needed to produce new novel antibiotics still very much exist (7). In fact, scientists at ETH Zurich theorize that there is a potentially infinite number of natural compounds that could aid in curing infectious diseases, provided an efficient method for finding them could be discovered. The problem is that the majority of drugs found in nature do not come in usable form, and consequently not easily recognizable or identifiable as drugs. "Natural active agents are usually very large molecules that often can be synthesized only through very laborious processes," explains Gisbert Schneider, professor of computer-aided drug design at ETH Zurich. However, if the mechanism of action of the drug could be fully understood, then it is potentially possible to design smaller, less complex molecules that can be more easily synthesized. Once synthesized, it would be a relatively simple

process to utilize the substance for pharmacological purposes (6).

In order to understand the mechanism of action of a potential pharmaceutical substance, scientists must observe which part of the pathogen it interacts with in order to inhibit its growth. In the past, the most efficient way to accomplish this was through a series of complex laboratory tests by which scientists could hopefully identify the mechanism of interaction with the pathogen and understand how it exerts its effect. However, this method is not only expensive, it is also highly inaccurate; minor interactions with other structures can moderate the substance's effect. Therefore, in order to properly utilize the vast amount of drugs that can be found in nature, we must develop a better way to understand and systematically categorize the mechanism of action of a substance. The question is, is such a thing actually conceivable? And if it is, could it ever be commercially profitable enough to gain the support it needs?

Sadly, until very recently the answer was believed to be no. But scientists at MIT may have just uncovered a way to make it work. The miracle solution they discovered? Combining biological sciences with its younger sibling: computer science. Using a computer program, scientists no longer have go through the tedious laboratory tests to discover the cause and the mechanism of action of a substance. Instead, the software does it for them. It takes the full, complex molecule and breaks it down into smaller, easier to understand fragments by sifting through an algorithm of chemical databases and finding potential interaction partners (see figure 2). Once the program has isolated the fragments of the molecule that are essential for the mechanism of action, it is significantly easier for scientists to synthesize a less complex molecule.

In addition to relying heavily on computer science, the algorithm the software uses is based on the organic chemistry concept of retrosynthetic analysis. This is a technique used in the planning of synthesizing organic molecules by working backwards, to see what are the simplest starting molecules necessary (5). The computer program uses it to find the "building blocks" of the molecule and figures out which individual fragments can best be used to synthesize a substance that produces the same effect. Prof. E. J. Corey won the 1990 Nobel Prize in Chemistry for his development of retrosynthetic analysis (6).

In testing this program, researchers discovered that the mechanism of action of archazolid A, a known tumor suppressor, is similar to the mechanism of action of a much smaller and less complex unsaturated fatty acid (6). The implications of this simple discovery are far reaching. If it becomes easier to replicate the effects of natural substances using simple substances, then a whole new source of potential antibiotics could be opened up.

The lack of new novel classes of antibiotics is a problem that has plagued scientists for decades. After years of trying new idea after new idea and after witnessing failure after failure, it turns out

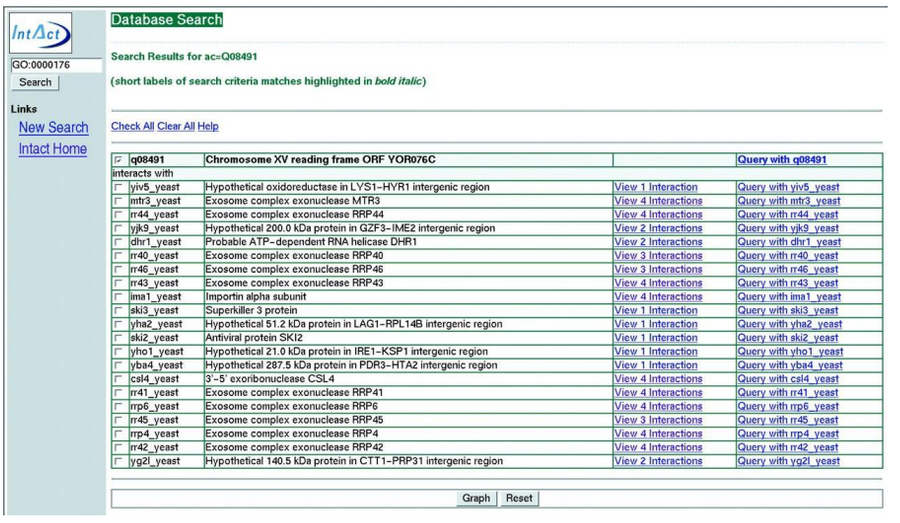

Figure 2: Screen shot of sample search, showing all possible interaction partners for a specific proteinwere discovered.

that the solution may be a lesson most commonly taught in a kindergarten classroom: We have to all work together. In an interesting application and extension of on-line gaming, scientists are capitalizing on the power of distributed thinking of the "crowd" and the ability of humans

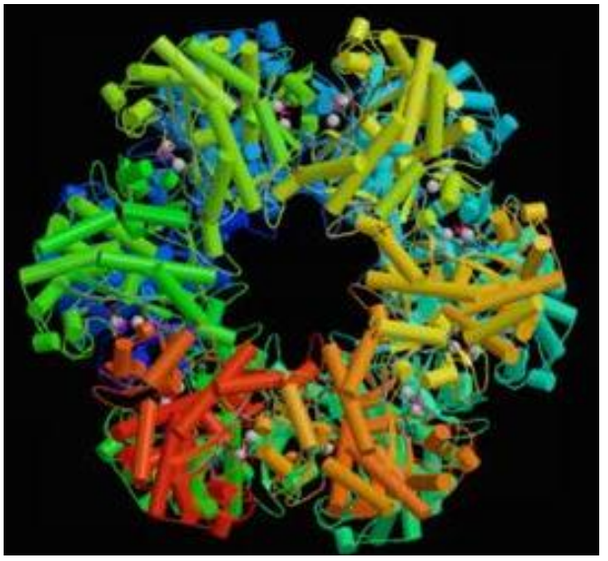

Figure 3: Example of 3-D conformation of protein

to think spatially and solve visual puzzles—a task that eludes even the most complex computers. They have created an on-line game called "Fold-it," which challenges players to compete, collaborate, develop strategies, accumulate game points and move to different playing levels — all while folding proteins into specific three dimensional shapes (Figure 3). It has already engaged more than 100,000 players around the world to help scientist understand the three dimensional structure of proteins to combat viruses such as AIDS and Ebola. Top players have come up with entirely new protein folding strategies that could lead to novel drug design, not only for pathogenic infections, but even for diseases like cancer. In 2011, Foldit players identified the structure of a protein that helps HIV reproduce (4).

By pooling together knowledge from biology, chemistry, computer and pharmaceutical science, the solution to one of this century's most troubling problem might be tantalizingly within our reach.

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BIOENGINEERED EARS

Rachel Jacobi '17

It is an unfortunate fact that over 3.2 million children are bullied every year, and 39% of them are bullied for unpleasant or deformed facial features (9). A large portion of these children suffer from ear deformities. In fact, one parent relates how her seven year old daughter is teased relentlessly about her ears. " 'One lady walked up to her and said "Oh my G-d, what happened to your ears?' " (7). Another case is 11 year old Ariana Adan, who was a repeated victim of bullying by her peers because of her ears, so much so that she attempted to staple them back to her head. Ariana finally underwent a painful plastic surgery to change her ears (10). A large number of children who suffer from bullying because of congenital ear deformities are victims of ear deformities that result from cancer or microtia, which is a congenital malformation of the external or middle ear that results in a small or abnormally shaped ear (5,11,12). But now, thanks to advances in the world of bioengineering, there will soon be an end to the torment suffered by children with deformed ears.

Researchers at Cornell University have created an artificial ear that looks and acts like an actual, natural ear (1). The bioengineered ears are replacements for the external ear, which is the outer part of the ear that include the auricle and the passage leading to the eardrum (8). Previously, the method available for surgeons was to take material harvested from the rib bones of young patients and carve and mold them into an ear shape before covering them with skin grafts. However, this method is difficult and challenging, as well as being immensely painful for the patients. The ears don't look natural either, and their performance is subpar (5, 6).

"Researchers at Cornell University have created an artificial ear that looks and acts like an actual, natural ear."

Now, the new method for constructing bioengineered ears is hugely promising. The process of composing these ears can be broken down in three steps; creating a mold of the ear using a 3D printer, injecting gel made from living cells into the 3D mold, and then allowing the ear to regrow its own cartilage (6). The design utilized in the first step is obtained by combining laser scans and panoramic photos of ears to make a digitized three dimensional image, all of which takes only about 30 seconds! Then the digitized image is

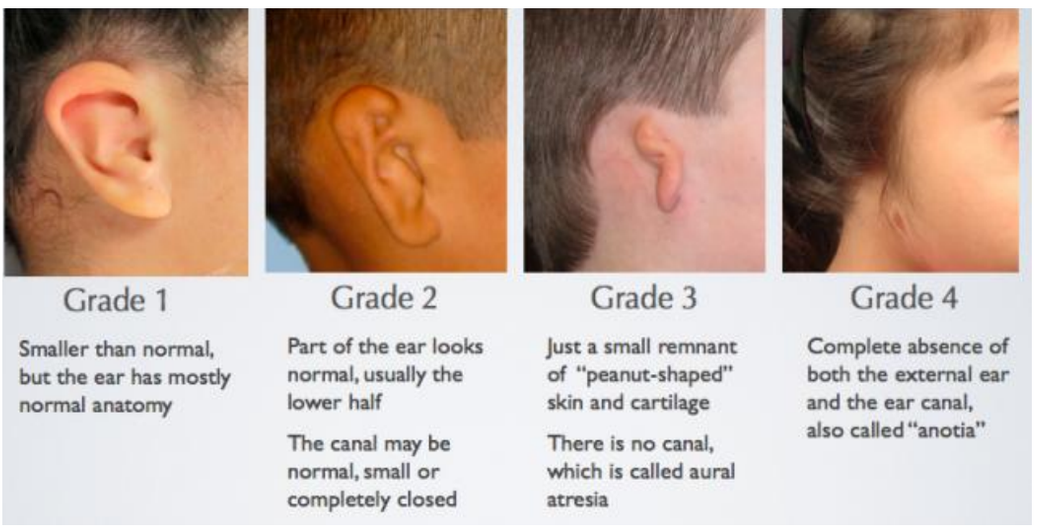

Figure 1: Examples of Microtia

converted into a solid ear, using the three dimensional printers used to assemble the mold. The success of the newer bioengineered ears over previous designs is largely due to the development of 3-D printers (3 & 5). Previously, without the accuracy of the 3D printers, the ears lost their

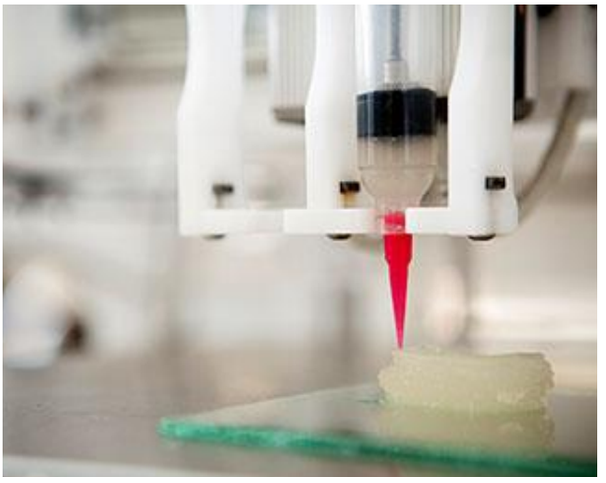

Figure 2: 3D Printing of mold

shape and/or the cells within them. The three dimensional printed versions are longer-lasting, and almost perfectly mimic the natural anatomy of the patients ear, which achieves the goal of providing a normal-appearing ear to children born with either a congenital ear deformity, or children with a deformity that occurred subsequent to their birth.

After the molds are created, animal derived collagen is injected into the mold, and then 250 million human cartilage cells are added. As the main mammalian structural protein, collagen functions as a scaffold on which the cartilage cells can grow. The high density collagen gel that was developed by Cornell researchers resembles the consistency of flexible gelatin when the mold is removed. During a brief observation period, the cartilage grows to replace the collagen scaffold of the ear. Dr. Jason Spector, one of the Cornell researchers, says "'eventually, the bioengineered ear contains only auricular cartilage just like a real ear.'"

The entire process is not a lengthy one in the slightest. It takes half a day to design the mold, a day to print it, about thirty minutes to inject the gel into the mold, and then the ear is trimmed and left to culture several days in a nourishing cell medium before its implemented. For the surgery of attaching the bioengineered ear, the malformed ear would be removed, and the bioengineered ear would be inserted under a flap of skin. The best age to give a child a bioengineered ear is ap-proximately age five or six, when the ear is 80% of its adult size (5).

These bioengineered ear replacements have many benefits. They can help individuals who have lost part or all of their external ear from various accidents or cancer. They can help children born with microtia, who have a missing or deformed external structure of their ear. They can improve these children's hearing as well, because many of these children's inner ears are intact, but they still experience hearing loss since the deformed structure of their external ear is unable to normally capture and conduct sound.

The only drawback is that sometimes the scaffolds that are created can't maintain their correct size, but at this point the benefits far outweigh the cons. The researchers at Cornell hope

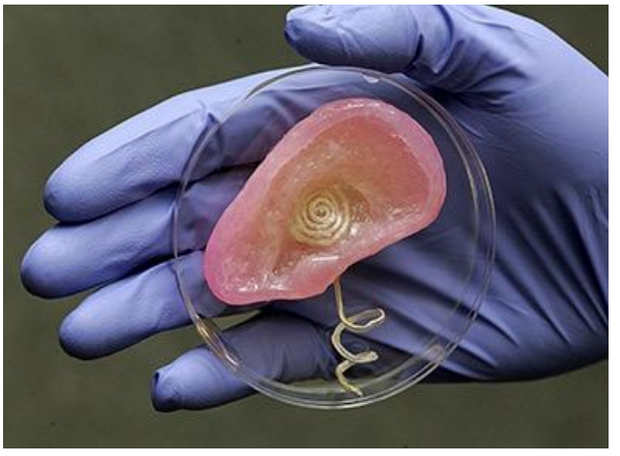

Figure 3: Bionic Ear

to be able to use human collagen in the mold in the future. The researchers estimate that within approx-imately a year, the first implant will be tested on humans (3).

Recently, there has been the development of what has been termed 'bionic ears'— an ear

that is a meld of biology and electronics. Using a 3D printer, scientists at Princeton have created an ear made up of a coil antenna and cartilage. This ear hears with the ability of a normal human ear (10).

Now, with bioengineered ears that look and act real, and bionic ears that can enhance and improve human hearing capabilities, children falling victim to bullying such as Ariana Adan, people whose cancer has resulted in deformed ears, and people born with microtia will no longer have to suffer. With these advances made in the fields of bioengineering, the problem of deformed or malfunctioning ears can soon be eliminated and one more reason for bullying eliminated.

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BONING UP ON GRAFTS

Miri Fried '15

"Break a leg!"—a well-meant phrase taken literally far too often. Over one million bone grafts are performed each year in the United States alone, and that number is growing. These procedures are performed for four main reasons: complex fractures which resist healing; fusion, typically in the spine, to heal two bones across a diseased joint; regeneration of bone lost to disease, infection, or injury; lastly, to help the bone heal around surgically implanted devices (2).

Although missing or damaged bone can be replaced by titanium, it pales compared to living tissue. The lack of bone marrow slows down metabolic functions, and it has recently been shown that titanium-based implants corrode and degrade, generating metallic debris. Also, because titanium is stronger than bone, a patient may unwittingly put more pressure on this implant, weakening the surrounding bone in the process. Two other types of grafting procedures do deal with anatomical bone: allografts, which use bone from a deceased donor, and autografts, made from a bone inside the patient's body (6). Neither is ideal. Donated bones run the risk of contamination and tissue rejection; patient-harvested bone can cause significant pain and damage at the site of the harvest, and it takes a long time to regenerate the necessary tissue. A less painful, risk free, and more efficient procedure is in high demand.

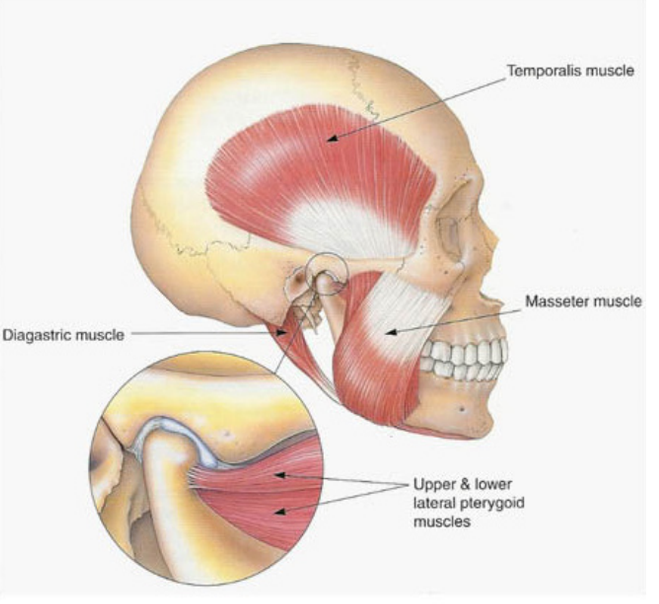

Figure 1

A team of researchers, led by Drs. Grayson (4) and Vunjak-Novakovic at Columbia University, recognized this problem and proposed to grow bone grafts in a bioreactor, using the patient's own stem cells (7). This way, the bone can actually grow with the patient after the implant and improve quality of life over time.

To test this idea, the team decided to start with a temporomandibular joint, found at the point where the jaw meets the skull at the front of the ear. Because it is extremely complex, the scientists felt that if they could engineer this joint, everything else would be simple by comparison. Another reason for starting with this joint is that roughly one out of four people experience disorders involving it, such as pain in the temporalis, masseter and pterygoid muscles, or chewing muscles, as well as jaw stiffness, painful clicking, or popping, and/or grating in the joint (5). Figure 1 depicts the temporomandibular joint, surrounded by the muscles mentioned above which allow it to function properly.

Next, the researchers designed a scaffold upon which to grow the bone. Scaffolds provide a medium for transport of gases, nutrients, and regulatory factors which promote cell proliferation and differentiation (1). Biological scaffolds are derived from human, or animal tissues, such as bone, but synthetic scaffolds, made from polymers, offer an alternative option. Recent innovations have shown that synthetic scaffold matrices printed using a 3-D printer allowed rat hippocampal neurons to thrive and form differentiated branched complex networks. Still, the researchers

decided to use real bone as a scaffold because it works in real life.

Using cell-stripped calf knee joints and digitized x-ray and MRI images from an anonymous patient as a template, the researchers programmed machines to carve human jaw joints. Next, they seeded each scaffold with three million human mesenchymal stem cells which develop into the tissues of the lymphatic and circulatory systems, as well as connective tissues throughout the body, such as bone and cartilage. The cells lined the pores of the scaffold, and were regularly fed with nutrients, growth factors, and oxygen in a bioreactor, an engineered device that supports a biologically active environment (3). The pattern and rate of perfusion (injection of fluid into a blood vessel in order to reach tissues to supply nutrients and oxygen), as well as the mechanical stimulation of the cells (which has been shown to influence differentiation of stem cells), guide the morphological growth of the bone tissue. Without this perfusion, only the surface of the bone remains viable. Death of the inner cells is particularly problematic, since these cells can release suicide induction signals to the remaining cells, resulting in apoptosis. The bone would begin to break down if it no longer receives the necessary stimulation.

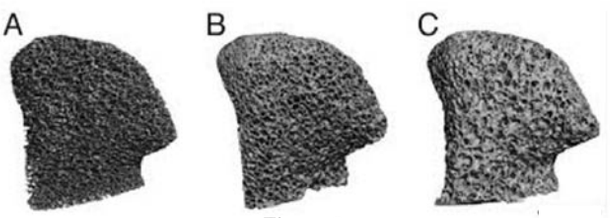

Figure 2

After five suspenseful weeks of cultivation, cell numbers increased up to 75-fold and the researchers saw functional bone tissue form (8). Figure 2 shows a temporomandibular joint at three stages of development. "A" depicts the scaffold with minimal tissue advancement on it. In "B," one can see the progression of the growth as the tissue starts to envelope the scaffold. Finally, in "C," it is evident that the bone is in its last stages of growth, and will soon be a fully developed jaw joint.

Other researchers and scientists, not associated with this project, called the work "stellar," "impressive," and "fantastic," because this was the first anatomically shaped piece of fully viable human bone created outside of the human body itself. Different research teams have tried to develop replacements for this same temporomandibular joint, but could only grow shapes not nearly as complex, or could only create imprecise versions, because they failed to provide the necessary stimulation and precise conditions inside the bioreactor (8).

In this study, mesenchymal cells taken from bone marrow were used to grow the bone, but researchers think it would be more efficient to take fat from the body, get rid of the fat cells, and be left with much larger quantities of mesenchymal stem cells than one could harvest from bone marrow. In addition, instead of relying on actual bone for a scaffold, they are now using synthetic mineralized protein, which is easier to mold and control. Researchers are also now attempting to grow blood vessels in a bioreactor, in the same manner that the bone was grown, to implant into the bone grafts to keep them alive once they have been placed in the patient's body (8).

"After five suspenseful weeks of cultivation, cell numbers increased up to 75-fold and the researchers saw functional bone tissue form."

Although the bone has not been tested in humans yet, it has been tested in an Immunodeficiency Mouse Model, which is frequently used to assess cells and scaffolds in bone tissue engineering, and for evaluation of stem cells. This trial demonstrated that in vivo, engineered bone tissue remained stable, with evidence of maturation, vascularization, and remodeling (7).

This innovation was the result of painstaking research, dedication and collaborative teamwork. By putting minds together, a novel viable solution to a taxing problem has emerged, which is certain to improve the long term prognosis for the millions of patients receiving bone grafts each year. Perhaps this new technology can be applied and extended to growing other tissue as well, making organ donation, matching, waiting lists, and rejection a thing of the past.

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DIVINE ORIGINS

Yocheved Butler '15

פרשת שמיני, פרק יא', פסוק ג' gives a general rule for which mammals Jews are permitted to eat:

כל מפרסת פרסה ושסעת שסע פרסת
מעלת גרה בבהמה אתה תאכלו:

"Any animal that has a cloven hoof that is completely split into double hooves, and which brings up its cud, that one you may eat" (10).

There are four mammals which the Torah commands the Jews not to eat because they each have only one of these two necessary signs. The camel (*gamal*), the hare (*arnevet*), and the hyrax (*shafan*) are each forbidden because they do not have split hooves, and the pig is forbidden because it is not *maaleh gerah*, which is usually translated as ruminant. Wouldn't we have known that these animals are not kosher even if the Torah had not explicitly told us so? Why did the Torah need to mention them specifically?

One possibility is that these animals were potential meat sources for the Jewish people because they had many other practical uses and "were commonly eaten by non-Jews (16)." The Torah needed to warn the Jews not to eat them because they would probably have been making use of them for their many other practical uses,

"Genetic analysis reveals that its closest living relatives are actually manatees, and elephants!"

to the extent that, in times of famine, Jews might think to turn to these mammals as an emergency food source. So the Torah says, "No, you may not eat them. They are not kosher."

The pig was domesticated from the wild boar thousands of years ago. Nowadays, people think of the pig as a meat animal, but in ancient times its lard was the most prevalent source of candle fuel and lubrication. Until the inventions of nylon and plastic, hairbrushes and toothbrushes were made exclusively from hog's hair, on account of its extremely stiff bristles (2). Camels, known as "the ship of the desert," are used as pack animals and for riding. A recent article, "The Date of Camel Domestication in the Ancient Near East," provides evidence that camels were domesticated as early as the third millennium BCE (3). Rabbits have soft fur that is great for making hats, gloves, and linings, among other things. And they reproduce like, well...bunnies! Their average gestational period is around a month, and females

Figure 1

typically birth six laurices in one litter; therefore, rabbits are a convenient, renewable fur and meat source (15).

What of the hyrax? What is a hyrax? The hyrax is a small mammal with hoof-like nails, looks like a rodent and has a short body and round face (Figure 1). Its distribution is limited to Africa and the Middle East. Although not ruminants, their mandibular motions are deceptively similar to

chewing cud. An adult hyrax usually weighs nine to eleven pounds, and is twelve to twenty inches long. Fossil evidence of hyraxes as big as a horse indicates that the modern hyrax's ancestors were much bigger than this small furry animal. Despite its superficial resemblance to a rabbit or mouse, modern day genetic analysis reveals that its closest living relatives are actually manatees, and elephants! (9) (Figure 2).

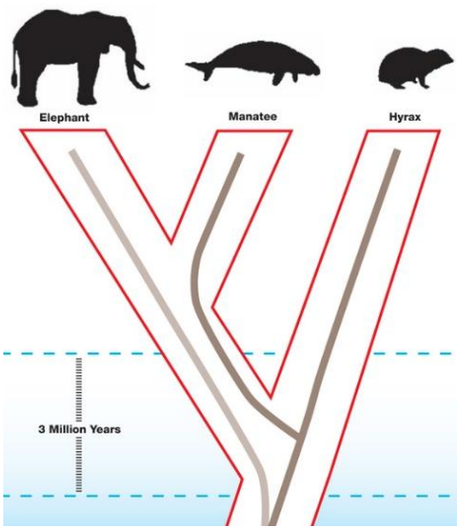

Figure 2: Phylogenic relationship between, elephant, manatee and hyrax.

There is no clear indication in the Torah how the hyrax was used in Biblical times, however, the many practical modern uses of the hyrax point to the possible roles which it must have played in ancient society. The aboriginal Ogiek of East Africa (18), geographically isolated by the Mau Forest Complex, to this day use hyrax skins as the main material of their traditional ethnic garments (12). Married women wear a cloak made out of a hyrax pelt, and unmarried girls use the pelt to make aprons. Additionally, the Ogiek use hyrax skin to make a bag called a "motoget" which is used to carry honey (11). Other East Africans people make rugs out of the soft hyrax fur (6). You can buy rugs and pillows made out of hyrax fur online (17).

One of the unique behaviors of the hyrax among all the other mammals is that they urinate and defecate into public latrines. Over time, this excrement thickens and fossilizes into a substance called hyraceum (1). Today it is used as a medicine and as an ingredient in perfume. The native people of Southern Africa, the Khoikhoi, use hyraceum powder to heal snake and scorpion bites, and they use a sticky mixture of hyraceum as a poison antidote and as a treatment for back and abdominal pains (13). It is likely that these people have been using hyraceum since ancient times. Afrikaner settlers in Gamkaskloof, a remote South African valley, have used hyraceum for many years as a remedy for colic, epilepsy, hysteria, and Parkinson's disease. Africans and Middle Easterners use hyraceum to treat convulsions, feminine hormonal disorders, and kidney problems (7). There are website which sell various perfumes made with hyraceum (8).

Recent research presents a fascinating medicinal use of hyraceum. As mentioned above, Gamkaskloof settlers use hyraceum to treat epilepsy and related ailments. When scientists extracted hyraceum with alcohol, some of these samples revealed a strong positive affinity for the GABA-benzodiazepine receptor. The graph below (Figure 3) shows the binding of flumazil to the GABA benzodiazepine receptor is competitively inhibited by ethanolic extract of hyraceum, especially at higher concentrations. The binding of a compound to the benzodiazepine receptor site improves the activity of the GABA neurotransmitter which works to prevent seizures and reestablish proper brain activity (13).

Perhaps the above described uses for the hyrax's skin, fur, and excrement explain why the Torah needed to warn the ancient Jews not to eat the hyrax. The hyrax is native to parts of Africa and the Middle East, including Egypt and Israel. (5). Jews living in Goshen until 1446 BCE [which is yetzias mitzrayim (Shoftim 11:26; Melachim I 6:1; Divrei HaYamim I 6:33-37)] would certainly have been familiar with the hyrax and its many uses.

Upon deeper introspection, this explanation falls short. At the time of Matan Torah, nobody in the Middle East had ever even seen a rabbit. We know this because in the 13th century BCE, Phoenician sailors were the first Middle Easterners to visit the Iberian Peninsula, the ancestral

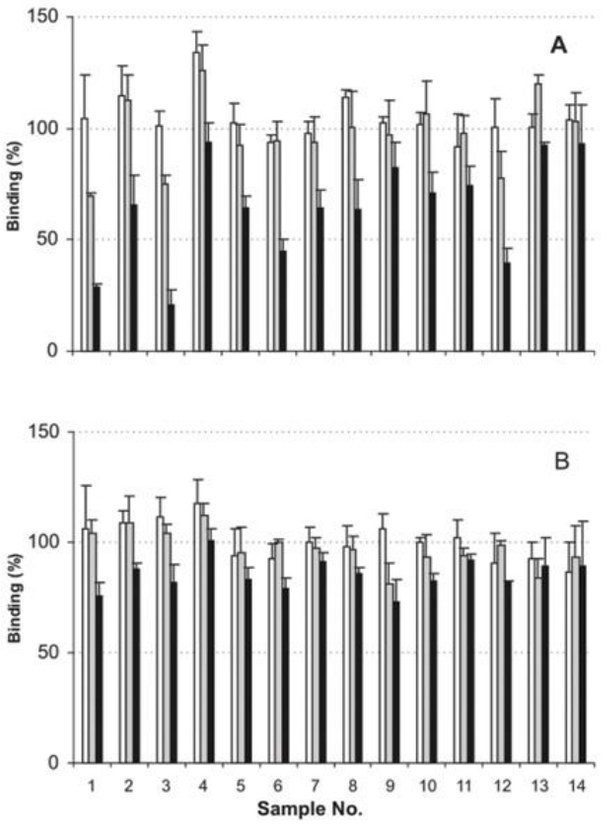

Fig. 1. Binding of [^{3}H]flumazenil to the GABA-benzodiazepine site in the presence of (**A**) ethanolic and (**B**) aqueous extracts of hyraceum. (□) 0.1 mg/ml; (▥) 1 mg/ml; (■) 10 mg/ml.

Figure 3

home of the rabbits. They saw them jumping around, thought them to be hyraxes, and called the land "i-shefanim" (אי שפנים) which translates into "island of hyraxes." Later on, when the Romans conquered this region, they modified the Phoenician name, and called it Hispania, gave rise to the name España, or "Spain" (14).

Furthermore, the rabbit was undomesticated in ancient times. For almost 2000 years, rabbits were happily living wild and free in the woods and cliffs of modern-day Spain and France until, in 600 CE, a group of monks in the Champagne region of France began raising rabbits inside their monastery walls for meat. When Lent— a period in which Catholics make vows of abstinence— came, they issued an edict which proclaimed that hairless rabbit newborns and fetuses were really a species of fish! Once word of this particular leniency spread, everybody wanted to raise rabbits, and very soon rabbits had spread throughout Europe and even to the British Isles via the monastery system (See Figure 4) (14). In the meantime, rabbits were still unknown in the Middle East and Africa, as we see when in 711 CE, the Muslim Umayyad Caliphate invaded and conquered Hispania. There, they saw rabbits, thought they were hyraxes, and so called them by the Arabic name for hyrax, which is wabr (16). And so, to this day, we call them rabbits.

Why did the Torah also need to warn the Jews not eat the rabbit, a furry animal similar to the hyrax, if firstly, it was unknown in the Middle East at the time and secondarily, it was undomesticated at its site of origination? The Torah needed to warn the Jews not to eat rabbits specifically because people in a later generation would eventually came to eat rabbits in a time of need. Considering the hyrax is wild (5) and the rabbit was not domesticated for thousands of years after the giving of the Torah, it is possible that the Torah's warning against eating each of these wild animals may have been the first indication to the ancient world that the hyrax and the rabbit were not the same species. In doing so, the Torah ensured that in future, Jews would never confuse the two (as so many ancient peoples had) and eat either one, as it would become clear in later generations that science classifies them as two entirely unrelated species.

Figure 4

In summary, the Torah had the foresight to warn Jews not to eat the pig, the camel, the rabbit, and the hyrax, whose ancient and currently realized practical uses result in other peoples' eating them in times of need. Study of the hyrax provides us with another weapon in our arsenal

of retorts to doubters of the Torah's divine origins.

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FIRST ROCK FROM THE SUN: LIQUID SILVER

Devorah Pinczower '17

In 1971, in response to a famine in Iraq, the United States and Mexico sent seeds of wheat to Iraq so that they could plant them and have food. Since it was too late for the planting season, families used the seeds instead to grind into flour, and make it into bread. Shortly thereafter, thousands were hospitalized and hundreds died, initiating a search for the culprit (14). The solution to the puzzle lay lurking in the sixth row, twelfth column of the Periodic Table with the element Mercury.

To understand what happened, we must first delve deep into the atomic and electron structure of mercury to understand the properties of this unique element (see figure 1). Unlike other metals, Mercury (electron structure: [Kr] $4d^{10}$ $4f^{14}$ $5s^2$ $5p^6$ $5d^{10}6s^2$), is a liquid at room temperature and pressures and is relatively unreactive. The reason

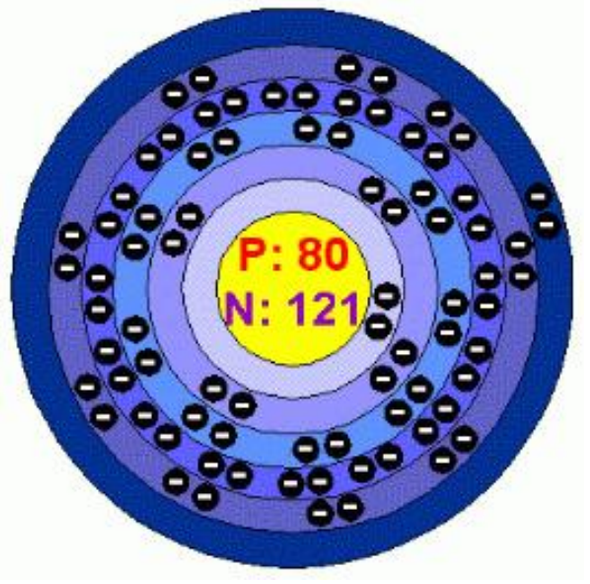

Figure 1

solids maintain their constant shape is that they have strong attractions between particles. Liquids less so and therefore, they assume the shape of their container. The strong attractions between atoms of metals that cause them to maintain their shape is called "metallic" bonds and is explained by the "electron sea model." Because individual metal atoms hold onto their valence electrons weakly, these electrons are freely shared between all the atoms collectively throughout the crystal. This also explains why they conduct electricity well, because the electrons are free to roam within the confines of the crystal. Each mercury atom, with 80 protons in its nucleus, exerts a strong controlling pull on its wayward electrons, and consequently less willing to distribute them to the collective group. Since it forms weaker metallic bonds, it is a liquid and conducts electricity less efficiently.

"Unlike other metals, Mercury is a liquid at room temperature."

There are certain electron configurations that are more stable than others. Greater stability implies that those electrons stay put. The most stable electron configuration is that of the noble gasses, s^2p^6, which explains their classic inertness. Mercury's valence electron configuration is s^2d^{10} which is the second most stable configuration, the metallic equivalent of a Noble gas. Cadmium, just above mercury, also has the s^2d^{10} configuration but its nucleus is relatively puny, containing only 48 protons, which exert less pull and control on the electrons. Furthermore, the electrons of the sixth energy level are not that much further from the nucleus than the fifth energy level. This phenomenon will not occur in gold ([Kr] $4d^{10}$ $4f^{14}$ $5s^2$ $5p^6$ $5d^{10}6s^1$), mercury's neighbor to the left and thallium ([Kr] $4d^{10}$ $4f^{14}$ $5s^2$ $5p^6$ $5d^{10}$ $6s^2$ $6p^1$), mercury's neighbor to the right which also have similar 6s orbitals. In gold, the 6s orbital is only half full, so it is easier for it to bond. In thallium there is a $6p^1$ electron which is also a half filled orbital, making it more reactive (1). Supporting proof for

this conjecture would come if sufficient quantities of Copernicium, Mercury's neighbor below it on the periodic table, could be synthesized, and if it would hang around long enough for us to observe its behavior. This element would have a predicted comparable electron configuration of $7s^26d^{10}$ and a massive 112 proton nucleus, with uber Mercury-like behavior.

Another example of mercury's unique behavior is the way its surface looks when filling narrow tubes. If you were to take two tubes, fill one with water and one with mercury, you would notice that they form slightly different shapes (see figure 2): Mercury is convex (left), while water is concave (right). Cohesive forces are intermolecular forces that keep molecules of the same liquid together. Adhesive forces are the attractions between the liquid particles and its solid container. The relative strengths of the cohesive and adhesive forces are what determine the shape the surface will assume. For example, water will not spread out on the surface of a wax cup because the cohesive forces within the water are stronger than the adhesive attractions between the water and the hydrophobic wax of the cup. The water will bead up. When water is in a glass tube, its meniscus is a concave shape because the water is attracted to the walls of the glass tube, causing the edges to be slightly elevated. Conversely, cohesive forces between mercury are stronger than the adhesive force between the mercury and the tube. Therefore, mercury's meniscus in a tube is a convex shape (15). Mercury's cohesiveness causes it to bead up on any surface and when beads come in close proximity they join (see Figure 3), to the delight of children in the 1950's, before its toxicity was well established .

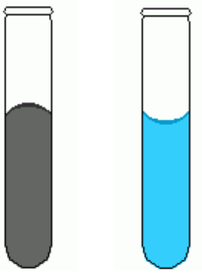

Figure 2

But why do we really care about mercury? Simply put, it is an environmental pollutant. Mercury gets into the environment through natural and unnatural causes such as volcanoes, coal powered power plants, as well as community and medical waste burners. Because mercury is found in coal, when coal is burned, mercury is released into the environment (4). It then settles down in wet and dry forms. Scientists conducting experiments in Nevada, measured the amounts of mercury in the soil. In the middle of testing, it started to rain, moistening the soil. When the scientists continued their testing after the rain, they found that the amount of mercury in the soil and the amount of mercury emitted had increased. The wetter a particular area was, the more mercury was found there. In some areas, the mercury level rose up to 6 times the amount that there was before the rain. Climate change will certainly factor into rising mercury contamination in the future (2).

Figure 3

Sometimes mercury contaminates water though sewage pipes and other waste dispensers. It will then change from inorganic to organic (methylmercury) mercury as it makes its way to fish, following the food chain to humans, birds and other organisms. Fish in Florida particularly have high mercury, and those who eat fish from that area at least once a week have too much mercury. The high levels of mercury in Florida come from the heavy rains which then contaminate the freshwater lakes and streams, and is consumed by the Floridian fish. Sewage areas in Florida were also found to be too high in mercury levels. This is as a result of waste from humans who ate too much fish with mercury, and even from dental amalgam fillings. This mercury then goes into landfills, water, or even the air. Fish that are found near gas or oil areas as well as birds and alligators who eat these Floridian fish suffer from

too much mercury. Wading birds in Florida are disappearing due to their consumption of fish that take in mercury.

There are three different types of mercury found in the environment, and each types has their own damaging effects. Methylmercury affects neurological development of children and babies in the womb. Infants are sometimes negatively affected by mercury in vaccinations, or their mother's milk if she has too much mercury, or fish. The National Academy of Sciences discovered that 50% of newborns suffer from ADD, dyslexia, learning or mood disorders, eczema, and asthma as a result of excessive exposure to mercury. Pregnant and nursing mothers as well as young children have to be especially careful not to have freshwater fish more than once a week (8). When a pregnant women consumes too much tuna or shellfish, the baby can experience thinking, attention, muscle, coordination, and nerve damage (6).

Since mercury is a liquid, it is readily vaporized. Elemental mercury can cause problems when inhaled, usually when something containing mercury breaks, releasing the mercury into the air (7). This type of exposure can cause nerve and emotional damage, kidney and breathing issues, and sometimes even death. The other form of mercury is in inorganic compounds. It can enter the body through the skin or mouth when one has contact with disinfectants and fungicides. This kind is usually found in school's labs and is the least dangerous (7). That is why Mrs. From's bottle of Mercury is kept in the locked poison cabinet. This type can cause kidney and nerve issues, memory problems, and muscle problems (6).

Despite its dangers, modern uses for mercury abound. Did you ever have to get a cavity filled? Remember having your mouth replete with metal tools and watching in horror as the dentist drilled at your tooth, watching pieces of your tooth fly in all directions? Ever wonder what they are doing that is so painful? Dental amalgam is used to fill cavities and is just one of many of materials used to fix decayed teeth. It contains mostly mercury, alloyed with tin, silver, and copper powder. When one gets a cavity, a dentist will remove the decay (hence the drilling), and refill the hole with dental amalgam. The liquid mercury within the mixture allows the dentist to shape and form it easily as it assumes the shape of the hole as it hardens (see figure 4). Because mercury is nonreactive, the filling is durable and likely to last for a while (9).

There is a slight risk involved in the usage of dental amalgam. Due to its containing mercury, in the process of filling one's tooth or even chewing, some vapor containing mercury may be emitted which is dangerous. However, the Center for Disease Control (CDC) confirms that there is little evidence to prove that dental amalgam causes the problems associated with mercury, such as brain and kidney damage (10). The FDA recommends that those who are likely to be negatively affected by mercury should consult their dentist before getting dental amalgam filling (9).

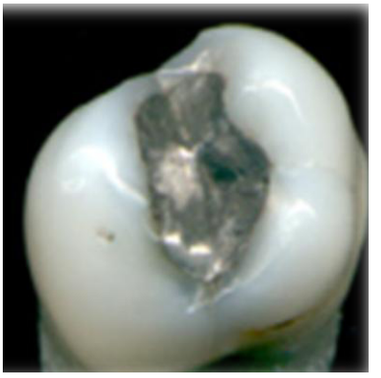

Figure 4

Mercury can also be found in fluorescent light bulbs and high intensity discharge bulbs used in street lamps, parking lots, and other public lights. Fluorescent bulbs last longer than incandescent bulbs and they are more environmentally friendly because they require less energy. They also help reduce the amount of mercury released into the environment. Because they require less energy, there is less of a need to burn coal which release mercury. The amount of mercury used in florescent bulbs has been reduced over time, however small amounts are still present. Therefore, we must recycle bulbs to prevent the release of mercury which occurs when they are improperly discarded and broken. Once it is recycled, both the

bulb and the mercury can be reused (16).

There are also many uses of mercury which we are not so familiar with in today's digital day and age. Mercury used to be used in thermometers because it is a liquid and a small increase in temperature will cause it to noticeably rise up in the glass tube and the opposite when the temperature drops. Mercury was well suited for thermometers because it expands uniformly at a constant rate. Mercury thermometers are no longer used because if the glass cracks, and mercury escapes, it is extremely lethal (12). A similar instrument containing mercury used to measure air pressure is a barometer (figure 5). Mercury is poured into a U-shaped glass tube sealed on one side. Air pressure pushes on the open end. When air pressure is high, it will push on the mercury in the open arm causing the level of mercury in closed arm to rise; conversely when air pressure is low. Because of mercury's density, one can use a reasonable amount of mercury to measure the pressure accurately (13).

Figure 5

Mercury is found naturally in the earth's crust, usually found in the form of the red ore cinnabar (mercury sulfide) (figure 6), but it can also be found pure. When it is found in the ore cinnabar, it is heated to around 580 degrees Celsius with oxygen. As a result, mercury in the form of gas leaves the ore, separated from the sulfur. The mercury is then compressed, washed with nitric acid, and distilled (5).

While we now know that mercury is dangerous, earlier generations and cultures did not. Mercury was used by the ancient Greeks, Romans, Chinese, and Hindus for medicine. Mercury was named for the planet Mercury and that is how alchemists referred to it before its chemical notation was given. Ancient civilizations also used mercury's cinnabar for paint pigment and cosmetics. Romans used mercury mines to jail their prisoners, causing many of them to die. Alchemists believed that mercury was a principle substance, therefore gold and other metals were made out of it. Diocletian, a Roman emperor banned alchemists' works out of the fear that they will make gold and become wealthy on the face of his economy. Ko Hung, a Chinese alchemist believed that mercury can cause long life, and used it for medical treatment. Other forms of mercury medical treatments have been around until the early 1900s (14).

Figure 6

What does all of this has to do with the tragedy in Iraq? The grain contained in it methylmercury to preserve the grain for longer storage and prevent molding. The nations who sent the grain dyed it red as a warning and put a skull and crossbones on the bags to make sure that the seeds were not eaten directly. But the skull and crossbones is a symbol only recognized by westerners, not Iraqis. There were also warning labels, but because most of the grain was made in Mexico, they were in Spanish. While there would have been no danger in eating the wheat that was grown from the grain, eating the seeds directly was dangerous as it still contained the methylmercury (14).

I believe that in the future, the need for mercury will decrease. Thermometers and barometers have gone digital and no longer require mercury. In addition, light bulbs are requiring less energy than they used to. There are other ways to fill cavities besides for dental amalgam, and despite their lesser durability, I am confident that they will find an equally suitable substance to do the job. This reduction in the need for mercury

will cause less mercury in the environment from coal powered plants, broken bulbs, and other man controlled sources. However, the mercury naturally found in the earth's crust is beyond our control. With new recycling awareness, and caution when eating fish, I believe that mercury will not play such a significant role in our society any more. However, maybe future studies will reveal a way to make a compound with mercury that will counteract its lethal properties so that it can be more useful to us.

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HAND IN HAND

Gabrielle Hawk '17

Nineteen year-old Ma Li's plans of pursuing a career as a professional ballerina came to a screeching halt— literally— when in 1996 she was injured in a car crash. When she regained consciousness in a hospital bed, something felt off. She lifted the blanket and found her right shoulder armless. Ma Li was devastated and stopped dancing. She doubted that a dancer could ever be graceful with a disarticulated arm (1). Ma Li's story will strike a chord in anyone who loves to dance.

Amputees must readjust psychologically, physically, and socially. From the moment amputation is considered, patients must psychologically prepare themselves for this big change in their life (5). Feelings of depression, anxiety and low self-esteem are maladaptive and can lengthen the adjustment period to the prosthetic (3, 5, 9).

"It felt like my arm. It was just such an amazing feeling."

Amputations that resulted from trauma can even cause the amputee to suffer from posttraumatic stress disorder (PTSD). Physically, upper-extremity amputees often suffer from chronic pain in their back, fully functioning arm, and even in their amputated "phantom limb." Sensations such as burning and cramping in an arm that was amputated can be disturbing (3, 5). Shoulder disarticulation amputees must also learn to function with only one arm. They have to relearn to tie shoes, button shirts, type on keyboards, and possibly drive with only one hand. In addition, amputees have to re-adjust socially. Without an arm, amputees may be stared at or asked blunt questions. These instances can harm their self-confidence that is often fragile after the operation. These awkward social occurrences in the beginning of their readjustment stage often cause amputees to become introverted for a period of time (5, 10, 11).

I conceived an idea to help amputees with a bionic arm that could attach to the frayed nerves. The signals transmitted from the brain would be detected by the prosthetic and translate it into arm movements. The prosthetic would need to include complicated algorithms on an internal computer to convert the impulses into electronic motion. I began research to see if a prosthetic like this existed.

Prostheses that are currently in use for shoulder disarticulation are limited in their freedom of movement. Only a single degree of freedom (DOF), or one mechanical joint, can be controlled with body-powered cables. The same is true of electromyographic (EMG) signals from the residual muscles. Myoelectric prostheses interpret the EMG signals and convert them into instructions for the machine's movement. The myoelectric sites that transmit the EMG signals are found in the chest and back, but are not intuitive control sources for elbow and wrist movements (10, 11). Furthermore, there are only three DOF currently controlled by myoelectric prostheses. Each joint must be selected to move, and selection generally requires switching the selected joint through co-contraction. Co-contraction is simultaneous contraction of the agonist and antagonist. This process makes it nearly impossible to operate multiple joints at once (10). There are other manual prostheses that generally require the user to switch between joints using his chin. Motor movement is extremely limited with the manual prostheses, even more so than the myoelectric prosthetics (12).

Targeted muscle reinnervation (TMR) is a new surgical process that may alleviate all of these issues. TMR enables amputees to control a prosthetic more intuitively and accurately. Four intact peripheral nerves from the amputated limb are surgically transferred to a target muscle in the

chest. The residual nerves grow into the muscle (See figure 1). Contractions within the muscle correspond physiologically to movements of the prosthetic (10, 11). TMR magnifies the motor information of the chest muscle movement and sensory electrodes in the prosthesis interpret the signals by complex electronic analysis into motor movement (10).

The patient works with an occupational therapist to control muscle contractions. It generally takes 10-15 weeks for the nerves to grow into and gain control over the host muscle. Once this occurs, the patient works on strengthening the host muscle signal so that the movement is strong enough to be detected by surface electrodes. He also learns to differentiate between phantom limb movements and the nerve signals directed towards the host muscle that are imperceptible at first but grow stronger over time. When the signals are strong enough, a TMR-controlled myoelectric prosthesis can be fitted. EMG signal sites that are distinct enough for control of different joints direct the prosthesis (11). The TMR prosthesis has more DOF than typical myoelectric prostheses because of the increase of myoelectric sites. The movement of the prosthesis is intuitive, because all of the signals are directed from the brain. The TMR prosthesis allows for simultaneous movement of separate joints, moving naturally like a human arm (10, 11).

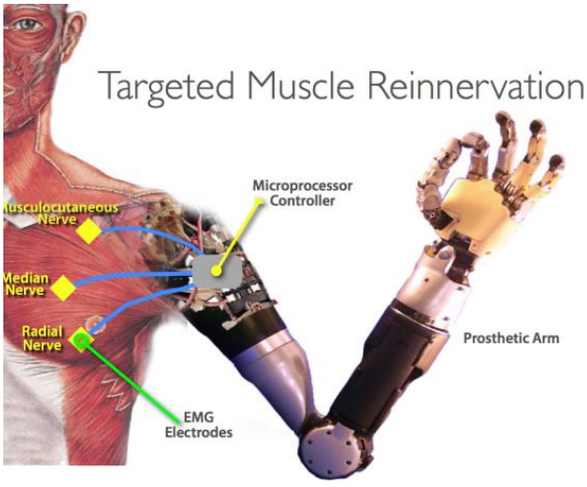

Figure 1

DEKA Research and Development Corporation, as well as other engineering companies, has developed a highly functional prosthetic arm that can be used with TMR patients. Fred Downs, National Director of the U.S. Department of Veterans Affairs' Prosthetics Division, and a veteran who himself lost his arm, remarked after using one such arm, "It felt like my arm. It was just such an amazing feeling," (4). Targeted muscle reinnervation is a process that may change amputees' lives forever. Prostheses are constantly being developed to give amputees a wider range of motion that will help them adjust faster and easier. In addition to shoulder disarticulation amputees, TMR is also used on elbow disarticulation (11).

With the exponential rate of growing technology, newer TMR prostheses may be capable of two-way communication to give the sensation of touch back to amputees. Several companies are trying to develop prosthetics with this feature. This addition can make a huge difference to amputees and the way they live their lives. People may be able to feel the touch of their children's or elderly parents' hands in theirs for the first time (See figure 2). In the near future, hopefully TMR will be available to all levels of disarticula-

Figure 2

tion in both upper and lower body extremity amputations. It will help ease the lives of dancers, like Ma Li, soldiers, veterans, sports players and all amputees. How fortunate for Ma Li, that my idea has already been brought to fruition and she will not have to wait for me to finish my schooling.

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HYDROPONICS

Rivky Kreiser '16

Defined as the cultivation of plants without soil, hydroponics "is rapidly changing the face of the world we live in" (4). Unlike traditional cultivation, hydroponic cultivation presents opportunities for cultivators everywhere. Whether in a desert, or in any arid environment for that matter, the possibilities aren't nearly as limited as they would be with normal cultivation.

Dear to all of us, Israel, together with the Netherlands, Spain, Canada and France, leads in the field of hydroponics. Not a rapidly developing field here in the US, hydroponics, with all of its advantages, has been somewhat overlooked due to its expense. The higher initial and operational costs, combined with the evidence that the conditions in which hydroponic plants grow stimulate the growth of salmonella, have been enough to stop the US from being a front runner in this field. Nevertheless, the many advantages have encouraged Israel and the European countries mentioned, to pursue hydroponics. Since hydroponics reduces the amounts of soil related insects, fungi and bacteria, it has a wide appeal. Furthermore, plants grow faster when there is more available oxygen in their root areas, and when they're more exposed to CO_2; therefore, it can be worthwhile for the cultivator, who would have much more control over the plant in general.

"The question is: which bracha would you make on hydroponically grown produce?"

Nonetheless, the million dollar question remains: What are the differences between hydroponic cultivation and soil cultivation? Both sides have positives and negatives. Hydroponics eliminates weeds and requires less water due to no evaporation or run-off, but as mentioned previously, its high initial cost is reason enough to dissuade people from using it. Additionally, everybody is accustomed to soil cultivation and wants to remain within their comfort zone. As a result of this, people are generally surprised to hear that there are actually no physiological differences between plants grown by either method. Additionally, with the decrease in arable land, hydroponics offers an alternative for growing food. Whether accepted or not, it may become very necessary in the future.

Hydroponics isn't just limited to growing a plant in water. "Any form of substrate or aggregate that does not include garden soil is also considered a hydroponic system" (5). Perlite, vermiculite, sand and rock wool are all commonly used substrates that provide no nutrition to the plant. Instead, a solution containing nutrients passes over the roots at regular intervals. Usually, "a nutrient solution is …pumped into [a] trough [containing the aggregate] at one end, and when the trough is flooded, the solution is drained out the other end" (6).

In a popular liquid growing system called the Nutrient Film Technique (NFT), "plants are placed in a polyethylene tube that has slits cut in the plastic for the roots to be inserted," and the nutrient solution is pumped through the tube to pass over the roots. When it's finished, the surplus is always recovered, replenished and recycled. In another type of liquid system called Aeroponics, "plant roots remain suspended in an enclosed growing chamber, where they are sprayed with a mist of nutrient solution at short intervals" (6). So whether a liquid or aggregate system is used, there is no lack of nutrients being supplied to the plant.

Currently, the idea of vertical farming has been proposed more and more often. In his Master's thesis, Skyfarming, Gordon Graff argues that vertical farms can work economically, and

Figure 1: Vertical Skyfarm

that they can also have other extreme benefits. He writes that "in California, an acre of lettuce sucks up between 1800 and 3500 cubic meters of water; [while] the Skyfarm consumes 14.4 cubic meters, 1/240th as much" (2). Sky farming could help the agricultural field, which currently uses about 70% of human water, preserve a most precious commodity (See figure 1).

Lettuce (Lactusa sativa) is one of the most commonly hydroponically grown vegetables on the market, but cultivators must watch out for water mold and regular greenhouse insects so the lettuce plants won't be devastated. Similarly, there is also a large market for hydroponically grown strawberries. Strawberries are such a popular fruit that they're in demand year-round, so to provide them to the masses, they could be grown hydroponically (See figure 2). It is interesting to note that these plants, which are scrupulously checked for insects by Jews around the world, are being grown in a way that the amount of soil related insects are automatically reduced.

Just recently, the benefits of cultivating medicinal plants in hydroponic systems were discovered. Since the cultivator has more control over environmental growing conditions, the "hydroponic cultures can have relevant results like uniform yield, with high percentage of bioactive substances and this kind of system can be the way to cultivate the medicinal plants in commercial purpose" (12). Furthermore, by using hydroponics to cultivate medicinal plants, the diversity of wilderness species is protected. With hydroponics, humans won't tamper with these wild species, to make them all produce uniform yields.

Approaching this from a Halachic perspective, the question is: which *bracha* would you make on hydroponically grown produce? Since it's not actually grown from the ground, are you supposed to make a *Ha'adama*? R. Shmuel Wosner answers yes, because he chooses to focus "on the larger picture of how the species normally grows". You would usually make a *Ha'adama* on a traditionally grown vegetable, so here there's no difference. However, at this point some countries "boast that they grow more flowers hydroponically than in any other way," (4) so there may come a time when the average vegetable will not grow in the ground. In contrast to R. Wosner, R. Ovadiah Yosef says that one should make a *Shehakol*

Figure 2: Hydroponic Lettuce and Hydroponic Strawberries

on hydroponically grown produce. He bases his argument on a similar case: mushrooms. In the Gemara, Abaye says that one would make a *Shehakol*, because "[mushrooms] do indeed spring up from the earth, but their sustenance is not derived from the earth!" (1). The *p'sak* however, is different when it comes to wheat products, because Dayan Falk says one would always make a *Hamotzi/Mezonos*, even if the wheat was grown hydroponically. Dayan Falk bases his answer on the Yerushalmi, where the *Amoraim* discuss a case where wheat was grown in soil indoors. Can one say the bracha of *Hamotzi ("…min ha'aretz")* if the wheat isn't from the land? The Yerushalmi discusses the importance of always saying the same bracha, but fails to give a clear answer. Based on this discussion of the importance of always making one same bracha, and the opinion of R. Wosner who says to always look at the big picture (the vast majority of wheat is grown traditionally) Dayan Falk says to make the regular *bracha* of *Hamotzi*.

Additionally, when it comes to Pesach one should avoid matzo made from hydroponically grown wheat, because in Pesachim it states that matzo and maror must be made from products purchasable with *ma'aser sheini* money. This condition prohibits mushrooms because they aren't grown in the ground, so likewise hydroponics could be a problem. Since we are especially careful on Pesach, we don't take any chances, and stick to matzos made from traditionally grown wheat. Furthermore, if one isn't sure whether his vegetables are traditionally or hydroponically grown, the *p'sak* would be for him to make a *Ha'adama* because most vegetables grow from the ground. But if/as that reality changes, poskim will have to reevaluate. The merging of expert knowledge of Gemara with science, and finding the appropriate analogous situations from which to draw a *p'sak*, will provide ample opportunities to demonstrate that halachic solutions to modern dilemmas can be found in our living Torah.

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JIGSAW PUZZLES: PUTTING THE PIECES TOGETHER

Shoshana Rosenthal '16

An appropriate symbol for autism awareness is a puzzle piece (see figure 1) because for years the condition was an absolute mystery. Behavioral patterns emerged, but the underlying reason remained elusive. Medications could be prescribed to target symptoms, but never the condition itself. No one could explain how classic autism, PDD-NOS (Pervasive Developmental Disorder-Not Otherwise Specified), and Aspergers Syndrome could all be different faces of the same disorder. In an exciting development, a piece of this puzzle has been found, changing the way Autism Spectrum Disorders (ASD) are viewed. Autism has a genetic basis. That genetic basis could ease the process of diagnosis and hopefully, by targeting the genetic product, lead to a medicinal cure.

Figure 1

Unlike genetic disorders such as Cystic Fibrosis or Tay Sachs, autism mutations are not limited to one gene and one location; mutations on almost a thousand genes can cause autism (15). Those mutated genes correlated to autism control various functions such as splicing, formation and function of brain neurons and synapses, the immune response, how DNA is wound up into chromatin, and many others. There are differing opinions as to how multiple mutations work together to manifest autism. Research shows that the effect of various mutations will converge on a certain location in the brain, depending on the genes involved, and the change in that spot could cause autism (5). Other evidence shows that one mutation can affect various parts of the brain at once, and those combined effects could cause autism. Many of the genes implicated in autism are regulatory genes; therefore, even small changes could have large effects (4). It may be that there is no one correct view on this matter because autism's genetic basis makes each case unique.

These mutations can either be inherited or occur de novo (spontaneously). Copy number variations are especially common in inherited mutations (10). Insertion mutations and deletion mutations also play a role in the genetic basis for autism (13). Single nucleotide variations are especially common in de novo mutations. When the mutations that cause autism are hereditary, they are sex-linked. Even when a de novo mutation occurs, 80% of the time, it comes from the father. All of this makes it more difficult for a girl to have ASD. The ratio of autistic boys to autistic girls is 4:1. However, when girls have autism, it tends to be more severe. The mutations that cause the disorder in girls tend to be larger ones that are more active throughout the brain and there tend to be more of those mutations. Inherited genetic mutations also tend to be recessive (15). Seventy-two mutations that were found to cause autism were milder forms of mutations that caused more serious diseases such as Crohn's Disease and Nonketotic Hyperglycinemia. It is suspected that neurological symptoms play a more important role in those disorders than was once thought, and that is why the disorders share the recessive mutation (1).

The reason ASD is a spectrum disorder could be that mutations in different genes lead to different symptoms. People with autism who have lower IQs, or are non-verbal, tend to have mutations that are more active in the brain while people with autism who have higher IQs tend to have mutations that don't affect their brain func-

tion as seriously (4). Specific mutations can cause specific combinations of symptoms, such as the mutation of CHD8, which causes autism with gastrointestinal issues, sleep problems, wide eyes, and a larger head (11). The wide variety of mutated genes affect a wide variety of neurons, but the cortical and striatal neurons, which make up the brain circuits controlling repetitive behaviors, thoughts, and motions, are affected in everyone on the autistic spectrum. This then becomes a criterion for anyone with the disorder (4).

While genetic mutations do cause autism, epigenetics (the pattern of methylated DNA bases which turns genes on and off by shifting on and off the DNA [see figure 2]) also plays a role in triggering ASDs. Researchers at King's College London, tested the DNA methylation at 27,000 spots on the genes of 50 pairs of identical twins, some having ASD, others not, and most where one twin had ASD and the other not. Everyone with ASD had certain identical methylation changes and also had additional methylation changes that differed depending on their autism symptoms. The severity of the ASD correlated to the total number of methylation changes from the norm (3).

The knowledge the epigenetics plays a major role in the development of autism will ensure that environmental factors are not shoved to the wayside in favor of genetics in determining what causes ASDs. The epigenetic methylation can be affected by pretty much anything in the environment such as food, chemicals, the age of parents at birth, and many more (16). The latter two factors listed have both been linked to autism. Older mothers have a higher risk of giving birth to children with autism (2). In 2012, polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs) joined the long list of chemicals that are taking the blame for the recent rise of ASDs, though these were confirmed through a study that analyzed brain tissue samples taken from Autism Speaks' Autism Tissue Program (7). But not every environmental factor was involved in the development of every case of autism. Genetics and epigenetics have shown us that every case of autism, PDD-NOS, and Aspergers is unique—with its own set of causes, symptoms, and possible treatments.

A genetic basis for autism opens up potential worlds that were previously closed to the autism community. The current diagnostic methods for autism involve observation over a period of time and behavioral evaluation by a mental health professional. This is time consuming and not typically performed until age two, usually even later, delaying intervention (12). However, now that it is known that autism has a genetic basis, a blood-test has been created to test for ASD. The test identifies specific genetic mutations, or biomarkers, known to cause ASD. Of all of the children identified as autistic through this blood test, only one was later proven a false positive (6).

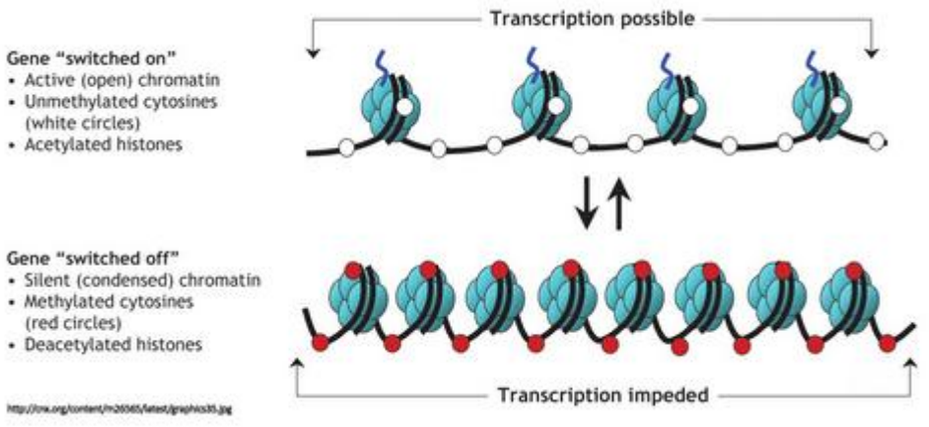

Figure 2

A genetic basis for autism not only eases the diagnostic process, but also opens the tantalizing possibility of a cure. Scientists are tracking the effects of the genetic mutations

and are trying to develop drugs to stop those effects from progressing. The approach one takes to the source of the ASD will determine the target of the remediation efforts- the location or the mutation. Either multiple mutations all converge at one location (5), or one mutation affects various parts of the brain simultaneously (4). No breakthroughs have been made yet, but the field is new and promising.

One example of genetics leading to a possible cure, or even treatment, is the discovery made by Arthur Beaudet. He discovered that a mutation in the X-linked TMLHE gene was a risk factor for autism, though a weak one. However, this study

"Given a choice, many with ASD would not give it up."

still has revolutionary implications. The mutation in the TMLHE gene causes an exon deletion, causing the body to not code for the protein carnitine. While autism has not been linked to carnitine deficiency, Beaudet and his colleagues believe that supplementing the diet with carnitine could be a treatment for autism (8). This is the first time that any treatment for autism involving diet changes can be given an explanation. The popular gluten-free casein-free diet helps many dealing with ASDs, but no one can explain how or why (14). Beaudet's study shows that the answer may lie in genetics.

The possibility of curing autism begs the philosophical question: "Should we?" Given a choice, many with ASD would not give it up. ASD brings with it an increased ability to focus, a better memory than usual, and other benefits (9). If this discussion is started now, it might be finished in time for the cure. Some of the pieces of the puzzle that is autism are starting to come together, but so much of the puzzle is left unfinished.

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LET THE SUN SHINE IN

Ayelet Huberfeld '17

Imagine the world without glass. The interiors of our homes would never be brightened by the sun, we might still be stuck in the geocentric model of the universe, and the study of microscopic cells would be set back a few hundred years. It is around us everywhere we look, in different forms, performing various functions. From drinking bottles, to windows and light bulbs, glass is an essential part of our lives, so much so that each year, the glass industry in America produces over 20 million tons of glass (3).

Figure 1

Glass is both natural and a man-made product. Fulgurites are glass formed by lightning strikes in the dessert (see figure 1). Manufactured glass has a long history, originating with the first records of glass production by the Egyptians in the 1500's BC; however, archeologists think that the practice originated in Mesopotamia, but there is no proof to that theory. They used glass to make beads, figures and glaze tiles. The glass produced by the ancient Egyptians was very different than our glass today. The glass was filled with air bubbles and clumps of non-melted sand (13). An ancient glass factory discovered by archeologists Dr. Thilo Rehren and Dr. Edgar B. Pusch proved that the Egyptians produced glass in large quantities. The site was used in the 1200's BC, and contains the remains of glass, raw materials and glass making tools (14).

"Technically, glass is a "frozen liquid", liquid that has ceased to flow, and not a solid."

In the 200s CE, Glass making became a competitive business as the Middle East and Greece started manufacturing glass. As time went on, the process was refined, and different metals were added to the sand mixture to color the glass. The new methods cost less allowing glass to be available to all, unlike previously, when glass was limited to the rich (13). In the 1000s, Italy became the center of glass production, even trading their products for gold (11). To this day, the glass produced at Murano, Italy is one of the most highly prized. The other European countries caught up and captured the glass making market, improving the process, and beginning to make windows. Centuries later, glass was refined and is used to make light bulbs and lenses for glasses, microscopes, and telescopes (13).

Glass is made of sand fused together with other chemicals, at very high temperatures. On its own, sand melts at the extreme temperature of 3,000° C, so other substances are added to reduce

the temperature. Most commercial glasses have a chemical composition similar to this: 70%-74% SiO_2 (Silica), 12%-16% Na_2O (Sodium oxide), 5%-11% CaO (Calcium oxide), 1%-3% MgO (Magnesium oxide), and 1%-3% A_l2O_3 (Aluminum Oxide) (1). Glass is transparent, allowing light to pass through it, hence its early usage as window panes, telescopes and microscopes. Galileo and Robert Hooke owe their fame to this property. Glass can be colored by adding certain metallic oxides to the sand mixture before melting. When iron is added, the glass produced is green; copper is light blue; cobalt is dark blue; and gold is red. Manganese dioxide takes the color out of glass, but in higher quantities it can turn the glass purple, and even black (2). Think of the Chagall stained glass windows at Hebrew University.

Glass has a very unique chemical structure. Technically, glass is a "frozen liquid", liquid that has ceased to flow, and not a solid. Glass is physically hard, but its molecules are randomly distributed, like a liquid. The chemical structure of glass is characterized as amorphous, meaning that is does not have a repeating pattern organization of its particles, as in Figure 2(a), compared to a crystalline solid as in (b). This causes glass to have a range of melting temperatures, during which it is semi-solid and can be formed and shaped (2).

The method of producing glass varies depending on the type of glass desired. For millennia, glass production was done only through glass blowing by hand (see figure 3). There are many modern techniques including the Blow and Blow process that uses mold and compressed air to shape the glass. The Press and Blow method is similar, but involves pressing the molten glass into many different molds (1). Additionally, modern methods of mass production include using industrial machines and furnaces (9).

The art of glassblowing is very specialized and requires high levels of skill. A hollow pipe is dipped into molten glass, sand mixed with other chemicals. The pipe is rotated to gather more glass, and removed, cooling to around 1000°

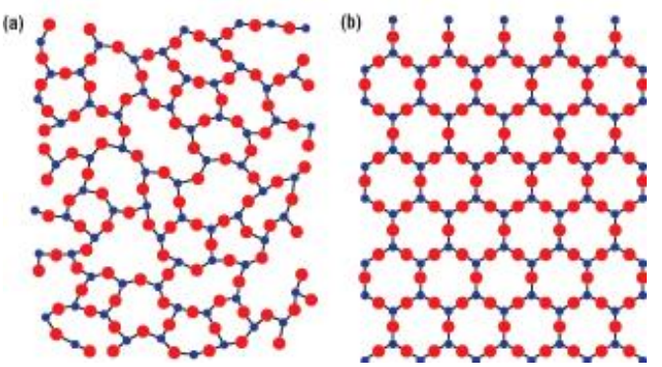

Figure 2a: Amorphous solid *Figure 2b: Crystalline solid*

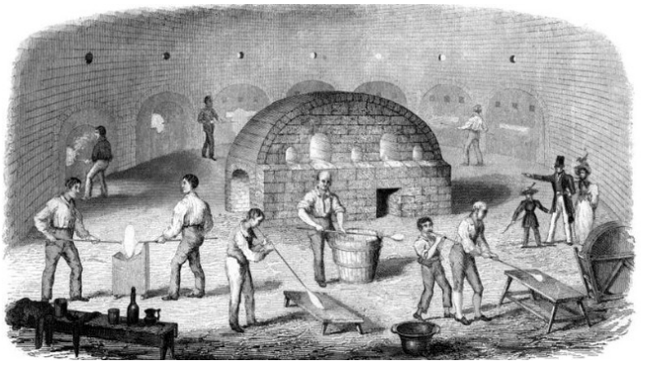

Figure 3

Figure 4

C. The glass is rolled, lengthened, reheated and blown into a shape close to the desired product. The glass is placed in a wet mold, and blown to the final shape (1). When executed skillfully, the product is a work of artistry or utility (see figure 4 on previous page).

In our times of increasing environmental consciousness, glass is 100% recyclable, but in 2012, only 34.1% of all glass containers were recycled. Using recycled glass reduces carbon dioxide emissions, reduces the amount of raw materials used, extends the life of the machinery in glass producing plants and creates more jobs. For every six tons of glass recycled, one less ton of carbon dioxide is emitted. Recycled glass can replace up to 95% of the raw materials in glass, saving natural resources. Glass can be recycled over and over, and the glass produced is equal in quality (4).

In Jewish law, the usage of glass has been a major debate between authorities throughout history. Generally, utensils can only be used for either meat or dairy because of the absorption of *bliot*. *Bliot* are micro flavors from the food that enter the utensil, which can be passed to the next food that the tool encounters. All materials absorb *bliot* through heat, spicy foods, or soaking. If a utensil was used for meat and dairy, it must be kashered, meaning purified. Some materials can never be kashered, included earthenware.

The Talmud does not give an overall decision, however it does bring the many opinions regarding the kashering of glass. The debate stems from the basic question of how to characterize glass. There are those that claim that glass is considered pottery because they are both made of sand, and therefore, glass also can never be kashered. Others hold that glass is like metal, which can be kashered, because both substances can be fixed through heat. The Avot de-Rabbi Natan claims that glass is in a category of its own that doesn't absorb any bliot. Through history, authorities have been split between these and many more opinions. It is accepted today that glass does not absorb *bliot*, and can be kashered, however, we should avoid using glass for both meat and dairy if possible (6).

Glass is an essential part of life, and has been for millennia. Glass production has improved over time, and has been refined to perform different tasks. There are many exciting new advancements that we can expect to see in the coming years. Firstly, engineers are very close to making completely shatterproof glass. The glass we have now is not perfectly shatterproof, because producing that requires a full understanding of the chemical structure of glass, which we do not have at this point. For decades researchers have been plagued by the strangeness of glass's chemical structure. Chemist Patrick Charbonneau is one of the many scientists researching glass, and although he is optimistic about the progress in recent years, he claims we are very far from fully understanding glass. By understanding the ways atoms organize, material scientists hope to find ways to make new glasses and manipulate the ones they've got (10). There are many other advances in the field of the environment. Glass is already a large component of solar energy converters, and the storage of radioactive waste. In the coming years, glass will continue to contribute to the discovery of clean energy sources (7).

Glass has helped shape history beginning in the 1500s BC, and will continue to change, improve and evolve as we improve our understanding of our world and move forward towards a more advanced era.

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PLAYING HOPSCOTCH

Esther Butler '17

Some discoveries are just so radically ahead of their time, that despite their incontrovertible proof, the scientific community is just not prepared to accept the shift in paradigm and labels the proposal ridiculous. Such examples include Copernicus' heliocentric view of the universe which replaced the commonly held belief that the earth was the center of the universe, and Priestly's oxygen theory of combustion which supplanted the phlogiston theory. Another was Barbara McClintock's discovery of jumping genes in 1942 at Cold Spring Harbor (3). She noticed regions on corn chromosomes replicate under stressful conditions. For this research she received the Nobel Prize for Physiology or Medicine in 1983. This 41-year gap depicts the challenges the scientific community had in accepting this phenomenon and Barbara McClintock's resilience in the face of scientific derision (6).

There are two classes of genes that relocate on chromosomes (11). The first class, retrotransposons, estimated to make up 45% of human DNA (13), originated in viruses. These genes replicate using 'copy and paste' method (15). DNA is transcribed into RNA, and then enters a new position on the DNA using reverse transcriptase which converts single stranded RNA into double helical DNA. The second class, transposons, constitute 3% of the human genome. These genes jump via 'cut and paste' method. A segment of DNA is sliced by the transposase enzyme at the DNA phosphodiester bond then the excised gene binds to a new location on the genome (11) (see figure 1). This forced a revision of the paradigm of genes and the genome: no longer permanently affixed segments of the chromosome, genetic elements are motile and the genome has plasticity (4).

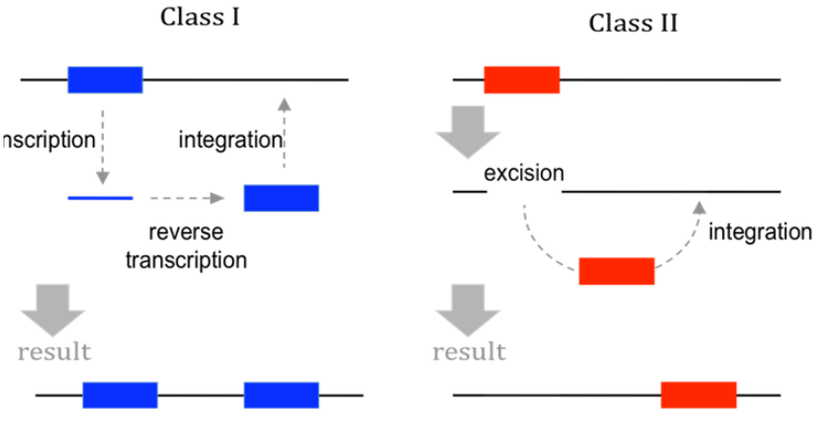

Figure 1: (CuboCube) Retrotransposition- Class 1 versus transposition- Class 2.

> *"This forced a revision of the paradigm of genes and the genome."*

One example of a retrotransposon is Long Interspersed Element 1, also known as Line 1 or L1 (6). L1 makes up 17% of human DNA (4) and there is a new insertion of L1 in 1 out of 112 births (13). Researchers at the Salk Institute for Biological Studies observed rodents exercising on wheels and encountering new situations. Exercise doubled the amount of L1 in the hippocampus, the area of the brain involved with memory and attention. This shows that jumping continues after conception (6). Neuroscientists at the RIKEN Brain Science Institute found increased L1 in human neural stem cells from patients with schizophrenia, and other mental disorders like Rett Syndrome, a branch of autism and Louis-Bar Syndrome, a neurological motor disease (8). L1 insertions result in a shifted genome, which is associated with the diseases hemophilia, muscular dystrophy and x-linked retinitis pigmentosa (13). L1 is also found in human

breast and colon cancer cells (9). Additionally, L1 encodes for enzymes reverse transcriptase and endonuclease (10), which facilitate jumping of other transposable elements (7).

Another retrotransposon is Alu, which is a Short INterspersed Element (SINE). It is non-autonomous, meaning it relies upon machinery provided by L1 to replicate and jump (12). There is a new insertion of Alu in 1 out of every 21 births (1). Alu makes up 11% of the human genome (9). Approximately 4% of genetic diseases can be traced to Alu, including breast cancer, hemophilia (12), neurofibromatosis (9) and obesity (2).

A third jumping gene is SVA, consisting of three parts: SINE, Variable Number of Tandem Repeats (VNTR) (9) and Alu (10). There is a new insertion of SVA in one out of 900 births (4). SVA makes up 0.13% of the human genome (14). SVA is non-autonomous (9) and retrotransposes via different methods. One way is to copy and paste a replica of itself. Another method is to jump inverted, so the beginning of the gene becomes the end. A third possibility is for VNTR to truncate or elongate. SVA has a Target Sight Duplicator (TSD) on each end, which can cause adjacent DNA and RNA to jump. SVA can cause breast cancer and Parkinson's disease and in 1994 Shen found SVA in retinitis pigmenotsa (10).

Around 45% of human DNA is motile. L1, SVA and Alu are the only three retrotransposons that are still mobile today and scientists are unaware of any active transposons (see figure 2) (4). Many environmental factors increase jumping, such as heat shock, viral infection, poisons, detergents and gamma irradiation, all of which can cause carcinogenesis. Researchers can now locate diseases associated with jumping genes (8). Still most jumping is neither harmful nor helpful to humans (13). In addition, some cells create proteins to inhibit jumping; for example the APOBEC3 family prevents the jumping of L1 and Alu (4).

Given the number of repeats in the genome, these shenanigans have been going on for a very, very long time. Scientists have wondered why host

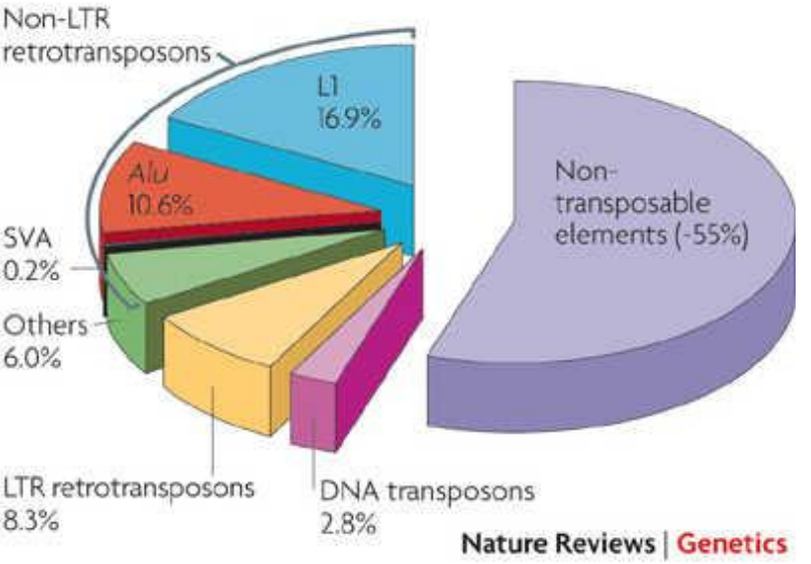

Figure 2

genomes have tolerated these playground hijinks with saintly forbearance. The answer comes not from genetics, but from ecology; they propose that this is a sterling example of symbiotic commensalism. Retrotransposons and the genome appear to be entangled in a delicate balancing act between the transposon's need for a healthy living host for its replication and the host's need for genetic diversity while limiting potentially harmful effects due to disruption of coding regions. Throwing a monkey wrench into the host's genetic machinery by random insertion of the transposate into coding regions will generate harmful mutations and demise of the host, and with it, the end of the transposate. Genetic diversity confers upon the host population a resource for natural selection and adaptation to stressful environmental changes. In a recent discovery, scientists identified a mechanism in yeast cells, where a subunit

of RNA polymerase III directs the integration of the transposed element into a noncoding region upstream of the transcribed gene. The transposon has achieved its goal with no harm done to the host genome; furthermore, the host genome benefits because it now increased genetic diversity (1). The children established and abide by their own playground rules.

McClintock's discovery of transposition refuted the theory of genes being immobile and affixed genetic elements. Retrotransposons copy and paste themselves into different parts on the genome. L1 creates machinery for Alu and SVA to jump. Jumping genes alter the genome, which may or may not create an abnormal protein (12). Thus the DNA present at birth is not merely a static blueprint for life (5) and an absolute determinant of the future; rather it is but a starting point for genetic plasticity and environmental interactivity. More fuel for the nature vs. nurture debate.

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SEND IN THE CLONES

Nechama Dembitzer '15

Contrary to popular thinking, cloning is not a modern technology—it is ancient. Humans have practiced plant cloning for thousands of years to produce offspring that are identical to the parents. Today there are many applications of cloning in agriculture that involve both plant and animal cloning. There is also a lot of current research in the field of cloning and with each new development new Halacha questions arise.

There are three main methods of plant cloning: cutting, cloning seeds and tissue culture. In cutting, a part of plant is cut off, such as a leave or a stem, and then placed in a different environment, such as root mix, to grow (9). The method of cloning seeds is a developing technology that involves the manipulation of twenty-four genes in plants that causes the production of seeds that are identical to the parents. This technology is revolutionary because it involves gametic reproduction, i.e. the production of seed, with the result of nongametic reproduction, i.e. offspring identical to the parent (3). In tissue culture, a piece of a plant is removed and then grown in a petri dish or test tube in the laboratory (see figure 1). After the plant has developed for a short period of time, it is then transplanted into soil and grows to be identical to its parent. This method has proved invaluable in preserving dwindling natural resources.

For example, Khaya wood is a valuable wood that is used for high-quality furniture and construction and in recent years the availability of this wood has been decreasing at an alarming rate. Scientists have used tissue culture to create a superior stock of Khaya wood and have increased its availability (1). In addition to preservation purposes, plant cloning has a variety of other benefits. Cloning plants enables the production of a variety of plants that has superior qualities. Instead of the traditional crossbreeding, this method of cloning can preserve desired characteristics in a species of plant after one generation (see figure 2). Also, it enables the reproduction of plants that would be unable to reproduce through traditional gametic reproduction, i.e. male plants by themselves, sterile plants or plants that have not reached maturity (8).

Figure 1: Tissue Culture Cloning

Figure 2: Cloned Plants

Plant cloning has proven to be beneficial in agriculture since ancient times and more recent developments in cloning technology has enabled the mass application of animal cloning in agriculture. There are a variety of benefits to cloning in agriculture specifically in the livestock industry. Firstly, animals that possess a desired characteristic, such as leaner meat, can be cloned to produce offspring that will possess that characteristic. Also, a prized bull may sell for as much as six hundred thousand dollars and if that bull can be replicated then a rancher has an opportunity for a large financial gain. Finally, cloning is especially useful in the dairy industry because females are the ones that produce the milk and so cloning females will ensure that more females are born

(see figure 3) (12).

Today, cloning animals is a reality; however, the development of the current technology took place over a large span of years and was a gradual development. The first process used to clone animals is known as Embryo Splitting. It was first performed in 1901 when Dr. Hans Spemann split a salamander embryo into two parts and that resulted in the birth of two distinct and identical

Figure 3: Cloned Animals

salamanders (8). In this early form of cloning, the technician uses an instrument known as a micromanipulator to split the embryo into two parts and then implants each half into an animal (see figure 4) (6). The result is two organisms that are identical; however, this method is not commonly used because there are many difficulties involved. Embryo splitting is both expensive and time consuming and it often produces yields that are lower than expected (13).

The development of Embryo Splitting led to the discovery of the next cloning process, Blastomeric Nuclear Transfer. In 1984, Dr. Steen Willadsen performed the first mammalian cloning when he cloned a sheep by using nuclear transfer (17). In the nuclear transfer procedure, a scientist removes the DNA from an unfertilized egg and then fuses it with an embryonic cell through an electric jolt. With a second jolt, the cell divides and then the resulting embryo is implanted into a surrogate animal (6). However, despite the exciting possibilities for the application of this procedure, there was little commercial use due to the same issues that occurred with embryo splitting (13).

Figure 4: Embryo Splitting

Perhaps, the most famous cloning breakthrough occurred in 1996, when Keith Campbell and Ian Wilmut cloned Dolly the sheep (see figure 5) (16). The cloning of Dolly was a breakthrough because it proved that adult cells could be cloned. Until then, cloning was always done on embryonic cells. With this new process used to clone Dolly, known as Somatic Cell Nuclear Transfer, researchers were better able to predict the characteristics of the resulting clone because they could study the adult on a more in-depth level than studying an embryo.

Figure 5: Dolly

Currently, Somatic Cell Nuclear Transfer is the process that is used to clone animals in agriculture and it involves the same process as Blastomeric Nuclear Transfer (see figure 6). The important difference between the two procedures is that an adult cell, not an embryonic cell, is used in Somatic Cell Nuclear Transfer (6). However, similar to the original cloning procedures, this process is imperfect. The success rate is extremely low, falling at around 0.1 to 3 percent. The inefficiency of the process is largely caused by Dystocia, birthing difficulties that endanger the life of both the child and the mother, and also by Large Offspring Syndrome. In Large Offspring Syndrome, the clone suffers from respiratory and circulatory issues that are due to enlarged organs (14).

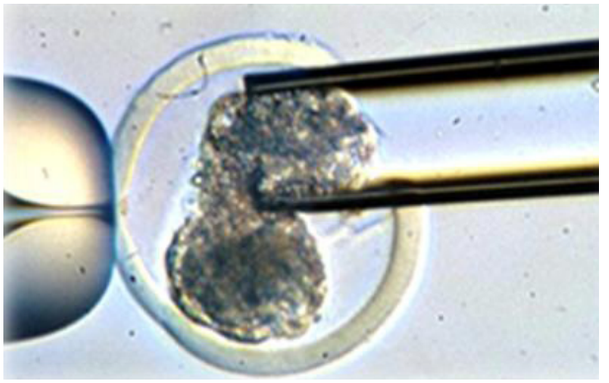

Figure 6: Somatic Cell Nuclear Transfer

Due to the abundance of difficulties associated with Somatic Cell Nuclear Transfer, there are many researchers who are currently trying to improve the procedure. A variety of approaches, including chemical and genetic, have been used to raise the low success rate. In fact, when Dolly was first cloned, she was the only success out of two hundred and seventy seven attempts. In 2001, Dr. Stice and his team at the University of Georgia cloned 8 calves with a success rate of 1 in 7, a markedly higher success rate than with Dolly, by using a chemical inhibitor to make the donor DNA more uniform (6). Another approach involves Epigenetic Reprogramming: the molecules that are added to the DNA that influence its expression. In 2014, Dr. Yi Zhang and Shogo Matoba at Harvard Medical School, found that there are mistakes in the epigenetics of the clone, which lead to fatal developments in the offspring. Dr. Zhang found that genes in the clone are silenced through histone methylation, but he was unable to explain the reason behind this. However, he did find that when the genes were activated through acetylation, the efficiency rate of the cloning increased by 6 to 8 percent (11).

In addition to perfecting the process, there is currently a team in London that is attempting to test the limits of the animal cloning process. The cloning of Dolly proved that an adult living animal could be cloned, but recently a team at the University of London's Department of Veterinary Embryology began the attempt to resurrect Eclipse, an undefeated eighteenth century racehorse, from preserved DNA. In 2014, the team succeeded in growing cells that contained Eclipse's DNA and they are currently attempting to use those cells to perform nuclear transfer and implant an embryo into a surrogate animal. The team predicted the birth of the foal in as early as 2015, but their prediction was too early and a foal has not been born yet (5).

With the rebirth of Eclipse in the horizon, there is a heated debate in professional horseracing whether a cloned horse should be allowed to race. This is only one of the many types of questions that may arise with the current developments in cloning. For us as Jews, the questions that we must focus on the most are those regarding Halacha. These questions arise especially when we discuss human clones (see figure 7). Today, it is illegal in America and in most other countries to produce human clones. However, there may be a time in the future where human clones are produced and then there will be the question whether a clone can be considered a human according Halacha.

The basis of this question is the Gemara that recounts a fascinating interaction between R' Zeira and Rava (4). In the passage, Rava created a golem, a human-shaped creature made from the ground, and sent it to R' Zeira. R' Zeira immediately killed the Golem and that illustrated that the golem is not considered a human because the Torah forbids the killing of a human being. A subsequent argument in the commentaries of the Gemara questions what are the requirements to be considered

Figure 7: Brave new world?

human according to Halacha. It is not that a human must be born from a womb or must be able to speak but rather, according to Rav J. David Bleich, to be human is to be the product of a human being. Therefore, a clone is human since it is the product of a human being, while a golem is not human because it is created from the ground. Both the Chazon Ish and R' Elchanan Wasserman agree with this interpretation (15).

Once we have classified human clones, there are still important Kashrut applications based on the classification of other cloned animals. The question is centered on the identity of the parent of the animal; according to Halacha is it the gestational mother, i.e. the mother the baby is born to, or the donor animal, i.e. the source of the cell that contains the original nucleus used? R' Chaim Soloveitchik explained that the status of animal follows the mother it is born to, the gestational mother, and does not follow its inherent characteristics, which it received from the donor animal. Therefore, the Rambam writes that an animal is kosher if it is born to a mother with kosher signs and there is a witness to the birth, even if the animal itself does not have the kosher signs (7). Based on this, if a pig is born to cow with the proper kosher signs, then the pig is considered kosher (2).

"According to Rav J. David Bleich, to be human is to be the product of a human being."

Cloning has a rich history and has been used for a variety of reasons by humans for thousands of years and is currently an important subject of research in the scientific community. However, for Jews, studying the topic of cloning is more than for scientific knowledge. As cloning research uncovers more questions than answers, it is glaring proof of God's infinite and incomparable wisdom in this universe.

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(SUR)PASSING THE TURING TEST

Zahava Sokolow '16

Drown a hipster by throwing him into the mainstream; kill everyone else by throwing them into the stream of consciousness. More than just an alliterative hook with which to captivate the reader's attention, this statement encapsulates the fears of a burgeoning corpus of modern day scholars and thinkers. They propose the provocative notion that consciousness is a property not exclusive to higher forms of life, but an integral property of complexity and connected communication between parts of the system. Furthermore, prominent pessimists of our day, Stephen Hawking and Elon Must, support their premonitions of a dystopian, apocalyptic future dominated by runaway rogue technology, and maintain that the ongoing development of Artificial Intelligence (AI) poses an existential thread to humankind (3). If consciousness, as defined by degree of complexity of connected systems, becomes intentional and with it the concomitant process of evolution, can the Terminator be far behind? That may be a very real possibility.

At the Allen Institute for Brain Science, neuroscientists have a radical idea for defining consciousness. It is a rather ancient philosophy, incorporating Panpsychism, the view that mind and soul are universal features of any matter (2, 7). Despite the fact that it is generally relegated to the domain of religion, many scientists, including Christoph Koch, are firm believers in adapted theories of this idea. Koch, who has spent three decades conducting research on the brain, maintains that consciousness is a fundamental property accredited to one thing: complexity. "The electric charge of an electron doesn't arise out of more elemental properties. It simply has a charge," says Koch. "Likewise, I argue that we live in a universe of space, time, mass, energy, and consciousness arising out of complex systems." Like gravity, it simply is (11).

A large part of this is based on the Integrated Information Theory, which provides a term, Φ, pronounced fi, an estimation of how complexly connected a system is (2, 7). Any system which has a Φ above zero, is conscious to a greater or lesser degree. A rock, for example, has no communication between atoms, and has a Φ of zero, while a human brain has many cells which signal and interact so rapidly, it conducts a higher level of connection than human to human communication. Similarly, the internet is a mode of communication, as it is not just one object or program. It includes around ten billion computers, and within a CPU of one single computer, there are billions of transistors. Roughly, this is equivalent to 10^19 transistors; in contrast, a human brain consists of approximately ten thousand fewer synapses. Technically, according to Koch,

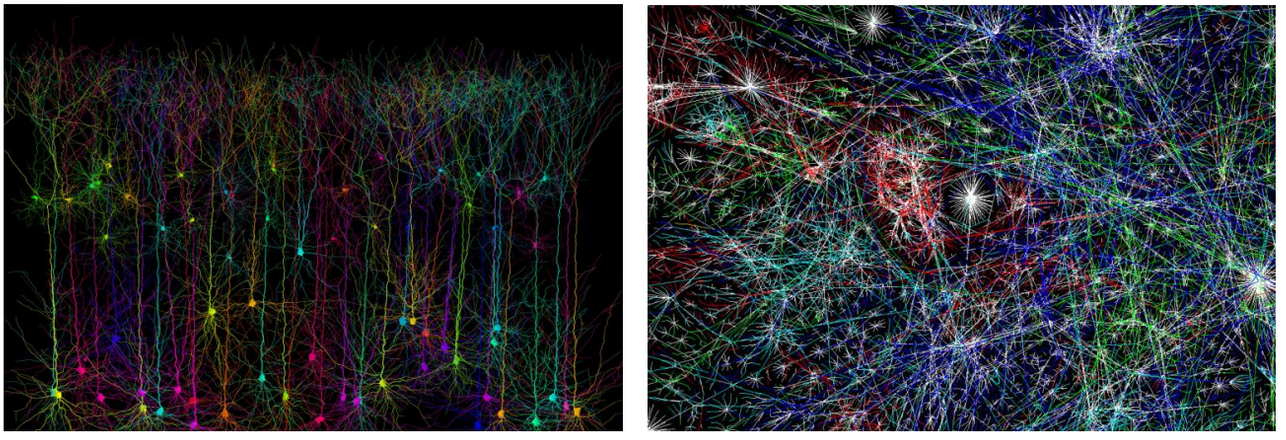

Figure 1: From neural connections to network connections, which is more conscious - the Internet, or its creator?

the internet is more conscious than we are (see figure 1) (2, 6).

The practical applications are abundant, and can be utilized in many situations. Often, a wrongly accused "criminal" sits in an interrogation room or a prison cell, awaiting his opportunity to plead his case before someone who will listen. But human interpretation is faulty, its biases undebatable; consequently, fifty percent of innocent victims are executed or remain on Death Row for over thirty years (4). James O'Shea, an alumnus of the Imperial College of London maintains that AI can fix this problem. Artificial Intelligence is the study and design of systems that perceive their environment and take actions to maximize chances of success; it attempts to ingrain in computer system abilities to mimic human capabilities (8 ,5).

O'Shea's invention, the Silent Talker, utilizes artificial neural networks to act as a "brain" for the device. This machine recognizes patterns in behavior, incriminating or not. Slowly, it builds an overall profile of its suspect, and has proven itself as this generation's polygraph. The inventors claim that its brilliance is in the recognition; it records the nonverbal conversation, identifying what are titled "microgestures", or subconscious physical reactions. Such signs include gestures that reflect stress, strain, or what psychologists identify as undue joy; the joy of successful lying. With the spread of such machines, an accuracy of nearly ninety percent has been achieved, and it is expected that artificial consciousness and neural patterns will increase in use, in turn increasing efficiency in the profiling of human behavior, including the signals of guilt or innocence.

In the 1970s, medicine was riddled with inefficiency due to limitation of diagnostic tools. Today, AI can provide bountiful benefits to medicine. Programs are created in which database information can be used to avoid multiple hypotheses and provide links and conclusions between symptoms – even in patients with multiple diseases. DXplain is an example of one clinical system, developed at a Massachusetts hospital. It is used to assist diagnosing patients by taking clinical findings: signs, symptoms, and laboratory data. It then produces ranked list of diagnoses. It provides justification for each diagnosis and suggests further investigations. The system contains a database of probabilities for over 4,500 manifestations that are associated with over 2,000 diseases. An earlier example of such inventions was created in 1974, titled MYCIN, utilized to propose diagnoses limited to hematological infections.

As humans, there are limits to the number of connections we can make and the rate at which we do so.

The benefit of these AI programs lies in the fact that a person cannot truly understand at a gut level what he cannot see. What fills the space between molecules? How far does the universe truly extend? How could a world such as ours be formed of mere molecules and energy? And while we can't truly wrap our minds around these ephemeral questions, we can still work with what we do comprehend to form basic connections — we can posit the Theory of the Big Bang; we recognize and work with vacuums. Our brains form the connections between bits and pieces, allowing us to begin to theorize how our world functions.

Alan Turing, widely considered to be the father of computer science and artificial intelligence, proposed a test in 1960 to distinguish between a human and computer, based upon a game of a series of questions and answers (9). Recently, there have been disputed claims of Artificially Intelligent computers that have passed the Turing Test (10). But can the most Artificially Intelligent computer lie back on a summer's night, contemplate the grandeur and majesty of the cosmos with reverence and awe and come up with astronomer Carl Sagan's famous line, "We are all made up of star stuff"? What does that

mean?

The elements which compose human cells—carbon, nitrogen, and oxygen—as well as many other heavy elements, were originally produced within the stars, from the original universe of Hydrogen and Helium. As stars age, they begin to run out of hydrogen, and start to dim. They subsequently die in a fiery explosion of its remaining gas, called a supernova. The "dead" stars continue to shine for a few days, and begins to disperse the particles of which it was composed into interstellar space (see figure 2). This well-tested theory links the ejection of gas into space to the formation of human cell structure. In essence, the atoms of a human body, and with its attendant complexity and consciousness, were created within stars that are currently deceased. What an inspirational, spiritual realization! (8)

As humans, there are limits to the number of connections we can make and the rate at which we do so. Diseases such as cancer, AIDS, and autoimmune disorders are often too complex to understand. With technologically enhanced pattern-making, systemic diseases and global pandemics could be anticipated, contained, and new treatments advanced. Worldwide research could be linked together to create something amazing – an uber knowledge system that is fully integrated, interconnected, interactive and "conscious." The deadliest of diseases could be tamed and targeted, treatments easily available.

You could say their bark would be worse than their byte. But, can even the most complex AI system ponder its origins, its purpose here on Earth and its ultimate destiny?

The terminator will just have to wait.

Figure 2: The remnants of Supernova 1987A, found in the Large Magellanic Cloud, a dwarf galaxy orbiting the Milky Way about 160,000 light-years from Earth.

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TRAFFIC CONTROL

Esther Malka Laub '16

An infant lays down for her nap. Inside her body a red blood cell makes its way down the super speed tunnel. With its oxygen payload, it flows from the lungs, making its way back towards the heart so that it can be pumped to the rest of the body. Together with others, it will squeeze through the capillaries in a Conga line to supply the body with much needed oxygen. Pump. Pump. Pump. The cell slides through the mitral valve into the left ventricle, slips through the aortic valve and climbs up to the aortic arch. Then traffic abruptly slows to a crawl. The cells advance slowly one at a time. What is causing this standstill? A congenital defect called a coarctation of the aortic arch — a narrowing in the arch of the aorta (see figures 1 and 2).

It is not known with certainty why congenital defects occur; although many scientists believe they are due to genetics or the behavior of the mother during pregnancy. Scientists suspect these congenital defects develop during the sixth week of pregnancy; one week after the heart begins to develop (1). The aorta and pulmonary artery simultaneously form when a wall like structure grows vertically in the developing heart giving rise to the two equally sized arteries. Because the aorta is a complex vessel and is nonfunctional while it continues to develop in utero, the fetus uses a temporary shunt pathway off the pulmonary artery. It is during the time that the aorta is forming that defects can appear (2).

The consequences of coarctation arise when the blood trickles to the rest of the body instead of flowing unimpeded. This trickle can cause the left ventricle to overwork and compensate by pumping even harder. Intervention during pregnancy is obviously difficult and risky. It is only after the baby is born that symptoms appear, such as high blood pressure in the arms, low blood pressure in the legs or feet, cold legs or feet, and loss of appetite and weight (2). Parents are usu-

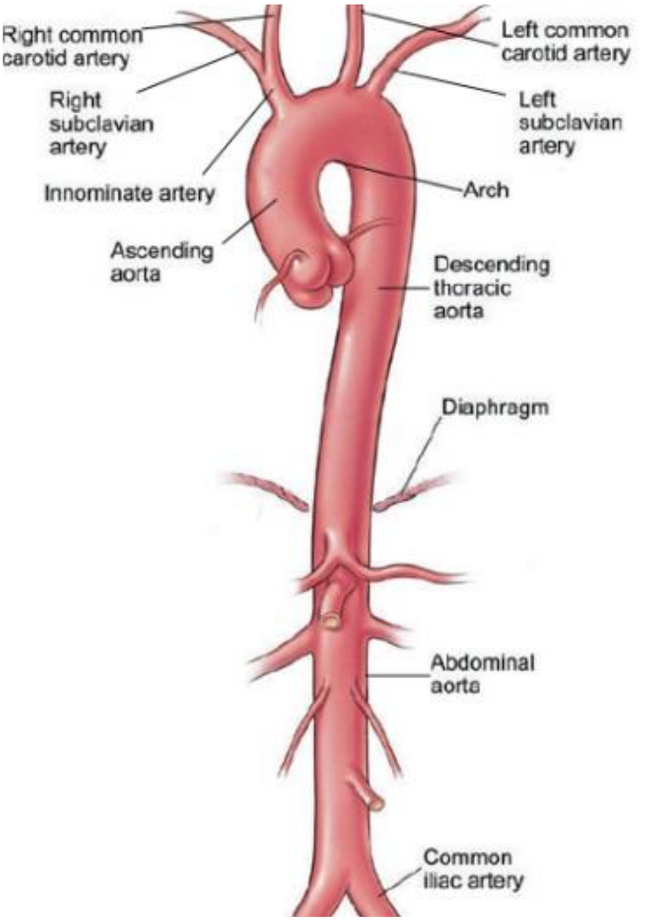

Figure 1: The aorta.

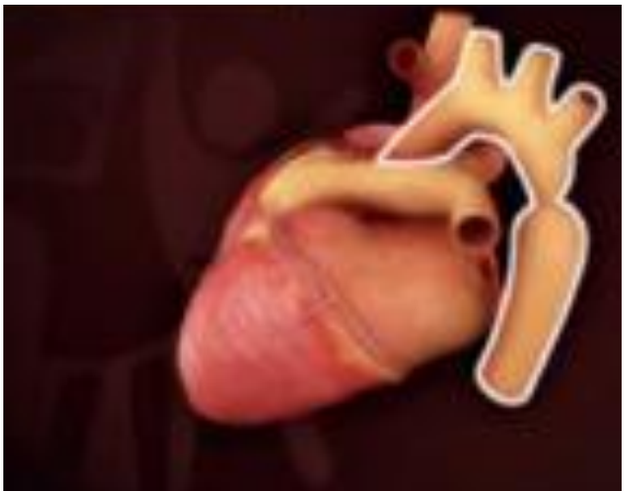

Figure 2: Coarctation of the Aorta.

ally not alerted to the symptoms to catch them early enough to avoid more invasive procedures.

A number of tests can be performed to make a definitive diagnosis including chest x-ray, electrocardiograph (EKG) and echocardiograph (echo). The EKG tracks the electrical activity in the heart and displays a repeating graphical pattern of the patient's atrial and ventricular contractions. The EKG pattern of coarctation is distinctly different than the normal patterns and an experienced technician can recognize the difference and make a diagnosis. The echo provides information in an entirely different modality. High frequency sound waves are bounced off the beating heart and subsequently converted into moving images of the heart displayed on a screen.

Once detected, treatment can begin. In less severe cases, balloon angioplasty can be used. A thin, flexible catheter with an uninflated balloon at the end is guided up the patient's blood vessel. When the balloon reaches the narrowing in the aorta, it automatically inflates and widens the artery so blood can flow (see figure 3). The balloon is removed immediately after the artery expands; in others it stays in the patient's body and becomes part of the aorta.

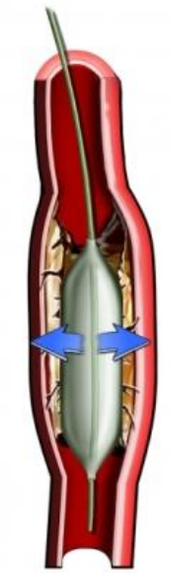

Figure 3: Balloon Angioplasty expanding the lower aorta.

In more severe cases surgery is required. Depending on the placement or width of the coarctation, different surgical remediation may be performed. In resection with end-to-end anastomosis, the narrow area of the aorta is removed followed by the reattachment of the aorta. Patch aortoplasty also requires the narrow area to be cut out, but a patch of synthetic material will be attached to widen the blood vessel. During a Left subclavian flap angioplasty a portion of the left subclavian artery is used to expand the narrow area. Finally, a bypass graft repair requires a tube to be inserted between the areas of the aorta to bypass the narrow area (1).

Figure 4: Real View Imaging's Holographic Heart.

Today, exciting new advances improve the treatments of a number of heart diseases. Real View Imaging, an Israeli start-up company, uses their proprietary technology to project realistic 3D holographic images without any type of eyewear. One of the newest advancements is the holographic heart which appears to be floating in space, allowing the surgeon to literally touch and precisely interact with the image. This unique breakthrough in digital holography and 3D interaction has opened up new doors in the operating room. One recent recorded case of using the holographic heart was during an evaluation of the Fontan Procedure, a two or three step operation to treat patients with hypoplastic left heart syndrome, where the left side of the heart, including the aorta, does not develop properly (3).

"I can manipulate [the holograph] to any angle just by touching the image"

In his presentation, Dr. Elchanan Bruckheimer said: "….I can manipulate [the holograph] to any angle just by touching the image….I can just mark what I want to see [on the holograph

by using a pointer], and I can use these markers for calibration, for guidance." (See figure 4) In taking the next step forward, Real View Imaging is currently working on a number of different configurations all based on the core holographic technology. One of these configurations is that of fetal holographic imaging. If that advance materializes, perhaps diagnosis of this conditions could be made in utero, and remediation can begin immediately upon birth. The ultimate hope is that holographic technology will become a beneficial tool in the operating room as well as for other medical research (4).

Back to our intrepid red blood cell. He now cruises through the superhighway without a hitch. He delivers his payload of oxygen to its proper destination with ease, and makes his way back for another circuit. Round and round he goes. The infant wakes up from her nap, rosy and hungry, ready to resume a normal life.

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Figure 1: myclivlandclinic.org
Figure 2:www.cincinnatichildrens.org
Figure 3: www.mountsinai.org
Figure 4: www.realviewimaging.com