LABYRINTH 2019

The Science Journal of Manhattan High School for Girls

TABLE OF CONTENTS

LABYRINTH ^{2019}: FOREWORD

Mrs. Brenda From, Chair, Department of Science

In her introduction to The Best American Science and Nature Writing 2002, Natalie Angier defines good science writing.

> *Yet, just as it doesn't take a doctorate in science, or even a decent high school transcript to appreciate the beauty of science, so too, it is not the scientist alone who can write forcefully and accurately about science... Good writing is clear, and it is interesting to read...Good writing, like good gnosis, is the product of greed, of writers who greedily claim their subjects for themselves and absorb every detail until the story is part of the latticework of their cells. Then and only then can they write with the passion of converts, of those who believe that this story is the most interesting story they have ever heard.*

I would argue that what you hold in your hands is a demonstration of science writing at its finest. We proudly present LAByrinth, the product of the greed of our students to grab hold of their education and demonstrate that they can write with clarity and style about a topic they have come to know intimately and passionately.

Projects of this nature can only come to light with the hard work and cooperation of a dedicated cadre of professionals.

- To Dr. Abi Haka, my fellow combatant in the trenches, who cultivated in her students the ethic of sustained effort as a necessary requisite for results of the highest caliber;
- To my fellow colleagues, Dr. Shaina Trapedo, Mrs. Jackie Rosensweig, Mrs. Batsheva Badrian, and Mrs. Penina Manies, who read the contributions and offered their constructive comments;
- To Mrs. Chani Kanowitz, the wizard of all things technologically related;
- To my student editors, Gitty Boshnack, Mia Lubetski, Ahuva Mermelstein, and Alicia Russo, who voluntarily took of their precious time and bore the burden of refining and honing the articles to perfection;
- To Noa Garfinkel for her sensitive artistry in designing the cover; and lastly but certainly not leastly
- To the dynamic duo Mrs. Estee Friedman, Principal, General Studies, and Mrs. Tsivia Yanofsky, Menahelet, for their expert stewardship of this remarkable school;

I owe you all my thanks and a debt of gratitude. I could not ask for a more supportive team.

This is the first time we proudly award the first place science writing prize to:

Shira Zelefsky

for her piece "Caution, Scientists with Scissors"

ACKNOWLEDGEMENTS

Mrs. Estee Friedman-Stefansky, Principal, General Studies

As the Earth rotates around the Sun, over 7 billion humans across the globe go about their day in different places, cultures and occupations. There is so much we know and understand about life on Earth, but even more that we wish to discover. Among us 7 billion, there are some who really wish to discover. They *crave* understanding.

Scientists question and probe the complexities of our reality — to better understand the natural and physical which govern our routine lives. At the heart of science is humility. Scientists acknowledge that in spite of all the terrific energy and achievement on Earth, humans are quite small in context of this great world. Scientists persist in observing patiently and questioning thoughtfully in their quests to access something new and fresh.

I am so grateful to Mrs. Brenda From, our Science Chair, for leading a department which fosters a rich understanding of the science content and cultivates the probing minds of our students. The journal you hold consists of discoveries each student has made — new understanding — of the science around us and within us here on Earth. Thank you to Dr. Abi Haka for also gifting our students with a love for science and to our student Editors, Gitty Boshnack, Mia Lubetski, Ahuva Mermelstein and Alicia Russo for devoting their time to the creation of this academic journal.

Congratulations to Shira Zelefsky on her excellent science research paper and to all the contributors who have observed, questioned and discovered.

A METALLIC TRICKSTER

Rebecca Gold

The waiter brings you a bowl of soup and a gleaming metal spoon. As you dip the spoon into the soup, it incredulously melts, turning into a puddle.

This "trick" spoon is made of gallium, a soft, silvery, metallic substance. Amazingly, it is a brittle solid at low temperatures, but liquefies at slightly above room temperature -- very rare properties for a metal. Gallium was discovered in 1875 by French chemist Lecoq de Boisbaudran, through a technique known as spectroscopy. He was examining a sample of zinc when he noticed two strange purple-colored lines in its spectrum, indicating that an unidentified contaminant was mixed into the sample (1). Further research revealed that it was the element number 31, previously predicted by Mendeleev to occupy the position in his periodic table under aluminum. Gallium, with the chemical symbol Ga, has important chemical and physical properties as well as naturally occurring isotopes, lending itself to many practical applications.

Gallium's location on the periodic table helps explain its properties. Gallium lies in the boron family of group 13 which contains boron (B), aluminum (Al), indium (In), and thallium (Ti). These five elements have three electrons in their valence shell. Gallium is a post-transition metal sandwiched between metalloids (non-metals) and transition metals. Gallium and the boron family elements, as well as tin (Sn), lead (Pb), and bismuth (Bi), are all relatively poor conductors (2).

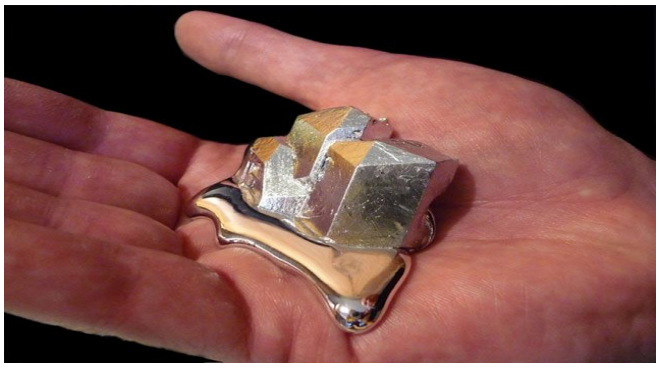

Figure 1: Gallium, with a melting point of 85.57℉, can melt in one's hand although it is a solid at room temperature.

In its natural state, gallium has a silver color. However, when gallium is finely ground, it loses its luster and appears gray. Gallium's liquid state has a higher density than the solid state, a property that is shared only by water and bismuth. Consequently, when liquid gallium solidifies, it expands 3.1 percent. This expansion must be considered when storing liquid gallium in order to prevent its container from rupturing.

At room temperature, gallium is a solid, but it is so soft that it can easily be cut with a knife. With gallium's melting point of 85.57 ℉, just 10 degrees above room temperature, gallium melts from the warmth of a human hand. However, when the piece of gallium is set back down, it will become a solid again. Additionally, gallium is known for having one of the greatest ratios of any element between its boiling point, 3,999 ℉, and its melting point, 85.57 ℉ (4).This means that gallium is in a liquid form over a very wide range

of temperatures because a substance at a temperature between its melting and boiling points is in liquid form. As such, gallium has to be heated to a very high temperature before it boils and turns into a gas.

In addition to physical properties, an important chemical property is its reactivity. For example, at high temperatures gallium reacts with most non-metals. It also reacts with both acids and bases (3). Additionally, gallium must be kept away from metal containers or glass because gallium reacts with most other metals and forms an alloy.

Gallium has some important isotopes. Isotopes have the same number of protons but a different number of neutrons. Two naturally occurring isotopes of gallium are gallium-69 and gallium-71. Radioactive isotopes are isotopes with an unstable nucleus that release excess energy by emitting radiation. Gallium-67 is an example of one of gallium's radioactive isotopes. It is commonly used to detect cancer. It can be found by the radiation it gives off in the cell, showing if the cancer has spread. One dose of gallium-67 can find cancer in the spleen, kidneys, liver, breasts, and bowel (3).

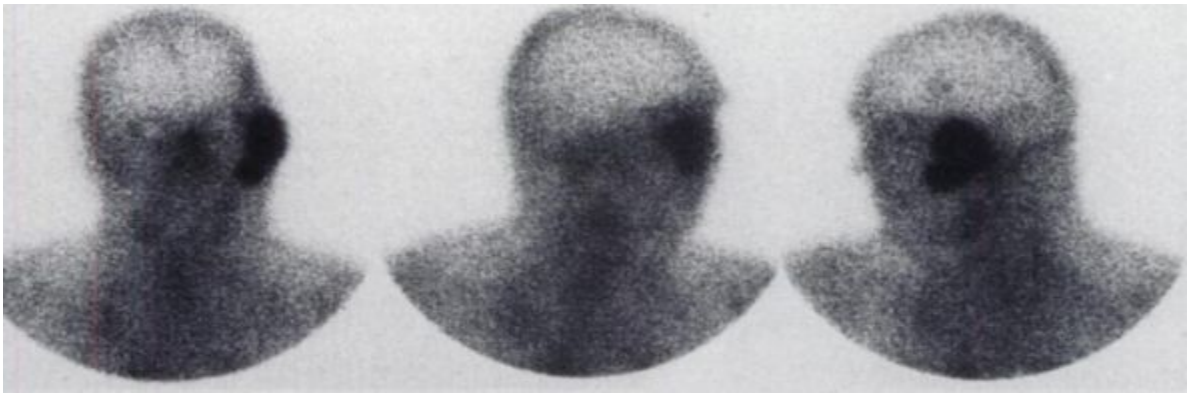

Figure 2: Gallium scans of three patients showing abnormal uptake in the left parotid region of the head represented by light regions. This is an example of how gallium-67 is used to detect diseases.

While gallium has applications in medicine, it is also used in many electric devices. About 95% of gallium is used to produce gallium arsenide (GaAs), which has many practical applications. For one, GaAs has the ability to convert an electrical current into light. An electric current has the ability to enter one side but not the other by a device known as LED- light-emitting diode. To produce LEDs, GaAs is used. A flash of light is created when an LED flows into a piece of gallium. By the push of a button on a calculator, an electric current flows into an LED and produces light (3).

In the making of lasers, similar devices are used. When an electrical current passes through a piece of gallium, the current produces an intense beam of laser light. A laser light emits electromagnetic radiation. In a laser, electrons absorb energy and emit photons which are all at the same wavelength, making the light very focused. GaAs has a high electron velocity as well as a high electron mobility. This is why it is used to make lasers; it is able to convert electrical current into light (3).

Another device GaAs is used in is transistors. This device is used to ensure the flow of electricity in a circuit by keeping the electrons flowing. The transistor also acts as a switch for electrical currents. The easy

flow and mobility of the electrons in GaAs contribute to the production of this device. Although GaAs does not conduct an electrical current like metals such as silver or copper, GaAs has many properties of a semiconductor, which is used to produce controlled electrical currents. A semiconductor can regulate the flow of electricity, providing the ability to turn on and off the flow of electricity. This is in contrast to a regular conductor which constantly conducts the unimpeded flow of electricity. Silicon is also used for transistors; however, GaAs has an advantage over silicon because GaAs produces less heat than silicon. With less heat, the transistors can work together to have a "higher computing capacity" (3).

Additionally, another practical application of GaAs is in the production of smartphones. It is mostly used in the LED lighting for smartphone displays. According to Ge and Liu, gallium is being studied for use in the cooling of smartphones. With its low melting point, gallium can absorb heat to maintain the temperature of the phone. Gallium can be mixed with other materials such as silicon dioxide to make its ability to absorb heat even better (5).

Because gallium has so many uses, its abundance must also be considered. Gallium is not found by itself in nature but is extracted as a trace component from the mining of other minerals such as aluminum and zinc ores. Gallium is fairly abundant, found at about five parts per million in these minerals (1). Gallium isn't produced in the United States but is majorly produced in France, Australia, and Russia. Currently, the supply chain is not in danger, but with its growing importance, this must be a significant factor in all trade negotiations.

As neat as it is to watch gallium melt right in the palm of your hand, its unique and fascinating features go well beyond that of a mere curiosity. Scientists will continue to research and explore gallium's promise in medicine and technology and surely discovery new ways to utilize this element in new and exciting directions.

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BE AWARE! WASH WITH CARE

Chavi Golding

The most adorable little boy, let's call him Max, was five years old as he was about to eat his lunch in his brightly painted playgroup classroom.

His small, growing mind immediately started weighing all its options. Max knew that he should be washing his hands before eating his macaroni, but the faster he finished eating, the faster he could return to those tempting Lego bricks. Max couldn't let Tommy get to those bricks before him, but both boys had previously been playing outside in the playground, and his hands were filthy. How dirty could they possibly be? If Mommy or his teacher were watching, they would surely be telling him to wash his hands. He plays with the question, and he makes the final decision to wash his hands fast, but skip the pink, bubbly soap.

Fast forward eighteen years later, Max was a smart and young aspiring architect standing in front of a public bathroom mirror, giving himself a pep talk before an important meeting. He knew that if he wanted to start his first business on his own, he had to land this job and excel at completing the perfect design for a school's playground. Suddenly, Max became anxious with excitement for his conference, and his childish characteristic of impatience returned to him. He knew that he would be shaking many other official-looking men's hands and touching a lot of other people's pens and papers. Max, eighteen years older and wiser, makes the final decision to wash his hands with his very own carry-on size antibacterial soap, instead of the building's regular hand soap.

We have all been taught, since we were very young, that keeping our hands clean is vital to avoid sickness and spreading germs. Many diseases and infections are spread by not washing hands with soap and clean water. We have reminders every day to perform this simple act. In public bathrooms, there are signs, and all of our friends and family are quick to remind us until we find ourselves telling others to wash their hands as well. One might ask, why use soap? What is the soap accomplishing in addition to the water?

Using soap to wash hands is more effective than using water alone because the of surfactants which lift soil and microbes from the skin. People tend to scrub their hands more thoroughly when using soap, further removing germs. Washing hands with soap has also been proven through multiple experiments to reduce respiratory illnesses, like colds, in the general population. There was an experiment done in a school where half the school had scheduled certain times a day to wash their hands, and the other half did not. The conclusion from the experiment was that washing hands reduces absenteeism due to gastrointestinal illness (stomach problems) in schoolchildren (1). The next question to ask would be: what kind of soap should people use? Is there a difference in effectiveness between regular soaps and antibacterial soaps?

Triclosan is one of the primary ingredients of antibacterial soap. Studies have shown that there is no added health benefit for consumers using soaps containing antibacterial ingredients compared with using plain soaps. Some claim that the ingredients in antibacterial soaps cause more harm than good. As a result,

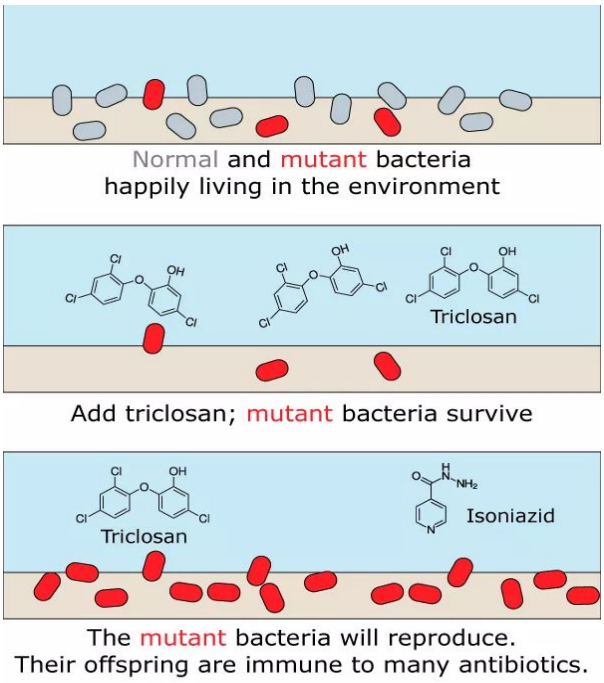
FDA issued a final rule in September 2016 that 19 ingredients in "antibacterial" soaps, including triclosan, were no more effective than using non-antibacterial soap and water, and thus these products are no longer able to be marketed to the general public.

Triclosan is also a part of hand sanitizers and certain kinds of toothpastes. There is FDA evidence that triclosan in toothpaste helps prevent gingivitis, *Colgate Total* being the only American Dental-Association approved toothpaste with this ingredient. However, the FDA doesn't allow companies to use triclosan in their products without premarket review (7).

Triclosan is a chemical which is famous for its exceptional germ-killing power, and for this reason, it's included in many consumer products. It has been around since the 1960s and it was originally used as a pesticide. Only in more recent years has it been used in personal care items, like toothpaste, toys, cleaning products, body washes, and soaps. In water-based products, triclosan acts as a preservative that also assists in fighting odors (4).

No other benefits to human health have yet been established to support its widespread use in other personal care and household cleaning products. However, despite this lack of proven efficacy, triclosan is so widely employed that 75% of human urine samples from both U.S. and Belgian population surveys contained this biocide (a poisonous substance), triclosan.

Triclosan has adverse long term outcomes. In experimental animal models, but not in human studies. Triclosan has been reported to be an endocrine disruptor, meaning it causes glands which secrete hormones directly into the blood when they are not needed (5). Triclosan can provoke cancer cells to grow, specifically breast cancer. It can also affect hormones and make it simpler for antibiotic-resistant bacteria to grow in noses and throats- which leads to diseases like pneumonia, a lung infection which can be life-threatening (2). It is unclear if all of these risks can happen in human bodies because these experiments were mainly tested only in cells or animals.



Triclosan is also harmful to the environment. There the pollutant can affect the bacteria that break down sewage (8). Studies have suggested that the chemical can kill off some good microbes, and it can make other microbes resistant to the antiseptic.

Triclosan is a biocide that kills a broad spectrum of microbial agents. In trials of toothpastes, triclosan is known to alter the oral flora. Whether it also changes the flora of the gut remains unknown, although it's found in the blood which indicates that the body absorbs it. Antibiotics have been proven to

increase body mass in animals, and limited data suggests similar effects in humans. Recent animal studies indicate that antibiotic use alters the gut flora, and that harms gastrointestinal metabolism.

Historically, during the Black Plague, Jewish people were brutally accused of causing the plague by poisoning the wells of the community. The Black Plague was a widespread epidemic that passed from Asia and through Europe in the mid-fourteenth century. In the span of three years, the Black Death killed one-third of the European population. They accused the Jews because the Jewish people were the only ones who didn't seem to be affected by the disease. In reality, a possible and logical reason why the Jews were safe is because of the Jewish religious law of washing one's hands each morning and before eating a meal. Considering that the plague took place in Europe around the 1300s, it is obvious that triclosan was not used when the Jews washed their hands, and they were saved without the supposed antibacterial triclosan soaps. Looking back at this time, we see the importance of washing our hands multiple times daily.

Returning to our story with Max, we can now understand that Max, as a toddler, should have used soap when washing his hands. In spite of that, it was not necessarily a brighter choice to use his antibacterial soap versus the building's regular hand soap and running water. For now, since the FDA has banned the use of triclosan in products, we don't need to worry about making such choices.

Washing your hands should not be taken lightly, or thought of as a simple reminder only meant for dirty toddlers. Additionally, it is crucial for every person to remember to wash their hands correctly. Instead of a bowl of still water that could become easily contaminated, use running water. Make sure to use soap, because the combination of the soap and water will get rid of more disease-causing organisms than using water alone. As following these steps, always keep in mind that any soap is effective at ridding the germs, there is no additional advantage to using antibacterial soaps, especially triclosan, which may even cause more significant problems in the future.

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A STICKY SITUATION

Ilana Katzenstein

My memories of preschool will always be associated with that musky smell of Elmer's Liquid School Glue. Since then, I have learned that not a single household, school, factory, or pretty much any place or anyone can function without glue.

Whether an arts and crafts project with a glue stick or building airplanes with heavy duty adhesives, it works every time. The question is: How does it work to magically make things stick together—permanently or temporarily? There are so many different versions and consistencies of glue, yet they can all be categorized under the umbrella of adhesives.

There are three parts of an adhesive bond; adhesive, adherent, and surface. The first step of forming this adhesive bond is for the adhesive to wet and spread over the surface of the adherends, the objects being glued together (1). But before the glue can stick to anything else, it first has to 'stick to itself' through the process of cohesion. This is the process in which the individual glue particles stick to each other to form one single entity (Figure 1). After this, there are many scientific theories and opinions as to how the actual bonding occurs. Some mechanisms include the absorption theory, mechanical interlocking, interdiffusion, and the electronic or electrostatic theory (1). The primary method of adhesion is the absorption theory. This theory states that the intermolecular or valence forces of the molecules in the surface layers of the adherends is the cause for their sticking. The second mechanism of adhesion is mechanical interlocking in which the adhesive flows into the pores of the adherends allowing the two adherends to bond and stick to each other. Another means of adhesion is interdiffusion which occurs through liquid adhesive dissolving and diffusing into the adherend. Finally, the electronic or electrostatic attraction theory suggests that there are electrostatic forces that develop between the adherends with different electronic band structures, causing these attractions to occur (1).

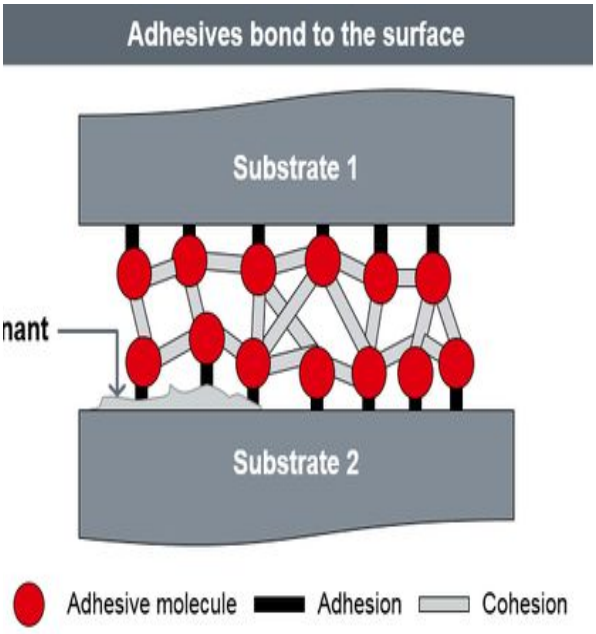

Figure 1: In the diagram, the substrates represent the adherends and the adhesive molecule represent the adhesive. The gray lines labeled "cohesion" represent the bonds formed between the individual adhesive molecules that make it sticky, and the black lines labeled "adhesion" represent the bonds formed between the adhesive and the adherend.

What comes to mind when I think of adhesives is the classic Elmer's School Glue, but it turns out that there are actually many different kinds of adhesives, including both natural and synthetic. Most natural

adhesives come from animal or vegetable origin; the primary sources of adhesives nowadays are synthetic, but natural adhesives are still used with many wood and paper products.

Although the human body may not be constructed through the process of "gluing", both human and animal muscles and ligaments are bonded through a series of proteins similar to adhesion. Animal glues come from mammalian collagen, a protein that is one of the main components of skin and bones (1). Today, collagen is even used in skincare and beauty products, and when treated with acids, alkalis, or hot water, becomes soluble and forms the basis for animal glue. Collagen proteins are made from molecules of long carbon and nitrogen backbones that stick together (8). The molecules react in the hot water by separating from one another, thus creating molecules that are available for bonding elsewhere, creating a sticky substance called gelatin (8). That basically means that the glue is made from the proteins of animal skin and fat. Gross? Maybe. This is the origin the old phrase of "sent to the glue factory" regarding horses who become old and outlive their usefulness, because a good portion of animal glues are likely from those old horses. Animal glue is not a recent technological innovation; even in the ancient world, Egyptians were using animal glue to make useful household items like furniture (8). Similarly, casein is a protein found in milk, and when dissolved in an aqueous alkaline solvent, it forms an adhesive that is generally superior to animal glue for wood bonding (1). Animal glue is actually not very reliable when it comes to long term stickiness. As explained above, animal collagen dissolves in hot water, therefore, unless kept in a completely cool, dry environment, the bonds will break causing it to lose its stick (8). But this can still be useful when something is meant to be temporarily sticky.

Just as there are animals that we don't necessarily picture as glue, many vegetables that we are accustomed to seeing on our dinner plates that can also form the basis of some natural glues. The primary forms of vegetable adhesives, starch and dextrin, are extracted from corn, wheat, potato, or rice, and are used in packaging and wallpaper adhesive (1). So next time you bite into a freshly grilled piece of corn just remember- that could have been glue! Natural adhesives are quite interesting to study because they are made from pets and things we can find in our refrigerators. Synthetic adhesives on the other hand, are most important and used more in our daily lives.

In recent studies, scientists researched the properties that allow certain sea creatures to be sticky (5). Shellfish and mussels that stick to rocks and ships are two classic examples. So that image of a cartoon starfish stuck to a rock in the middle of the ocean is actually due to the wonders of the adhesive bond. Because this exciting development in the glue industry is bio-inspired, it may have significant medical applications like utilization in organ transplants (5). This type of adhesive is particularly interesting because it combines the two forms of adhesives– it is bio-inspired and produced naturally, yet it is being made into a synthetic glue.

Like starfish and other water creatures, geckos also have this sticky superpower. They can actually climb up a vertical wall, and I can assure you, they don't use Elmer's glue! Rather, according to Robert Espinoza, a biologist at California State University, what makes geckos' feet sticky are setae, miniscule hairlike structures (7). The way the setae stick to walls and other surfaces is actually due to the London Dispersion

Forces of Attractions between neutral molecules. According to Duncan Irschick of the University of Massachusetts there is more to this phenomenon. Gecko foot tendons are located on their skin and when they come into contact with a surface they stiffen (7). This creates a distribution of forces and an effective adhesion.

Once I graduated from preschool, liquid glue was not as popular anymore, and at some point between third and fifth grade I made the bold transition to Scotch Tape. I never really thought of tape as a glue, but it turns out that adhesion is what actually makes it sticky. This kind of synthetic adhesive is called the pressure sensitive adhesive because the adhesion occurs when there is pressure applied to the adherend; when you tape two things together you press down to make them stick. Louis H. Sharpe concludes that pressure sensitive adhesives are sticky because they are viscoelastic (2). This means that they will wet the surface to which they are pressed, and then, because of their elasticity they will resist separation (see Figure 2). Benjamin E. Russ explains that there are two components of the stickiness of tape: the aforementioned adhesion and cohesion. Adhesion is the binding of two separate molecules while cohesion is the binding of two similar molecules (2). When the molecules are similar, the cohesive force causes the molecules to stick, which is the case with the glue molecules, resulting in a sticky substance. When the molecules are unlike one another, the adhesive force holds the molecules together, which is the case with the glue molecules and the molecules of the substance it is sticking to (see Figure 1). Therefore the stickiness of tape is caused by both cohesive and adhesive forces. According to researchers in the industrial tape division at 3M, a formidable adhesive manufacturer, there is absolutely no chemical reaction or bonding involved in adhesive bonding using pressure sensitive adhesives like tape. Rather, what determines the strength of the adhesion is the degree of freeness of the flow of the glue onto the surface, which depends on the surface energy of the adherend (2).

When I was younger, I remember not being allowed to use super glue because it is so sticky that it can glue your fingers together; now I understand why. Super glue is another synthetic adhesive. Super glue was actually invented accidentally by Harry Coover. Dr. Coover first came across this adhesive, known as cyanoacrylates, when he was experimenting with acrylates for use in gun-sights during World War II and realized that it was too sticky to work with but, he disregarded this potentially groundbreaking discovery (3). Later, 1951, he collaborated with a researcher, Fred Joyner, at Eastman Kodak's laboratory in Tennessee. They were testing compounds for a temperature resistant coating for jet cockpits and when they got to compound number 910, they discovered that they could not separate the two lenses where it was spread in order to take a

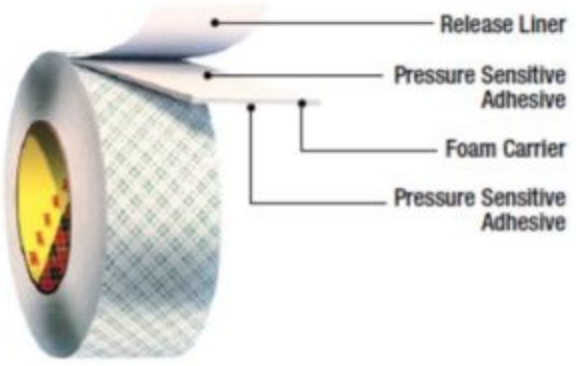

Figure 2: In the diagram, the image of the double sided tape highlights the way the pressure sensitive adhesive works. With the double sided tape the adhesion is actually happening on both sides and pressure is equally applied to the adherends.

Pressure Sensitive Adhesive

in

reading of the velocity of light (3). While their initial reaction was complete panic, Dr. Coover saw this as an opportunity. Later on, his serendipitous mishap hit the market, and the first Super Glue was called Eastman 910 after the place and subject of his discovery. Can you imagine that the super glue we rely on today, and that can be found in any local store, was all invented by mistake?

When I think of synthetic glue what comes to mind is arts and crafts and small household fixes. However, nowadays adhesives are used in heavy metal machinery, as well. New advances in the joint industry use adhesive bonds in place of mechanical bonding of CFRP (carbon fiber-reinforced plastics) joints. However, there are still two issues with the traditional adhesive bond: the strength of the bond is low and it is unstable. Because of these issues, a new method was introduced called ultrasonic vibration-assisted bonding, and it is an improvement from that of the traditional adhesive bond. According to the study, because of the high-frequency vibration between the adhesive and adherend produced by the ultrasonic vibration, the adhesive penetrates the roughness of the surface which improves the adhesion strength and stability (6). While it may sound simple, the process in which this bond is formed cannot be done with a Popsicle stick and some school glue, rather it has many steps and is actually quite complicated. First, the adhesive is spread on the bonding surface, then the aluminum joint is placed into a tube slowly rotating while the ultrasonic tool is touched to the surface of the bonding joint (6). The position of the surface and the vibration time and pressure are set accordingly. After much research and experimentation, the study concluded that the strength of the adhesive bond increased significantly due to the ultrasonic vibration.

While it may seem as though glue has only come to common use in the mid 1800's, in recent studies archeologists found evidence of Neanderthals using forms of glue 200,000 years back. They found stones covered in tar that was distilled from the bark of a birch tree, which they produced 100,000 years before Africans first began to use tree resins and other forms of adhesives (4). Archeologists performed numerous experiments to figure out how the Neanderthals were able to produce this adhesive tar. They discovered many methods of using the birch bark to make tar; yet, they will never know exactly how they made the adhesive 200,000 years before. While they may never know exactly how they made the tar, it is interesting to note that many years back, even before trade and travel, people needed something sticky to bind objects together and they used the resources available to them to make one of the earliest forms of adhesive glue.

Glue is a perfect example of something that evolves over time. In ancients times people figured out how to create useful everyday things such as furniture with their own forms of glue. And now, hundreds of years later, scientists are figuring out how to use glue to save lives. Polyethyl glycol (PEG), is a long chain polymer that is highly attracted to water (9). Since it is so water thirsty, it has the ability to fuse cells together by detracting all the water molecules from between them. In a Nobel Prize winning experiment, César Milstein and Georges Köhler discovered that they can use PEG to create "hybridomas" which dehydrate the cells and break the cell membrane (9). This groundbreaking discovery was proven to cure numerous cancers and other diseases through its miraculous ability to create new cells by bonding the old cells together. Recently, neurologists have become exceedingly interested in PEG's ability to fuse cells in regard to spinal cord injuries that often cause paralysis (9). This experiment is still a work in progress, however, being that it is

having significant positive effects on animals, scientists are feeling optimistic as they come closer to a final cure for spinal cord injuries.

I use glue all the time in my daily life, but I never used to think twice about how adhesives work. The sun comes up, streams flow downhill, and glue makes things stick- that's just the way the world works. But it turns out that there is much more to it. There are many scientific forces playing a role in this miraculous process called adhesion, and it is not one that should be underestimated or taken for granted. This is true with everything in life. Nothing can be perceived by how it functions on the basic level; there is always a greater force and an explanation for how things work and nothing just happens on its own. In our world we often make the mistake of taking things for granted. However, through my research of the adhesive bond and the scientific and historical background of glue, I have learned that everything has a precise and intricate design and structure and it should be recognized and appreciated that Hashem runs the world in this wondrous way.

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HONEY- HISTORICAL, HEALTHY & HEALING

Tamar Lewin

The Father pushes the toddler's blonde hair from his eyes. He knows that soon all the toddler's long hair will be cut off and in its place will be a kippah.

The Rav sits down next to the father and his son and points to a laminated sheet of paper with honey drizzled over it.

"Aleph," the Rav says, "Can you point to the Aleph?"

"Aleph," repeats the child as points to the letter and he licks the honey the honey off his small chubby finger.

"May the Torah always be as sweet as honey," the father whispers.

In our culture and many others, honey is a beloved and universal substance that has different uses and properties. It is also an ancient substance with records going back thousands of years. Honey is fascinating because while it seems to be a simple product, enjoyed by children and adults alike, it is quite complex. Most people know that honey is useful for eating and cooking. Some people also know that there is something about honey that makes it unsafe for infants to eat before the age of one. However, what most don't know is that it also has medicinal and antibacterial properties which makes honey super fascinating and far more interesting than what meets the eye.

The first record of beekeeping is believed to be from paintings that were found in caves in Spain that date back to the year 7000 BC. In Cairo, Egypt, historians have found records of beekeeping in a sun temple that dates back to the year 2400 BC. Bees were represented in hieroglyphics and, because they were beloved by kings, were often used as a symbol of royalty. The Egyptians used honey as a sweetener, as part of the embalming process, and as an offering to their gods. As far back as 2600 B.C.E, scholars have translated a formula from hieroglyphics, in which the Ancient Egyptians used honey, together with grease and cloth fibers, as a balm to heal wounds. Greeks and Romans used honey for food, such as in cakes, cheeses, and meats and as offerings to gods as well. The Greeks and Romans also used honey to remedy wounds but also intestinal diseases. Hippocrates, a Greek physician who is considered to be one of the fathers of medicine, did not prescribe many medications but he did encourage the ingestion of honey, combined with other substances such as vinegar or water, as a remedy for pain or fevers. Because it was such a valuable commodity, beekeeping became a popular job at that time. Soon, after the development of Christianity, honey and beeswax became essential parts of religious services. (Honeyassociation.com)

Honey has a variety of uses, and it comes in different forms. It also has a very stable shelf-life and never spoils, as long as it is kept in a well-sealed container. Honey has been discovered in ancient Egyptian tombs, making it thousands of years old. Because honey is acidic and contains very little moisture, these conditions help it stay well-preserved because bacteria are unable to grow. The stomach of bees contains an enzyme that makes its way into the honey and this enzyme also contains substances that inhibit the growth of

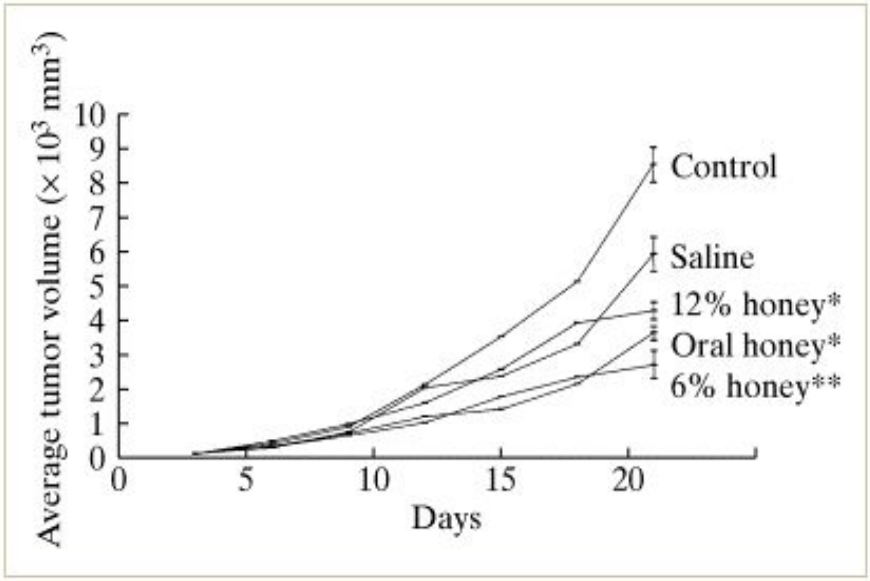
bacteria. Among the different types of honey are the commonly known clover, orange blossom, and buckwheat as well as the less known alfalfa, eucalyptus, sage, and neem varieties.

Each variety of honey has its unique characteristics and therefore is useful in different ways. Clover honey is used to regulate blood pressure and cholesterol levels, provide antioxidants, to assist in healing coughs and sore throats and to treat minor cuts and burns. Clover honey was used, in addition to blueberry honey, to determine its effectiveness against oxidation when in salad dressings. The antioxidant properties can contribute to treating many health problems. For example, they can help prevent cancer, and they heal wounds and infections. They can also treat heart, brain, and immune system diseases. These compounds can also be used for food preservatives (Khalil 14).

Other versions of honey have different uses. Buckwheat honey, in addition to having antioxidant properties, also has enzymes, vitamins, and minerals and it has antibiotic properties. It helps treating diabetes, correcting iron deficiencies, and treating infections from bacteria. For example, in a study done in India, honey was found to help the body absorb iron which was useful in treating patients with iron deficiencies. (Sharma 124). Bee honey was also found to protect the body's immune system while fighting allergies.

Incredibly, it also has been studied as an anti-cancer agent. Bee honey is effective in fighting some cancer cells. "*In vitro* study showed that diluted honey affected the growth patterns of some bladder cancer cells" (Akaza 219). Research is continuing to be done to see how else it can be helpful as an antitumor mechanism, as well as to understand precisely what qualities honey has that gives it this characteristic. The image below shows the effects that honey solutions had on the average tumor volume, and it is clear that the effect is an auspicious one because the volume decreased when exposed to the honey solution.

Another study that involved the use of honey for cancer research, conducted by Israeli researchers, looked at the effect that honey had on patients suffering from head and neck cancers. It has been found to prevent the buildup of oral mucositis because scientists recognized honey's ability to heal wounds and burns. One such study, as seen in Image 1 below, was not able to reach a specific conclusion because of insufficient data, but the researchers did admit that there were some excellent results. However, researchers did admit



that the "results of the study support the potential for a mix of manuka and kanuka (honey) essential oils as a gargle to prevent mucositis" (Yarom 3217).

Table 3 Summary of study findings for honey

Name of agent	Route of administration	Cancer type	Treatment modality	Indication	Author, year	Effective	Overall level of evidence	Guideline determination	Comments
Honey	MW	H&N cancer	RT	P	Khanal 2010 [39]	Y	III	No guideline possible	Honey compared to lignocaine MW Honey extracted from beehives of the Western Ghats forests
Honey	S&S	H&N cancer	RT	P	Biswal 2003 [41]	Y	III	No guideline possible	Honey extracted mainly from the tea plant, *Camellia sinensis*
Honey	S&S	H&N cancer	RT	P	Motallebnejad 2008 [40]	Y			Honey extracted from Thymus and Astragale in the Alborz mountains
Honey	S&S	H&N cancer	C/RT	P	Rashad 2009 [42]	Y	III	No guideline possible	Honey extracted from the clover plant *Trifolium alexandrenum*

MW mouthwash, *S&S* swish and swallow, *H&N* head and neck, *RT* radiotherapy, *C/RT* chemo-radiotherapy, *P* prevention

Not only does honey help relieve sore throats, but it also has medicinal properties in the realm of wound-healing. As far back as ancient times, honey has been "known to possess antimicrobial property as well as wound-healing activity" (Mandal 154). Honey has been used in ancient times as an antibiotic to fight against bacteria. Today, as diseases are becoming immune to the various forms of antibiotics that have become available, researchers are moving back to traditional and ancient remedies, including honey. A certain type of honey called *L. scoparium*, "has been reported to have an inhibitory effect on around 60 species of bacteria" (Mandal 155). So while it continues to be effective in helping to soothe sore throats, it has many more critical functions in the realm of health and wellness.

Honey has been known to have both antibacterial and antifungal properties. Honey has been proven to kill bacteria such as *Salmonella Shigella*, enteropathogenic *Escherichia coli* and Vibrio *cholera*- all of which are dominant causes of morbidity and mortality worldwide (Zumla 384). This characteristic is extraordinary considering how ordinary honey seems to be. Honey has also been shown to treat burns, certain types of ulcers, and even wounds as a result of surgery. When honey is applied to surgical incision sites, the wounds healed faster and with less bacterial growth. Other studies have shown that when honey was given to children, in addition to rehydration fluid, it shortened the length of time that these children suffered from bacterial diarrhea. Another study, conducted with mice, showed that wounds healed significantly faster when honey was applied than when not (384).

Honey contains these healing properties for several reasons. There is an enzyme in honey called glucose oxidase that produces hydrogen peroxide within the substance. The amount of hydrogen peroxide that is present depends on the level of the glucose oxidase which is determined by the bee and the type of

flower pollen. Honey contains another enzyme called catalase which helps the wound to absorb water, allowing the wound to become clean and to heal faster and prevent infection (Zumla 384). Honey is also very thick and provides a solid barrier against particles and other elements that can cause infection. The fact that honey contains a high sugar content, as well as a low pH level prevents the growth of bacteria and other substances. Another essential characteristic of honey is that it keeps the wound moist which allows it to heal more quickly and more effectively. Honey has also been found to help the body with the absorption of both water and sodium.

Aside from the mundane use of Honey, it can also be a very beneficial and vital medical substance. There is still much that needs to be researched and discovered about honey and its healing properties. Scientists believe that the various types of fructose contained in honey can help with the treatment of leprosy. Honey is valued for its well-known characteristics such as its delicious taste and its versatility as an ingredient. It has also lent itself to traditional medicine, playing its role in fighting bacteria and healing wounds. What needs further study is how else honey can be utilized in the world of medicine. "The time has now come for conventional medicine to lift the blinds off this 'traditional remedy' and give it its due recognition" (Zumla 385).

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FROM FARM TO FRAPPUCCINO

Chana Lipschutz

"[It] Is planted in Adar and groweth up and is gathered in Ab" describes an Arab physician in a treatise on a little bean.

He concludes his paragraph with saying that it is a mistake for people to drink the processed liquid extracted from this bean with milk as they will be in danger of leprosy (1). This is irony at its finest as today many people drink it with lots of milk. And caramel. And an extra dollop of whipped cream. But what about the bean that's at the center of everyone's favorite pick-me-up?

In the ninth century, a shepherd from Ethiopia named Kaldi noticed that his goats became more energetic when eating berries from a certain bush. He tried the beans and experienced the same rush of energy as the goats did. He took these beans to a religious figure who was skeptical of this new discovery and threw them into the fire. A delicious aroma wafted up from the fire as the beans roasted and so began the world's obsession with coffee. (14) This is a legend and whether it is true or not, C. Arabica's origins lie in Ethiopia and by the end of the fifteenth century, the bean had made its way across the Islamic world. Coffee was probably introduced to Europe by Muslim merchants in the sixteenth century. By 1700, there were 2,000 coffee houses in London frequented by working class men. Coffee has been credited with increasing the sobriety of these men who previously drank lots of ale. Today, coffee shop chains such as Starbucks and Dunkin Donuts give people all over the world their morning boost. And it is all caused by one little bean. (10)

Let's start with the origins of the coffee bean. Coffea Arabica is a member of the Rubiaceae plant family. A family of flowering plants, these white flowers will eventually produce cherries. The "seeds" of these cherries are what we call coffee beans. There are many steps involved in growing the perfect coffee beans, before they can be processed. Firstly, they have to be grown in ideal place of growth where they can mature and grow properly. Although Coffea Arabica's origins lie in Ethiopia, today it is grown in Latin American, Asian, African and European countries. For commercial purposes, coffee beans are grown in large scale nurseries or even small scale farms. The plant is tolerant of different climates, having a range of suitable zones that are defined as "Hot-Wet," "Constant," "Cool-Dry," "Cool-Variable." These zones vary between 945-1580 meters above sea level. Air temperature should be between 18-23 degrees celsius. (2) At a higher temperature the coffee plant will grow at a faster rate, which can reduce the quality and cause severe damages to the plant's health. Shadier regions seem to be better areas to plant coffee. Coffee plants grow better under more humid conditions, and research has shown that planting under trees that provide shade, versus planting in direct sunlight increases the humidity levels thereby increasing the plant's growth. (5)

The soil the plant is grown in is also important to consider. It is most preferable for the acidity levels of the soil to be between a PH of 4.1 and 6.3 (2). While coffee beans can tolerate a wide range of soils, volcanic soil is best because of its multitude of nutrients, such as carbon and nitrogen (3). Even if the soil is

nutrient dense, often its nutrient supply will not be enough to sustain a growing coffee plant. This is where fertilizer comes in. Experiments show that when soil is fertilized with nutrients such as Phosphorus and Nitrogen, there is about an 1,000 kg increase in bean yield as opposed to when not fertilized. (2)

If one was interested in growing their own coffee plant instead of just popping into Starbucks, they would need to buy some green Coffee Arabica seeds. A dark brown bean would not have the potential to germinate because it has already been roasted. A bean's viability is its potential to germinate. Coffee seeds generally lose their viability after six months of being picked from its mother plant. However, they can be properly stored in humid condition for about 1-3 years, although there is a significant decrease in cup quality as storage time increases (3). Coffee has a specific germination type called "intermediate." This means that coffee seeds can still be viable even when it is partially dried of its natural moisture.

There are many factors that affect the germination process of Coffee Arabica beans. The process begins with a red cherry. Inside a red cherry lives two coffee beans and each coffee bean has layers that add nutrients, body, and flavor to your cup of coffee. The fruit has three layers, exocarp, pulp, and mucilage. The exocarp is the outer skin of the fruit, then comes a layer of pulp or mesocarp, the final layer, the flesh of the fruit is called the mucilage; a slimy layer that is usually removed through various methods of coffee processing. The parchment or endocarp serves as a separation layer between the fruit and the seeds. The parchment contains chlorophyll, responsible for the green color of a raw coffee bean. Each bean is encased in the silver skin or spermoderm. Finally, under all those layers is the bean. The bean has an embryo that is involved in the process of germination (8). The endocarp acts as a barrier to the growth of the embryo and can often delay or prevent germination (11).

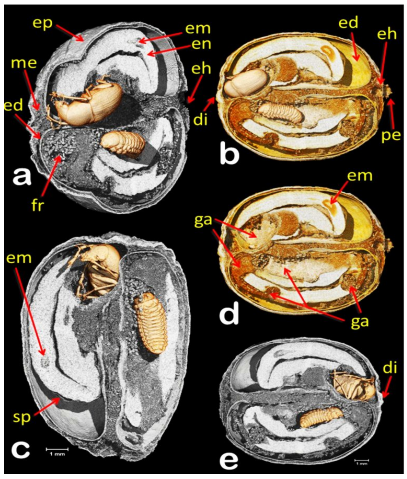


Figure 1
A coffee bean weevil is depicted inside a bean. Di - disc, ed - endocarp, eh - entrance hole, em - coffee embryo, en - endosperm, ep - epicarp.

Research has shown that an enzyme called Endo-β- Mannanase will help quicken seed germination by breaking down the endosperm barrier through hydrolysis of the mannans (polymers of mannose). Hydrolysis is the chemical breakdown of a compound due to a reaction with water. The enzyme is more effective when the bean is subject to various methods of processing, such as fully washing, semi-washing, and drying, versus no interference (12). Therefore, a coffee farmer must be extremely selective when choosing the method of preparation for the germination of the beans.

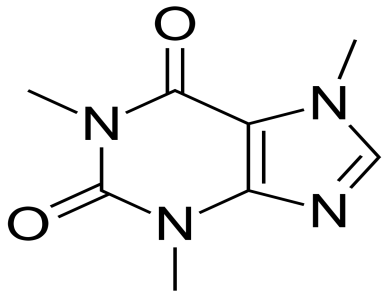
What happens to the bean as the plant grows? Eight weeks after the flowers of the C. Arabica plant self-pollinate, cell division occurs inside the seeds. This is the pinhead stage in which there is little to no growth of the bean inside the fruit (13). Next comes rapid periods of growth of the fruit that ends about seventeen weeks after pollination. Now, the outer layers (integument) of the bean have fully grown to accommodate the endosperm (food storage part of the bean) which

consumes the integument until it's all gone except for the silver skin. The coffee bean is now formed. When first formed, the bean is jelly-like but hardens over the next couple months (9).

Growing coffee does have its risks. There are all sorts of diseases and insects that can easily affect the bean due to environmental change and improper maintenance. In 2013, Roman Lec's two thousand dollars worth of borrowed fertilizer was of no help. Jose Obispo Tax Tale was having even more trouble feeding his eight kids. The perpetrator? "La Roya," the notorious coffee rust (7). This fungus is just one of the many diseases that will cause damage to the coffee bean and its massive industry. In 2013, coffee dependant countries such as Honduras and El Salvador declared a state of emergency when the rust barreled its way through coffee plantations and farmers were desperate. Often the coffee berry will be infected and this will affect the seed's roasting quality as opposed to harming the physical seed. Coffee Berry Disease is especially prominent in Africa, and dark brown spots will blanket the cherry about 4-14 weeks after the plant flowers. However, many of these potential epidemics can be controlled by careful selection of seeds to germinate a new plant, as in the case of oily spot and coffee berry disease. These are both fungi that are derived from the same pathogen group (*Colletotrichum kahawae*). Maintaining proper balances of soil acidity, humidity and shade can also decrease risks.

Unfortunately, this isn't the only disease that ravages coffee plants; there are also tiny insects which destroy coffee. The coffee weevil is an insect that measures about 4-5 mm long, and is infamous for infesting stored coffee, however, researchers have seen weevils burrow into coffee berries from the field (6). The female weevil enters the coffee berry and lays eggs inside the berry. The eggs will grow to become larvae by living in and feeding on the beans, and then exit by chewing a hole through the disc, the area that connects the two seeds, or beans of the coffee berry. The coffee weevil not only damages the beans with physical holes. It also affects the grading to measure the quality of the bean.

But what is so significant about coffee that around 120 million people depend on it daily (12)? The caffeine of course! An eight ounce cup of coffee contains around 100 grams of C8H10N4O2, (caffeine's molecular formula). Caffeine is a methylxanthine alkaloid, which is a substance containing xanthine (an organic compound) from which many stimulants are produced. The natural process for turning xanthosine into caffeine is a complex one, with the coffee plant using various enzymes to rearrange atoms of xanthosine until eventually a caffeine compound is formed (14). Caffeine is a naturally occurring alkaloid in coffee and although is not classified as an addictive, has similar properties to those of popular drugs. Dopamine is a chemical that has several pathways for neurotransmitters in the brain, and controls motivation and rewards emotional responses. Caffeine heightens dopamine's alertness in the brain. This is why one gets that rush of energy and alertness after downing a steaming cup of coffee. As mentioned before, caffeine is not an addictive but it can lead to withdrawals if one is too dependent on it (13). Doctors



do not advise drinking more than 400 mg a day. If one drinks the right amount, caffeine could decrease the risks of Parkinson 's disease, stroke, heart attacks and other cardiovascular diseases.

Learning about a coffee bean's growth process, not only helps increase awareness of our bodies' health, but also the health of our environment. Researchers have found a link between extreme weather and coffee rust. Imagine not being able to pick up your Espresso Frappuccino® because of some fungus? It is important that we are conscious of nature's well-being because it is the catalyst of so much good in our society. Coffee fuels millions of people's days, whether they pick up a steaming cup for pleasure or out of necessity. Millions of people across the world start their day the exact same way with a piping cup of morning energy. And all this starts with one little bean.

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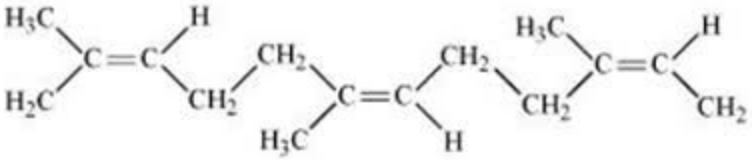
RUBBER

Nechama Mandel

Think about your erasers, your shoes, ponytails, latex gloves, balloons, the tires of your car, and even your mattress. What do all of these things have in common?

They're all made of a polymer of isoprene, chemically combined with sulfur and heat, also known as vulcanized rubber. In 1770, chemist Joseph Priestley noticed that "rubber" can rub off pencil marks from a piece of paper better than any other substance could; and hence the name, rubber. Whether hard or soft, natural or synthetic, rubber is used consistently throughout our daily lives, mostly without us even noticing. (2).

There are two types of rubber: natural and synthetic. Natural rubber is a polymer of isoprene. The structural formula of isoprene is C_5H_8, or, five carbons and eight hydrogens. Natural rubber is made when many monomers of isoprene combine to form a long polymeric chain (2) (8).



Molecules of isoprene bond to form a chain of polymers, resulting in natural rubber

Natural rubber comes from a rubber tree, and it is obtained in the form of latex. Rubber trees can be found in many areas, but the best type of tree is in Brazil, called the *Hevea brasiliensis*. While the *Hevea brasiliensis* may be the most popular rubber tree in the world, rubber is also cultivated from trees in Southeast Asia and in western Africa.

Throughout the 19th century, many powerful European countries were colonizing in Africa and Asia. Interestingly enough, one of the main reasons for colonization in Africa was to obtain one of Africa's most important natural resources at the time, rubber. Latex is the name given to a substance that comes from the rubber tree, as well as many other plants. It is obtained by stabbing the rubber tree to allow latex to flow out, and it continues to flow unless the tree is plugged up. Rubber is produced from the latex that is extracted from the *Hevea brasiliensis* by processing and clumping the latex to eventually get the substance that is used in many of our daily appliances (1).

Latex seeping out of the Hevea Brasiliensis

Natural rubber has been utilized for centuries in many different ways. However, synthetic rubber is a more recent discovery. Prior to the discovery of synthetic rubber, natural rubber had properties that would change with the weather. In summer, the rubber would become sticky and develop a bad smell, while in the winter, the rubber would become hard, and brittle, and eventually, crack. Then, a discovery was made. With the right amount of sulfur and heat, rubber will vulcanize and can then be used for different activities, and in any season. Vulcanization is the process of adding heat and sulfur to rubber, making it harder and more elastic. Vulcanization is vital to the use of rubber as it gives rubber its properties of hardness, elasticity, resilience, and strength. When rubber is vulcanized, it can never be reversed. This contributes to its useful properties because if the vulcanization process were to undo, rubber would not be able to be used in any object that requires vulcanized rubber. For example, if vulcanization would not remain and it would reverse, during the summer, our car tires would become sticky and would start to smell, thus making them unusable and unstable. Therefore, the process of vulcanization is essential for important utilities and devices that we cannot even imagine life without (3).

Rubber's fascinating properties give it the ability to be used anywhere from a balloon to engineering materials and machinery. The covalent bonds which bind the monomers together are extremely strong and elastic; however if the bonds were to be stretched beyond their limit and break, they will never reconnect, despite the strength of the bonds. A study was done at Harvard to attempt to make self-healing rubber. Those conducting the research wanted to form the polymers in a way that the rubber can break and then reconnect, these would be reversible bonds. The researchers wanted to combine the covalent and reversible bonds, however, they soon found that the bonds do not like to mix. They developed a way to yield the bonds together, and formed a tough self-healing rubber, so when pulled, the rubber can snap back to its original shape and size. Of course, there is still more research and experimenting to be developed, but this discovery can lead to many new inventions and further discoveries that are waiting to be brought to light (5).

Rubber can be either soft or hard, and each of these physical properties allow rubber to perform different functions. Cross-links, which exist in polymers and other complex molecules, form when two

different chains of atoms are bonded together. The more sulfur that is added to rubber, the more cross-links it has, thus, making the rubber harder. Soft rubber will contain a small percentage of sulfur, and therefore, less cross-links. Because there are not many cross-links in soft rubber, it is flexible and elastic. The more sulfur that is added, the harder the rubber gets. So in rubber bands, for example, there is not a lot of sulfur because it is stretchy. However, in car tires, there is more sulfur because the tires cannot be too soft or flexible, or else they would melt. (2)

Rubber is used so much in our daily lives that we tend to take it for granted. For example, without rubber, almost every professional sport would either cease to exist, or be completely changed. Footballs, basketballs, baseballs, soccer balls, tennis balls, and golf balls are all made of rubber. Both footballs and soccer balls are made of vulcanized rubber. The core of a basketball, baseball, and tennis ball is a ball of rubber. The outside of a basketball is leather and rubber, the outside of a baseball is yarn, and the outside of a tennis ball is a hollow wooden shell. Despite the differences on the outside, all three are internally made of rubber. Lastly, the golf ball, formerly made of wood, is now made of rubber and plastic. Initially, rubber was used to make golf balls, but the golf balls would start to melt from exposure to the hot sun and then become sticky. With the advent of synthetic rubber they can now be used even under the hot sun (2).

While rubber may not be as sticky as it once was prior to the discovery of synthetic rubber, it does still have a sticky texture that is used in many everyday items. What makes rubber sticky is the fact that it is stretchy. Because of its malleability, rubber can be molded, shaped, and easy to grip. It is for this reason that rubber is used for the handlebars of a bicycle, as the rubber helps one grip the handles without slipping off, and without getting stuck to the handlebars. Additionally, rubber is used for the back of a post-it note. It is not sticky enough to stick somewhere forever, but it can still stick for a period of time. Rubber's adhesiveness allows it to perform many functions which contribute, not only to our daily appliances, but also leads to new knowledge in science and in the medical field. (8)

Further studies are being conducted to use synthetic rubber in medical procedures. Specifically, scientists would like to replace a knee meniscus that was previously removed due to injury, with polyurethane to mimic natural meniscus. Polyurethane is an elastomer, or artificial rubber, with the properties of synthetic rubber and plastic. This substance is being used as a synthetic meniscus implant. Patients who have had knee injuries involving the meniscus, have often suffered later in their lives from arthritis in the knee joints. This fairly new method of meniscal replacement has offered relief to patients who formerly endured knee pain. The polyurethane is placed where the meniscus was before removal, in order to separate the two bones that rub together, which is the cause of arthritis. Patients have felt relief from their knee pain once this artificial rubber was placed between their joints (4,7). From personal experience with knee injuries, I think that this discovery can be an essential use in our society. I had a torn meniscus in my left knee and had it repaired. This could have potentially led to future knee pain, and seeing that I don't want to get arthritis, it is comforting to know that there is an alternative to the natural meniscus.

Rubber has been changing our lives for centuries, and the world would not be the same without it. Starting at natural rubber and being transformed into synthetic rubber and then finally, vulcanized rubber, it always has a new function, and contributes to our lives on a daily basis. From professional sports to tissue replacements, advancements in science with regard to rubber have made a positive impact on activities that have become natural to our lifestyle. Without rubber, many daily activities, sports, discoveries, and modes of transportation would not be possible.

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HUMAN GROWTH HORMONE: A TALL TALE

Rivka Notkin

A 47-year-old man was admitted to the hospital with cerebellar syndrome. He had been experiencing neurological problems for six months such as involuntary movements, paresthesia, difficulty walking and memory lapses.

His condition quickly deteriorated and he became bedridden, dying a mere five months later. At autopsy, he was diagnosed with Creutzfeldt-Jakob disease (CJD), a rare, degenerative, fatal brain disease caused by improperly folded proteins in the brain called prions (1). It is related to bovine "mad cow" spongiform encephaly and most people contract it from eating meat from cows with BSE (Bovine Spongiform Encephaly) (2). But this wasn't the case for this man. In the 1970s, when he was nine years old, he was injected with a small dose of human growth hormone to test for growth hormone deficiency. Results came back negative and he did not qualify for further hGH treatment. However, just one dose of human growth hormone caused his death from CJD, 38 years later. He contracted CJD because the growth hormone he received was isolated from the pituitary gland of a cadaver who had CJD.

Human growth hormone (hGH), also known as somatotropin, is a protein comprised of 191 amino acids. It is secreted from the pituitary gland and is mainly responsible for many growth-related functions in the human body, one of which is height (3). Physicians have known that growth hormone deficiency is a cause of short stature for centuries. The most famous person to ever have been GHD is probably Charles Stratton, born in 1838. He performed as General Tom Thumb in P.T. Barnum's famous circus (4). Photographs of Charles Stratton and his wife, Lavinia Warren, display the clinical effects of severe growth hormone deficiency.

Charles Stratton at his wedding to Lavinia Warren, 1866

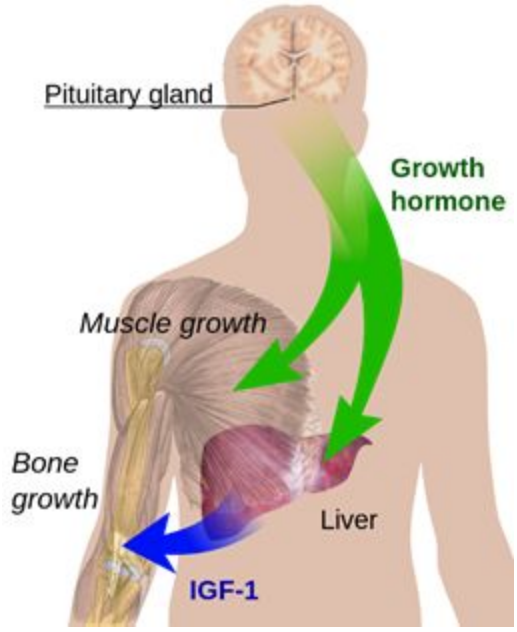
Insulin harvested from animal pancreases can be used to treat diabetes. However, growth hormone harvested from animal pituitary glands does not work at all in humans because of differences in the protein structure between species. So, before the advent of genetic engineering, any growth hormone used to treat growth hormone deficiency had to be harvested from human pituitary glands which was done by pathologists during autopsies. HGH extracted through this method began to be commonly used in the late 1950s. The first doctor to treat GH-deficient patients with

cadaver-derived growth hormone was Maurice Raben. However, isolating sufficient growth hormone to treat more than a few dozen patients was impractical.

To increase the limited supplies of cadaver-derived hGH, the National Pituitary Agency was formed by the U.S. National Institutes of Health in 1960. This agency was in charge of collecting human pituitary glands, extracting the hGH, and distributing it to a few pediatric endocrinologists. Supplies remained severely limited, and only the shortest GH deficient children could be treated. From 1963 through 1985, only about 7,700 children in the U.S. and 27,000 children worldwide were treated with cadaver-derived hGH. The shortage of cadaver GH worsened in the late 1970s as the autopsy rate in the U.S. declined (5).

Typically, there are fewer than 350 cases a year of CJD worldwide. However, in 1985, four people who were treated with cadaver-derived GH in the 1960s developed CJD and as a result, cadaver-derived hGH was immediately removed from the market. Between 1985 and 2003, a total of 26 cases of CJD occurred in adults having received GH before 1977.

Choh Hao Li, a Chinese-born, American scientist, is the physician/researcher most closely identified with the quest to produce enough human growth hormone to supply the growing demand (6). He was born in China and immigrated to the U.S. in 1935 to work at the University of California, Berkeley, first as a postdoctoral student and then as a professor. Dr. Li was the scientist who first identified the 191 amino acid sequence of human growth hormone. In 1970, he successfully synthesized hGH, at that time the largest protein that had ever been synthesized. In 1958, Dr. Frederik Senger was the first scientist to determine that every protein has a unique amino acid sequence. He was able to determine the sequence by breaking the proteins into segments using various acids, which were then separated based on their size and charge. He used this knowledge to add amino acids one at a time to the growing protein molecule. The first protein he synthesized was insulin, for which he won the Nobel Prize in 1958.



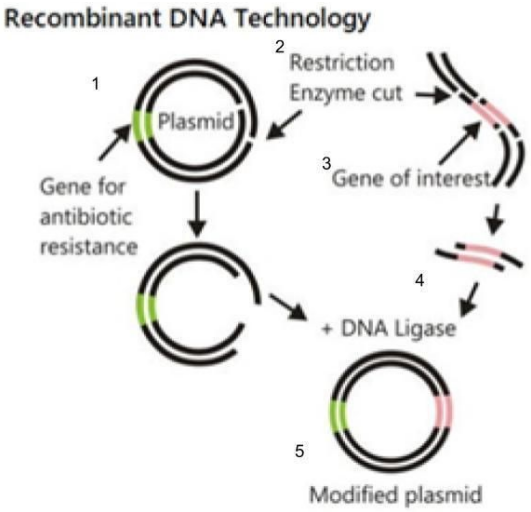
Schematic of growth hormone effects in the body (8).

Natural Growth hormone secretion begins with the hypothalamus, a gland located underneath the brain near the pituitary gland, which secretes two hormones that control the release of GH by the pituitary: growth hormone-releasing hormone (GHRH) and growth hormone-inhibiting hormone (GHIH). The pituitary senses the level of both hormones and releases a pulse of GH, usually one hour after the onset of sleep. Growth hormone stimulates growth in two ways; The first is by binding to a GH receptor on the surface of cartilage cells and the second is by signaling the production of IGF-1 (Insulin-like growth factor 1) in liver cells, which stimulates growth in a variety of cells throughout the body, specifically bone and cartilage cells. IGF-1 binds to receptors

on target tissues such as bone and skeletal muscle and induces hypertrophy (7).

Genentech, founded in 1970, was one of the first biotechnology companies in the world. Although it wasn't the first entity to develop the genetic engineering methods, also known as recombinant DNA technology (9), it was the first company to be able to produce commercial quantities of proteins using fermentation of *E. coli* bacteria with recombinant DNA. Although the first protein produced at a commercial scale was human insulin, the first protein the company successfully synthesized in its labs was actually human growth hormone (10).

Recombinant DNA technology combines the DNA sequence of human growth hormone, along with a promoter sequence, with the DNA of a common bacterium called *E. coli* (11). E. *coli* is utilized because it is easily accessible, simple to use, and reproduces rapidly First, The genes that code for growth hormone are isolated from the q22-24 region of human chromosome 17 using restriction enzymes. These enzymes identify specific places in the DNA, latch onto the desired genes, and cut the sequence away from the chromosome. The end result is the complete gene that encodes growth hormone. Next, the gene is transferred to a plasmid, along with a gene for antibiotic resistance. A plasmid is a ring of genetic material that is not a chromosome but replicates along with a cell's chromosomes (12). The gene is attached to the plasmid with DNA ligase. Then, plasmids are placed in a solution of *E. coli*. The plasmids "jump" into the *E. coli* after a process known as heat shocking. After the plasmids are accepted, the bacteria is cultivated. Not all of the bacteria accept a plasmid, so in order to separate the futile *E. coli*, antibiotic is added to the solution. The *E. coli* accepts the plasmids, which have the gene for antibiotic resistance in addition to the gene for hGH. Then the *E. coli* rapidly reproduce and billions of *E. coli* with the gene for hGH are created. The protein production machinery of the bacteria produces the human growth hormone along with their bacterial proteins. Afterwards, the hGH is separated from inside the bacteria, and purified through a complex process, isolating the proteins by size, charge and hydrophobicity. Once the newly created hGH is isolated, it is ready to be administered to patients via injection.



Schematic of DNA cloning (13): Recombinant DNA technology. [1] Plasmid with antibiotic resistance. [2] restriction enzyme is cut. [3] Gene of interest (q22-24 region of chromosome 17) is selected from human DNA. [4] Gene of interest is isolated. [5] Gene of interest is implanted in the plasmid.

In 1981, Genentech successfully began producing hGH at commercial scale in *E. coli* and clinical trials of the recombinant hGH began later that year. Luckily for patients, in 1985, the same year that cadaver-derived growth hormone was pulled from the market for spreading CJD, Genentech received FDA approval to launch Protropin. Protropin is a drug containing lab synthesised hGH, which patients can use to enhance their height and muscles. When Genentech launched Protropin, the price of a one year of treatment was $10,000 to $30,000 per year, making it the most expensive drug in the U.S. In 2016, the worldwide market for human growth hormone was $3.7 billion with sales split among 10 different competing brands (14). Global sales of growth hormones continue to grow 7.5% annually and are predicted to top $7.1 billion by 2025 (15).

Athletes use hGH to improve their muscle mass and power, and doping is a major problem in professional sports. HGH levels in the blood are hard to detect, because of its short half-life (about 20 minutes), and because hGH levels in blood return to normal about 12 hours after injection (16). HGH has been banned in professional sports since 1989, and it was completely undetectable until the 2004 Olympic Games. It was then that scientists started using new strategies, such as blood testing for IGF-1 and IGFBP-3, biological markers of GH doping (16). Unfortunately this method is extremely flawed, and scientists have yet to develop a test that can be used to legally accuse someone of doping.

Unlike early cadaver-derived Growth Hormone recipients, who had adverse side effects such as CJD, recombinant growth hormone recipients today reap only benefits. Today, children who inject hGH from a young age grow taller than their projected height with very few reported adverse events. Despite the fact that many people have negative associations with genetically modified organisms, in this case the genetic modification of microorganisms has had profound clinical benefit for hundreds of thousands of adults and children.

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STYROFOAM: DANGERS EXPOSED

Dina Rothman

When you buy takeout food, do you ever wonder how the container keeps the food hot? Is it safe for the food to be in it and what happens to the container after it is thrown out?

The only way to find answers to these questions is by delving into understanding styrofoam. In 1947, Ray McIntire, while working for Dow Chemical Co., accidentally created styrofoam. McIntire was actually trying to create a polymer that was flexible like rubber to be used for insulation but, he had the wrong hypothesis (5). Instead of the chemicals mixing together, they evaporated and became polystyrene foam - better known as styrofoam. A few years later, Dow Chemical Company sold and trademarked the product as styrofoam. Styrofoam serves as a good insulator and is cheap to manufacture and therefore it is used by many businesses in their product manufacturing.

Due to its strong and stiff quality, polystyrene became popular for insulating buildings (called blueboard) and pipes. It's also used for craftwork such as the green foam blocks utilized by florists in flower arrangements to help keep flowers fresh. Furthermore, styrofoam is a good sound barrier and is therefore used for making home theaters and recording studios.

Polystyrene's ability to fully insulate is its unique feature. In an experiment done at NC State University, the researchers compared the insulation of styrofoam and other petroleum-based insulators to bio-based foam insulators, which are made from cellulose (8). As seen in Figure 1, the researchers found that the insulation value of styrofoam was 1.55% greater in comparison to the bio-based foam boards which had a mere insulation value of 1.47%. Therefore, styrofoam was found to be an effective insulator and this is why it can be used to insulate things like houses. Additionally, styrofoam is lightweight, strong and available all over the world. However, the dust/powder formed from polystyrene can mildly irritate eyes, skin, and sometimes affect the respiratory system (7).

Polystyrene foam is a hard translucent polymer plastic material that at an elevated temperature becomes bendable. This flexibility enables it to have both physical and electrical insulating properties (6). Styrofoam is made when small polystyrene beads are warmed and then squeezed together by a machine and formed into the desired shape, whether it be plates, cups, bowls, or takeout containers. For instance, styrofoam cups are made out of styrofoam and air

Table 4. Thermal Conductivity and Thermal Resistivity Properties of Foams

Sample	Density (g/cm^3)	Thermal Conductivity (W/m-K)	R-value (°F.h.ft^2/BTU)
Bio-based foam board	0.100 (8.16) A	0.045 (0.88) A	3.14 (1.47) C
F150	0.03 (0.35) C	0.033 (0.69) B	4.37 (0.79) B
GG	0.04 (0.03) BC	0.033 (0.39) B	4.43 (0.39) B
SF	0.04 (3.79) B	0.026 (1.56) C	5.59 (1.55) A
Parentheses indicate the coefficient of variation (COV,%); A, B, and C indicate the significant differences between the treatments.			

Figure 1: In a study comparing foam boards on the market, it concluded that Styrofoam (Bio-based foam board) was found to be the best insulation product of the ones it tested because it had the best thermal conductivity values (7).

(7). Polystyrene foam is weaker than normal styrofoam and is used often by restaurants and stores to sell and give takeout food and drinks. In addition, the packing "peanuts" are made of styrofoam and are utilized for shipping fragile items since it is helpful in preventing products from shifting during shipping. With the increase in internet shopping over the recent years, there has been an increased demand for peanut use (3).

However, polystyrene is hazardous to the environment. When styrofoam was first introduced, chlorofluorocarbons (CFCs) were used to expand the polystyrene beads to make them into foam. Yet, once it was discovered that CFCs cause the ozone layer to weaken thereby enlarging the hole in the ozone layer, CFCs were replaced with less harmful gases (1). However, polystyrene even without CFCs is still dangerous. The process of making polystyrene pollutes the air and creates large amounts of both liquid and solid waste. The National Bureau of Standards Center for Fire Research identified 57 chemical byproducts released during the combustion of polystyrene foam (3). The foam's base material, styrene monomer, causes cancer and is a neurotoxin that is destructive to nerve tissue (1). When it is heated or in contact with fatty or acidic foods, styrene can leach from the polystyrene containers into the food and beverages contained within it (2). For example, the Louisiana Agricultural Experiment Station found that the eggshells of eggs that were being sold in polystyrene containers had styrene monomers which would pose a major health concern if one were to eat those eggs (3).

Figure 2: This picture illustrates that even after trying, the Styrofoam does not decompose. The polystyrene might break into small pieces but it just forms a different shape than it started out from. Water makes it expand making it appear as if there is even more of it.

Long term exposure to small quantities of styrene can cause neurotoxic problems such as fatigue, nervousness, and difficulty sleeping. It can also cause hematological problems such as low platelet and hemoglobin levels, cytogenetic, chromosomal, or lymphatic abnormalities problems. Styrene can also cause irritation to the skin, eyes, upper respiratory tract, and gastrointestinal organs. Chronic exposure can affect the central nervous system causing depression, headache, fatigue, weakness, and a decrease in kidney function. It also has been shown to adversely affect the menstrual cycles of women. Furthermore, in the process of making polystyrene, it lowers the amount of ozone in the air leading to poor air quality which can negatively affect a person's respiratory and immune system (3).

Styrene is also not biodegradable meaning, it will take thousands of years to break down. As a result, styrene products cause an enormous litter problem that primarily affects the oceans since this is where the materials accumulate (1). Sealife is also harmed because they eat these floating bits and pieces thinking that it is food (2). These floating particles can obstruct an animal's airways and also cause cancer and digestive problems for them. Additionally, even if the particles are avoided, the resources that sea life needs to survive become contaminated (3). Another reason for the vast amount of pollution created through production is due to the fact that a lot of the polystyrene is only for a "one-time use". For example, someone who receives it in the mail as packaging or uses it as a take-out container throws it away right after it is used (7). The only way to

make styrene biodegradable would be by superheating the styrofoam into styrene oil which would release its own toxins, such as toluene, into the world (1). Toluene is a chemical known to adversely affect the brain and nervous system in animals and humans. In addition, it can be harmful to major organs such as the liver, kidneys, and lungs while also impairing immune function (1). Interestingly, in 2015, a group of researchers from China found a type of worm that can live on eating polystyrene foam (1). Although these worms are not yet used in practice, it is possible that these worms could serve as a safe solution for the future to degrade styrofoam.

Since there is no good way to recycle styrofoam, in addition to the fear that its chemicals could leach into the soil and water, the New York City Department of Sanitation banned both the ability to sell and recycle foam items in New York City (4). This ban was established in January 2019, and businesses that previously used styrofoam will have until June 30, 2019 to stop using styrofoam products. The government is suggesting that businesses use more recyclable and biodegradable products such as paper, aluminum, rigid plastics, or glass to mention only a few of many alternate solutions. Therefore, the next time you order takeout food, before being distracted with the negative effects styrofoam causes you and the world, do not be surprised if your dinner comes in a non-styrofoam container.

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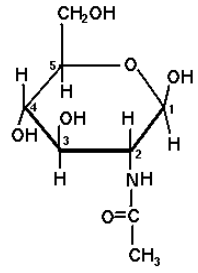
THE OTHER BUTTERFLY EFFECT

Sara Sash

Ephemeral, ethereal and evanescent, butterfly wings are a source of endless fascination, evoking wonder as they gracefully flutter through the air.

With their vibrant hues, mesmerizing patterns, and gossamer like fragility, people fall in love with its majestic beauty and intriguing colors. What they don't realize, is that a butterfly wing is a lot more complex and interesting than ever imagined. Let's begin a journey through the wondrous world of the butterfly wing.

We'll start with the structure of the butterfly wing. The base of a butterfly wing is a thin colorless membrane that is made of extremely skinny strands of chitin with the diameter of three nanometers. To give this a frame of reference, a nanometer is 1 millionth of a millimeter. Chitin is a long-chain polymer of N-acetylglucosamine that are joined together in a reaction through an enzyme called chitin synthase. The bonds within the chitin are very strong which is what makes chitin so sturdy (4). Those bonds also doesn't allow chitin to grow, and therefore butterflies will often shed a layer of their wings (12).



N–acetylglucosamine (NAG)

Butterfly wings are covered with millions of scales. This is why butterflies are part of the insect family called Lepidoptera, Greek for "scaly wing." Each of the scales are covered in ridges in a specific arrangement, and on top of those ridges are even *more* ridges. Because the wings are like this, they have structural coloring, meaning their colors aren't pigments, rather, the colors evolve because of the specific pattern of ridges overlaying the wings. Light reflects off the wings differently depending on its structure, giving different species of butterflies different colored wings. This is the reason butterfly wings are iridescent, seeming like their colors are changing as they move. Because a butterfly's wings colors originate from its structure, as it shifts through the light, the wing reflects differently because the ridges are angled differently towards the light (2). And that's the structure of the butterfly wing. As you can imagine, poor defenseless butterflies make a tasty target for birds and other predators (5). Therefore, different butterflies have evolved in a few ways to keep those pesky predators away.

The first is called "Batesian mimicry" in which the butterfly wings evolve spots to make them look like species of butterflies that are poisonous to the predators (7). An example of Batesian mimicry is seen with the Monarch and Viceroy butterflies. The Monarch butterfly is toxic to predators because of the milkweed they eat. The viceroy butterflies are palatable, however, they are not targeted as much because of their wings' resemblance to the wings of the Monarch butterfly (8). The second way butterflies avoid predators is called "Eyespots" in which the butterfly wings evolve spots that resemble an eye. Eyespots are a series of concentric circles made of pigmented cells that surround a center containing a black pigment. From a distance this looks

very similar to an eye. The Owl Butterfly is most famous for the big eyespot on its wing that looks like the eye of an owl, that scares away predators by making it seem like it is actually a much bigger animal. In 2007, a new Owl Butterfly species with orange wings and a wingspan of 4 inches was discovered and the rights to name was auctioned off and sold for $40,800. There hadn't been a new butterfly from the Owl Butterfly family named in 100 years, until this new butterfly was named after Margery Minerva Blythe Kitzmiller. The naming rights were bought by her 5 grandchildren who wanted to honor their grandmother, and now the butterfly is called the Minerva owl butterfly (9).

Kalligrammatid lacewings and modern Owl Butterfly

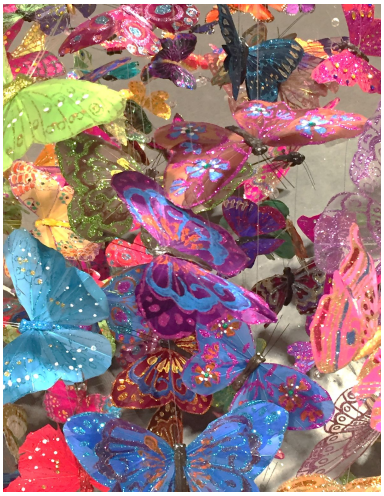
During the Mesozoic Era, there were insects called Kalligrammatid lacewings that have been extinct for over 120 million years. Scientists have been doing research on a fossil of this insect and it seems to have many characteristics of butterflies we see flying around today.

The fossil has remnants of an eyespot on its wing that is very similar to the eyespots of the Owl Butterfly, as well as a tubelike mouthpiece like that of the modern butterfly. However, even though their wings may have looked similar, the butterfly and the Kalligrammatid lacewings are completely different species and are not genetically related (6,10).

It's a good thing butterflies found a way to outwit their predators and are still around today, because the butterfly wing has inspired advanced technologies and medical treatments. One example of an advanced technology is a new type of display technology called IMOD. The electronic displays that most people use are Liquid Crystal Display technology (LCD). These screens use red, green, and blue pixels to display colors and images. LCD has a light source from the back, so that when light passes through the screen it will hit the pixels before your eyes so it will already be colored when the light hits your eye. Unlike LCD which uses pixels, IMOD uses a structural coloring system. It works by having a huge amount of tiny plates that shift around to create reflective shapes, set up between two reflective membranes. These plates, like butterfly wings that are iridescent, are able to move fast changing their position, and essentially the image shown, very quickly. This allows for a better display of videos and animations. They are also better for reading ebooks or online articles because they don't have a backlight that tire out your eyes. Because IMOD only needs electricity to change the position of the plates and doesn't need to power a backlight, they are faster to charge and don't lose their battery as quickly as LCD (3).

One example of a medical treatment that was inspired by butterfly wings, is an implant to help treat glaucoma. Glaucoma is one of the most common causes of blindness. When the pressure rises inside the eye, it harms the optic nerve. There are some medications that can help with Glaucoma, but scientists are looking for a more efficient solution to help Glaucoma patients. Hyuck Choo, a scientist from Caltech, has been working on eye implants that would serve as sensors to check pressure inside the eye. He became interested in the properties of the Longtail Glasswing Butterfly wing. The Longtail Glasswing Butterfly has wings that

are almost completely transparent, and are covered with miniscule pillars that are 100 nanometers in diameter and spaced 150 nanometers apart. The wings have a property called 'angled independent reflection,' meaning they redirect the wavelengths of light so no colors are reflected. Choo had already developed an eye implant for these purposes, but the problem was that it would only be able to give the correct measurements if it was at an exact perpendicular angle in the eye. Using the model of the Longtail Glasswing Butterfly wing, Choo created a copy of the wings made from silicone nitride, to be used for eye implants. The structure of the implants make them almost transparent, like the Longtail Glasswing Butterfly wing, so patients can check the pressure in their eye at any angle. These implants are also extremely hydrophilic, and once inside the eye, it is covered with a layer of water protecting it from cells that usually attach to themselves to eye implants. These implants, created using the fascinating properties of a butterfly wing, help Glaucoma patients stay in better health (8).



While our journey through the wondrous world of the butterfly wing has come to an end, it has opened up a path leading to a new and exciting adventure. There is still so much more to know about the butterfly wing, and scientists are discovering something new every day. So the next time you see butterflies flying around, don't just be infatuated by the pretty patterns of their wings, try to remember how amazing a butterfly wing is. From their complex structure, to staying one step ahead of predators, and being used as the inspiration for advanced technologies and medical treatments, the butterfly wing is truly awe inspiring.

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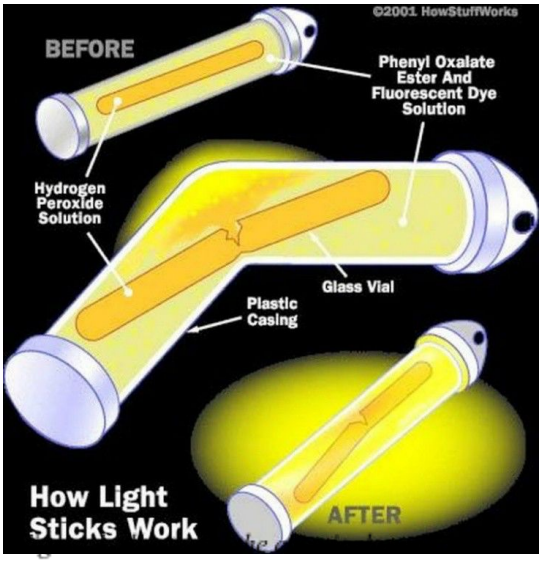
GLOW STICKS

Ahuva Scharf

Crack—the children run around to receive their illuminated bracelets, necklaces or rings shrieking happy birthday.

The birthday girl, is lit up by the various forms of the stick that illuminate the black sky as the neon colors reflect on her face and make her smile glow even brighter. Glow sticks are handy since they do not require a power source makes it an accessible item. But what actually makes the glow stick glow? Without the 'crack' of the stick, it is only a colored plastic tube. There must be some chemical reaction happening inside the tube to account for the change in luminescence. Glow sticks, have become helpful in a variety of ways beyond the festive to include military, and hospital uses. In addition glow sticks can be used for locating men in the navy and aid in catching aquatic amphibians. Despite all its good uses, glow sticks are extremely easy to break and spill all over children and guests; for example when girls in my grade decided to cut the glow sticks to see what is inside, they spilled it all over their clothing. The oozing chemical seems dangerous and so there has been controversy about negative effects of exposure to the chemicals on skin.

Like fruits, glow sticks have an outer peel and an inner layer filled with juice. In the outer tube, there are molecules of the chemical phenyl oxalate ester (diphenyl oxalate) and a fluorescent dye. In the inner tube, there is hydrogen peroxide, also called the activator in this case. When the inner glass tube is broken (by bending the stick), the hydrogen peroxide solution is released and it reacts with the diphenyl oxalate to produce products, including the unstable chemical dioxetanedione. This product decomposes to carbon dioxide, releasing energy (4). The energy is then absorbed by electrons in dye molecules that jump up to the higher energy level. The electrons subsequently go back to their ground state and release the absorbed energy in the form of light. Each glow stick has a slightly different color due to their different chemical makeup.



occurs in order for the glow stick to start glowing, Including before the glass particles break and after, which leads to the chemicals mixing and the electrons releasing energy in the form of light.

Interestingly, glow sticks were first used in the military for various emergency purposes including emergency lights, target markers, landing zone markers and locating lost divers (3). The reason glow sticks are valuable for the military and the navy is they are waterproof, can tolerate extreme weather conditions, and their glow can be seen from a mile away.

With global warming exacting an increasing toll on many species, it is important to be able to capture these species in order to study them to see if their numbers are being stressed and the causes of their decrease in number. Amphibians, are particularly sensitive to ecological disturbances because their lifestyles are both terrestrial for their adult stages but aquatic for their reproductive and immature stages. They are the proverbial "canary in the coal mine." However, funds for study of amphibians are in limited supply. Amphibians are not cute or cuddly like their mammalian counterparts. Glow sticks offer a very cheap way to increase their capture in the traps set. An experiment was done in 2007 by Kristine L. Grayson and Andrew W. Roe, professors at the University of Richmond, to see if glow sticks are an effective method to catch cold blooded vertebrates. There were 52 traps with small bracelet glow sticks and 52 without. They wanted to see how many amphibians they can capture per trap. Even though many of the glow sticks were defective because of the low price, the ones that did light up were more successful than the traps without glow sticks. They found that the average amount of newt trappings using glow sticks, increased by 273% and a 93% increase for tadpoles. More male species were caught than female species. But that could be due to a different environmental reason, rather than one gender being more attracted to the glow stick than the other. In addition, environmental conditions such as light may reduce the number of captures. Data from this experiment showed that moonlight can impact the activity of aquatic amphibians since the study shows that sunlight and moonlight affect the amount of amphibians captured (5).

In a blackout if doctors were able to give their patients glow sticks instead of tags, it would be so much easier to detect the more serious cases thereby saving lives. Glow sticks can 'survive' without electricity and rain, thus in case of an emergency if the hospital did not have electricity they would still be able to see the condition of the patients waiting to be seen by a doctor. This is an effective and inexpensive way to make sure every person is being seen and taken care of. Data shows that with the help of glow sticks the average time saved on getting to patients was 2.58 minutes, and the average collection time was reduced by 31.75% (7). Doctors commented that this system is extremely helpful as the patients were visible to them faster and allowed them to better organize the cases in order of priority.

Although glow sticks have many positive uses, clinicians were concerned as to whether glow sticks were toxic because they contain the chemical dibutyl phthalate which is very dangerous to ingest in large amounts and can cause anaphylaxis. However, they observed that patients who were exposed to the chemicals in glow sticks either through their skin, eyes or mouth only had irritation at the site of exposure. Additionally, the symptoms that were experienced were minor. There was a total of 118 incidents of exposure in Colorado's Poison Control Center during January 1, 2000, and April 1, 2001. This included 72 males, 8 young adults, 18 teenagers, and 96 children. In addition poison control received 108 phone calls about ingestion, nine about eye exposure and one for skin exposure. Anyone exposed to a leaking stick experienced a minor reaction including irritation in the mouth, throat or skin. But four specific children experienced symptoms of nausea, vomiting or a distortion of taste. All adult exposures occurred either on holidays or the weekends which is approximately half of the exposures (62/118). Fortunately, according to this study, most of the

patients who were exposed to glow sticks did not experience any major symptoms, only irritation to the exposed areas (6). Additionally, I found another study which bolsters my earlier finding that exposure to glow stick chemicals is rarely dangerous. A study done in New South Wales, concluded that 94% were children from ages 14 and younger and rarely did the exposure result in medical complications (2).

After conducting more research, I discovered that glow sticks can also be used to demonstrate color mixing and color addition by science teachers. This can be achieved by having students examine the glow sticks with a hand held diffraction grating to see the spectral emissions (1). By observing which colors are emitted, the students can see which colors need to be combined to result in a particular color.

Glow sticks utilize the chemical reaction between hydrogen peroxide and phenyl oxalate ester to create a useful and affordable light. They are employed by the military, fishermen, and hospitals for various different goals. Despite some concern for their safety due to the dangerous chemicals in glow sticks, they have been found by clinicians to be nontoxic and are a great help to society in all their different uses.

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INKING IT IN

Nava Schwalb

Ink is synonymous with history. Were it not for ink, there would be no historical records.

Conversely, history is full of ink. Like history and the men and women in it, ink has evolved. From the compounds used in cave paintings, to parchment, human skin, the printing press and to most recently, handheld video games, Kindles, and iPads, these rely on reusable ink that sits below the surface of the screen. The chemical makeup of ink has changed over time to suit the needs of both the writer as well as the medium upon which ink is used. There are many types of ink, such as iron gall ink, carbon-based ink, tattoo ink, and invisible ink. Ink is defined as a liquid that is used to write. There are a range of pigments and dyes which are incorporated into ink that both provide it with its distinctive color and facilitates adherence to various mediums. The pigment can also influence the texture of the ink, thus impacting the selection of writing implement that can be used (1).

Cave art dating back to the Ice Ages.

Iron gall ink was one of the most common inks found on scrolls from ancient times. Ink was used for writing and art. Iron gall ink is made from gallnuts, iron sulfate, water, and gum Arabic. Each ingredient contributed to the unique quality of this ink. The gall nuts provided the tannins (which made the ink dry), the iron sulfate (made the ink difficult to erase), the water was the solvent, and gum Arabic both bound the components together as well as contributed to the ink's color (2). Researchers are unsure why after the passage of time ink turns from black to brown (1).

Example of ink used to decorate one's body.

During the medieval period, red was the primary color of ink used. Red was the ink of choice because it stood out the most, and when a person would see red, they would immediately go to the part of the passage. The black ink was iron gall ink, and the red ink was carbon-based. During this time, the inks used were either the iron gall ink or carbon-based inks. Carbon-based ink was made of tar, oils, animal fats, resins, and charcoal, which were mixed with gums to improve adherence to parchment. One of the benefits of using carbon ink is that, unlike iron gall ink, it didn't damage the paper. A drawback of carbon ink is that it often smudges. Carbon ink is not recommended for use on documents that were intended for preservation. If the intention was to preserve a document and carbon ink had been used, the

document would have to be stored in a arid environment. When people wanted to color the ink, usually they would use crushed insects or colored organic materials found in the earth (2).

Another application for ink is used in tattoos, also referred to as body art. In ancient Japan, tattoos signified that you were a part of criminal activity. Nowadays, tattoos are considered a means of expressing one's self, yet people don't think about the safety hazards when getting them. Tattoo ink is not ink. Tattoo "ink" is composed of pigments that are suspended in a solution, and it does not contain vegetable dyes. Currently, these pigments are primarily composed of metal salts. The purpose of the suspension solution is to help disinfect the pigment thoroughly to enhance its applicability. Tattoo application is associated with health complications. In fact, 68% of people with colored tattoos experience medical complications. After tattoo application, a person can experience redness and bumps near the application site and some progress to a systemic bacterial infection which may warrant hospitalization (3). Although some tattoo ink may have non toxic pigment, others contain metals that can be metabolized into toxic substances. Many tattoo inks are not approved for contact with the skin at all. Additionally, analysis of some tattoo inks has revealed that they contain printer toner and car paint.

During the revolutionary war, the Americans and the British used another form of ink, invisible ink. Invisible ink was composed of ferrous sulfate and water. The ink was used in between the lines of visible text so that no one would suspect any hidden content. Invisible ink is easily smudged; therefore, anyone handling a letter containing invisible ink had to be very careful. To decipher the invisible ink, a person would either place the letter adjacent to a source of heat or directly apply the acid. When in contact with heat, the acids in the invisible ink convert into a different color and become visible. Nowadays we can activate invisible ink in via the application of chemicals. Two colorless substances are combined and then applied to the invisible ink; the resulting chemical reaction renders the invisible ink, visible (5).

A more modern, unique form of ink is Gallium(Ga) based liquid metal ink. In a recent study, the potential use of liquid metal ink as bio-electrical sensors, specifically as electrocardiogram (ECG) electrodes were evaluated. In a standard ECG, electrodes are attached to the skin of the arms, legs, and chest to detect the electrical signal from the heart. There are currently several different types of ECG electrodes, each with its own unique set of challenges including high cost, physical discomfort, and reduced signal transmission. The authors in this study sought to determine whether gallium-based liquid metal ink could be used as a potential bioelectrical sensor when directly applied to the skin. They performed both rabbit and human experiments and found that the liquid metal printed electrodes worked as effectively as the traditional electrodes. This new form of liquid metal ink has the potential to advance medical science (6).

Another potential role for ink is in the field of criminal science. As digital printing technologies have advanced, so has the science of forgeries and counterfeiting. Forensic scientists hope to analyze the ink used for printing to help verify the authenticity of documents. Even more helpful would be the ability to identify the specific printer on which the document was printed. However, black inkjet printers are particularly challenging to identify. A study by Kula et al. evaluates a particular new technology, capillary electrophoresis.

Capillary electrophoresis is a process that helps identify a substance based on its electromagnetic properties. This is similar to fingerprints in an item at a crime scene, and there are certain identifiable traits that characterize it. The authors found that this technology requires a small amount of ink for analysis and provides a reliable means of identifying components of ink distinctive to specific inkjet printers (7).

A more personal, relevant role for ink is in the writing of Sifrei Torah. Sifrei Torah are created using a specific type of ink call D'yo. D'yo has specific qualities - it must be black, long lasting, and must contain only kosher ingredients. There seems to be some controversy as to the exact composition of D'yo, some saying that there are specific ingredients, while others disagree and state that as long as the ink is composed of kosher ingredients it is considered a kosher Torah scroll. Those that assert that there are specific ingredients indicate that the basic ingredients that all kosher ink must have include are water, oak, gallnut, gum arabic, soot, logwood, and copper or iron sulfate. These components don't seem distinct to D'yo as that is what most inks were composed of at that time. An analysis of the ink used for the Dead Sea scrolls found that it was either carbon-based ink or iron gall ink. Both these inks were very durable. Durability is an essential characteristic as Torah scrolls are transmitted from generation to generation, and some have lasted up to 2,000 years.

Throughout time, the use of ink has progressed from cave drawings to body art. The content of ink has evolved, and the mediums have changed as well. In 2019, there is a multitude of inks that may be applied to a range of mediums. One thing has not changed; ink continues to be used as a means of communication. Whether it is a tattoo artist in ancient Japan, a secret operative during the Revolutionary War or a modern-day printer, each has used ink to convey extraordinary concepts and messages. Ink has played a dual role in man's history. It has facilitated the communication that has enabled human civilization and culture to evolve while simultaneously providing a means to document this change.

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CAN'T LEAVE HOME WITHOUT SILICONE

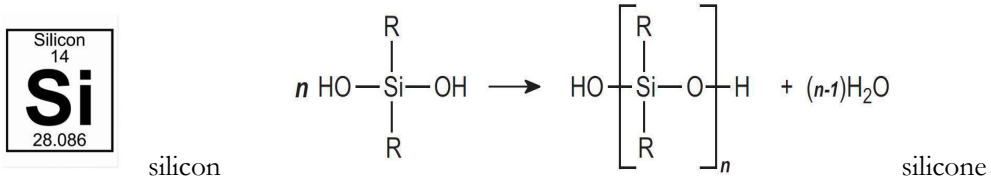
Tzirel Shteierman

You may know it as the substance that makes up balloons and bottles, but did you know that Neil Armstrong used boots with silicone soles to make the first footprint on the moon?

Although it seems insignificant, many developments have been made in silicone. Now silicone has so many uses in technology, construction, and beauty products that it's almost impossible to go a full day without having some use or contact with the substance!

Most people confuse silicon with silicone but they are actually two very different things. Silicon is a naturally occurring chemical element, whereas silicone is a synthetic substance. Silicon is the 14th element on the periodic table, it's a metalloid, and it is the second most abundant element in the earth's crust. Silicon also is rarely found in its pure form. Silicone, in contrast, is a synthetic polymer made up of silicon, oxygen, and other elements, most typically carbon and hydrogen (2). Silicone is generally a liquid or a flexible, rubber-like plastic, and has several useful properties. The difference between the two is evident when you look at the elemental structure of each (see figure 1).

Figure 1



silicon silicone

Often discoveries in science take place with the help of many people. Silicone did not have one person discover it, but it did have many people discover little parts to it that led to the final product and function of silicone. It began in 1823, the Swedish chemist, Jöns Jackob Berzelius, first managed to isolate silicon by itself, taking his research further, he heated silicon in chlorine. The result was silicon tetrachloride, one of the materials still used to produce silicone. After Berzelius's work, Henry Sainte-Claire Deville, in 1854 discovered crystalline silicon. Finally, after all the different research and compositions of silicone, J.F. Hyde ran the first research to produce commercial silicones in 1930. Using Hyde's research, in 1940, the English chemist, Frederich Stanley Kipping gave the material the name "silicones" because they were "sticky messes." However, Kipping did not establish the use of silicone. Further, he believed there was no practical use for the material.

Once silicone was developed, the next step was to find a use for it. This too was the result of multiple experiments conducted by various scientists. Important steps were taken by R. Müller and E.G. Rochow to develop different methods for silicones synthesis, synthesizing silicone with a variety of other elements to give it different properties which enabled its use for industrial purposes. Dr. J. Franklin Hyde of

Corning Glass further developed the application of silicone. He produced the first commercially useful silicone product; he used silicone to infuse and coat glass cloth for electrical insulation. Silicone was even accidentally used to create a fun children's toy. In 1949, James Wright, a GE engineer, was looking for a rubber substitute. He mixed silicone oil with boric acid, and the product was commercialized and called Silly Putty, one of the fastest selling toys in history (5).

As mentioned above, silicone has many properties which make it useful for many products. One feature of silicone is that it has a high heat resistance (2). Silicone rubber withstands high and low temperatures far better than most rubbers. It can be used at 302°F with almost no change in its properties; it can even withstand use at temperatures as high as 392°F for 10,000 hours! Silicone rubbers are therefore suitable as a material for rubber components used in high-temperature environments such as voltage line insulators, automotive applications, sportswear, and footwear. In addition to heat resistance, it is also long lasting and easy to clean and maintain, making it perfect for all kinds of kitchen wares such as oven mitts, spatulas, tongs, and panhandles.

Most people don't realize that they come into contact with silicone products daily, as silicone appears in approximately half of all makeup, hair, and skin products. Furthermore, silicone lends itself to applications in the medical field as well. Numerous medical implants and lifesaving medical devices utilize silicone and its wide range of properties. Whether the implant is entirely made of silicone or not, most implants at minimum use silicone as an outer protective layer. Silicone is highly stable and resistant to decomposition by heat or water, thus making it perfect for any limb implant as it reduces the need for additional follow up surgeries. Besides, silicone's thickness and texture, resembles human fat, and firmness, allowing for far more realistic implants and prosthetics. This was a significant breakthrough in the medical field, which helps many suffering from handicaps, defects, or injuries to feel comfortable with how they look and even helps recipients live with a better quality of life.

As if kitchenware, beauty products, and medical devices weren't enough, another primary use of silicone is in the construction industry. Silicone is ideal for applications in construction because of its high durability and insulation resistance (2). One of the many ways silicone is used in construction is to help exterior paints and coatings last longer and not fade with the sun, salt, pollution, and, age. Another way silicone is used in construction is as sealant (see figure 2). It ensures that important structural materials stay in place. These sealants also add flexibility to building structures, allowing materials to absorb movement caused by wind or earthquakes without compromising the integrity of the actual support structure. Silicone sealants in buildings can also make buildings more energy efficient by preventing hot or cold air from leaking in or out through even the smallest cracks (1). Structural silicone glazing is used to protect and maintain the long-term quality and appearance of a building, as coatings do not stain or streak even on older structures. It can also help when restoring historical buildings, monuments, and landmarks such as the Tower Bridge in London. What's unique about silicone in renovations, is that it can

help renovation experts to restore a structure without affecting the appearance of the original material. Another version of silicone rubber is used extensively as an insulator to caulk around windows and opening in all new construction work.

Even though silicone is used in many products, there is no clear answer as to how safe it is. Many experts consider silicones to be nontoxic and safer than nonstick alternatives with perfluorinated chemical coatings (3). However, other studies tested the release of siloxanes from silicone bakeware into milk, baby formula, and a solution of alcohol and water. Nothing was released into the milk or formula after six hours, but after 72 hours in the alcohol solution, several siloxanes were detected. Siloxanes are considered potential endocrine disruptors, and some have been linked to various types of cancers (4). Another health concern involves not necessarily the actual usage of silicone, but the form that the silicon takes to make its way into your body that is harmful to the body. The silicate particles embed themselves permanently into the lung tissue making it harder to breathe and substantially over time, weakens the immune system and the overall condition of the body (6). Besides the health aspects, silicone presents an environmental threat because it is seldom recycled. Although silicone products can be collected by specialized recycling companies that will typically down-cycle it into oil that's used for industrial machines, it is rarely accepted in a curbside recycling program. Therefore, just like plastics, silicone can be "down-cycled," but most of it ends up in landfills where it won't decompose for hundreds of years!

For just one substance, silicone has a wide range of uses that many would think could not be done by the same product. Numerous products that have silicone in them that many will find shocking. For example, "Post-it's" stick with a tape made from a silicone base and it is found in the internal structure of a computer keyboard which gives the keys a springier feel, allowing them to bounce up after pressed. Now, in the 21st century, silicone is everywhere: shampoo, cooking molds, phone screen covers, microprocessors, solar panels, and more. Many say that silicone, like a business, is better with multiple partners.

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8. Figure 2: silicone

MAYBE IT'S MAYBELLINE

Henny Weiss

You're late for work, and all you can do is quickly get dressed and get ready, with little to no time for makeup. The only thing you have time for is mascara.

It takes 15 seconds to swipe the dark pigment onto your eyelashes. Done. No makeup, but the mascara has finished your last-minute look. All you needed was black pigment in a little tube to make your eyes pop.

Mascara is a universal essential in a woman's makeup routine. Its pigment and formula are designed to make eyelashes bolder and longer. The earliest records of mascara were used in the times of Ancient Egypt, around 4000 B.C.; a substance known as kohl was used to darken the eyelids and eyelashes. It was made of galena, or lead sulfite and malachite. Honey, water, and charcoal were mixed together with the kohl to keep it from running, creating the first waterproof mascara. Egyptians first created this formula to prevent direct sunlight from causing damage to their eyes. The deep black saturation would block the sun's rays, so it would not harm people's eyes (5). In recent years, the FDA banned kohl, as it is highly toxic because it contains lead and antimony (salts of heavy metals), which may cause lead poisoning (3). However in the past, this mixture was so popular that it was also used during the Greek and Roman times. During the Victorian Era, women spent the majority of their day experimenting with makeup. They put in great effort to make their lashes longer and darker. They would heat ashes and elderberry juice together to make a thick substance and would apply the heated mixture to their eyelashes (1).

A kohl mascara applicator from ancient Egyptian times displayed in the Brooklyn Museum.

However, the familiar formula for mascara that we use today wasn't invented until the 19th century, by a man named Eugene Rimmel. He was a chemist who developed the cosmetic with petroleum jelly and luckily it caught on quickly. In 1915, another inventor appeared on the scene: Thomas Lyle Williams. He further developed the popular beauty regimen when he made a similar substance for his sister Mabel. At age 19, Williams saw that Mabel would apply mascara by mixing Vaseline and coal dust on her eyes. As he watched her do this, he was struck with inspiration and decided to manufacture it and call it "Lash-Brow-Ine." Later, he renamed it "Maybelline" in honor of his sister who had inspired the product. The name Maybelline is a portmanteau of the words "Mabel" and "Vaseline." In 1917, his product became increasingly more popular and the worldwide company, Maybelline took off (1).

In the early stages of mascara, applying the product was a messy process. Mascara was compacted into the form of a pressed cake and was applied with a wet brush. The pigment was combined with soap

flakes, a fragile material that would easily fall apart. This made it difficult for the consumer to use, as the compacted product would break easily and therefore be quite messy to deal with. Another variation was a cream mascara, packed into a tube. The content would be squeezed onto a brush and applied to the lashes. The cleaner and easier solution wasn't invented until the late 1950s when Helena Rubinstein, a big influence on the beauty industry of America, invented a way of applying mascara with a wand. In the 1930s, a mascara brand called Lash Lure was stocked the shelves across the United States, designed to permanently coat the lashes. Its main ingredient was comprised of a hair dye called asaniline and a chemical called p-phenylenediamine, which left women blind and gave them horrific blisters on their face and eyes. P-phenylenediamine is an organic compound with the formula $C_6H_4(NH_2)_2$. It is a chemical used to dye hair and is known to be used in the art form of henna tattoos. (2)

Mascara is made of three primary ingredients: wax, oil, and pigment. Pigments in mascara today contain iron oxide (Fe_2O_3) and titanium oxide (TiO_2) to give mascara its colorization. It is a polymer that coats the lashes and a mineral ingredient that provides the black color in pigments. It is vital for creating that bold black color we all know and love. Some mascara formulas also include ultramarine blue ($Al_6Na_8O_{24}S_3Si_6$), which is a saturated blue pigment that was originally made by grinding lapis lazuli into a powder. The word originates from the Latin word "ultramarinus" which means "beyond the sea."The color pigment was popular but expensive during the Renaissance when it was used by painters to make colorful masterpieces (1). Pigments are used as a color base for mascara, varying from black to brown to even white. Oils used in mascara formulas consist of linseed oil, eucalyptus oil, lanolin, castor oil, and sometimes sesame oil. The wax used in mascara comprises of carnauba wax, paraffin wax, and beeswax. Additionally, dodecane ($CH_3(CH_2)_{10}CH_3$) is used to make mascara waterproof, preventing it from running and crumbling. To stiffen eyelashes and make the formula clumpier, companies use ingredients such as methyl cellulose ($C_6H_7O_2(OH)x(OCH_3)y$) and cerasin ($C_{18}H_{18}O_6$) (6).

Over time, mascara has immensely improved to fit the consumer's needs, transforming from kohl filled pigments, to caked mascara, to mascara in a tube. The ingredients used have also drastically improved, becoming safer over time. The invention of mascara has had a significant effect on the beauty industry with its purpose to enhance a woman's eyes. Mascara is a worldwide popular cosmetic that can be used when in a rush and on the go, or to add the finishing touch to a full makeup look.

This is an ad for Lash Lure in 1938 and its harmful effects - pre FDA regulations.

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IT'S ALL IN THE MIND

Essie Abittan & Faigy Eisen

Do you have trouble falling asleep? Johnny was a boy who thought he needed a pill to fall asleep every night. Little did he know, the pill was really just a candy.

When he did not receive this "pill" he was unable to fall asleep. Ever have a lucky charm? When you brought it with you to school to take a test you did well, and when you left it at home, your performance suffered. These two examples show the power of a placebo. A placebo is a harmless pill, medicine, or procedure prescribed more for the psychological benefit to the patient than for any physiological effect.

In the past, it was known that certain substances have healing powers outside of any medical properties intrinsic to the substance itself. Called the "placebo effect," it was attributed to the patient's trust in the treatment. Ted Kaptchuk is one of the key researchers involved in the expansion of the understanding of this phenomenon. Before placebos became a well known positive treatment, about 30 years ago, it had a derogatory connotation, called pharmaceutical quackery (2).

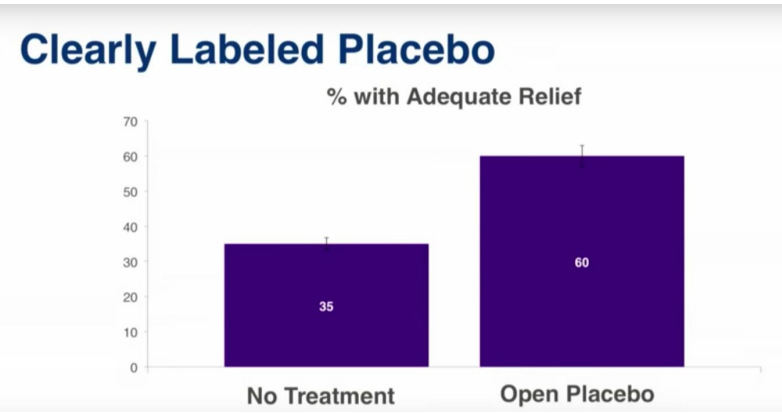
The fact that our minds have the power to find a treatment to heal has been recognized for centuries and for hundreds of years, placebos have been in use. In fact, Benjamin Franklin used the placebo effect in the 1750s to heal patients who were paralyzed. He treated these patients with electric shocks and the patients experienced short term recoveries. Franklin was unsure if the electric shock actually healed the patients or if it was the expectation that it would heal that made them recover. Nonetheless, he continued to treat people, without knowing the science behind it (11).

More recently, in a study to test the effects of a placebo treatment in patients with a cough associated with acute upper respiratory tract infection, patients were given either vitamin E tablets dissolved in water or just plain water. All the patients gave consent and were told that the aim of the study was to investigate the effects of vitamin E treatment on cough. The real goal of the study was to examine the effect of placebo on cough, with vitamin E given as a placebo and not as an active treatment and the plain water was used as the control. The patients who received the vitamin E, stopped coughing significantly and reported relief from much of the pain of the cough associated with acute respiratory tract infection. The results demonstrated that placebo treatment has significant antitussive activity (4).

In another experiment 270 patients suffering from chronic arm pain were given either a placebo pill or placebo acupuncture (where patients had needles inserted into nodes known to have no effect). Those who received the placebo acupuncture were warned of swelling from the needles and those who received the placebo pills were warned of becoming sluggish, known side-effects of the real treatment. The patients were also told of all of the benefits of the real version of these treatments. Almost one third of the patients reported some of the side effects. A majority of the patients returned with results of their arm pain subsiding.

The placebos were able to alleviate a significant amount of the pain. More patients who received placebo acupuncture reported positive results over placebo pills. This may have been because they have taken pills in the past and acupuncture was novel to them, so they may have had higher hopes. This shows the healing process is not only from the medicine, but from our belief in the medicine (8, 10,12,13,14,15,20)

Kaptchuk performed a few open-label placebo (where the placebo was clearly marked "placebo") experiments to demonstrate the effect is not exclusively due to deception. Over the course of three weeks, fifteen patients with Irritable Bowel Syndrome (IBS) were given a placebo pill labeled placebo, with an explanation of why the placebo might have a positive effect on the patients. The other fifteen of the patients were the control group, who received no treatment at all. Thirty percent of the patients who received no treatment reported less pain, demonstrating that time can produce recovery on its own. Of the patients who received the known placebo pill, double the number, 60% of them, reported pain relief. Patients who receive a real drug for IBS also report around a 60% pain relief. This proves that placebos can work whether the patients know or do not know they are receiving a placebo. This also proves that placebos do have an aspect of alleviating pain and the ability to heal. It simultaneously proves that this IBS drug may not be effective solely because of the medication contained within, it may only be working because of the placebo effect inherent in any treatment. (8, 12,13,14,16,19).



This graph, created by Ted Kaptchuk, represents the IBS open label placebo experiment described above, specifically the difference in pain relief between the 2 groups.

In another open-label placebo experiment, individuals suffering from chronic lower back pain were gathered and split into two groups and were asked to rate their pain. One group was told to continue to take 'treatment-as-usual' (TAU group), the second group was given an 'open-label placebo' (OLP group) which was a clearly marked placebo bottle, to take two placebo pills along with their normal treatment. Three weeks later the group reconvened to discuss the change in their pain levels. Surprisingly, the OLP group reported 30% in pain reduction while the TAU group reported only a 9% reduction in everyday pain and 16% in maximum pain. The placebos were able to alleviate the pain significantly, which is a power of the placebo.

This chart illustrates the outcome of the experiment described above. Specifically, this table compares the change of pain of the TAU and OLP groups, before and after the 3 weeks of treatment (6).

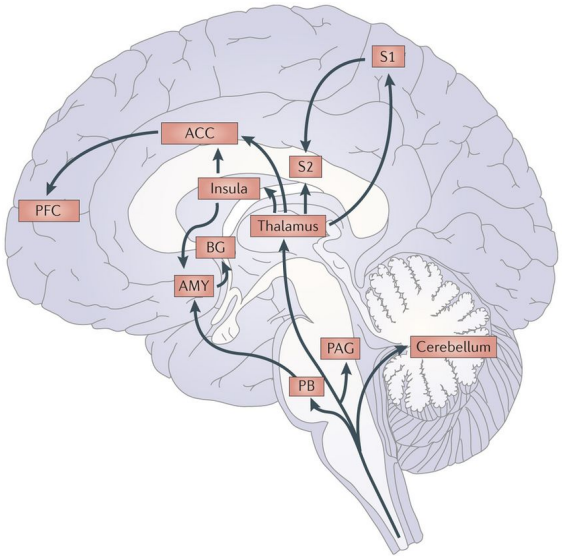
Table 2

Adjusted mean (SD) improvement and percent changes on outcome measures at 3-week endpoint, with effect sizes and analysis of covariance summary statistics.

Outcome	TAU (n = 42)*		OLP (n = 41)		Effect size, *g*	Mean square		$F_{(1,80)}$	*P*
	Mean (SD)	% Change	Mean (SD)	% Change		Between	Error		
Pain (10-point scale)									
Minimum	−0.56 (1.80)	−25	0.54 (1.73)	16	0.62	22.60	3.03	7.45	0.008
Usual	0.44 (2.13)	9	1.48 (1.79)	30	0.53	21.87	3.73	5.87	0.018
Maximum	1.12 (2.09)	16	2.15 (2.45)	30	0.45	21.45	4.91	4.37	0.040
Composite	0.24 (1.61)	5	1.49 (1.68)	28	0.76	30.10	2.73	11.02	<0.001
Disability (RDQ)	0.02 (3.73)	0	2.86 (3.91)	29	0.74	162.71	13.45	12.10	<0.001
Bothersomeness*	0.78 (2.61)	14	1.44 (2.46)	24	0.66	8.94	5.25	1.71	0.195

* n = 41 in the TAU group, *df* = 1,70 due to missing baseline data for 1 participant.
OLP, open-label placebo; RDQ, Roland–Morris Disability Questionnaire; TAU, treatment as usual.

There are multiple parts of the brain that respond to nociceptive pain caused by damage or inflammation. When somebody takes a placebo, these parts of the brain have a measurable reduction of activity. Using an MRI, researchers observed that placebos activate a pathway to the spinal cord and brain that releases endogenous endorphins (suppressive neurotransmitters), which help us tolerate pain. Similar to when a mother kisses a child's scraped knee, endogenous endorphins are released when we think the healing process will begin, reducing pain (14, 15).



This image displays the pathways from the spinal cord that travel throughout different parts of the brain that together create the reaction of pain (21).

Placebos have multiple benefits and impacts on our lives. Before a drug is approved as effective for the general public it must be tested against a placebo. If the drug is less effective or equally as effective as the placebo, the drug must be perfected. Without the help of these placebo we would be consumers of multiple insufficient drugs. A placebo is also advantageous as it has no side effects. If a doctor is unsure if a patient is having real side effects from a drug they can give placebos to the patient. If the patient still complains about the side effects the doctor will realize there is nothing to worry about. Moreover, if a patient takes drugs for headaches, like Advil, multiple times a week a doctor might be worried about ulcers. The doctor can prescribe the patient a placebo pill that looks like Advil and is the same price. If the placebo works this can limit the fear of ulcers. There may be a time where we will not have side effects to painful illnesses like cancer

because of placebos. Placebos can improve the quality of life for cancer patients. Not only that, but using placebos will not cause negative interactions between multiple drugs. These benefits are all important for our health and prove that placebos can be useful for various reasons (15,16,17,19).

In roughly the past ten years, a new area of placebo research, called the placebome, has come to light, taking the placebo to the next level. The placebome describes whether or not you are genetically programmed to respond to placebos, and the extent of the response. Scientists have known for quite some time that some people are more prone to experiencing the placebo effect over others. In short, it depends on certain chemicals such as opioids released from the brain and the amount released is dependent on a person's genetic makeup (20). Since genome research is still in its infancy, not much development has been made.

The American Medical Association allows placebos only if the patient gives consent, although they allow the doctor to be vague with the consent form. This is an ongoing debate throughout the medical world whether or not it is ethical to administer placebos without the patient's consent which will allow the placebo to achieve its full capability. The question remains today, is it ethical to give placebos without consent?

The Placebo has come a long way from "quackery" to bona fide therapeutic intervention. Placebo use can be expanded to sports, mental health, etc. Our confidence will increase and we will have the ability to use every moment to its fullest. If our minds have the potential to heal, what else can our mind do, given the opportunity?

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FILLING IN THE BLANKS

Etta Feuer

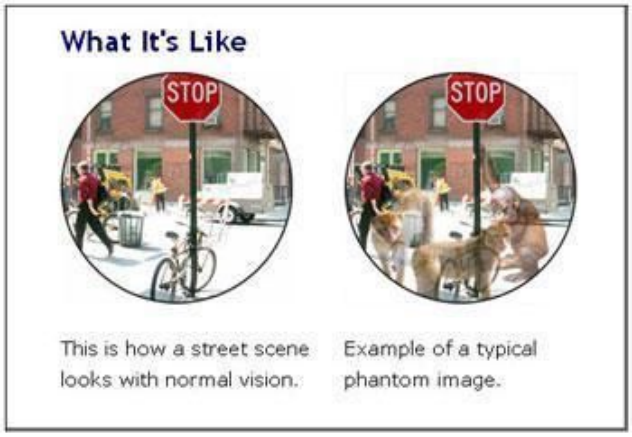
After being diagnosed with eye disease, glaucoma in 2006, Bee was used to being blind. However, when she went shopping with a friend one Saturday morning, Bee's routine outing was interrupted.

As she tried placing items into her cart, a thick mud, with pretty windows of color, started sliding down, not allowing her to put her hands through. It all seemed so real. Bee reasoned that it must have been from too much black coffee, but after staying away from it for a week, Bee experienced the weird sensation again and knew something was wrong. Bee was then diagnosed with Charles Bonnet syndrome. (9) Charles Bonnet Syndrome causes people with eye conditions to see false images, yet patients understand these images are just hallucinations so, oddly enough, it is not a mental health problem. Even though syndrome has a negative connotation, patients disagree on their feelings towards it. Some blind patients find it disorienting and others long for an opportunity to see anything—even if it is fake.

This syndrome came to light in the 1960s when a Swiss philosopher and biologist Charles Bonnet took to publishing his blind grandfather's "visual" experience of birds and buildings in his work, *Analytical Essay on the Faculties of the Soul.* In 1902, Swiss scientist George de Morsier published Bonnet's grandfather's hallucinations in a psychology journal called the *Archives of Psychology*. However, only in 1967 was it called Charles Bonnet Syndrome by Morsier. Interestingly, Charles Bonnet also started to have visual hallucinations later in life, similar to how he described with his grandfather. (3)

Charles Bonnet Syndrome develops in various types of eye conditions; from the most frequent cause, age-related macular degeneration, to less common, cataracts, glaucoma, and diabetic eye disease. When your brain is not receiving information from the eyes, it tends to fill in the gaps with false images. (1) It is sometimes referred to as Phantom Vision Syndrome because of its likeness to Phantom Limb Syndrome. Just like a patient feels pain from the area that their amputated limb used to be, Charles Bonnet Syndrome patients see images from where their eyes used to send messages. (3) When one's retinal cells are unable to receive images and then relay them over, the visual cells in the brain compensate by creating images. Even patients who suffer partial vision loss, like glaucoma that only affects the peripheral vision, can still be diagnosed with Charles Bonnet Syndrome

(4)



Even a normal sighted person can experience Charles Bonnet Syndrome–like hallucinations. A Harvard study was done to determine how sighted people would react by blindfolding them to block messages from being sent to the visual centers of the brain. The results showed, if people were blindfolded for a long, uninterrupted period of time, they too would experience visual hallucinations. (5) Therefore, Charles Bonnet syndrome is the brain adjusting itself to a new experience: blindness.

The blue moose in this image is an example of what a patient with Charles Bonnet Syndrome might experience. (3)

The hallucinations are categorized into simple and complex. Simple hallucinations include shapes, colors, and patterns and complex are more vivid, detailed pictures of people, animals, and plants. Patients with severe vision loss tend to see complex hallucinations. (6) The exact symptoms of Charles Bonnet Syndrome differ with each patient and for some it is chronic, but the hallucinations normally do not last very long and get shorter and less frequent over time.

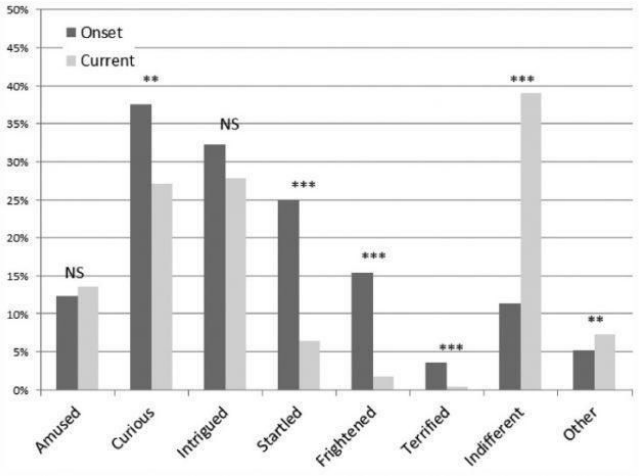
The Charles Bonnet Syndrome hallucinations come from the person's thoughts and feelings. As one patient explained, when he was reading a book, the characters appeared in front of him. (7) The hallucinations are not interactive and can be described more like a movie where the patient is totally separated from the images.

Charles Bonnet Syndrome is most prevalent amongst the elderly (around 70-85 years old). It is difficult to ascertain any information about the condition due to underreporting. Many diagnosed with Charles Bonnet Syndrome will not mention it to anyone, even spouses, in fear of being labeled crazy or mentally ill. Charles Bonnet Syndrome is fairly uncommon, making it easy for doctors to misdiagnose and assume it is a mental health issue. In a Ted Talk from 2009, Dr. Oliver Sacks discusses a Charles Bonnet patient he had. When he first met her in her nursing home, a nurse informed him that the patient seemed to be going crazy. After talking to her about her hallucinations, Sacks deduced that she must have Charles Bonnet Syndrome. (2)

Dr. Susan Hirshfield, a clinical psychologist at the Earle Baum Center for the Blind, fell upon Charles Bonnet Syndrome when she came to the understanding that visual hallucinations do not necessarily indicate mental illness. This realization has helped many patients feel content with their condition. Dr. Hirshfield now warns her Living with Vision Loss class about Charles Bonnet Syndrome. She said that 5 out of 15 participants reported having visual hallucinations after learning about the condition. Because of the understanding Dr. Hirshfield and the other specialists at the center have, these patients feel relief knowing they are still perfectly sane. (8)

Diagnosing the syndrome proves to be difficult. Some doctors do it by eliminating other etiologies, and when only left with the option of Charles Bonnet Syndrome, they determine that the patient has the condition. Charles Bonnet Syndrome differs from other diseases that produce hallucinations because it only involves sight. (1)

Emotional responses to Charles Bonnet Syndrome hallucinations. (10)



As of now, there are no treatments for Charles Bonnet Syndrome, yet there are different tricks a patient can do to get rid of the hallucinations as they are happening. These include engaging with others, listening to music, standing up, or going outdoors. But one can even just start easily by closing and then opening one's eyes, turning on a light, and distracting yourself from the image by looking away. (3) Some doctors recommend antipsychotic medications, but the risk of side effects is too high. While a definitive treatment has not been found yet, it is important for patients to continue seeing an eye doctor to monitor the condition. Specialists may call for certain surgical procedures to help with or even resolve Charles Bonnet Syndrome like removing cataracts. (1)

Case	Frequency	Duration	Localization	Risk factors	Position of eyes	Benignity	Time of the day	Associated features
1 - 50 ys, woman with myopia	Daily	Seconds	Monocular (left eye)	Sensory deprivation	Open	Yes	Anytime	None
2 - 64 ys, man with macular degeneration	Daily	Minutes	Binocular	Sensory deprivation	Closed	Yes	Nocturnal	None
3 - 81 ys, woman, retinitis pigmentosa and glaucoma	Weekly (2 days per week)	Seconds	Binocular	Sensory deprivation	Indifferent	Yes	Nocturnal	None
4 - 63 ys, man with cataracts, myopia and hemianopsia	Weekly (4 days per week)	Seconds	Binocular	Cerebrovascular disease	Open	Yes	Anytime	Hemiparesis
5 - 50 ys, woman with AION	Weekly (3 days per week)	Seconds	Binocular	Cerebrovascular disease + Sensory deprivation	Indifferent	Yes	Nocturnal	None
6 - 35 ys, male with retinitis pigmentosa	Weekly (2 days per week)	Seconds	Binocular	Sensory deprivation	Open	Yes	Nocturnal	None
7 - 37 ys, male with toxoplasmic retinochoroiditis	Daily	Seconds	Binocular	Sensory deprivation + AIDS	Indifferent	Yes	Anytime	None
8 - 39 ys, male with retinitis pigmentosa	Weekly (5 days per week)	Seconds	Binocular	Sensory deprivation + alcoholism	Indifferent	Yes	Nocturnal	None

A study was conducted to understand the differences between Charles Bonnet Syndrome hallucinations and other causes. 8 patients were brought in with varying eye conditions and Charles Bonnet Syndrome. The average time until they developed symptoms for Charles Bonnet was around 3.5 years. This chart displays the results. (11)

Even though Charles Bonnet Syndrome is technically harmless, it still concerns patients because it can be a frightening experience. People describe confusing scenarios where they understand it to be fake, but find it difficult to connect with reality during these visual hallucinations.

However, others enjoy these images because it gives them a chance to see what they otherwise are unable to experience in the visual world. David Stewart, a patient of Charles Bonnet Syndrome, discusses his experiences positively in an interview with Robert Krulwich for NPR. Because of his retinitis pigmentosa, Stewart had not remembered what color looks like. Stewart expressed gratitude for his hallucinations because now he can see color and enjoy vision even if it isn't real. (7) Dolores, another Charles Bonnet Syndrome patient, calls her first experience with the condition frightening. However, her other hallucinations—flowers coming out of walls—never scared her.

There are many support groups for people dealing with vision loss and more specifically, confronting their new reality: Charles Bonnet Syndrome. There are still so many known unknowns and unknown unknowns that it will be a while until researchers can fully understand the syndrome. So many people have it, yet it affects everyone differently. Unfortunately, there is not much to do about it other than wait, but knowing that doctors believe and care for them is often sufficient to alleviate symptoms. With Charles Bonnet Syndrome, peace of mind for patients is enough.

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THAT SLEEPLESS DEATH

Noa Garfinkel

To die, to sleep;
To sleep: perchance to dream: ay, there's the rub;
For in that sleep of death what dreams may come
When we have shuffled off this mortal coil,
Must give us pause:
(*Hamlet* 3.1.72-76)

One morning in the summer of 1764, an Italian doctor living in Venice awoke with a stiff neck. He noticed his pupils had constricted to pinpricks, and he had trouble walking. That night he started to have trouble sleeping, and began twitching and sweating uncontrollably. These symptoms gradually worsened until he was completely unable to sleep, could not walk, and had difficulty breathing. No matter which remedies he tried, sleep would not come. He became paralyzed, and two months later, he died from the oppressive exhaustion.

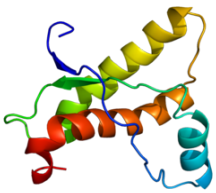
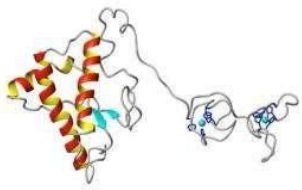
This doctor was well respected in the medical community, but regardless of this, no doctor he went to was able to offer him a satisfactory diagnoses or remedy for his condition. Sleep, still a mystery to contemporary scientists, was even more so to those in the eighteenth century. Physicians at the time still followed what Aristotle posited in his book *On Sleep and Dreams*; that everything capable of being active had to experience a nearly equal period of inactivity in order to continue functioning. In addition, Aristotle believed that sleep was caused by the digestion process; after a person had a meal the fumes from digestion went into the veins, to the brain, and then to the heart where the cooling of the fumes brought about sleep. So the Venetian doctor consumed very large, rich meals before attempting to sleep. He would sit drowsily with his stomach bloated, but would never pass into the blissful sleep which he so craved. Physicians gave him the legendary medical *triaca,* or treacle (syrup), which was thought to cure everything from fever to the plague. But that too did not allay his worsening state. When he died in November 1765, the parish records state his cause of death simply as that of a heart defect (6).

Not only was the doctor claimed by this terrible condition, but its mysterious symptoms continued to be passed on in his descendants for the next two hundred years. The progression would always be quite similar; striking suddenly around one's fifties, and worsening until one died, seemingly from the unbearable exhaustion. Physicians would diagnose multiple sclerosis, Parkinson's, encephalitis, or schizophrenia - but none of these diagnoses satisfactorily explained all aspects of the condition (7). It was not until 1986, two hundred and twenty-one years since the recorded death of the Venetian doctor, was the mystery solved.

The name of the disease is Fatal Familial Insomnia (FFI), first described by Professor Elio Lugaresi and his team at the University of Bologna (9). Its name tells all; none of its patients ever recover, it is an

autosomal dominant genetic disorder, and its most prominent symptom is that of total inability to sleep. It is an extremely rare disease that affects only one in thirty million people, and about forty families worldwide. The symptoms, which include progressive insomnia along with autonomic, cognitive, motor, and endocrine dysfunction, usually start when the patient is middle aged, around fifty years old, and the health of the patient progressively worsens until they die (3).

Additionally, FFI is part of a family of human prion diseases, sometimes referred to as transmissible spongiform encephalopathies (TSEs), meaning that parts of the brain become sponge-like. A prion is a type of protein that can cause normal proteins in the brain to fold abnormally (12). The gene that codes for the creation of prion proteins is called PRNP (14). Since the function of a protein is determined by its shape, the affected proteins wreak havoc in the bain, causing diseases in both humans and animals such as Creutzfeldt-Jakob disease, Kuru, Scrapie, Gerstmann-Straussler-Scheinker syndrome, and Bovine Spongiform Encephalopathy ("mad cow disease"), among others (13). Prion diseases are rare, affecting about one in one million people (12). Prions were discovered in 1997 by American biologist Stanley B. Prusiner, who won a Nobel Prize for his work (16). They are still a bit of a mystery as the function of prions in their healthy form is not yet known even though they are present in all mammals (13). What is known is that the damage caused by the diseased prions is similar to the damage caused by Alzheimer's and Parkinson's diseases (1).

A:  B: 

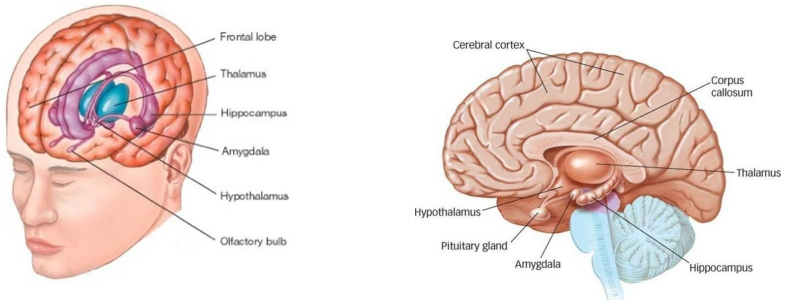
A: This is a diagram of the protein encoded by PRNP when it folds normally.
B: This is a diagram of the protein encoded by PRNP when it does not fold normally (notice the extra sequences).

Credits: https://neuroscientificallychallenged.com/blog/know-your-brain-prion-diseases and https://phys.org/news/2009-04-disruption-copper-key-prion-diseases.html

The study of prions is quite fascinating and is one of the many theories of disease. Prion diseases can take three forms - genetic, infectious, and accidental or sporadic (12). Also, their entire existence is controversial since calling something infectious implies a disease of living organisms, but proteins are not living in the first place. D. T. Max discusses the prion controversy in his book *The Family That Couldn't Sleep.* He cites Louis Pasteur's famous 1863 experiment where Pasteur boiled milk, thereby killing all microscopic life in it, and showed that the milk could be kept sterile if nothing living went into contact with it (11). Medicine would have taken a different turn had infectious prions been in that flask of milk. Prions are incredibly difficult to disinfect - high heat, radiation, formaldehyde, and bleaches all do not affect prions. Also, prions bond to metal and survive in soil. When the prion protein misfolds, it infects normal proteins to

misfold and spread. This dispersion of the protein is referred to as conformational influence, whereby the misfolded protein bonds to healthy proteins and causes them to misfold. Cells with misfolded proteins weaken and die, causing the brain of a prion disease patient to become full of holes where groups of cells have died, so much so that one patient when looking at his brain X-rays said it looked as though someone had shot him with a .22 shotgun (6). In an FFI patient, these misfolding proteins eat away at the thalamus until none of its functions can be properly executed.

What is it about the thalamus that when infected causes certain death? The thalamus is a small structure located above the brainstem, between the cerebral cortex and the midbrain.



This is a diagram of the human brain from two perspectives, showing the location of the thalamus in the inner region of the brain. Credits: ruwimgt.pw/cortex-system.html and www.quora.com/What- are-the- most-important- parts-of- the-human-brain

Its main function is to relay motor and sensory signals to the cerebral cortex and regulate the body's sleep cycle, appetite, and temperature - all functions of the autonomic nervous system (4). This means that when diseased prions start appearing and spreading in the thalamus, all of its functions are impacted. Matthew Walker, in his book *Why We Sleep*, explains it well. The thalamus is a sensory gate in the brain that must close in order for sleep to start. As a result of the destructive prions in FFI, the thalamus is stuck in a permanently "open" position. Patients are unable to turn off their conscious perception of the world which is a necessary prerequisite for sleep. Additionally, all of the signals the brain sends to the body to prepare for sleep - lowered heart rate, blood pressure, metabolism, and body temperature - are unable to be passed down the spinal cord because of the prion damage to the thalamus (10). As seen with the Italian doctor mentioned above, one affected by FFI starts shaking and sweating, and becomes an insomniac which causes confusion, hallucinations, and uncontrolled body movements (5). As the thalamus is progressively eaten away by the diseased prions, the patient will completely lose the ability to walk, talk, or sleep. This causes the coma which comes right before death, usually eighteen months after diagnosis (3).

The course of diagnosis is quite varied as many symptoms overlap with other neurodegenerative diseases. When symptoms appear, diagnosticians focus on ruling out other similar curable neurodegenerative diseases before diagnosing the patient with FFI. This is done using CT and MRI scans. If the patient does have FFI then there will be changes specifically in their thalamus. Additionally, FFI can be ruled out if the

patient had a history of insomnia without presenting the other common symptoms of the disease. Patients are then tested to see how the disease has affected them by addressing their cognitive and motor abilities. Gene sequencing can be done to see if the person has the mutated PRNP gene. Other prion diseases cause similar symptoms such as Creutzfeldt-Jakob disease, Gerstmann-Straussler-Scheinker syndrome, and variably protease-sensitive prionopathy (13). There are currently no known treatments for FFI and treatment is focused only on palliative care since the average course of the disease is so short (5). There is an ongoing research study being conducted in Italy, where the antibiotic doxycycline is being tested not as a treatment, but as a preventative measure for those at risk for developing the disease. It started in 2015 and is following ten carriers of the disease who have not yet presented symptoms of FFI while on the antibiotic over a ten-year period (2).

It makes sense that so few treatments options are available for FFI patients because without sleep, a person cannot function. And sleep, such a crucial part of human life, remains an enigma even to modern scientists. It seems paradoxical that one of the most important processes of the human body is to seemingly do nothing at all. It is one of the first acts a person learns to do; a fetus begins to sleep and wake at thirty-two weeks' gestation. D. T. Max phrases it well when he notes that one of the first functions the brain learns is to turn the body off (6). During sleep, the body not only sorts through memories, but it repairs itself by removing waste products, repairing the heart and blood vessels, balancing hormones, growing, developing, and building the immune system (15). The one third of our life we spend sleeping is what gives us energy to live the other two thirds. It therefore follows that in patients with FFI, where the regulatory systems of the thalamus have been destroyed by misfolded prion proteins, sleeplessness and its terrible effects ensue.

Throughout conducting research for this intriguing disease, the wonders of the human body were made apparent with every book, article, anecdote, and diagram. In Birkat Asher Yatzar, we say that "G-d… fashioned man with wisdom," which can mean that when G-d created man, He gave him the gift of wisdom. It could also mean that G-d used wisdom when He created man, as is demonstrated in the precise balance of his organs and functions (8). This is certainly true in FFI where the misfolding of a protein, such a small entity, can have such profound effects on a person. Additionally, our Rabbis realized what a miracle sleep is when they instituted the Hamapil prayer, which includes the wish that G-d "…lay me down to sleep in peace and raise me awake in peace" (8). May we all be blessed with such peaceful rest.

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AT THE TIP OF YOUR TONGUE: THE POWER OF SENSORY SUBSTITUTION

Chedva Levine

Everyone has a dream for their future and Rajesh Malik is no exception. His dream is to play soccer, and for an educated psychologist, this might sound both arbitrary and juvenile.

However, Malik is blind from birth, and despite the challenges that come along with his lack of sight, he worked his way through school, ultimately earning a doctorate. Despite the remarkable courage it took to achieve what he did, Malik set his eyes on a more arduous goal. Most people thought his goal was impossible, and many likely still do. Rajesh Malik wanted to play soccer with his 7 year old son. How can a blind person play soccer? Incredibly, he did, and not only was he able to begin playing soccer, but once he was given a remarkable treatment, he was able to see different shapes and distances, and even navigate a maze without bumping into any walls.

The solution he found for blindness is BrainPort. Malik met with Dr. Maurice Ptito, who used Brainport equipment to restore vision to a congenitally blind man. This amazing feat is accomplished through sensory substitution. Discovered by Dr. Paul Bach-y-Rita, sensory substitution allows the brain to utilize a different area than is typically used and sense images from there. Put simply, it transforms sensory input in one form, to an output of another.

A man administering the BrainPort technology. The wire in his hand carries messages from an internal radio which pass on visual information to his tongue. This replaces the need for typical vision, which occurs in the eye. Wicab.com

Sensory substitution relies on the knowledge that interpretation of all the senses takes place in the brain. For example, if vision occurred only in the eye, and didn't require interpretation in the brain, then these functions could not be accomplished through alternate means. As a consequence, the electrodes in the back would not be able to receive sight messages because the neurons in the back are not designed to respond to light. However, because vision occurs primarily due to functions of the brain and not the eye itself, the necessary information concerning the environment can be acquired from other sources, including the aforementioned back.

In 1835, Johannes Muller first explained how these messages work with the *Law of Specific Nerve Energies*. He claimed that the brain interpreted action potentials (electrical impulses) from different sources differently, depending not just on the source of the stimulus but also the area of the brain which responds to

it (Kalat, 154). This subtle detail is what allows for sensory substitution. A message sent from the tongue, is typically routed to the frontal lobe and interpreted as "taste". If it can be intercepted and rerouted to the occipital lobe, where vision is processed, then the taste message would be interpreted as sight. With an effective device, you can see with your fingers or even your tongue.

There are a fair number of conditions that result from the discombobulated messages of the sensory neurons. One such condition is synesthesia. Synesthesia occurs when two senses are intertwined and misrouted. For instance, when some synesthetes hear music, they also see certain colors. The causes of synesthesia remain unknown, but it is likely related to the same process that neuroscientists use to intentionally exchange the control of different senses (5). This concept is not so foreign to the mind of a non-synesthete. I personally have experienced a scenario which is similar to what a synesthete experiences. In my notes throughout high school, I have habitually paired specific colors with certain categories; for instance: purple for key figures, green for places and pink for dates. Remarkably, I have recently noticed that my mind visualizes the color purple when I hear of a person mentioned in those classes. The word I picture in my mind correlates with the neon purple highlighter I frequently dash across my notes. Benjamin Franklin, Mahmud Gandhi, Ruth Bader Ginsburg, they all have a commonality in my mind: their color. Although the neurological connection between my personal experience and that of a synesthete is as of yet unsupported, it remains an interesting parallel.

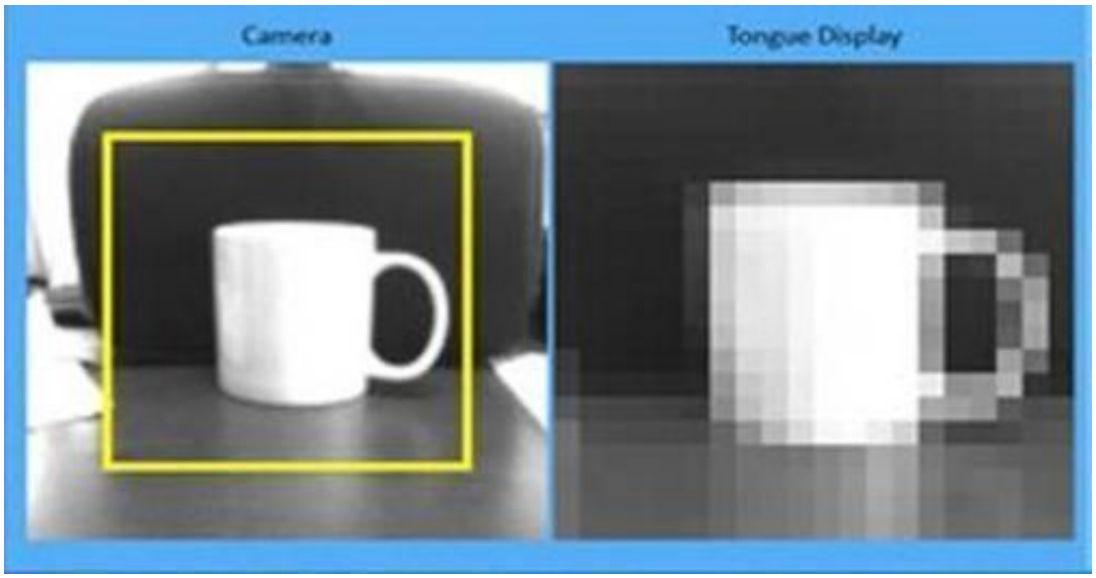
If the brain has a mechanism for redirecting sensory information to other pathways as in synesthesia, perhaps it is possible to piggyback on that ability for our own needs. Dr. Paul Bach-y-Rita, inventor of the BrainPort, also had starry-eyed aspirations, which were tied into understanding how the brain interprets information. Bach-y-Rita's legend lives on as the father of sensory substitution, but he also had a tremendous impact in the advancements in scientific knowledge about neuroplasticity. Neuroplasticity is the incredible ability of the brain to form new connections throughout life. Donald Hebb, a mid-nineteenth century Canadian psychologist, explained the molecular process in which this occurs. Hebb's research involved the forming of a bond between synapses, where messages are typically fired across a space from one neuron to another. Over time, the two neurons establish a more sustainable connection.

Barbara Arrowsmith is a clear example of the astounding nature of neuroplasticity. Arrowsmith's life story tells like a tale of intellectual rags to riches. She had an extraordinarily challenging childhood. Arrowsmith grew up with terribly severe disabilities, she was lagging behind her peers by a massive amount. At age five, she didn't know her ABC's, her speech was hardly coherent, and given directions, she rarely could understand new ideas. In fact, her life was so miserable that Arrowsmith attempted suicide multiple times because her disabilities had a major impact on her self-worth. Arrowsmith worked throughout her life to overcome her shortcomings, spending hours upon hours memorizing information from texts for tests. After learning of neuroplasticity, she created exercises for herself according to her understanding to stimulate the applicable connections where her brain's signal was 'weaker' (2). They were exceptionally effective, and resulted in her opening a school, fittingly known as the Arrowsmith school, which applies her ideas to a

structured school environment. Arrowsmith later spoke at a Tedx talk, which has over one million views, about her experiences and the strategies she used to physically manipulate change in her brain.

Paul Bach-y-Rita was a believer in the idea of neuroplasticity. He was devastated after his father, Pedro, suffered a stroke, so he dedicated a tremendous amount of effort into researching and testing cures for his brain damage (4). The doctors predicted minimal chances of survival, and even lower chances of returning to normal life. Bach-y-Rita, in a joint effort with his brother, succeeded in restoring his father to complete health. Pedro was back at work a year later, and within five years it was indiscernible that anything had ever happened to him (3). After Paul's father's death, an autopsy revealed massive damage in Pedro's brain stem, and the neuropathologist could hardly believe what she saw. But this was not the greatest of Bach-y-Rita's discoveries (3).

Bach-y-Rita created a device, BrainPort, which utilizes both the ideas of sensory substitution and neuroplasticity. BrainPort was one of his last projects, and he implemented a lifetime's worth of learning and research into producing it. BrainPort works through an inserted camera in the tongue, which interprets optical information. The camera translates the light into radio signals which are turned into spatially encoded electrical signals. These patterns of electrical signals stimulate the neurons of the brain and then they are subjected to interpretation like all other patterns of stimulation. (1)



The device Bach-y-Rita invented to give vision to a blind person.
https://www.closingthegap.com/brainport-v100-oral-electronic-vision-aid/

The difference here is that the stimulus originates from a camera– a foreign entity– and proceeds to the brain's internal functioning. Over time, the brain learns to use this information to see. This is a captivating

conclusion, for it defends in clear terms the miraculous nature of neuroplasticity. This creation is what allowed Malik, and many others, to regain their vision.

In 2015, the FDA approved BrainPort as an official medical device, and with time, it will likely increase in renown, and consequently, in popularity. This idea is supported by the late neurosurgeon, Oliver Sacks. Sacks wrote a feature article for Discover Magazine, in which he singled out his greatest hope for science in the next 30 years. He distinguished sensory substitution, mentioning the late legendary neuroscientist, Bach-y-Rita, as a great hope for the future (6). Sensory substitution is a recent novelty, and with increasing research, it is likely to result in future developments. Already, it's been used for cochlear implants, another major aid to people with hearing loss. A device that gives sight to the blind and hearing to the deaf, now that sounds nothing short of miraculous. Perhaps Rajesh Malik and Bach-y-Rita were really wishing for the possible impossible.

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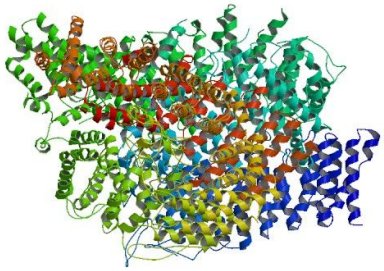
HUNTINGTON'S DISEASE: THE MUTANT MONSTER

Alicia Russo

Rebecca Ambrose is one of the thousands of people whose family was devastated by Huntington's Disease (HD), a disease they never knew existed.

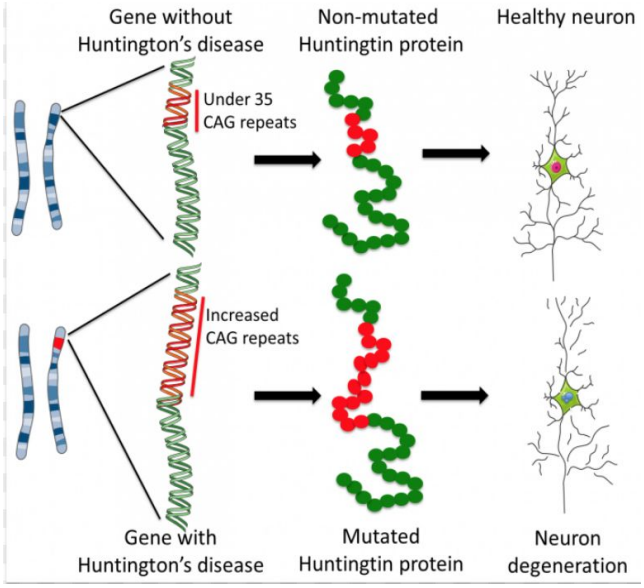
After losing her mother, uncles, aunts, grandparents, and great grandparents to this horrific disease, Rebecca is faced with a crucial decision. Should she get tested for HD and then live under a cloud of imminent death or is ignorance bliss? Since Rebecca's mother had the disease, and Huntington's is autosomal dominant (a disease on regular chromosomes, as opposed to sex-linked which are more easily inherited), Rebecca has a 50% chance of inheriting the threatening gene. A test was created to diagnose Huntington's even before symptoms are discovered. However, this was of no help to Rebecca's family as her great grandmother only found that she had the disease after Rebecca's grandfather was diagnosed. For many years doctors mistakenly believed Rebecca's great grandmother had Parkinson's since the symptoms are very similar. Thus, the disease was allowed to continue on to another generation. Unfortunately, the disease still didn't stop in the next generation, Rebecca's grandfather, as he was diagnosed too late to make any reproductive decisions for himself or his children. Rebecca already had a son of her own when her father was diagnosed. Thus, the disease was passed on to a fourth generation. At this point, Rebecca wondered whether it was even worth being tested as there is no cure for HD. Knowing that she carries the gene would tell her son that he only has a 50% chance of living past age 40, which is a terrible burden. However, the knowledge would also allow him to make decisions that his ancestors never got to make. He can decide whether or not he wants to risk having children as he could potentially pass the gene on to them (7). While it is not a welcome choice when faced with a terminal illness, any measure of control is a small victory.



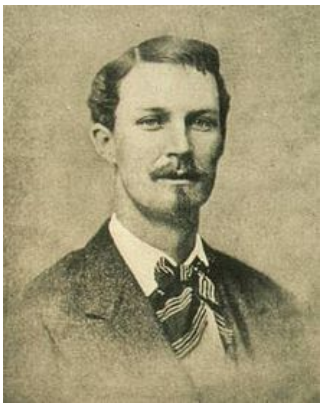
Three dimensional "ribbon" model of correctly folded Huntingtin protein.

Huntington's Disease is a disease that presents itself with uncontrollable spasms, neurological disturbances, and cognitive decline. It affects one in every 10,000 people or about 30,000 in the US (5). HD is caused by the incorrect folding of a protein known as Huntingtin. Much like the ABCs make up the words that we use on a daily basis, the amino acids make up the proteins that our body need to maintain normal function. The Huntingtin protein is located on the fourth chromosome in humans, and when in normal condition, has around 3,144 amino acids (8). The exact function of the protein is unclear, but it is known that it plays a vital role in the nervous system. Within the cells, Huntingtin is involved in protecting cells against apoptosis (pre-programmed cell death), transporting materials, creating bonds between proteins and other structures, and signaling (6). The Huntingtin gene contains a trinucleotide repeat (repeat of nucleic acids that form amino

acids) of cytosine, adenine, and guanine (CAG) that codes for the amino acid glutamine, which is needed to synthesize proteins. It is necessary for all basic processes like learning, fighting disease, and dealing with stress (15). The overproduction of glutamine can damage many of our essential functions. Once the DNA changes for this gene and this trinucleotide order is repeated more than 35 times, the RNA is copied to be brought to the ribosomes to make the protein Huntingtin, and it produces a newly folded protein known as mutant Huntingtin or mHTT. This new mutant protein is the cause for increased neuronal decay, meaning that the damage done to the brain with HD is a result of dying neurons. The higher the count of the repetitions of CAG, the more severe the disease will be (9). This phenomenon is known as anticipation (13). For example, someone who has a 36 to 39 CAG count will have a less severe case of the disease than someone who has a 40 or above count (10). Once again when compared to the ABCs, if we add letters to words they no longer mean the same thing. So too when we add extra amino acids to our sequences, the proteins no longer code for the same thing. When the protein is mutated so that its primary structure has changed, it results in the loss of neuronal function in many areas of the brain. One such area is the basal ganglia, circular structures on either side of the center of the brain, specifically in the striatum. The basal ganglia have many functions in the human body, including controlling voluntary movement, mood, and cognitive function (1). This damage occurs through the degeneration of GABAergic and cholinergic interneurons which play vital roles in neural circuitry, the different networks of neurons, and activity (14). Thus, one of the first symptoms of Huntington's disease is involuntary jerking motions as the patients lose control over their motor skills, and dementia usually follows. These symptoms are very similar to those displayed in Parkinson's disease. Thus, there have been many misdiagnoses of HD as Parkinson's.



Huntington's disease was first discovered and described in medical journals in the Middle Ages. They didn't have a name for the condition, but they described the symptoms as what we now recognize as Huntington's disease. Later, the disease became known as 'Chorea', the Greek term for dancing, based on the jerky movements that are symptoms of the disease. The first real breakthrough came in the early 1870s, when George Huntington published a paper called *On Chorea*, that thoroughly explained the diseases appearance (3). He described the apparent occurrence of an autosomal dominant disease, decades before the scientists discovered the theories of Mendelian inheritance (4).



Additionally, in the English colonies, the disease had started appearing, and was called "megrims" by the colonists. People who were suspected of the disease were burnt at the stake for witchcraft as the jerking gestures seemed like a reenactment of the crucification of Jesus. In fact, it is now believed that many of those murdered in the Salem Witch Trials were in fact suffering from Huntington's disease.

In the mid-1950s, Americo Negrette a Venezuelan physician, chanced upon a town, San Luis, where he noticed that many of the inhabitants suffered from jerking hand motions. Intrigued, he took a detailed history and concluded that he was dealing with the same cases that Huntington had previously explored. Unfortunately, medical society turned a blind eye to Negrette's findings. In 1972, a coworker of Negrette, Ramon Avila-Giron, took videos of Negrette's patients to the US where the HD Centenary Celebration was taking place. The doctors and scientists finally agreed that the disease found in San Luis was in fact HD, and the data was published. This one community was the largest single population of HD in a single town. By 1900 about 300 people in this small town were burdened with the disease, and over 100 were 50% likely to get it as they aged (4). Continuing the research of this population resulted in an extreme medical breakthrough on March 26, 1993. After many years of searching for the direct cause, a group of scientists had found the direct DNA cause for HD (2). The gene responsible was found at the tip of the fourth chromosome, and while all of us carry that gene, scientists discovered that those who suffer from HD have a mutated version of the gene (11). These results were then published by the 58 scientists in a medical journal called *Cell*.

Today, a test has been developed for the genetic mapping of the Huntingtin gene. Blood is taken from the patient for a DNA sample which is then analyzed to see how many times the trinucleotide is repeated. Based on that number doctors can determine the nature and extent of the patient's risk. However, there is no official cure for Huntington's disease. The treatments that exist mainly deal with the symptoms. There are drugs like xenazine, benzodiazepines, and antipsychotics, which help with Huntington's chorea (involuntary jerking gestures). HD also affects a patient's mood as it invades the basal ganglia. Thus, HD patients are advised to take antidepressants and mood-stabilizing medications.

Scientists have continued the search for a cure and are conducting clinical trials for their experimental designs. For example, gene silencing therapy to reduce the amount of mutant HTT is being developed. By reducing the amount HTT, the less the mutation is expressed. Like with ABC analogy, the less extra letters added on to a word, the closer you are to deciphering the word. There are two types of gene silencing therapies. First is antisense oligonucleotides in which synthesis of proteins is blocked by not allowing the ribosomes to copy the material from the RNA which allows for less production of mHTT. The other type of gene silencing therapy is RNA-interference (RNAi). This therapy allows for RNAi to be brought into a cell with the mHTT and enables the RNAi to destroy the RNA. Doctors hope that this treatment can help slow the advancement of the disease. Additionally, one more consequence of HD is inflammation in the brain or encephalitis. Thus, another treatment that can reduce the damage caused to the brain by Huntington's disease is laquinimod. Laquinimod enters the brain crossing the blood-brain barrier and prevents apoptosis

(pre-programmed cell death) thereby preventing neuronal decay and helping with the cognitive struggles of an HD patient (12).

While science has made much progress in understanding and treating Huntington's disease, we still have no complete cure. We have made significant advancement in understanding the cause of Huntington's disease through discovering the Huntingtin protein and the trinucleotide repeat. In understanding the repetition of the CAG trinucleotide repeat that causes the mutation in the Huntingtin protein, we can begin to understand the depth to which Huntington's disease affects the brain and how to prevent it before the symptoms arise. In developing the test for HD we have enabled people to make proactive decisions and be informed of the monster that lies under the bed. Only this deeper understanding can allow us to have all the information needed to further our research and help families like Rebecca Ambrose's whose lives are controlled by this terminal illness. Although we still have a long road ahead, our recent discoveries give rise to great hope for a break in the hereditary chain of this mutant monster.

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THE MASQUERADE BALL

Elona Ryba

In 2009, Dr. Nancy Edcouch, a researcher for the General hospital of Massachusetts, sat around a kitchen table accompanied by one of her latest patients, Terry Sweeney; a former firefighter who had suffered an injury that damaged part of her social brain.

The social brain is the part of the brain that allows us to interact with other people. Six Polaroid photographs of six different women were displayed on the table in front of them. One of the pictures showcased was of Sweeney's own mother, the others being total strangers. Dr. Edcouch instructed Miss Sweeney to tell her which of the six pictures was of her mother. Following her instructions, Sweeney looked down at the photographs, squinting hard as a look of confusion washed over her face. She just did not know.

What Terry Sweeney suffered from was a mental deficit known as prosapognasia; the inability to recognize the faces of familiar people. As Miss Sweeney herself experienced, most forms of

prosopagnosia results from damage to a specific part of the brain; the inferior occipital areas (occipital face area), which, more specifically, is the right Fusiform Gyrus *(Figure 1)*. Experiments performed using PET scans and fMRIs demonstrate that the Fusiform Gyrus is the area of the brain solely responsible for facial recognition. The data collected by Nancy Kanwisher, a professor in Neuroscience, backs up these facts. She used FMRI scans to trace the area in the brain responsible for facial recognition. The participants of her experiments were shown images of both faces and objects at a constant rapid speed, while their brains were being scanned. Through the images, Kanwisher was able to observe that a specific part of the brain demonstrated an increase in activity when showed faces of any kind, concluding that the Fusiform Gyrus was indeed responsible for facial recognition. Furthermore, if brain damage occurs in the Fusiform Gyrus area, only facial recognition is impaired and nothing else. This would explain Miss Sweeney's inability to recognize her own mother after her brain injury, even

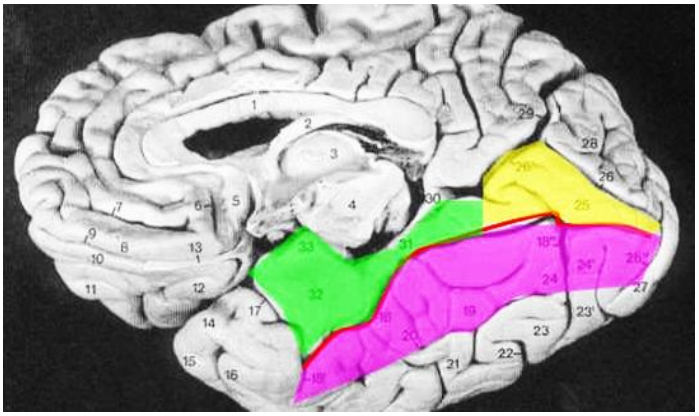


Figure 1: Facial Recognition Areas:

This image is taken from the results of an experiment performed at Stanford University (California), where Neuroscientists placed electrodes all around a subject's head to track the area of the brain that will be the most responsive to faces. The Fusiform Gyrus (number 19,24, and 18), located on the bottom portion of our brains as part of the temporal and occipital lobe, showed the most brain activity. This experiment demonstrated that the fusiform gyrus is the area of the brain responsible for facial recognition.

though her peripheral vision was perfect. Our brain has a specific area reserved only for the ability to recognize faces, and when damage is done, we lose that capability forever.

As human beings, the ability to recognize faces in one of the most important stages of our developmental process. Since birth, faces are our first form of self-expression and step towards social interaction. Studies done on the reaction of newborn babies to faces, show that we are trained to recognize human faces from as little as three days old. Recognizing faces insures the likelihood of successful human social interaction, and is an integral part of our community-based society. When impaired, the function of the human brain's face identity recognition system cannot be substituted in full by other brain regions. Therefore if the brain suffers brain damage in the areas responsible for face recognition, even brain plasticity can never give back the ability to recognize faces again.

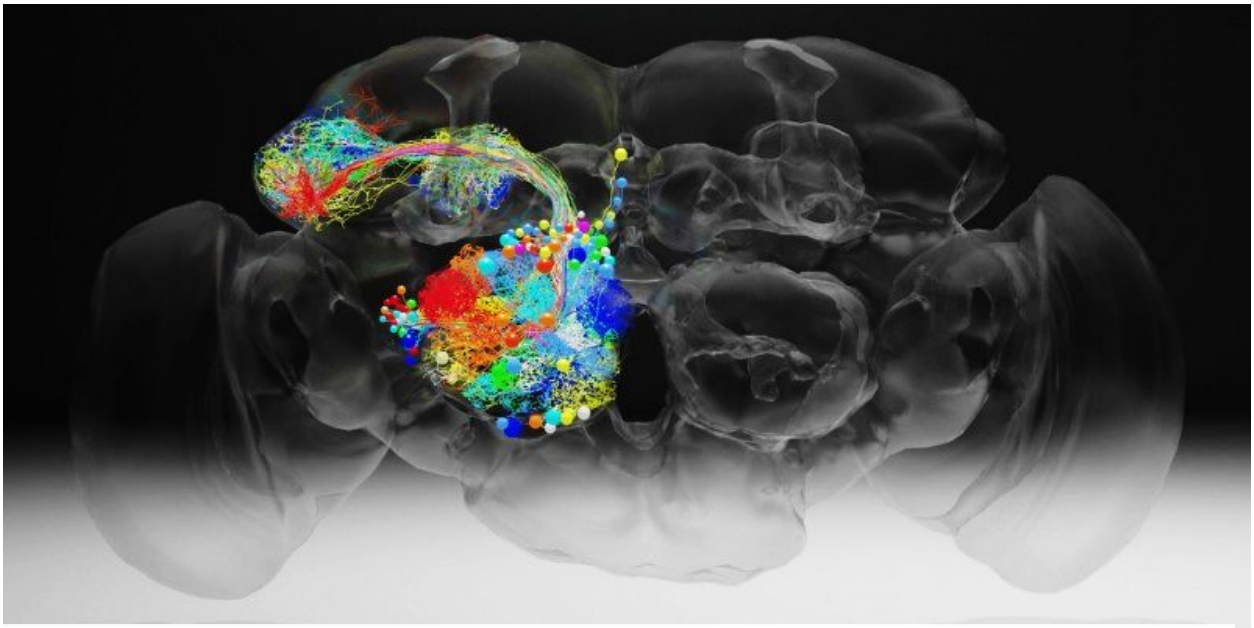
Why is recognition of faces so important that it is given exclusive real estate in the brain? Charles Darwin proposed that facial recognition may be one of the most integral part of societal evolution, as it could have helped distinguish between friend and foe. As societies began developing, and humans were living more and more in close-knit and socially complex communities, surrounded by faces, the innate human need to recognize safety developed into the ability to distinguish between faces. This, in turn, became a sort of survival method. It ensured that humans would further be able to recognize danger.

Hailing from a Greek compound of the words *Prosopon* (the face) and *agnosia* (non- recognition), this mental deficit was first introduced to the world back in 1947 by Joachim Bodamer; a German neurologist who published the first paper on prosopagnosia by reporting on the decreased face recognition of two soldiers after brain damage occurred in one of the battlefields during World War Two. Before Bodhamer, there was a notion of visual agnosia, which is an impairment in recognition of visually represented object, but the notion that there would be agnosia from particular things, such as faces, was thought to be ridiculous. Following Bodmamer's report, a couple more cases were reported and published, establishing prosopagnosia as a mental defect caused by damage to the temporal and occipital lobe.

Although the only cause of prosopagnosia listed thus far is as a result of brain damage, in 1991, a man by the name of McConachie added to the causes, by being the first to report a case of prosopagnosia without any history of brain tissue damage. From there, the notion that prosopagnosia can also be a hereditary defect was born. It is important to note that prosopagnosia is the first mental defect that affects one ability to internalize or comprehend what one is seeing. It is suggested that hereditary prosopagnosia is caused by a single mutation in one or more genes. As stated previously, if the system is damaged or not fully formed from childhood, there is no getting it back later on in life. Children born with prosopagnosia will have a "life-long face deficit disorder."

In 2005 a study was done to examine the extent of prosopagnosia on the mass population. It concluded that about 2.5% of the Caucasian population had prosopagnosia, and that about six million people in the United States have prosopagnosia. But even after all that, the truth-of-the matter is that it is very hard

to diagnose prosopagnosia. There is no true test that can determine face recognition dysfunction. Unlike Dyslexia, there is no general intelligence test that can be taken, as schools do not regard it as a skill set. A child with prosopagnosia will have no difficulty learning, which leads to the discovery of the mental deficit much later on in life, as this kind of impairment cannot be observed from an early age. Until today, there are no treatments for prosopagnosia, whether it be hereditary or caused by brain damage. An article described the situation of the deficit by saying that "just like people with autism, one must learn to accommodate living with prosopagnosia, as there is no cure." The hope of discovering a treatment or solution for this metal deficit is still very much new, as neuroscience itself is at it starting point. The hope is that as brain research progresses, and we find out more information about the brain itself, we will be able to discover a solution to prosopagnosia and other visual agnosia. Today, neuroscientists and researchers are conducting experiments with the hope to come up with better diagnostic criteria. They are also working on implementing educational and training programs that will hopefully be able to accommodate those plagued with this very peculiar mental deficit.



The fruit fly brain contains 100,000 neurons, which can now be traced in detail (colored threads) using a dataset that includes roughly 21 million images. Credit: Z. Zheng et al./Cell 2018

Specifically, scientists at Janelia Farms Neuroscience Institute are furiously working on an enormously ambitious project called the connectome. Similar to the Human Genome Project at the end of the twentieth century, the goal is to map out the wiring circuitry of every single neuron in the human brain. With over a hundred billion neurons, this task is daunting, requiring a tour de force cooperation of science labs around the world using the most sophisticated of imaging technologies, systems analysis, statistical modeling of networks, computational biologists, and theoreticians. So far, these researchers can now trace the path of any one neuron to another in the whole brain of the fruit fly, and they have set their sights on the mouse.

Scientists can now see and explore neural wandering traces of 300 neurons in this mammal (5). The Human Genome Project answered many questions, while generating equally as many new questions and avenues of research. Similarly, the connectome project might possibly provide the answers to solving the Prosopagnosia riddle, while simultaneously revealing complexities yet to be imagined.

I wonder what it must be like, to see but not to *really* see. To know that you are looking at a face, but not know which face you are looking at; to not know what identity this face holds. Patients with prosopagnosia can understand that they are looking at a face, yet they have no idea to whom this face belongs. It has no identity, no name. To them, we all become, literally, faceless. One patient who suffers from prosopagnosia described it as walking through a very busy street, surrounded by unfamiliar faces, and knowing that you are looking at a human face, but none of them look distinct. They all look the same. Hopefully in the near future, these and other mysteries of the human brain will be resolved.

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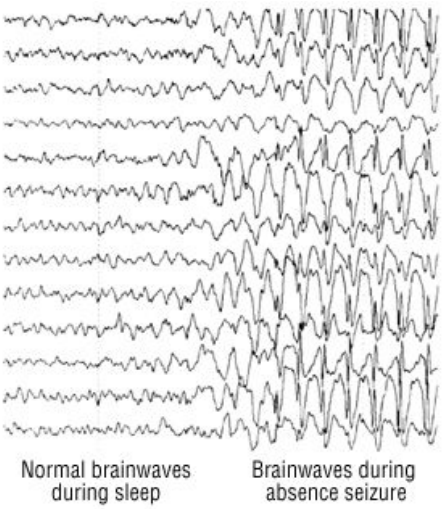
A MEMORABLE MIND

Bayla Weiner

Seven year old Henry Molaison (H.M.) was out walking when he was in an accident with a bicyclist that knocked him out for a couple minutes. As a result of this collision, Henry suffered from constant seizures, a condition that forever changed his life (1).

He developed a severe case of epilepsy, a neurological disease where neuronal activity becomes disturbed, causing strange sensations, emotions, and behavior. This condition often leads to convulsions, muscle spasms, and loss of consciousness. Anything that disturbs the normal pattern of neuron activity - including illness, brain damage, and abnormal brain development--can lead to seizures (5). At first Henry experienced slight seizures that were rather insignificant, but with the passage of time, his seizures became more severe. By the age of 16, Henry was experiencing seizures constantly, with at least ten a day. Unfortunately, this lead to frequent mockery from his peers, eventually leading to his dropping out of high school. Thankfully, he returned a while later and was able to graduate and receive his high school diploma (1).

Epilepsy can be caused by several factors, one of which can be genetic influence. Many types of epilepsy have been linked to mutations in genes that provide the instructions for ion channels that help regulate neuronal signaling (5). For instance, most infants with Dravet Syndrome, which is a type of myoclonic epilepsy of infancy with seizures beginning before the age of one, carry a mutation in the SCN1A gene that causes seizures by affecting sodium ion channels. In Henry's case, due to the link to his accident with the bicyclist, it demonstrates that his seizures were caused by head trauma as opposed to genetic influence. Even with only these two examples, they illustrate the varying causes for epilepsy such as head trauma, brain conditions, infectious diseases, prenatal injury, among other developmental disorders. Since Henry's seizures only began after his collision, doctors concluded that the trauma to his head resulted in his lifetime's epilepsy.



There are many symptoms that illustrate that one suffers from epilepsy. These indicators include staring spells, confusion, jerking movements of the limbs, loss of consciousness, or psychic indications including fear, anxiety and hallucinations (5). With regard to Henry, the only symptom he displayed was the uncontrollable jerking movements, commonly known as seizures. Although symptoms vary based on the type of epilepsy one possesses, an epileptic usually will experience the same kinds of seizures each time. Doctors often diagnose epilepsy by conducting a brain scan known as an Electroencephalogram (EEG) which is a kind of test that detects abnormalities in both brain waves and

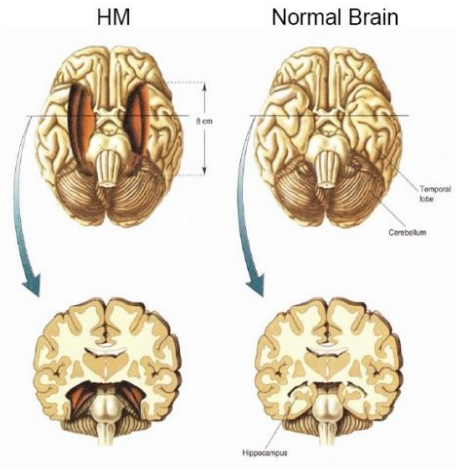
electrical activity (4). As demonstrated in Figure 1, the brain waves during normal sleep are rhythmic and regular, whereas during an absence seizure, brainwaves are irregular and uncontrolled. An absence seizure is one that starts from both sides of the brain simultaneously. In Henry's case, because his epilepsy was so severe, both he and his parents were willing to try anything to prevent his constant seizures.

Henry's severe epilepsy consumed his ability to function, he therefore sought treatment to relieve his pain. Epileptic treatment varies tremendously and can be something as minor as a diet change or a serious surgical procedure. Treatment is dependent upon the age of patients and the type of epilepsy he or she possesses (5). Specific diet changes can help control seizures when medications are either ineffective or cause negative side effects. One dietary change, known as a ketogenic diet, is a high-fat, low-carb diet that helps prevent seizures because a chemical known as ketone is produced when the body uses fat for energy. Using ketone for energy instead of glucose prevents seizures in some children. When one transitions to a ketogenic diet, the brain adapts to burning ketones for energy since the glucose supply is restricted. Interestingly, a major ketone known as Beta-Hydroxybutyrate (BHB), is considered a more optimal energy supplier than glucose as it provides more energy per unit oxygen used then glucose can (5).

Furthermore, medication also helps reduce seizures for epileptic patients. In July 2018, the FDA approved the use of a cannabinoid based drug known as Epidiolex to treat two specific kinds of epilepsy - Dravet Syndrome and Lennox-Gastaut Syndrome (6). In a clinical trial in 2019, a group of patients suffering from Lennox-Gastaut Syndrome participated in a placebo controlled experiment where they were given Epilodex. In order to qualify for this trial, patients had to be between ages 2-55 and must have experienced two or more atonic seizures (which are partial or complete loss of muscle tone due to temporary alterations in brain function) a week for a 28 day period. Patients were issued cannabinoid drugs based on their body weight. The trial consisted of a total of 225 patients, 76 received 20 mg of the cannabidiol drug, 73 were given 10 mg of the cannabidiol drug, and 76 occupied the placebo group receiving no drug. Patients who received the cannabidiol drug experienced a greater reduction in drop seizures than those who were given the placebo. This recent study shows the continued research in the medical field of neuroscience to help future epileptic patients better treat their disease (3).

Treatments including medication, surgery, and dietary change sound promising and have proven to be successful for many patients. However, when Henry suffered from severe epilepsy in the mid-20th century, doctors were only at the experimenting stage and slowly learning through trial and error. Henry originally was prescribed standard medications to reduce seizures such as Dilantin, Phenobarbital, Tridione, and Mesantoin, but when these proved to be ineffective, doctors were forced to consider a more radical, potentially dangerous, procedure. On August 25, 1953, Dr. William Beecher Scoville performed surgery on Henry's brain where he removed Henry's medial temporal lobes in both hemispheres, including the hippocampus and most of the amygdala and entorhinal cortex, as illustrated in Figure 2. Scoville performed this surgical removal since he derived from his research that the hippocampus was involved in causing epilepsy. Additionally, other doctors had been successful in reducing the amount of seizures by removing half

of the hippocampus. Dr. Scoville daringly decided to remove both hemispheres of Henry's hippocampus. Sadly, this surgical experiment altered Henry's life forever, more negatively than the collision with the bicyclist all those years earlier (1).



Henry now developed a condition more critical than any seizure he had ever experienced—anterograde amnesia. Anterograde amnesia is a form of memory loss that prevents one from forming new memories. Long term memories from before the event remain intact while short term memories are either impaired or nonexistent (7). Through Henry's surgery, the hippocampus which first appeared to be primarily responsible for seizures and irrelevant to other human processes, was discovered to have an effect on much more. Dr. Scoville's decision to remove Henry's hippocampus revolutionized the field of neuroscience as it became evident that the hippocampus plays a key role in the ability to commit events to memory, which was a function that Henry was robbed of (1). However, the operation did prove to be successful in reducing his constant seizures which illustrated that epilepsy, or at least the cause for seizures, is rooted in the right and left medial temporal lobe.

Epilepsy remains a prevalent neurological disorder affecting millions of Americans today. Geneticists research and experiment with genes that interact and produce a specific epilepsy syndrome in order to learn more about the role of genetic influence to the causes of epilepsy and hope through this to find a cure. Henry Molaison's condition shed more light about memory than epilepsy yet his experience with epilepsy was one of the most severe cases ever publicized and is no matter to be disregarded. It uncovered the source of seizures in the brain of an epileptic, while also revealing that the hippocampus plays an important role in one's ability to remember. Scientists, determined to discover effective medication for seizures, continue to research symptoms and brain activity of epileptics in hope of finding a cure for those suffering from this disorder.

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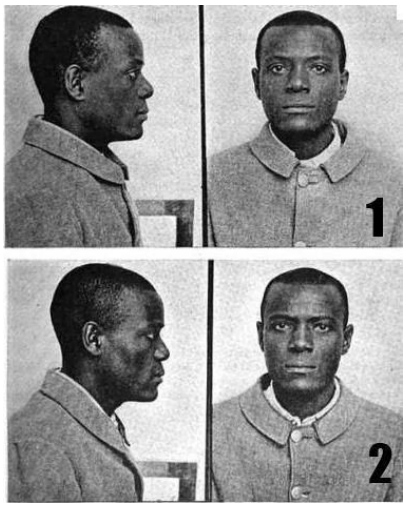
FINGERPRINT ANALYSIS: FACT OR FABLE?

Esther Bertram

Two men, one a murderer and one a first-time offender. Both look uncannily alike. Both happen to come to the same prison.

This case gave birth to our modern day use of fingerprinting. In 1903, an African-American man named Will West was arrested and brought to Leavenworth Penitentiary in Kansas. West denied any previous arrests, but the record clerk took his Bertillon measurements. Collecting ones Bertillon measurements was the primary way to identify criminals in the U.S.A. and Europe between the 1880s and early 1900s. Created by Alphonse Bertillon, a French criminologist, in 1879, the Bertillon System was based on the principle that each human being has distinct body measurements that set them apart, allowing them to be uniquely identified (5). Law agencies began implementing the Bertillon system which dictated specific body parts that were to be measured such as the breadth of the head, the length of the head, the left foot, and the middle finger (4). The system also required a photograph or a "mugshot" of the criminal to be taken. The Bertillon measurements and photographs of the criminal were recorded, creating a filing system that allowed law enforcement agencies to identify people who committed multiple crimes.

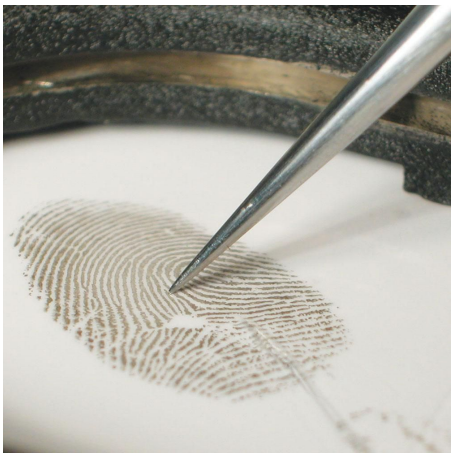
However, Will West was not lying when he claimed he'd never been to Leavenworth Penitentiary before, and after examining his measurements, the clerk at Leavenworth made a strange discovery: Will Wests' Bertillon measurements matched the Bertillon measurements of another inmate in Leavenworth named William West, who was serving a life sentence for murder. To make matters even more confusing, Will West and William West looked nearly identical. Their respective prints bore no resemblance to the other's (3). After almost three decades, the Bertillon System, popular and widely accepted in the U.S, began showing its unreliability. The West Case was instrumental in disproving the Bertillon System, while simultaneously proving a new identification technique to be more reliable: fingerprint analysis.



Fingerprint analysis replaced the Bertillon System and became the dominant identification method in America. Fingerprint experts began analyzing prints found at crime scenes with known prints of a suspect to determine if they originated from the same source or if they did not. There are three types of prints that investigators find at crime scenes. The first is patent prints. Patent prints are visible fingerprints that form when a substance such as blood or ink is transferred from a finger to a surface, thereby leaving behind a visible print. Patent prints are collected through high-resolution photography. The second type of print investigators found are known as latent prints. Latent prints are

invisible prints, formed by the body's natural oil and sweat that are left on another surface. Investigators discover latent prints by dusting surfaces with fingerprint powder, and upon finding a fingerprint, they photograph it, then lift it from the surface with clear tape. Alternatively, to preserve the evidence more effectively, investigators may examine the area with a light source. The last print investigators found are three-dimensional prints which a person leaves behind on soft surfaces such as wax and soap. Once investigators have a patent, latent, or 3-D fingerprint, the analysis begins (6).

Investigators use an analyzing technique called ACE-V. The first step is *analysis,* where analysts determine if a fingerprint is of high enough quality for comparison. If the print is found to be of poor quality, then the examination ends, but if not, examiners move on to the second step: Comparison. Comparisons are made by analysts who view fingerprints side by side to determine if they are a match. The analyst compares small details between the prints using a loupe and a ridge counter. A loupe is a small magnifier used to view minute details of the print. A ridge counter is a pointer, used to count the friction ridges, or raised patterns, on the print. The third step is *evaluation*, in this step, the examiner decides if the prints are from the same source or different sources. The final step is *verification*, in which another examiner analyzes, compares, and evaluates the prints. The second examiner may agree with the original examiner's conclusion or disagree based on his analysis (6). This process can be analogous to a difficult "spot the differences" game.



In the early 20th century, the first systematic use of fingerprinting in the U.S began. In 1911 fingerprints were first accepted as evidence in an Illinois court and successfully convicted a guilty man of murder. On September 19, 1910, just after two in the morning, Clarence Hiller, a railroad clerk, awoke to discover that an intruder had entered his Chicago home. Hiller rushed to confront the intruder, and the two men fell down the staircase after engaging in a scuffle. The intruder fired three shots, two of which hit Hiller, and then fled, leaving Hiller to die from gunshot wounds. The intruder, later identified as Thomas Jennings, didn't get far and was stopped by police less than two miles away wearing bloody, torn clothes and holding a revolver. However, those were not the only things that made him suspect to authorities.

Authorities found four fingerprints from a left hand on a freshly painted railing below Hillers' window. Police photographed and then cut off the railing itself, to use as evidence in court. Authorities identified the window as the point of entry used by the intruder. Jennings had been released from prison a few weeks earlier, and therefore police had his fingerprint card on file. Four fingerprint examiners analyzed Jennings' prints, concluded they were a match and provided expert testimony in court. Jennings' defense attorneys argued in court that the fingerprint evidence was invalid since the technique was still new and developing. Despite this, the jury voted to convict Jennings who was sentenced to death by hanging. This

case became even more prominent after advancing to the State Supreme court in 1911. Jennings' lawyers argued that the new fingerprint technology should not be permitted in courts, but the Illinois Supreme court ruled that fingerprint evidence was allowed and upheld the ruling of the People v. Jennings, in which Jennings was sentenced to death (1).

While fingerprint analysis has been one of the common forms of identification for the past century, it is not foolproof. The error rate for fingerprint analysis is not known, but many studies have been done on its reliability. A study done in China, published in 2015, helps illuminate the faultiness of fingerprint analysis. Forty analysts were given five fingerprint cases where the identity of the prints had already been determined. Two of the cases contained fingerprints that originated from the same source, while the remaining three did not. The analysts used the ACE method to determine whether the fingerprints were a match, not a match, or inconclusive. The study explains how three examiners, with varying degrees of experience ranging from one year to twenty-five, concluded that the prints in case four were a match when in actuality they were not. The study, therefore, found that fingerprint analysis is at times inaccurate since the interpretation of fingerprint evidence depends heavily on the judgements of fingerprint examiners as well as the fact that there is a lack of clear definitions of the methods used by the examiners during the assessment and analysis of prints (2).


Trial 4

Today, people acknowledge that fingerprint analysis, while very helpful, is not 100% accurate, mainly due to human error. For example, in 2004, a man wrongfully accused of terrorist activity was found innocent after erroneous fingerprint analysis was revealed. Brandon Mayfield, an Oregon attorney, and the veteran was charged with involved with involvement in the Madrid bombing, which killed 191 people. The Spanish authorities, unable to identify a latent print found on a bag containing detonators and explosives, turned to the U.S government for help. The FBI linked the prints to Mayfield, who was in the fingerprint database due to his military work and a minor crime. Mayfield claimed he was innocent, and that he had not left the United States in ten years, yet FBI Senior Fingerprint examiner Terry Green concluded that the latent print was a "100% identification" of Mayfield's prints. This claim was found to be false when the Spanish police, found the true owner of the prints, Ouhnane Daoud, an Algerian national living in Spain. The FBI retracted the information and issued an apology to Mayfield. This example further illustrates the need for perfecting the science in the area of fingerprint analysis.

Many argue that there is no scientific basis for fingerprint analysis. This argument, coupled with the fact that fingerprint analysts reach conclusions based on partial judgments makes fingerprint analysis faulty (7). An AAAS report concluded that because there is no clear way to estimate the number of people in the world who share characteristics found on a print, there is no scientific basis for identification. However, on

the other hand, fingerprint analysis is constantly improving and remains a helpful technique that authorities continue to use to identify criminals. Fingerprint analysis has successfully identified and convicted thousands of guilty people, consequently making our justice system more efficient and reliable.

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INTELLIGENT PLANT CRIME SOLVERS

Miriam Mermelstein

When thinking of solving crime, DNA evidence, ballistics, toxicology, and other more commonly used forensic techniques get all the press. However, unbeknownst to many, Forensic Botany has recently been credited as a big asset in solving multiple crimes.

Forensic Botany is the application of plants and plant parts—such as pollen, seeds, leaves, wood—to criminal investigations, legal-rulings, and or disputes. In order to aid an investigation, forensic botanists can utilize multiple subdivisions in the botany field; including *palynology* (the study of pollen), *systematics* (the classification of plants), *dendrochronology* (the study of tree rings), and *ecology* (the study of ecosystems).

Although a relatively new discipline applied to forensics, botany has provided significant and even crucial evidence in the conviction of criminals. Aside from plant remains being found almost everywhere, these plants can provide multiple sources of evidence: both *macroscopic* (visible to the naked eye), and *microscopic* (invisible to the naked eye). Additionally, because of their *morphological* (structural) diversity, scientists are able to identify their specific species, and through that identification, elicit other crucial information. For instance, through the identification of a specific species, forensic botanists can determine the season or geographical area in which a crime was committed, if a suspect was present at the crime scene, or if a body was moved after the murder. Through the use of this identification, we can pinpoint multiple factors of the crime scene, and ultimately aid in the conviction of a criminal. A prime example of this can be seen in the figure to the right (Figure 1), in which specific hooked seeds transported from a burial site and later found on a murderer's clothing, were used to convict the murderer.

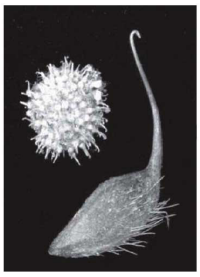

Figure 1

Primarily, forensic botanists focus on making a connection or relationship between evidence and a crime; placing a suspect at a crime scene, or identifying where the crime took place based on evidence found. For example, pollen, a powder like substance that is released by plants, is transported by wind, and therefore can be easily found on clothing, hair, or skin. If a rare type of pollen is found at or near the crime scene (Figure 2) and subsequently found on a suspect, forensic botanists can use their skills to place the suspect at the scene of the crime. Every area is a somewhat specific signature of pollen, grain, or other plant parts; these 'signatures' can act as an identifying component to where the original crime took place, who was involved, and if the body was moved or not. This was indeed one of the primary methods

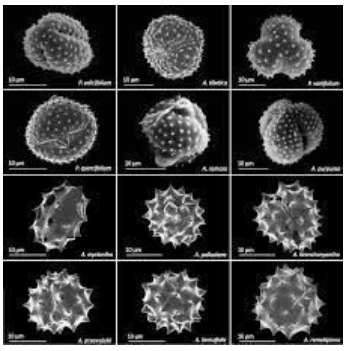

Figure 2: A variety of rare types of pollen that could be found on a crime scene.

used to evaluate botanical evidence found at the scene of the Almodovar Case of 1942, which ultimately solved the crime.

In the Almodovar Case of 1942, Louise Almodovar's body was found in the tall grass of Central Park, New York on the night of November 2, 1942. Louise's husband, Anibal Almodovar, a Puerto Rican sailor living in New York, was arrested as the main suspect and eventually convicted of the murder. After discovering seeds of various species of grass found on the suspect's (Anibal Almodovar) clothes, famed forensic toxicologist, Alexander Gettler, passed on the evidence to Dr. Joseph J. Copeland, Professor of Botany and Biology at City College. Using his extensive knowledge of botany, Dr. Copeland identified the seeds as a rare species (Plantago lanceolata, Panicum dichotomiflorum, Eleusine indica) which could only be found in the Central Park area where Louise Almodovar had been strangled to death. This species could only be found in New York City, thereby placing Anibal Almodovar at the scene of the crime.

However, this was not the only component in the case which involved forensic botany.

Aside from the primary method of using forensic botany to form a basic connection between a suspect and the scene of the crime, botanical evidence can also be used to determine the elapsed time since death. Plants, specifically roots, and the study of *dendrochronology (*the study of tree rings) are useful in determining the time passed since a murder, as tree rings and roots grow in annual cycles, and their growth rings can help with the timing of an event. The annual growth rings vary with environmental changes, possibly providing a timeframe of the event, sometimes even centuries later. Even damage to the annual root growth as the result of a crime, can identify the time lapse since the event occurred. Certain plants grow in specifically known cycles providing additional strong indications of certain time frames. Essentially, forensic botanists are able to discern how young/old a plant/tree or seed is, which can surprisingly be very useful in botanical evidence found by criminal investigations. This in fact was the method used in disproving Mr. Anibal Almodovar's alibi brought about in the case mentioned above.

Mr. Almodovar produced an alibi claiming he went to a nightclub in the area at the time of the murder. He also commented that he had taken a walk in Central Park two months prior to the murder. He insisted the seeds found on his clothes must have been from this previous visit to the park. Dr. Copeland then again used the study of botany to disprove the suspect's alibi, testifying that the seeds discovered had only matured within a week or two, and not two months ago as Anibal had stated was the last time he was in Central Park. This nullified the suspect's alibi and subsequent explanation, placing him at the scene of the crime within the time frame of the murder. After a brief trial, the suspect, Anibal Almodovar, was found guilty and convicted for the murder of his wife, Louise Almodovar. The use of botany certainly aided the case, as it placed the suspect at the scene of the crime and ultimately led to his rightful conviction.

Cleary, multiple subdivisions of forensic botany can be extremely useful in criminal investigations. For example, an additional asset of forensic botany is its' ability to uncover *clandestine graves*, graves which are concealed, as well as determining the time elapsed since death. Plants can help uncover graves attempted to

be hidden; revealing a crime that otherwise would not have been discovered. When soil is disturbed by a foreign object, action, etc., additional plants will quickly fill the empty surface until the area is fully recovered. However, the new vegetation will never be exactly the same as the original species; thereby indicating a disturbance in that particular area.

Despite all of the above qualifications and indications of its significance, there are limitations and errors that can be made. When forensic botanists are dealing with evidence that is easily contaminable and decayable, they must be extremely careful to document, protect, and preserve the evidence, in order for the results to be accurate and for them to be admissible in court. Additionally, certain plants (such as pollen), are very common and thereby particularly hard to connect to a specific area. Furthermore, scientists must be careful to ensure the botanical evidence was present at the time of the crime, and not freshly blown in from surrounding areas when the investigation actually took place. In terms of error rate, there is no exact statistic for forensic botany, because it is a relatively new discipline, and is not yet commonly used.

Despite its potential, the use of botanical evidence is scarce and not growing, as it requires specialists who have extensive knowledge in both botany and crime scene investigation. There are very few academics who have extensive knowledge in both of these specialties. Through the few cases that have utilized botanical evidence, its viability and utilization in criminal courts is clearly seen as accepted and valuable. However, until organizations realize its significance and pursue the necessary steps to attain it, Forensic Botany will not be the common method investigators turn to in solving a crime.

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MURDERING LIES

Shira Safrin

The polygraph, more commonly known as a lie detector test, is a forensic technique used to help solve cases by determining if the suspects involved are guilty of committing a crime they deny.

John Augustus Larson, a police officer with an academic doctorate, invented the first polygraph in 1921 and it was further advanced by his student, Leonarde Keeler, who added a galvanic skin response which takes note of the electrical changes in a person's skin. This machine was later purchased by the FBI to serve as a prototype for the modern polygraph (5). In 1945, scientist John E. Reid developed a device that recorded muscular activity accompanying blood pressure changes, adding to the sensors that are used in a polygraph machine (1).

When direct evidence for a case is lacking, the main technique involves an interrogation which is done using a polygraph test. To take a polygraph test, four to six sensors are placed on the subject's fingers, and occasionally arms and/or legs, as seen in Figure 1, to test various physiological responses such as breathing rate, pulse, blood pressure, and perspiration which are all recorded on a graph. Next, the subject undergoes a brief control question test, where he is asked a few simple questions in order to establish a normal rhythm from which the interrogator will be able to spot a difference. Once that's taken care of, the real interrogation begins and the polygraph shows any noticeable body changes that occur when the subject responds.

Figure 1

However, the polygraph technique is not always accurate; while physiological changes are accurately recorded, the reasons behind those changes aren't necessarily because the subject is lying. The changes that a polygraph detects can sometimes be caused by anxiety, confusion, fear or PTSD. For example, an intoxicated or drug-induced person can fail a polygraph test even if he is innocent. Unfortunately, since guiltless people can fail lie detector tests due to other circumstances, wrong convictions and imprisonments sometimes ensue. Overall, according to the Federation of American Scientists, "the predictive value of the screening use of the polygraph would only be 50 percent" which means that only half of the lie detector test results are accurate (6).

The polygraph technique has become a standard aspect of the criminal investigation, especially in the United States. In 1935, America first put Keeler's machine to the test. As journalist Jessica MacNeil wrote,

"He used his device on two accused criminals in Portage, Wisconsin, and the results were submitted at trial. The subjects were convicted of assault" (3). This was the first time of many times a polygraph was used in the United States. In Europe, there are various opinions held on the polygraph technique and the continent is divided; Holland and Germany reject the use of lie detector tests while Belgium has performed the most polygraph tests in any European country (4). Even in Asia, Israel has rejected the use of lie detector tests. The United States, however, continues to implement the polygraph technique in their forensic investigations and interrogations. In recent years, a hand-held lie detector was developed to be utilized by U.S. Army forces in Afghanistan. While the polygraph technique may accurately portray physiological changes, further developments continue to be made to enhance the accuracy of this powerful forensic tool.

One famous murder case that was solved in a mere four days employed the polygraph technique to convince a suspect to confess ultimately resulting in a wrongful conviction. On March 26, 1980, a superintendent walked into Renee Walker's apartment in upper Manhattan to find her dead body covered in a blanket. Through an autopsy, the body was assessed to have been killed three days prior. Renee Walker worked as a computer operator in a bank and was a 31-year-old woman with an 11-year-old son who was at the hospital at the time the murder took place. While the scene was lacking evidence such as a murder weapon or fingerprints, Detective Charles Mattson began the investigation by interviewing neighbors and relatives, including Matthew Johnson, an eighteen-year-old orphan, who was her suspected killer (7). At different times, Matthew reported Walker as being a friend, acting "like a mother to [him]," while he also admitted to having an argument with Walker about a relationship in which he was entangled on the night of the murder (7).

Johnson originally testified that he had seen Walker briefly on Sunday, the day of the murder, to discuss the ten dollars that she owed him. He also claimed that at that time he heard the voice of another male tenant in another room in the apartment even though he didn't actually see him. Afterward, Johnson helped his uncle, Mr. Ellison Rhodes, who lived in the same building, to remove garbage and when they finished Johnson went home. Having no solid evidence upon which Detective Mattson could accuse anyone of the crime, Mattson asked Johnson, Mr. Rhodes, and Victor Walker, who was the male tenant whose voice Johnson claimed to have heard, to take polygraph tests. They all agreed and their lie-detector tests were administered on April 1st by Detective Peters. Mr. Rhodes and the tenant Victor Walker both passed their tests flawlessly, while Peters noted that when Johnson underwent the exam, "the needle almost jumped off the graph" (7). Due to the undeniable accusatory results of the polygraph test, Johnson gave up the right to remain silent and he confessed.

However, at the hearing before the judge, Justice Kleiman, Johnson mentioned how he had been treated badly and felt coerced into falsely admitting to the crime. Johnson argued that Mattson refused to "give him any food or cigarettes unless he confessed" and the detective supplied him with what Johnson claimed was unknown information about the murder, including that Walker had been struck with a statue (7). Additionally, there was a 37-minute videotape of Matthew Johnson confessing, but Johnson insisted that

this was only because Detective Mattson had told him threateningly "we got to have a confession out of you, Johnson" and this was the only reason Johnson agreed to participating in making such a video (7). The interrogation went on all night, until "questioning was terminated at 1:45 A.M." which Johnson also blamed Detective Mattson for not allowing him the basic necessity of sleep (8).

In the end, because of his admission of guilt, on April 28, 1980, Matthew Johnson was indicted on a charge of murder in the first degree. Since the invention of the polygraph in 1921, many technological advances have allowed the technique to be further developed. While a polygraph test may be a good initial step in the investigative process when direct evidence is lacking, ultimately using the lie-detector results to coerce a suspect into confessing out of exhaustion is wrong. However, the polygraph served its purpose by showing the physiological changes that happen in a person's body when he is undergoing interrogation and while there may be more developments needed to perfect the technique, in the Walker murder case and other forensic crime scenes, the polygraph stands as a substantial and effective interrogation tool.

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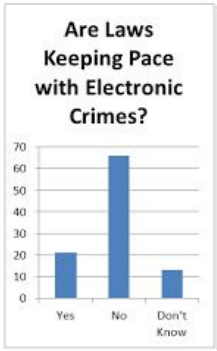
DIGITAL FORENSICS:
A NEW YET VITAL WAY TO SOLVE CRIMES

Rivky Samel

Digital Forensics is a relatively new branch of science used to solve and investigate crimes using digital devices. Given the recent widespread use of digital devices, digital forensics has become a very prevalent way of solving crimes.

Any devices that store data are within the realm of digital data. Some examples are: computers, laptops, smartphones, thumb drives, memory cards, external hard drives, and video cameras. Two organizations, SWGDE, the Scientific Working Group on Digital Evidence, and a subunit of NIJ, the National Institute of Justice, have developed methods of evidence collection and acquisition so that it would be admissible in court. All evidence must be handled carefully so it is not ruined or damaged. Chain of custody is very important in ensuring the validity of the evidence and making sure it has not been tampered with. This is true in all forensics but is especially important when handling digital evidence because it's easier to tamper with. Chain of custody includes: evidence, being date and time stamped, proper logs of who came in contact with the evidence, and sometimes it's necessary to have tracking devices on evidence to ensure only authorized persons came in contact with it. (1, 7)



Digital forensics is a technique that searches and analyzes computer systems for information to find potential evidence in a trial. Digital evidence is used in many crime scene investigations, but there are some unique aspects to computer investigation. The first step in digital forensics is identification; finding out where information is stored on the computer. Data can be found on a computer's hard drive, servers, flash drives, and network equipment. When entering a crime scene, forensic scientists must evaluate the scene to determine where information can be stored. It helps to understand the environment of the scene to make decisions on what "artifacts" will be found. Artifacts are digital evidence found at a crime scene. All devices are different and transmit different types of artifacts, therefore the more evidence that's uncovered the clearer the picture becomes. (2)

The second step is preserving the evidence. The preservation of evidence is crucial because if a piece of evidence loses its credibility it is no longer acceptable in court. There are a few methods to make sure evidence is preserved and not changed. For one, chain of custody paperwork is extremely important. This paperwork documents everyone who has come in contact with the evidence. That way when presenting

evidence to the court this paperwork helps explain treatment and actions towards the evidence. Another useful technology in preserving evidence is a Write Block. This allows investigators to view digital evidence while blocking their ability to alter it. Additionally, in order to preserve evidence investigators create a forensics image of the data. By doing so they create a copy of the data so they can perform analysis and investigation without tampering with the actual evidence. (3)

The next step in many cases is recovery. Almost always there is some sort of data that needs to be recovered. These may include deleted files from normal OS processes, intentionally deleted files, password protected files, and damaged/corrupted files. Recovering these artifacts are key in solving a case, because the more information is recovered, the fuller the picture becomes. Once identification and recovery are complete, investigators can then move on to analysis.

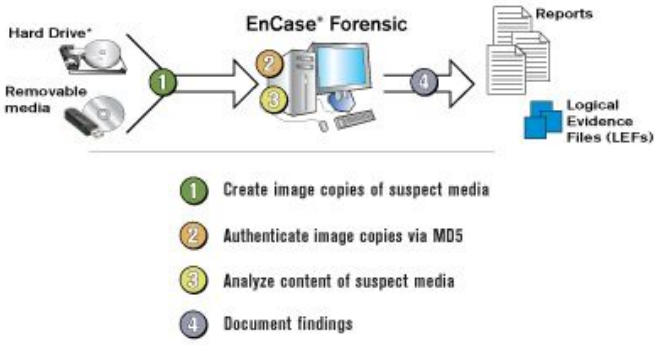
Analysis is the most important part of the entire investigation. This is where the hard work and expertise of a forensic investigator comes in. There are several apps and programs to find artifacts locations such as memory, registry and event logs. The most important point is to gather as many artifacts as possible, and there is no shortage of them. A single act on a computer can create up to five artifacts. For example, Skype will sync chat history going across all devices. This proves incredibly helpful in piecing together a much clearer picture of the crime.

Once the investigation is complete the final step is the presentation of evidence. This is usually done in a case report. Following all the steps above and documenting the process makes the final report that much easier. Hopefully, if the investigation is successful, the information found will lead to some sort of conclusion. (2, 3)

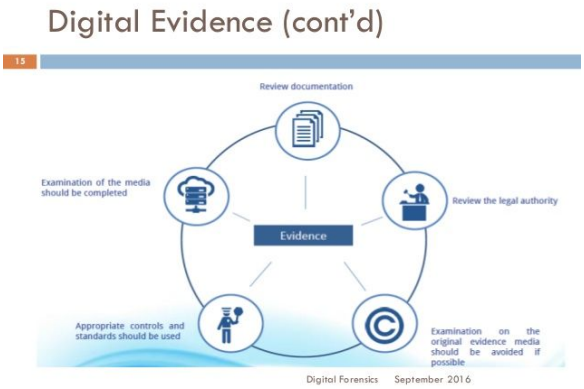
The problem with digital evidence is that it's very easy to manipulate and change. Therefore courts have to establish strict rules to make sure the evidence submitted isn't tampered with or changed. Since digital forensics is relatively new, no hard and fast rules have been set yet, however, different courts have different standards. There are five guidelines set though for courts to follow.

1. The evidence must be relevant to the particular issue in the court case.
2. When evidence is non-testimonial (stated by a witness) it must be shown to be authentic.
3. When evidence contains intentional assertive statements to prove the truth of the matter they are considered hearsay and are inadmissible in court (unless one on hearsay exceptions).
4. The original writing rule must be met when digital evidence is presented in writing, recording, or photograph. The original writing rule is that a lawyer does not need to use the most probative evidence, it's up to him which he uses.
5. Probative value of evidence is measured against it being unfair or prejudice. These guidelines are in place to prevent faulty or contaminated digital evidence being presented in court. (4,5)

Digital forensics is a relatively new field in forensics. Computer forensics was originally some law enforcement technicians who loved computers. Then in the 1990's a major change took place; investigators and technicians realized that digital forensics was a field that needed to have standard technicians, protocol, and procedures. This field suddenly needed attention as the age of technology was upon us. A bunch of conferences were held in the Police Staff College at Bramshill in 1994 and 1995, during which modern British digital forensics methodology was established. Since then new technologies were made and digital forensics became more sophisticated and mature, but the basic rules and principles remain the same. (1)



On September 7, 2012 Daniel Carlos Garcia and Kaushal Niroula were accused of stabbing Clifford Lambert, a 74 year-old art dealer, to death. With the incentive to con Lambert, Garcia obtained his phone number and address. Niroula, therefore, posed as an attorney who represented the estate of May Department Stores Co., heiress, Florene May Schoenborn. He then informed Lambert that he had inherited some valuable artwork from the estate. Lambert and Niroula set up a meeting at Lambert's Palm Springs home. On the way Miguel Bustamante and Craig McCarthy joined and together they stabbed Lambert to death. Later that same day Garcia started using Lambert's debit card and opened a new account under Replogel's identity. Replogel was an attorney who was one of their co-conspirators. They then wired $245,000 out of Lamber's account, completely depleting it. In the case against him, Garcia argued that police were "inserting texts on his phone," in an effort to frame him for the crime. For this reason, prosecutors hired Jonathan Zdziarski, a digital forensics expert. Zdziarski was able to access Garcia's phone and prove that these texts weren't tampered with. Additionally, he was able to uncover deleted texts that included an order to kill Lambert. This digital evidence led to Garcia's ultimate conviction and he was therefore sentenced to life in prison. (6) This case shows the importance and validity of digital evidence and the relevance it has in modern crimes.



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CAUTION: SCIENTISTS WITH SCISSORS

Shira Zelefsky

Wouldn't it be amazing if we could stop the spread of malaria, prevent retinitis pigmentosa, diabetes, sickle cell anemia, HIV, and even cure cancer, all with the snip of a pair of molecular scissors?

This all may seem futuristic and perhaps unrealistic, but this past November, a Chinese scientist announced that he used CRISPR— a cutting edge form of genetic engineering—to prevent newborn twins from being susceptible to HIV. While this is a historic event for genetics, scientists from across all fields agree that there are many ethical concerns with using CRISPR at this stage of research, especially in humans. Since CRISPR has only been around for a few years, scientists and ethicists are unsure of how safe it is. As more studies show that CRISPR can cause many unwanted genetic mutations, it has become clear that more research is needed before CRISPR should be tested on humans.

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a mechanism used by bacteria and archaea to protect themselves from invading viruses. It accomplishes this by recognizing and destroying the viral DNA, thereby preventing the virus from infecting the host cell. On a molecular level, the CRISPR locus is made up of multiple components, including the CRISPR array, tracrRNA, and four genes which code for the proteins cas9, cas1, cas2, and cns2 (See figure 1). The CRISPR array contains spacer regions, areas which contain copies of genes from multiple viruses that have previously invaded the cell. These are used as a guide for the CRISPR complex to identify the target genes that need to be cut in order to disable invaders. The spacer regions are then separated by regulatory repeating regions that are palindromic and regularly interspaced throughout the array (which is how CRISPR gets its name). The CRISPR locus also contains tracrRNA (trans-activating CRISPR-RNA), which once transcribed, hybridizes with crRNA (CRISPR-RNA, which is transcribed from the CRISPR array) to form the guide RNA. The guide RNA bonds to the cas9 protein, activating its function of searching for a DNA sequence that matches up to the sequence from the spacer region on the guide RNA. When such a sequence is found, the cas9 protein uses a short DNA sequence a few bases away from the target site called PAM (protospacer adjacent motif) as a grip to secure the target DNA to the cas9 protein. After the target site is secured onto the cas9 protein, cas9 uses two enzymes—HNH for the complementary strand and RuvC for the non-complementary strand—to cut the target DNA three bases upstream from the PAM site. (4)

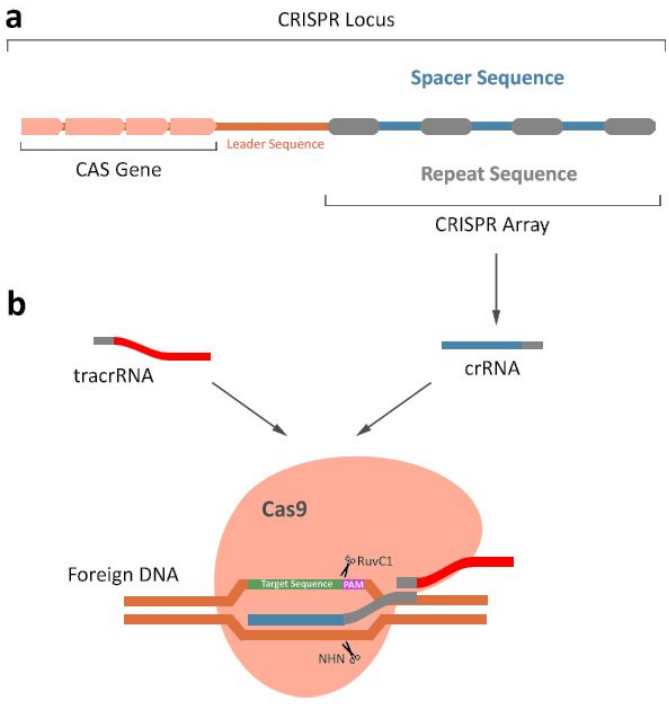

Figure 1

Researchers realized they could engineer CRISPR to locate not just a viral DNA sequence but any sequence in any organism's genome. This can be accomplished both in-vitro and in living organisms, by inserting different genes into the spacer regions so that the cas9 complex's target gene matches the gene being edited in the organism. Scientists can use this mechanism to edit the genomes of organisms and gain insights into specific gene function.

When CRISPR is used on the genomes of other organisms, the cas9 will cleave the targeted part of the genome, instead of an invading viral gene sequence. After the gene is cleaved, the cell will try to repair the DNA in a method that is very imprecise and error-prone. This results in many inaccuracies which render the gene debilitated and incapable of coding for anything, essentially "turning off" the gene. Scientists can then use this to remove a gene that is mutated or study how specific genes affect the phenotype of an organism.

Another application of CRISPR is that it can be used to edit and fix genomes. To accomplish this, scientists use the regular method of splicing out a mutated gene, but instead of letting the cell replace the hole with incorrect and faulty bases, they insert a strip of DNA whose ends are complementary to the exposed ends of the original DNA. This can be used to replace the mutated parts of a gene with a healthy segment, allowing scientists to heal genetic diseases in embryos at a level of precision unlike any previous form of genetic engineering. (2)

While CRISPR has many beneficial applications, not all aspects of CRISPR are as ideal as they seem. In an experiment on embryonic stem cells, Allan Bradley, from the Wellcome Sanger Institute in the UK found a significant number of mutations, such as deletions and rearrangements, on the CRISPR target site,

caused by the splices made by the cas9 complex. These mutations occurred on a very large scale, ranging over many kilobases, possibly giving mice diseases such as cancer. (9) Bradley explains that because we don't know the full effects and risks CRISPR may bring, we shouldn't rush into using CRISPR in human trials without further research and understanding of how it causes these mutations. (5)

In addition to mutations at the cleavage site of CRISPR, studies have also shown that CRISPR can be prone to creating off-target edits, which can lead to harmful mutations. These edits occur when a high level of similarity between an irrelevant section of DNA and the true target site causes the guide RNA to misidentify the off-target location as the intended target. The guide RNA accidentally hybridizes to this off-target location, and eventually lead the cas9 to splice that region. Mutations like these can be quite common. In a letter written to Nature Methods, Schaefer et al. describe an experiment done on mice treated with CRISPR. When analyzing the genomes of the mice after they had been treated with CRISPR, the researchers found 164 indels (insertions or deletions) and 1,736 SNVs (single nucleotide variants). Five of these indels and twenty-four of these SNVs were found to have resulted in off-target mutations that altered the protein expression. These figures reflect that the number of mutations in the genomes of the mice that were treated with CRISPR was significantly higher than the number of mutations that occur in the average mouse due to spontaneous mutations. (7)

A reliable method to identify off-target mutations is essential for further CRISPR research. However, for a while, no method was available to reliably identify the amount and types of off-target mutations occurring as a result of CRISPR. This changed with the development by Akcakaya et al. of a technique called VIVO (verification of in vivo off-targets) to better identify off-target mutations in genomes that have been augmented with CRISPR. To test this method, VIVO was first used with a promiscuous guide RNA that was deliberately chosen because its target site closely matches many other sites in the genome. Therefore, this guide RNA was extremely likely to mistaken off-target locations in the genome as the target locations, which would create many off-target mutations for VIVO to identify. When this promiscuous guide RNA was used, VIVO detected 3,107 off-target cleavage sites which could cause many stable mutations. Since clinical uses of CRISPR would never use a guide RNA with that many sites on the genome closely related to the target site, VIVO was then tested with a guide RNA that was less similar to other parts of the genome. Under these conditions, fewer off-target cleavage sites were found, reflecting the lower degree of sites similar to the guide RNA. Through the use of VIVO, these researchers found significantly more off-target mutations than previous studies had reported, leading the scientific community to become increasingly more skeptical of CRISPR. (1)

Because of these potential issues with CRISPR, there are many different opinions on how this new technology should be treated. A writer for the Nature editorial board argues that even though CRISPR may carry certain risks, these risks must be weighed against the benefits of CRISPR. The author argues that just because a treatment comes with risks, these risks shouldn't overshadow the treatment's benefits and completely disqualify the treatment from being used. Therefore, the author argues that while CRISPR

shouldn't be used to unnecessarily enhance our genomes, CRISPR should be used to heal life-threatening genetic diseases where the risk can be tolerated. (3)

Jennifer Doudna, co-inventor of CRISPR explains that since CRISPR now makes it much easier for people to get access to genetic engineering, there is a greater urgency to discuss and create guidelines for the ethics of CRISPR. She believes that while research on CRISPR should continue, alteration of human embryos should be suspended until further research is done on the effects CRISPR may have, not only on the individual but also the people descended from that individual. Due to the many genetic interactions that can happen while cells are developing and reproducing, all the possible consequences must be considered. We need to thoroughly study how edits to the genome can impact embryo function and development before using CRISPR on embryos. Doudna, along with many other scientists, calls for ample apprehension in regards to CRISPR, specifically when it is used to edit germline cells. This is because while changes in adult somatic cells will only affect that individual, it is unclear whether CRISPR will negatively affect the numerous individuals that will inherit the CRISPR edits made in their ancestor's genome. While Doudna doesn't call for a ban on all germline gene editing, she does call for multiple efforts to be taken to ensure safe use of CRISPR, such as increased communication of the possible risks involved with germline gene editing, and for scientists to collaborate and come up with guidelines for how CRISPR should be safely used.(6)

In addition to the scientific concerns of CRISPR, there are also religious and ethical concerns regarding the use of genetic engineering. According to Rabbi Shabtai Rappaport, while genetic engineering has the capability to remove genetic disorders, there is also a concern that genetic engineering may be appropriating G-d's power and that this may be viewed as "playing G-d." Rabbi Rappaport also points out that since our knowledge of genetics is not complete, we may be unintentionally introducing harmful mutations to the genome.

In Vayikra, 19:19, it says, אֶת־חֻקֹּתַי תִּשְׁמֹרוּ בְּהֶמְתְּךָ לֹא־תַרְבִּיעַ כִּלְאַיִם שָׂדְךָ לֹא־תִזְרַע כִּלְאָיִם וּבֶגֶד כִּלְאַיִם שַׁעַטְנֵז לֹא יַעֲלֶה עָלֶיךָ׃, You shall observe My laws. You shall not let your cattle mate with a different kind; you shall not sow your field with two kinds of seed; you shall not put on cloth from a mixture of two kinds of material." (10) According to the Talmud Yerushalmi, "חֻקֹּתַי", my laws refers to the laws of creation—rather than legal laws—making the introduction of this פסוק the reasoning behind the איסור of כלאים. The רמב"ם expands upon this idea, saying that the reason behind the prohibition of כלאים is that when G-d created the world, He instilled in all the animals the ability to reproduce so that each species could survive for as long as G-d wills the world to continue. G-d ordered that every organism only reproduces within its own species so that every species continues as long as possible. Therefore, the רמב"ם says that anyone who interbreeds two organisms is essentially suggesting that G-d didn't complete creation, so he must complete it himself by creating this new species.

With this in mind, it may seem that genetic engineering isn't sanctioned by the Torah. However, upon closer look at the practicalities of the Halacha, the חזון איש says that the איסור of כלאים doesn't apply to interbreeding through the use of artificial insemination, but rather only through natural reproduction.

This doesn't contradict what the רמב"ם says, because what the רמב"ם discusses only applies to nature, G-d's creation. Therefore, man is permitted to tamper with nature using technology. This is allowed, because while G-d prohibited man from tampering with creation in a natural way, He also gave man the ability to improve upon creation and develop the technologies to do so.

By this logic, the חזון איש allows artificial insemination, because it is considered an unnatural technology. Applying this line of thought yields the principle that the more advanced the method of genetic engineering, the more sanctioned it will be by Halacha. (8) Based on this, it seems that the CRISPR-cas9 mechanism would be permitted, since although it started as a naturally occurring mechanism in bacteria, when it is used in humans it is altered so that it has a new target site and in some cases, instead of disabling a gene, it can replace it with a healthier version.

Rabbi Rappaport also addresses the concern that genetic engineering may unintentionally cause harm to the genome. Rabbi Rappaport brings up the halacha of מַעֲקֶה in Devarim, 22:8,

כִּי תִבְנֶה בַּיִת חָדָשׁ וְעָשִׂיתָ מַעֲקֶה לְגַגֶּךָ וְלֹא־תָשִׂים דָּמִים בְּבֵיתֶךָ כִּי־יִפֹּל הַנֹּפֵל מִמֶּנּוּ: – When you build a new house, you shall make a parapet for your roof, so that you do not bring bloodguilt on your house if anyone should fall from it." (22:8) (11). חז"ל understand this פסוק to mean that while in general, we must maintain a high degree of safety, we only have to ensure that the appropriate safety measures have been taken and not necessarily avoid all things that have the potential to be dangerous. For example with regard to the halacha of מַעֲקֶה, one is allowed to build a tall house, as long as a fence is built around the roof. Even though a fence doesn't ensure that no one will fall off the roof, because the appropriate safety measures were taken, the fact that there is a slight chance someone may still get harmed is not an issue. (8). According to this view, CRISPR would be allowed assuming enough research has proven that CRISPR is safe to use and measures have been taken to prevent as many off-target mutations as possible.

While CRISPR may seem like the cutting edge solution to many genetic diseases, in actuality there are many ethical and practical issues that need to be worked out before CRISPR can be tested on humans in clinical studies. While CRISPR has the ability to replace faulty genes giving it the potential to cure diseases, there are many flaws that must first be addressed. Multiple experiments have found CRISPR to be prone to create mutations both at the target site and also at other points in the genome. Because of the multitude of mutations created, scientists continue to debate if the risks of CRISPR outweigh the benefits, especially in the lesser known area such as the development of CRISPR-edited embryos. In addition to scientific concerns, there are also Judaic concerns (i.e.כלאים) with the ethics of altering Creation which is yet to be determined by our major halachic authorities. Needless to say, halachic authorities would deem this relevant only if ample research proves it is safe enough. This approach jives with most scientists of today who urge further research before using CRISPR on people.

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