LAByrinth 2106 SCIENCE JOURNAL OF MANHATTAN HIGH SCHOOL FOR GIRLS

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"בראשית ברא אלקים את השמים ואת הארץ"

Ms. E. Friedman, Principal, General Studies

ACKNOWLEDGEMENTS

Science is a transformative and precious human experience. It is more than a body of knowledge to be acquired by memorizing facts and principles; rather, it is a perspective of thinking and producing precise reliable explanations of natural phenomena through the development of reasoning (both inductive and deductive), testable predictions, creative problem solving using models (both conceptual and mathematical), and inquiry.

Here at MHS, our students are learning that scientific knowledge is constantly undergoing revision due to increasingly sophisticated instrumentation and that the road to our present knowledge has been circuitous and subjected to rigorous scrutiny. We love that our students are confident participants in the science discourse that continues to play a prominent role in our society. We love that they see how science matters. This science journal is beautiful because of its authenticity ---- it reflects our students' original work from start to finish.

I am so grateful to Mrs. Brenda From, Chair of our Science Department, for inspiring our students to live and learn by Einstein's mantra, "never stop questioning." I thank her for her scholarship, guidance and desire to make science and Hashem's Wonders come alive for our students, not only in their minds but in their hearts, as well.

Brenda From, Chair, Department of Science

FOREWORD: *Things that go bump in the night.*

When I was young and had trouble falling asleep at night, the scary monsters would rear their ugly heads from under my bed and cast their creepy shadows on the wall. My mother would soothe me by showing me that the shadows were just the tree branches outside my window swaying in the wind. I still sometimes have trouble falling asleep. Only now, the monsters have morphed into a different worry.

I worry about my students and the impact of runaway technology on their educations. I fear that Google has taken on the role of a modern day Dr. Frankenstein, and created a monster over which we have no dominion. Are we conducting a huge unregulated, uncontrolled experiment on the minds of our youth by enthusiastically embracing the use of technology and allowing it to invade every nook and cranny of our lives? Should we not instead exercise the cautionary principle, pause to take a deep breath and evaluate the evidence and consider alternatives, before we jump blindly on the next bandwagon to roll down the pike?

Apparently, I am not alone in my concern, nor is it unique to our age. As *Shlomo HaMelch* put it, "*Ein chadash tachat hashemesh*."

Socrates fretted about how the technology of writing affected wisdom. Neuroscience has posited that literacy has had a transformative effect on the architecture of the human brain which has no evolutionary equivalent in the rest of the animal kingdom (2). It remains to be seen how much more so the effect of technological facility.

The digital age has vastly increased our ability to collect, store, and retrieve data, albeit perhaps at the cost of our personal memories (1). Has our reliance on smart devices, which summon facts and answers on demand, decreased our need and ability to recall facts and logically tease out relationships unaided? If we are what we know and what we remember, what does that imply about what we will become if we relinquish these capabilities to silicon based alternatives? Is there a danger that computers may supplant us as our cognitive systems struggle to keep up with the reams data we now produce? If so, what hath Google wrought? I wish my mother can come into my room and dispel my demons. How fortunate are we that Hashem gave us the gift of *Shabbat* so that we can unplug for 25 hours a week.

Drawing on contemporary neuroscience, one could contend that, unlike computers and Google, the brain relies on affective emotional experiences to organize facts into patterns and to produce narratives about future courses of action. You hold in your hands the product of the power of human cognition working in synergy with the power of technology. My students have given me hope; they have unambiguously demonstrated that technology has not hijacked the power of their minds. They have tamed the monster and subjugated it to perform their bidding as a tool towards higher cognitive thought. They learned to test the validity of Google searches, critically evaluated the results they found, and wove strands of facts into a beautiful tapestry of color and texture. Like my mother's calming stroke, I can now fall asleep.

This year's edition of *LAB*yrinth, the Manhattan High School for Girls annual science journal, is the product of our students' intellectual curiosity, fertile creativity and demand for educational rigor. I applaud their efforts; it is not easy to carve out time from already packed schedules for these extra activities. The submissions contained herein are drawn from two sources: entries to various science competitions (Dupont Challenge, Intel Social Science Competition, Design a Brain Experiment, Jerusalem Science Contest, DNA Essay), and the tenth grade chemistry element research project. This publication is accordingly divided into two units: Meeting Modern Challenges and In Her Element. I was charged with the unenviable task of selecting the articles to include from an embarrassment of riches. Not only are the articles brimming with authentic scholarship, but they are written with lucidity, style and passion. They clearly demonstrate their authors' dedication to understanding the physical rules governing our world through the prism of their uncompromising adherence to their *Yiddishkeit*. *Kol HaKavod*!

They have tamed the monster and subjugated it to perform their bidding as a tool towards higher cognitive thought.

My heartfelt appreciation to Ms. Estee Friedman, Principal of General Studies, for her continuing support and guidance, to Mrs. Tsivia Yanofsky, School Principal and Menaheles, for her critical analysis, to Ms. Chani Schwartz, for her wizardry in all things technology, to Ms. Ayala Magdar, for her meticulous proofreading, to Mrs. Shoshana Kops and Mrs. Katie Manheimer, my fellow comrades in the trenches, to the ELA faculty, who instill in our students the love of the written word, to the entire faculty at MHS, who by personal example inspire our students to strive for excellence, and most of all to my students, to whom I dedicate this issue.

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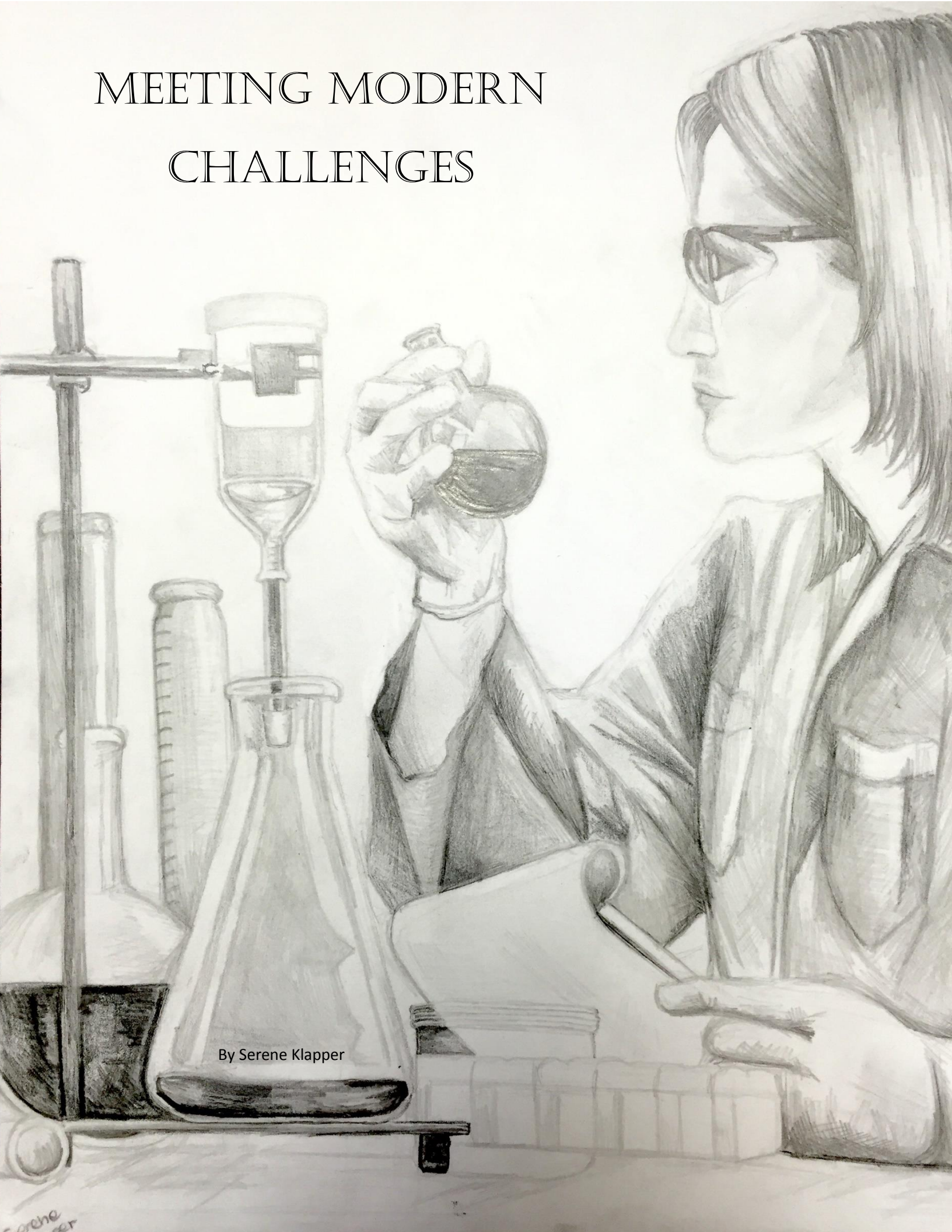
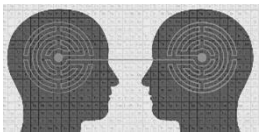
Meeting Modern Challenges



By Serene Klapper



Deena Abittan

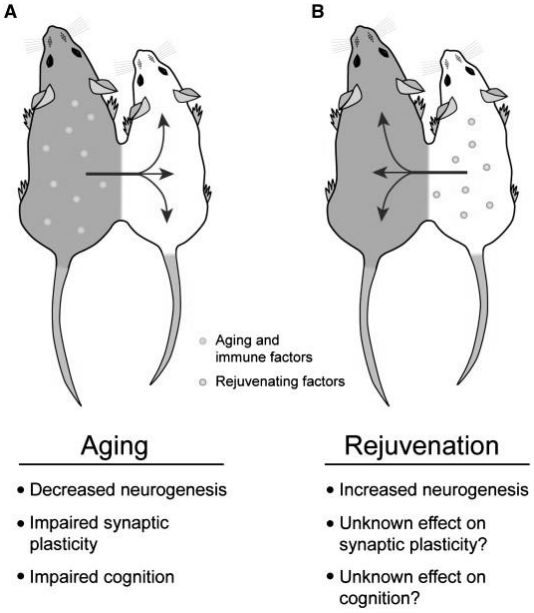
PONCE DE LEON MEETS COUNT DRACULA

The chronologically younger mouse slowly ambles towards the water dispenser while his older counterpart sprints towards the exercise wheel. Have the two switched roles or has someone discovered Ponce de Leon's fountain of youth?

Harvard University stem cell researcher Amy Wagers thinks she might have. Her research focuses on Geroscience, the study of understanding age-related diseases (5). She perfected the art of parabiosis, the process of uniting the vasculature of two living animals, and used it to stitch together an old mouse to a young mouse in order to study the effects of the infusion of blood from the younger mouse on the health of the older (2, 9). Previously, the mice were matched for gender, size, and genetics in order to ensure compatibility and minimize any surgery-related complications (2). Throughout the attachment, the blood from the younger mouse flowed into the body of the older mouse and the blood from the older mouse flowed into the body of the younger mouse. The results demonstrated a drastic change in the health circumstances of both mice (7).

As a result of the younger blood now coursing through its body, the biologically older mouse experienced a series of health improvements. The older mouse experienced restored muscle and liver cells, enhanced brain cells, improved memory, increased strength and endurance during exercise, and restored genomic integrity (2, 7, 10). In addition to improving many internal aspects, the older mouse scored higher on a water-maze test and a memory test (7, 10). While the older mouse injected with younger blood exhibited many improvements, the opposite was true for the younger mouse. As a result of infiltration of the older blood in its bloodstream, the younger mouse prematurely aged and the growth of its new neurons was stunted (7, 11). The hunt for age-promoting factors in old blood and youth promoting factors in young blood was on. The age accelerating factors were subsequently identified as cytokines and other inflammatory proteins, but identification of the youth promoting factors was far more elusive (4).

Wagers began the painstaking process of isolating



blood proteins in the younger mouse that exhibited a diminished presence in the blood of the older mouse. After much research, the protein growth differentiation factor 11 (GDF 11) was identified as mainly responsible for the positive response of the older mouse to the younger blood (9).

GDF 11 acts as an antiaging agent by regulating stem cell activity and rapidly repairing function to cell tissue (2, 9). Because GDF 11 levels drop with age, organs of older mice have a more difficult time restoring the cell tissue, thus contributing to the decline of their health. By injecting young blood, more GDF 11 was injected into the older mouse, thus re-stimulating its stem cell activity and causing its cell tissues to repair faster (1, 2, 9). With the injection of younger blood, the influx of GDF 11 helped facilitate quicker reparation throughout the body, rejuvenating muscle, brain, nervous, heart cells, and mitochondria (4, 3, 9, 10). Additionally, the GDF 11 from the younger blood also improved the mouse's memory, sensory, sense of smell and grip strength (1, 3, 9, 10). In a separate experiment, aged mice were given injections of GDF 11 alone and cell function increased after only two weeks (8). Lastly, the GDF 11 made the mouse's fur look shinier, made them look younger, and relaxed the tightening and thickening of the heart (1, 9, 10).

Just because it was a success in mice does not automatically ensure success in humans.

GDF 11 is a protein found in humans, mice, frogs, and some insects (1). The gene belongs to a conserved family of growth factors that control cellular processes and is responsible for aiding cell growth and reparation (1). Conclusively, GDF 11 rejuvenates youthfulness by reversing accumulated DNA damage (8). In another study, scientists found that stem cells are influenced by their systemic environment, therefore, injections of GDF 11 can reduce stem cell generated age-related issues by altering the chemical environment (4).

Just like mouse blood, human blood contains GDF 11, leading scientist to be hopeful about doing these transfusions in humans soon. Although the introduction of young blood did wonders for the mice, introducing it to humans needs to be approached cautiously. Firstly, just because it was a success in mice, it does not automatically ensure success in humans (9). Additionally, the introduction of too much GDF 11 can cause rapid cell reproduction, which can increase cancer risks (2). Wager's work has come under close scrutiny and other groups have found conflicting results. They chemically induced muscle damage in mouse skeletal muscle and then regularly injected the animal with three times as much GDF 11 as Wagers had used. Instead of muscle repair, the group found that muscle damage worsened because the ability for self-repair had been inhibited (14). Clearly, more research is needed before human trials are initiated. As in all biology, too much of a good thing is not necessarily better.

Because of the lack of blood donors, scientists are looking into alternate ways of capturing the GDF 11 protein to perhaps create a drug (1). Thus, if scientists unearthed an effective method to increase the amount of GDF 11 in an older person's blood, their remaining lifetime would be more enjoyable and healthier. It is most important to clarify the misconception that this will eradicate aging; in fact, it can delay but not eradicate aging.

This work has significantly increased our body of knowledge of Geroscience. Other avenues of research include telomere lengthening, dietary restriction, and NAD precursors to enhance

mitochondrial function, among others. By attaining a better understanding of the process of aging and related diseases, more effective medications could be created, saving many lives, and improving the quality of life for our increasing senior population. It is estimated that by the year 2050 the senior population of the US will be over 88.5 million people. It is also estimated that the number of people afflicted with Alzheimer's will reach 13.8 million by the year 2050.

Imagine if all of these efforts can turn back the clock and Alzheimer's will no longer be a dreaded disease of old age. Although it may take a few years for this mechanism to be perfected, we are on the path to creating improved quality of life. While GDF 11 might not increase longevity and lifespan, it could make a substantial improvement to the quality of life of the aged. Perhaps Count Dracula was on to something.

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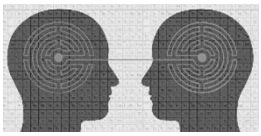
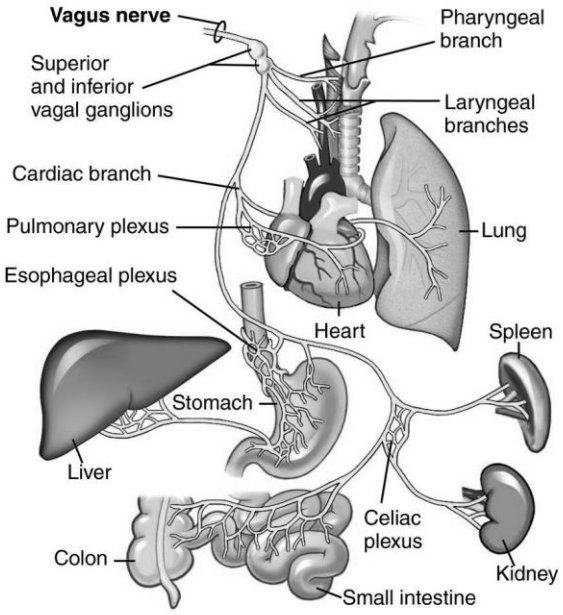


Esther Butler

WANDERLUST: VAGUS NERVE

Clutching his cane, the elderly gentleman groans in pain. He looks up to see grey clouds forming, humidity rising, explaining his swollen joints. Months ago, he stopped treatment for his Rheumatoid Arthritis (RA) due to the side effects, and his new medication is not effective. He longs to run after his grandchildren, and with vagus nerve stimulation (VNS), it may be possible.

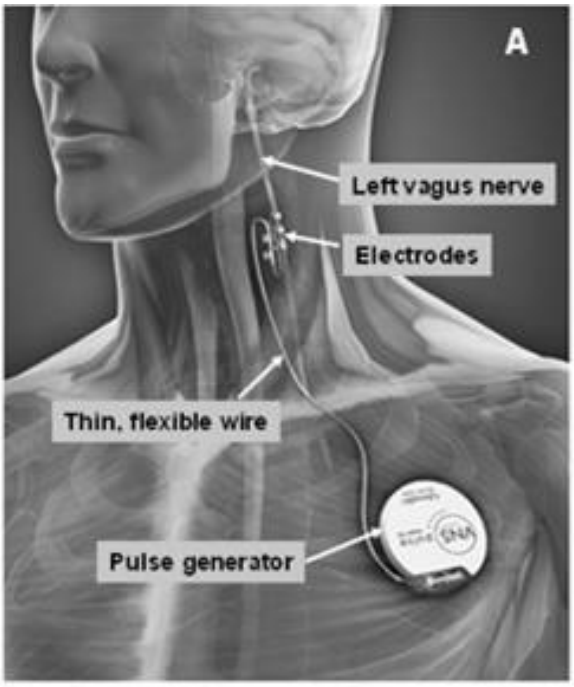
The vagus nerve is located in the neck, and runs from the brain stem until the spleen, spreading into the chest with thousands of nerve fibers extending to the heart, lungs, stomach, and other abdominal organs. It controls heart rate, and is involved in digestion, inflammation, immunity, and gag reflex (5). It is therefore appropriate for this nerve to receive the name "vagus", which is Latin for wandering (3).



One of the major accompanying factors of RA is inflammation of the joints. Use of VNS to achieve relief for RA began with a study of rat inflammation. A common method of studying inflammation is to chemically induce inflammation by injecting carrageenan into the hind paws of rats. In the year 2000, such an experiment was performed, and the rats given an anti-inflammatory drug experienced diminished swelling. During this study, it was observed that in the presence of this drug, the vagus nerve was more active. However, when the vagus nerve was cut, the drug was not effective in reducing the paw edema. This suggests the involvement of the vagus nerve in reducing inflammation (2).

The process of the vagus nerve sensing and responding to inflammation is called cholinergic anti-inflammatory pathway (CAP). CAP can be triggered by electrically stimulating the vagus nerve. Following vagus nerve stimulation (VNS), a reflex travels through the splenic nerve, resulting in a cascade starting with the production of the hormone norepinephrine. This causes T-cells in the spleen to produce acetylcholine and ultimately reduces cytokine production, the cause of inflammation. Thus, VNS reduces joint inflammation for patients with RA. Current drugs and treatments for RA are commonly rejected by some patients because of side-effects, reducing the effectiveness of the drug (2). VNS offers these patients hope for relief from the debilitating pain of RA and improved joint mobility.

In order to stimulate the vagus nerve, a device needs to be implanted or placed externally on the body. In 1990 an internal stimulating device was developed to treat illnesses as diverse as asthma, autoimmune diseases, Crohn's disease, and epilepsy. In 2011, VNS devices were implanted into four women and four men with RA. After 42 days of vagus nerve stimulation for one to four minutes a day, six of the patients improved by at least 20 percent, and two of these six were completely better (5). One year later, 100,000 vagus nerve stimulators were implanted. During surgery the device is tested to ensure that the patient will respond to the stimulation (2). Implanted devices have the advantage of automatic stimulation, however, it is more expensive than an external device, and if it needs to be replaced or removed additional surgeries are required (3).



Electrodes implanted onto the vagus nerve with an external stimulator.

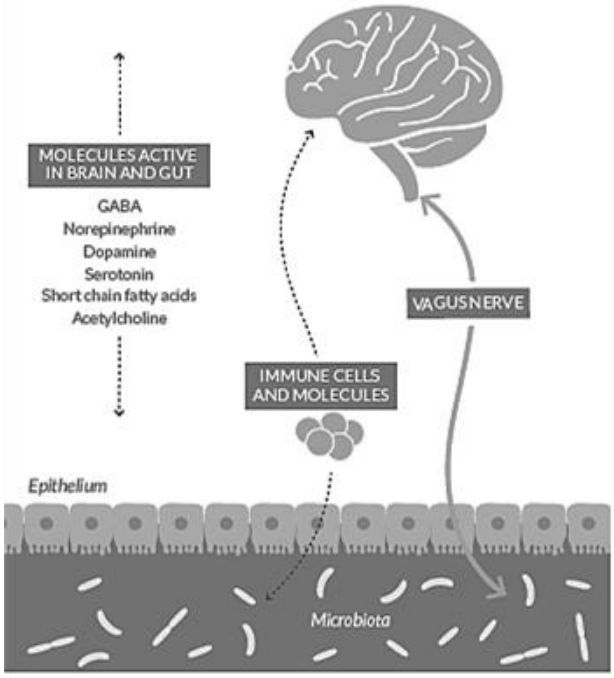
A common use of VNS is in patients with seizures. In 1997, the FDA approved implanted stimulators for those who do not respond to conventional therapies for epilepsy. In a trial following 59 patients for 15 years, the only side effects were found during times of stimulation and these included hoarseness, neck pain and coughing (5). The vagus nerve is stimulated to prevent seizures, since it connects to parts of the brain where seizures often originate. Since there are few pain fibers in this nerve, it allows for electrical stimulation to reach the brain without invasive surgery (6). With an external stimulator, a patient can add additional stimulation to avert a forthcoming seizure (3). This compares to other current forms of treatment for epilepsy with medications that are fraught with both short and long- term side effects. Another option for patients who have epilepsy originating in a defined portion of the brain, not involved in vital functions, is to have this tiny segment surgically excised to prevent future seizures (1). *For the application of vagal nerve stimulation in treatment of depression, see Rachel Jacobi in this publication.*

A different option is an external self-stimulator, which can be built into a smartphone case (3). When the patient needs to stimulate the nerve he places the device on his neck (5). High frequency signals are used to travel through the skin, as they do not elicit pain receptors. Around half of the frequency is absorbed by the skin, but it is still high enough to activate the vagus nerve. Since it is a handheld device, the voltage can be personalized and adjusted as needed (2). This stimulator has been approved in Europe and the U.S. Food and Drug Administration is currently reviewing the device. Another company is in the process of testing a stimulator to be placed on the ear, beneath the tragus, since part of the vagus nerve runs beneath the skin of the ear (5).

The field of VNS is expanding rapidly. To ensure that patients will benefit from the procedure, initially one should receive an external stimulator, and once it has proven efficacious, a patient can then have a device implanted (3).

This gives new meaning to the phrase, "Follow your gut instinct."

The function of the vagus nerve in a variety of conditions has expanded in recent years. In addition to the vagus nerve playing a role in epilepsy, it has also been recently found to be involved in the communication network between the ecosystem of symbiotic bacteria living in the gut, called the microbiome, which produce various mood changing neurotransmitters such as serotonin and norepinephrine, and the central nervous system. Scientists do not clearly understand exactly how these messages travel along the vagus nerve, but they know it is important. When the vagus nerve is snipped in mice, gut bacteria no longer have an effect upon behavior (4). These findings could possibly spawn a whole new generation of neurological interventions for conditions that so far have been so resistant to traditional pharmaceuticals. Imagine instead of popping Prozac, you could just eat your yogurt that has been enriched with a specifically designed cocktail of bacteria, or better yet, eat food that will not only feed you, but feed your "feel good" bacteria. This gives new meaning to the phrase "follow your gut instinct" and definitely warrants further investigation.



Meanwhile, back to our opening vignette. His grandson throws a ball and our elderly gent races, making a perfect catch. He pulls out his iPhone taking a selfie with his grandson, treasuring this moment. He holds his phone, containing more than his contacts and pictures; it is cased with a stimulator that gave rise to this joyous occasion.

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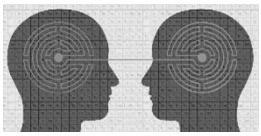


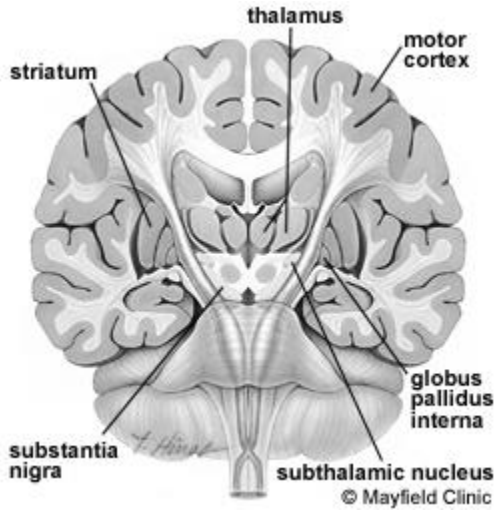
Estee Gerber

NOVEL INTERVENTIONS FOR PARKINSON'S DISEASE

He died too soon at the early age of 76. Not from natural causes, but from a disease that is the "14th leading cause of death in the United States" (10). First, he noticed tremors on one side of his body, so he stopped his weekly tennis outings. Then, his posture began to resemble the old men from his late grandfather's old age home. It became harder for him to go to work every day. He started having tremors on both sides of his body, which was a source of great embarrassment during his marketing meetings. He moved progressively more slowly and soon it became too difficult to get out of bed. During the last stages, he was confined to his bed, alone with his aid (1). On the morning of July 17, 2013, he passed away in his bed. Cause of death: Parkinson's Disease (PD).

Parkinson's Disease is a neurological progressive disorder. Statistically, men have a 50% greater chance of developing this disease. The average age of diagnosis is 60, however 4% of people with PD get diagnosed before the age of 50 (3). PD can be caused by Lewi bodies in brain cells, genetic mutations, loss of norepinephrine, environmental toxins etc. However, it is the loss of dopamine (DA) producing cells deep in the substantia nigra that results in the typical clinical symptoms such as poor balance, tremors and poor control of movement.

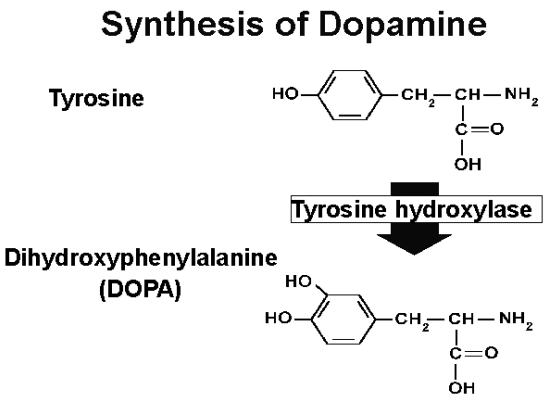
The death of these cells initiates a domino-like cascade of events starting with reduced DA available for neural transmission in the corpus striatum, leaving most of the dopamine receptors unstimulated (2). For reasons unknown or unclear, this leads to over-stimulation of the subthalamic nucleus (STN) which then blocks the globus pallidus interna (GPI) and causes the rigidity and the poor motor-use symptoms of PD. The over-stimulated GPI causes an over-inhibitory response on the thalamus, resulting in a decrease of thalamus secretions and then tremors (4).



Mild PD can be categorized by movement symptoms on one side of the body or a change in walking, facial expressions and walking. Moderate PD is when symptoms progress further and cause movement symptoms on both sides of the body and trouble with coordination and balance. Symptoms that continue to progress to advanced PD cause cognitive defect and usually patients are unable to walk and move (1). Symptom advancement and development is caused by a further loss in level of dopamine (5).

One of the most common treatments of PD is L-Dopa. L-Dopa is created by the biosynthesis of the amino acid, L- Tyrosine. It is a precursor to many neurotransmitters including DA. DA is unable to cross the blood brain barrier, but L-Dopa can.

Therefore, L-Dopa taken orally allows a small amount of the L-Dopa to cross the barrier and then increases the dopamine levels, thereby reducing PD symptoms for a short while. The issue is that L-Dopa is metabolized by aromatic L-amino acid decarboxylase (AADC), which also exists in the peripheral nervous system. Consequently, the majority of the orally administered L-Dopa will be converted into dopamine in the peripheral nervous system instead of in the brain. To prevent the conversion of L-Dopa into dopamine outside of the brain, L-Dopa is taken with Carbidopa which inhibits the action of AADC in the peripheral nervous system. However, orally given L-Dopa will eventually reduce the amounts of naturally made L-Dopa and after taking it for 5-10 years, result in dyskinesias, which causes tics and involuntary muscle movement. This makes it difficult to control voluntary movements (7).



There is however hope on the horizon for suffers of PD in the protein Bcl-2. It prevents apoptosis by interfering with action of apoptotic proteins such as BH3 (9). Apoptosis is cell suicide and certain proteins are able to induce or prevent apoptosis. Insertion of Bcl-2 into the substantia nigra of people with PD may offer an alternative therapy to L-Dopa by halting death of dopamine producing cells, returning dopamine levels to normal, and ultimately ending motor and movement symptoms. Also, Bcl-2 will be able to directly halt the progression of neurodegeneration, unlike pharmaceuticals. Bcl-2 will cause little to no side effects, unlike L-Dopa.

There is one caveat however. In order to be effective, the Bcl-2 would need to be administered to people who have PD, but whose DA cells have not yet started to die, because once initiated, apoptosis cannot be reversed. Since their symptoms would not yet have appeared, they would be unaware that they are candidates for this treatment. Five to twenty years before symptoms for PD start to appear, patients begin to lose dopamine producing cells. People with a first degree relative with PD have a 4-9% chance higher of developing PD so they would be likely candidates (3). Additionally, 80% of patients will complain of loss of smell, constipation and acting out in dreams before the onset of clinical symptoms of PD (6). Men and women who claim to struggle with all or most of these indicators most likely have PD, but their symptoms have not started yet.

Other ways to find such people is by using a DAT (which measures levels of the dopamine transporter), a PET scan, or a Unified Parkinson's Disease Rating Scale (UPDRS) (8). Also, a blood test that shows increased levels of the protein alpha-synuclein, which is released in groups before symptoms appear, would be an indicator for whether someone will develop PD and would be a candidate for Bcl-2 injections.

By inserting Bcl-2 into patients who have not yet begun to experience symptoms, we may be able to slow or maybe even stop the clinical symptoms that destroy thousands of lives every year. PD affects more than 1 million Americans and 7-10 million people worldwide. Every year, 60,000 Americans are diagnosed with PD (3). Parkinson's is a disease that is catastrophic not only for its victims, but also for their loved ones. It is incredibly difficult to watch any human undergo such a transformation to the point where they are unable to function independently and maintain a quality of life. PD is degenerating, devastating and deadly, but by collaborating and putting ideas and minds together, symptom relief and even reversal could be discovered in the future and we would be one step closer to creating a better, safer, and happier world for future generations.

It is incredibly difficult to watch any human undergo such a transformation.

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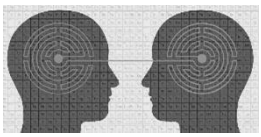


Gabrielle Hawk

GUIDING LIGHTS

When medical students learn the anatomy of the body, they study colorful charts with red arteries, blue veins, and yellow nerves. However, in real life tissues are varying shades of pink and red, and oftentimes it can be hard for surgeons to distinguish between the tissues they are working on – especially when it comes to cancer. This creates a steep learning curve for medical students to surmount before their knowledge can be applied in surgery.

Even once a surgeon has identified the cancer, he still has a lot of work ahead of him. He must work carefully to remove it and leave surrounding tissues intact. After the surgeon removes as much of the tumor as he can, he sends a sample of surrounding tissues to a pathologist to check for any residual cancer. It can take up to twenty minutes for the pathologist to go through each specimen, and so the surgeon, nurses, and anesthesiologists often wait for about an hour while the patient remains on the operating table. Quite often, the pathologist advises the surgeon to re-enter the patient because some residual cancer remains on the tissue. The surgeon will then send additional specimens to the pathologist and repeat the process until s/he is confident the cancer is removed.

Despite the long time spent in operation, surgery is typically the most successful method of getting rid of cancer. Once the cancer is removed, the patient is healed. However, doctors must keep an eye on metastatic sites post-surgery to watch out for recurrences. Recurrences are common for many cancers since it is difficult to know for sure when every cell of cancer was removed. For example, malignant glioma cancers have a recurrence rate of 80% and breast cancer has a recurrence rate of about 30% after conservation surgery. Doctors will often check the Sentinel Lymph Nodes – the lymph node that drains first in the cancer – to check the metastases. This is used particularly in breast cancer as a way to circumvent the need to excise nodes that are hard to reach. This still requires a surgery to remove the sentinel lymph node for ex vivo pathology tests, and quite often a pathologist will even find residual cancer while reviewing the final specimen a few days after surgery. Now the doctor must bring back the patient that had thought he was cured for additional surgery or treatment such as chemotherapy.

What if there was an easier way for surgeons to distinguish cancerous cells from normal tissue, in vivo?

So many complications arise with cancer and surgery in general. What if medical students could transition more easily into the performance of real surgeries? What if there was an easier way for surgeons to distinguish cancerous cells from normal tissue, in vivo? What if surgeons could remove the entire tumor in the initial surgery and reduce the risk of recurrence?

A recent solution to these problems faced in cancer surgery is fluorescence guided surgery (FGS). Fluorescence guided surgery is the insertion of fluorescent molecules that target cancer cells to illuminate them. The molecules contain fluorescent dye and are made up of three main parts. A polycation gives the molecule "stickiness" so that it can bind to cells. A polyanion acts like a backing to

the "sticker," so that the molecule will not stick to every cell in the body. The polycation and polyanion are bound by a third molecule that can only be cut by a specific enzyme, such as a protease enzyme found only in cancer cells. When the molecule is injected into a patient, it is cut by the enzyme found only in cancerous cells, and the polycation is able to stick to the cancer cells. The fluorescent dye attached to the polycation is then released into the cell to light it up.

Aside from identifying cancer cells, similar three-part molecules can be synthesized to stick to nerve cells or other types of tissues. This is extremely important in prostate cancer where there are tiny nerves that generally grow into the tumor but cannot be seen. Approximately 60% of men who undergo prostatic surgery experience nerve complications, as surgeons follow the path of the known anatomical structure of the nerves, but the structure is not entirely known. It is still being elucidated and the tiny nerves that are often embedded in the cancer cannot be seen. With FGS, the nerves can be lit up so the surgeon knows exactly where to make incisions to excise the tumor.

Fluorescence lights up through the emission of energy from chemicals in the dye. When light hits the chemicals, the electrons absorb the energy and jump to higher energy levels. The electrons are unstable in these higher energy levels, and so they stabilize by releasing energy in the form of light. Different chemicals have different absorption and emission spectra for light, and therefore they are perceived to be dyes of different colors.

For the dye to fluoresce, it must absorb a light wavelength with a higher energy level than the dye. This is because the electrons emit a small amount of energy through vibrations as they fall a couple of energy levels. Only afterwards do the electrons jump down to a much lower level and emit light. If the light has an equal or lower energy than the atom, the electrons will not jump to higher energy levels and emit light.

Unlike the popular belief, the fluorescent chemicals do not require UV light to be seen. Any light that has a higher energy than the spectra of the specific dye used will cause the dye to fluoresce. For surgeons, this means that they do not have to subject their patients to the potential harm of UV light during surgery. Rather, the operating rooms can have some blue lights that have high energy levels and can be switched on during FGS.

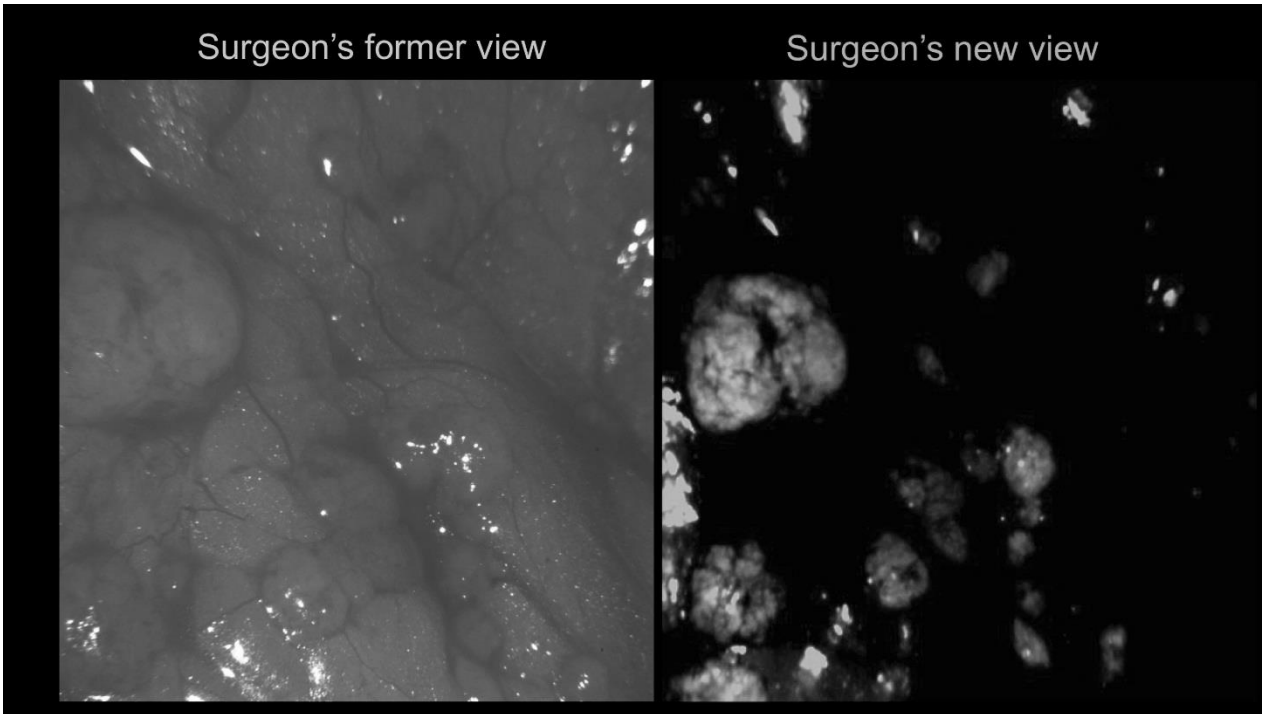
One advantage fluorescence has, besides its ability to be seen by the naked eye, is its ability to penetrate tissue. A tissue that fluoresces can be seen even if it is covered with normal tissue. This specific property of fluorescence enables surgeons to know where exactly the cancer is even if it is not on the top side of the tissue.

FGS is a major breakthrough in operating technology. Light has always been an important part of surgery. The body is dark inside so surgeons have to illuminate it in order to work. This is why surgeries have traditionally been in the early morning hours – to take advantage of sunlight. Operating rooms also used to be on the top floors of buildings where skylights could be installed to let in light for surgery, such as in Mass General Hospital. With the invention of the light bulb, and many subsequent types of light bulbs, operating room have been lit with white light. With the invention of the light bulb, (*See Rachelli Brunner in this publication)* and many subsequent types of light bulbs, operating room have been lit with white light. The idea of fluorescence guided surgery adds another dimension of light that enhances the surgeons' vision.

FGS has also proven to reduce the positive margins—the amount of surrounding tissue with lingering cancer cells—since each individual cell is illuminated and can be excised. Positive margins are actually quite rare when FGS is used. FGS also reduces the amount of time that a patient is in the operating room as the surgeon generally does not need to send more than one specimen to the pathologist to be sure that the entire tumor is removed. Additionally, it can prevent harmful incisions on the wrong kind of tissue and illuminate tumors hidden beneath normal tissue. Finally, FGS can reduce the learning curve necessary for a student to perform a surgery because the different organs and tissues can be color coded. Perhaps one day in the near future the surgeon will perform surgery on patients' whose bodies light up like the diagrams in a textbook and human anatomy will be color coded across the world.

There is a concept in Judaism that everything in the physical world is a parallel to something in the spiritual realm. Just as there is a molecule that can be inserted into the body for guidance, so too, Hashem gave us all a guiding light. The first thing Hashem created was אור, and the Passuk says, "וירא את האור כי טוב" – The light, or revelation, was good. When good is revealed, we can see the קדושה. קדושה is our אור. If קדושה is hidden, then the world becomes a dark and confusing place. Only light allows us to see the beauty of the world.

Hashem created the world to have שכינה גלוי, He wanted us to be able to see Him and all the good in the world. However, we can only have בחירה if we live in darkness. If all of the קדושה was revealed to us, there is no doubt that we would all follow *Hashem's* Commandments. This is why the תורה begins with the letter ב. If we look behind the ב, we can find אור א. If we just look a little bit past the



View of localized region in peritoneal cavity of an ovarian cancer patient as seen with the naked eye (left) or with the aid of a tumor-targeted fluorescence dye (right).

darkness of the world, we can find קדושה everywhere—but we must CHOOSE to look. And when we look, we can find קדושה in both the world and in the תורה.

After every day of Creation, the Passuk notes that *Hashem* saw everything כי טוב—this is the same phrase used to describe the אור. This means that every day Hashem pulled some ניצוצות קדושה, some sparks of קדושה, from the אור/ קדושה of the first day. The כלי יקר notes that the sun, moon, and stars are called מאורות – מן האורות. They were created from the קדושה of the first day.

We see from בראשית that everything physical has קדושה. In the days of משיח, the כליפה that covers the קדושה will be taken off and we will be able to see the קדושה of everything physical. Even such physical items as stones will be screaming to be used for something holy. The *Gemara* tells us that even the fruit will warn people not to be מחלל שבת by accidentally leaning on a fruit tree.

We can also find קדושה in the תורה. תורה is called אור. We have four levels of learning תורה to achieve clarity: פשט, רמז, דרש, סוד. The פשט is not always so clear, in fact it sometimes seems to contradict itself. The deepest level of סוד, however, lights up the תורה with clarity. סוד shares it meaning with רז which has the same גמטריא as אור (207). The אור החיים explains that two words with the same גמטריא must have a connection. So what is the connections between רז and אור? He continues and explains that when we learn על פי סוד/רז, everything becomes clear and lit up. It allows us to see *Hashem* clearly and see the קדושה.

Artificial light only exists when it is connected to a power source. In contradistinction, the light of קדושה is always there even when we do not see it. Just like we all know that wifi exists even if it is invisible, so too קדושה exists even though it too is not visible. It is hidden. The only difference between גלות and גאולה is the letter א – when משיח comes, the אור will be fixed in place and will enable us to see the קדושה in everything physical in the world.

All we need is to use our בחירה to reveal *Hashem*—if we can just reveal the א, we can bring the world to גאולה

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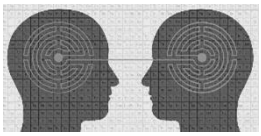


Rachel Jacobi

THE LIGHT AT THE END OF THE TUNNEL

Imagine Sally, who has spent almost sixty years of her life in a perpetual state of depression, and has *twice* come to the brink of suicide. Now imagine a magic bullet for this woman, something that will fully cure her and allow her to live a life that she, like every person, deserves. Karl Deisseroth, a leading neuroscientist in the newly emergent field of optogenetics, has come mighty close. He implanted a device in Sally's collarbone that sends burst of electricity to the vagus nerve about every 5 minutes. This results in the depression and darkness draining from Sally, leaving her feeling as cheerful as the next person (3). The brilliance of this device leaves us with the question: what is optogenetics, whose science and rapid development allowed for Sally's relief?

Optogenetics is defined as control over specific events within specific cells of nervous tissue, by applying the tools of genetic engineering and optics. A set of genes for light sensitive receptor channel proteins (opsins) are inserted into a targeted neuron and when expressed, opsin makes the neuron "light-obedient." This means that when exposed to light, the channel proteins will open to allow the passage of ions into the cell and the neuron will be activated. The neuron will now transmit signals when exposed to light (6). This tool within neurons gives scientists a level of precision that was previously unachievable, due to the complicated nature of the mammalian brain, which contains tens of billions of intertwined neurons, each with its variety of neurotransmitters (biochemical messengers). This only scratches the surface of the brain's complexity (5).

Francis Crick, in a 1979 *Scientific American* article proposed that the primary problem to solve in neuroscience was the ability to control one cell, or one type of cell in the brain, without altering another cell. Switching neurons on and off using great temporal precision would help scientists understand how neurons relate to one another to control behavior. Electrical stimuli and drugs do not have this level of sensitivity and therefore cannot achieve this, but Crick speculated almost twenty years after his original conjecture that light might just be the control tool to achieve the cellular specificity that drugs and electrical stimuli lack (5).

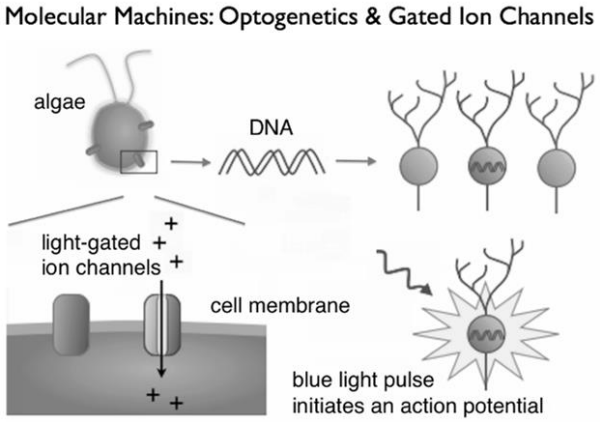
This work contained the key that Crick and the neuroscience community needed to unlock their problem.

In 1971, Walther Stoeckenius and Dieter Oesterhelt, working at the University of California, discovered that photons of green light activated bacteriorhodopsin, a protein produced by a family of halophilic (salt-loving) bacteria that acts as a single-component ion pump. This is the basis for generating action potentials in neurons, and how photoreceptors in the mammalian eye work. This work contained the key that Crick and the neuroscience community needed to unlock their problem. If the genes for expression of photoreceptor proteins could be introduced into neurons, then targeted neurons could be made to fire when exposed to light.

A few years later, the first demonstration of how photoreceptor proteins could control neuroactivity was provided by Gero Miesenbock. He genetically engineered a virus to act as a vector to carry the

gene for the photoreceptor protein and insert it into cultured cells. When these cells were exposed to light, the neuron would fire! It was through this breakthrough that optogenetics was born (1).

The usefulness of this discovery was improved upon by two graduate students at Stanford, Karl Deisseroth and Ed Boyden. They transmitted channelrhodopsins (ChR2 gene) into cultured neurons and once it was inside, they projected beams of light onto the cells and the target cells began to respond immediately. They were able to carry out Cricks initial proposal; by pulsing the light, they controlled the neuronal activity. Deisseroth and Boyden continued to see if this could work in animals (the first experiments were in vitro). An impossibly small optical fiber was planted in the part of the brain that hosts the motor neurons controlling the mouse's whiskers. When a blue light was turned on, the mouse's whiskers moved!



Deisseroth's treatment activated these cells using flashes of light delivered through fiber optic wire. This treatment allowed for the direct manipulation and controlling of specific cells' behavior. Numerous new opsins have been discovered that respond to different colors of light. Some respond to infrared light as well, which is beneficial since it penetrates tissue and eliminates the need for practices such as implanting optical fibers. A recent study shows that optogenetic methods were able to reduce anxiety in mice. A light sensitive neuron was created in their amygdala, and a single flash had the effect of the mice moving to the center of their home cage and away from the walls. (1).

So far, humans have not been subjects of optogenetic studies, but there are many avenues being explored that have the potential to change thousands of people's lives. Optogenetics holds much promise for the recovery of vision. Experiments on mice with a photoreceptor deficiency have showed that their retina regained photosensitivity. Light treatment on humans suffering from certain blindnesses would be a major improvement to the current unsatisfactory method in which photosensitive chips are implanted in the human eye (6).

Parkinson's disease (PD) can be currently treated through drugs, or Deep Brain Stimulation (DBS). (*See Estee Gerber in this publication*.) While the results of the DBS treatment, in comparison to drugs, have been quite impressive, DBS still contains a few flaws. During this treatment, parts of the target area are not under perfect control; the optogenetics method would offer greater precision. The targeted structure in the brain would be activated via light sources without any of the side effects that DBS can bring. This can hold true not only for PD, but perhaps for Epilepsy as well, because both Epilepsy and PD affect only certain areas of the brain's cortex (6).

There can be much progress made with neurological diseases such as Sally's because the advantage that the precision of light stimulation provides much potential for neurotherapy. Imagine the possibilities for Sally and people like her, if they did not have to go through the difficult process of electrically stimulating a vagus nerve (*see Esther Butler in this publication*), but could instead have a

light turned on to fix any neurological problem. People suffering from blindness would have drastically improved chances of gaining their sight through more effective technology. Patients with Parkinson's disease, or even Epilepsy, would have much greater chance of improved quality of life with a treatment that holds such great levels of precision.

Who would have imagined the tricks we could learn from a tiny, "simple" bacterium.

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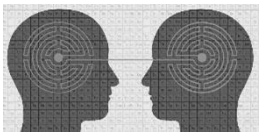


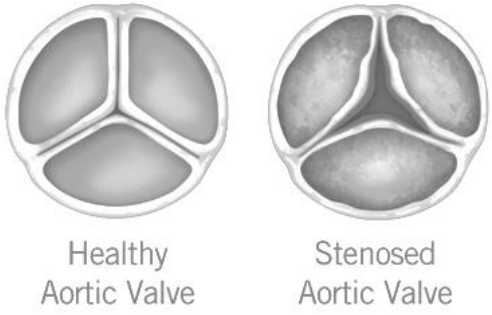
Esther Malka Laub

MENDING A BROKEN HEART

Imagine you are at work typing on your computer when you feel a strong chest pain. You recently felt it during your weekly gym class, but today is the first time you feel it while performing minimal activity. As you get up from your chair, you feel a sudden dizziness and a shortness of breath. Moments later, you are sprawled out on the floor, unconscious. Oh, and I forgot to mention, you had aortic valve replacement surgery thirty years ago, and like thousands of other people worldwide who had a valve replacement, yours just malfunctioned.

Some things in life are innate, others are developed over time. My love for cardiology is definitely inborn. Although I cannot pinpoint when I started saying "cardiologist" or when I began to collect newspaper clippings about the heart, I do know that when *The Wall Street Journal* published an article entitled *Clot Risk in Heart Valves*, on October 5, 2015, I not only made the article a part of my collection, but also internalized the intensity of the situation at hand, or in the heart.

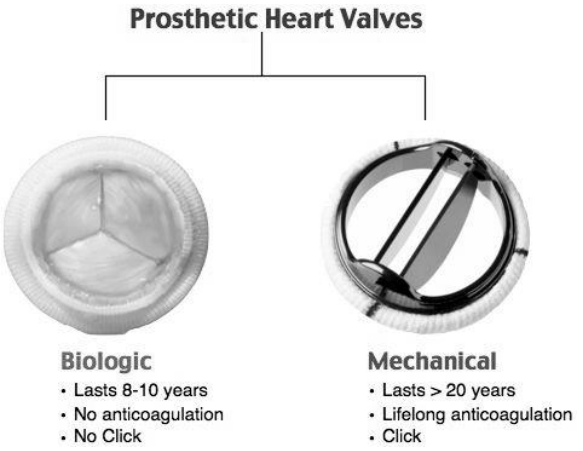
The Food and Drug Administration and



cardiologists have been warning patients that aortic valves from animal tissue can develop tiny blood clots, causing the valves to malfunction. These findings were shocking, as the valves have been used in patients with malfunctioning valves for three decades. The worst part? Cardiologists have no idea what to do for their patients (1).

Prosthetic heart valves have been used since the mid-1960s. They are broadly divided into mechanical heart valves (MHVs) and bioprosthetic heart valves (BHVs). MHVs are made of synthetic material including polymers, metal, and carbon, whereas BHVs are made of biologic tissues which are mounted on a fabric covered plastic frame, called a stent. MHVs are more durable, but their need for long-term anticoagulant therapy make them unsuitable for older patients. In contrast, BHVs are safe to implant because they are functionally similar to the native valve, they do not require long-term anticoagulant therapy, and are therefore, associated with reduced risk of hemorrhage (2).

Many tissues and different animal species' aortic valves have been tried with varying results. Today, the most commonly used BHVs are those from pig aortic valves and calf pericardium. While the use of either one may be guided by patient age and other considerations, the United States and Europe have mostly used tissue rather than mechanical valves (2).



Why is there suddenly an issue? No one is sure. Cardiologist Eric Topol said that the idea that such a finding could emerge after so many years is "remarkable." Moreover, Topol said there has always been an "accepted dogma" that BHVs lead to less clotting, and therefore, the issue was never investigated (1). So what are patients with malfunctioning valves supposed to do? As of now, there is no solution to this particular issue, however, there are many new advancements in medical technology that may result in finding a solution to the problem.

In October of 2009, Eric Topol spoke at a TEDMED event. He predicted that by 2016, doctors would no longer use stethoscopes, rather, they would use smaller and better forms of technology via mobile devices. As Topol said: "…The future [is] wireless, medical devices." Topol anticipated that one would be able to monitor all vital signs including heart rate, blood pressure, oxygen level, and temperature from a smartphone. Additionally, if a woman is expecting, she can monitor the fetus' heart rate. This is all possible by using technology that is wired, or wireless, from the intensive care unit to a smartphone. The goal: to keep people out of the hospital, or as Topol said, "the most expensive bed in the world" (3).

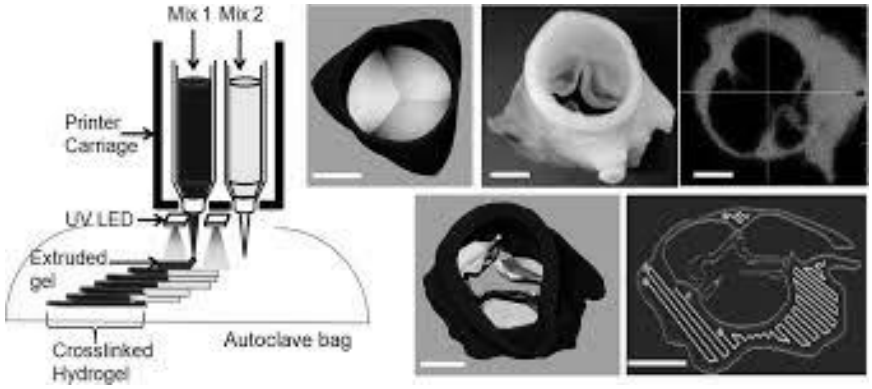
One would be able to monitor all one's vital signs from a smartphone.

The stethoscope may be replaced, but by what? GE created a handheld ultrasound which is as small as a phone. That means that not only will it be easier to handle (as opposed to the huge machines that are widely used today), but the ultrasound can also be easily transported to patients worldwide, and results can be sent to any phone across the world. Additionally, technology allowed us to replace the Holter Machine, a portable, 24-hour electrocardiogram machine that is hooked up to the patient via wires, with a little patch that can go over the chest. It is a lot neater, and a lot more effective, as the patient can wear the patch for two weeks. It not only measures cardiac rhythm, but also heart rate, fluid status, temperature, respiration, and oxygen levels (3).

Although these new technological devices will be helpful in monitoring the heart for possible issues, they cannot prevent the issues from taking place, nor can they fix them. Fortunately, scientists have been working diligently on the 3D printer which, since last year, has printed bone, ear cartilage, skin, blood vessels, and a heart valve (4). The heart valve was created by Jonathan T. Butcher, an associate professor of biomedical engineering at Cornell University. Butcher's team constructed the valve by using computer-assisted manufacturing blueprints that allowed the bioprinter to deposit ultra-thin layers of living cells, including smooth muscle cells and valve interstitial cells, upon each other, following a precise geometric pattern that matched the heart valve dimensions. A dual-syringe system was used to mimic the structure of the valve root and leaflets, two key valve structures. The team successfully

created living aortic valve conduits that strongly resembled a functioning valve (5).

While Butcher's valve is a huge advancement both in the 3D printing and the medical fields, only one issue remains: Butcher's valve was made from living cells, which could ultimately be rejected by the patient's body as any prosthetic or biological replacement could be. However, in the future, I hope that my passion for cardiology will allow me to use a patient's own stem cells for printing so that their body will definitely accept the replacement valve, allowing them to return to the office, and their weekly gym class, together with the thousands of people worldwide who have had a valve replacement.



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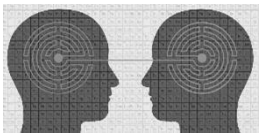
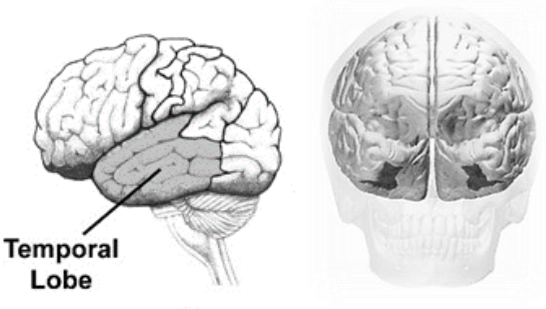


Devorah Pinczower

MOZART ON THE MIND

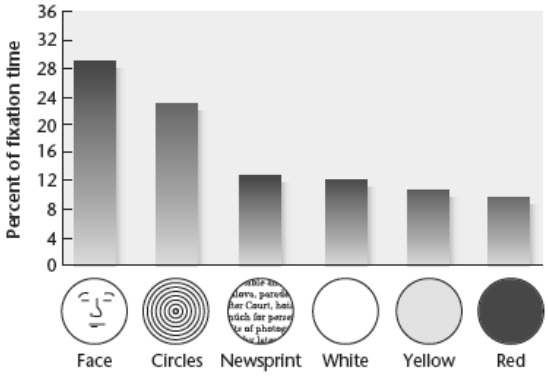
Jessica walks into the preschool down the block. Her eyes scan the room, but she cannot seem to find her daughter. A child is tugging at her skirt calling her "Mommy," but she has no idea who that child is. She knows she dressed her daughter in the identical outfit this morning, but she does not recognize the face. Jessica suffers from prosopagnosia, a neurological condition that results in the inability to recognize faces. While devastating for sufferers, research into prosopagnosia helps to advance our understanding of how the brain functions as an integrated unit despite the fact that it is divided into areas specialized for unique functionality. Furthermore, research into prosopagnosia might lead to relief for Alzheimer's patients who also have trouble recognizing faces of loved ones.

While most regions in the brain can perform multiple functions (such as music and spatial reasoning, discussed later in the paper), evidence demonstrates that the function of face perception is exclusively processed in its own area. This finding is termed the face specificity hypothesis (1). The fusiform gyrus (a fold in the cerebral cortex), located in the inferior (lower) temporal cortex (*see figure*), has been highly implicated in facial recognition. When it is damaged, prosopagnosia results.



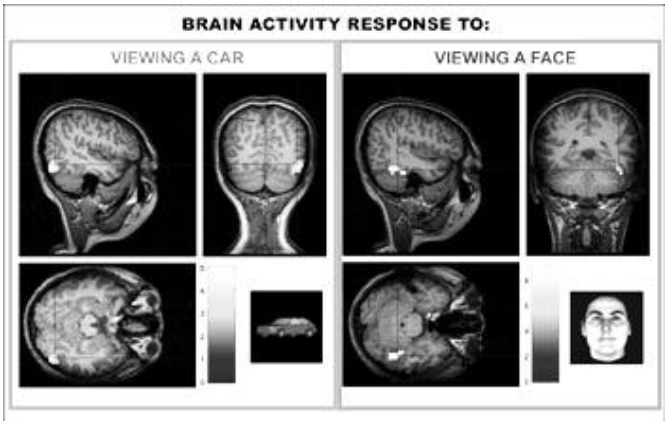
Fusiform Face Area (11)

People with prosopagnosia can read, so their issues have nothing to do with vision, and they can recognize voices, so it is not related to memory either (3). It should come as no surprise that the human brain has an area exclusively devoted to recognition of faces given the fact that human newborns are predisposed to pay more attention to faces than other stationary displays (20).



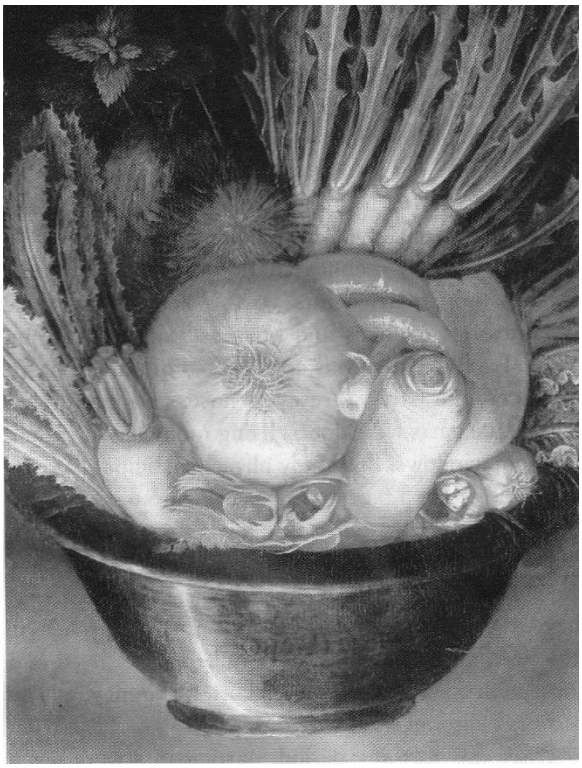
In the 1990s, PET scans showed activation in the fusiform gyrus when face stimuli were shown, particularly on the lateral (away from center) side of the mid-fusiform gyrus. This specific area is called the fusiform face area (FFA), and can be observed through functional Magnetic Resonance Imaging, fMRI (1) which measures increased blood flow and glucose uptake in the brain. This shows which parts of the brain are more active while performing certain tasks (14). Experiments have proven that the FFA plays a part in face identity, meaning a person can recognize a specific individual. Proof of this phenomenon is that the area affected by prosopagnosia is very close to the FFA area, as both are in the fusiform gyrus (1).

The hypothesis that face perception is perceived in a separate area from object perception has been proven through patients with prosopagnosia. Some patients with prosopagnosia have been able to identify objects, but were unable to recognize faces, different areas of the brain (1). This hypothesis has also been supported through fMRI studies with monkeys which showed that there are face selective areas in their temporal lobe as well. In a recent experiment, Tsau aimed electrodes that measure electrical stimulation, a feature of all neurons, at face selective areas of the cortex, and 97% of the cells that were responsive, suggesting that the two functions are performed in only responded to faces, not objects (1).



Object vs. Face Perception (17).

Further proof that the location for object recognition is different than for facial recognition is through their different mechanisms. The inversion effect shows that the decrease in activity when the stimuli are turned upside down is greater with faces than with objects. In addition, with the part-whole effect, subjects are able to better identify which two faces have the same body parts when they are on the face than when the parts are shown separately. This proves the holistic hypothesis which states that faces are processed as a whole, not by their individual parts. The holistic hypothesis does not work with objects. Because facial recognition and object recognition are processed differently, it can be inferred they must be located in different areas of the brain (1).



Face Inversion Effect-turn the page so that this picture is inverted; you will notice that your brain processed it differently (15).

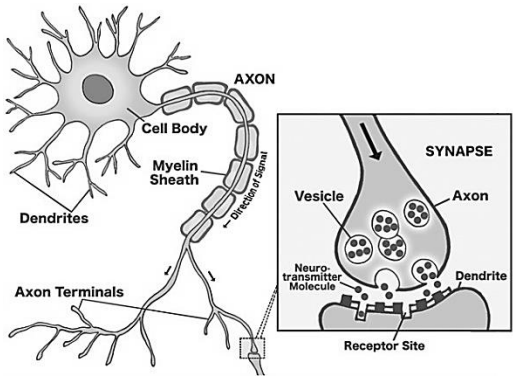
After listening to Mozart, test subjects performed 8-9 points higher on IQ tests.

Are there any tricks in the modern neurologist's tool kit that can ameliorate the damage of prosopagnosia? Sadly, there are no medications (which usually are associated with nasty side effects) or surgeries that can offer sufferers relief. However, there just might be something, which on the surface seems rather benign and unlikely, but if proven to be effective, would have no downside and would be pleasurable to boot. That something is called the Mozart Effect. Rauscher discovered the

phenomenon where listening to Mozart music enhances one's spatial reasoning abilities. After listening to Mozart for at least 10 minutes, test subjects performed an average of 8-9 points higher on their IQ tests as measured by the Stanford-Binet scale (2) which measures multiple types of reasoning, knowledge, and processing skills (16).

PETs and fMRIs have shown that music is processed in many areas of the brain, including the prefrontal, temporal and precuneus regions, which are also areas activated by spatial reasoning tasks. This overlap suggests a possible mechanism of how listening to music affects spatial reasoning abilities (2). Furthermore, the benefits of listening to Mozart, as compared to other composers, was higher in epilepsy patients and individuals with autism (2, 5). Studies done in Ursinus College have shown that when Alzheimer's patients listened to Mozart, their spatial reasoning increased as measured by an increase of EEG signals (6).

Hughes discovered that Mozart music has repetition about every 30 seconds. It has been demonstrated that synaptogenesis during development increases in enriched sensory environments and that repetition of the stimulation causes a strengthening of synapses already formed. Repetitive stimulation causes more and stronger synapses to be formed consequently, and communication between neurons is enhanced (6).



A typical neuron highlighting the synapse (18).

It was previously thought that symptoms of Alzheimer's disease were caused solely by the accumulation of Tau protein in the neurons, which coagulate into plaques and tangles which ultimately results in cell death. While that is still true, recent research has uncovered that the immune central nervous system cells, called microglia, start to attack the synapses, causing them to shrink and die, further weakening neural connections. Not only are there fewer neurons in Alzheimer's patients, but the neural connections are weakened as well. These are the same microglia that are active for the first few years of life during synaptic pruning, and is a key process in neural development (7, 19). *See Kayla Samet, "Synesthesia," in this publication.* Perhaps Mozart affects Alzheimer's patients because it is a repetitive sensory stimulation and will therefore help with the formation of new synapses to replace the connections that were lost due to the disease and strengthen the synapses that remain (10).

Since the temporal lobe is where the fusiform gyrus, implicated in facial recognition, is located and where the perception of music and spatial reasoning are also processed (3), one can hypothesize that the Mozart Effect could also improve the ability to recognize faces. This speculative hypothesis has been generated by the author and has not been tested, but is worthy of preliminary trial. If the association can be demonstrated, then this could offer relief for patients with prosopagnosia. Because they have difficulty in recognizing faces, listening to Mozart will help increase blood flow into the FFA, thereby activating the fusiform gyrus. Another patient population where this effect could be extremely beneficial is Alzheimer's. Patients with Alzheimer's exhibit difficulty with recognizing faces of family members. Because it is demonstrated that Mozart improves spatial reasoning in Alzheimer's patients,

it is altogether possible that it will also help them with facial recognition.

If this hypothesis proves to be correct, Jessica, and many others who suffer from prosopagnosia or Alzheimer's will once again be able to recognize their friends and family. Imagine her relief if she could recognize her daughter's face from the crowd when she picks her up from school. Who would have thought that something so simple might be just what the doctor ordered.

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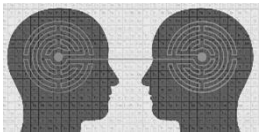


Rachel Retter

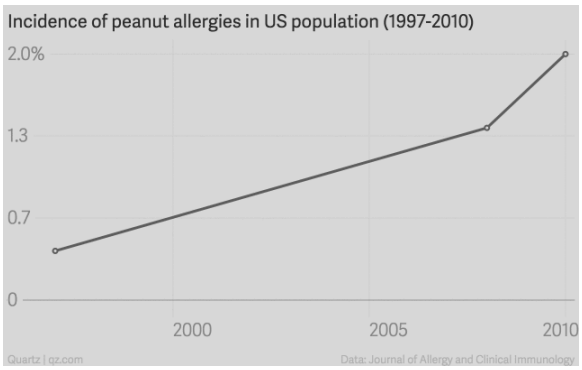
THE BAMBA EFFECT

It seems that lately everybody in the world knows about food allergies. Maybe they have watched their friend pull out a foil-wrapped sandwich when the school was serving a meal they could not eat, or maybe they saw their schoolmate run from the room to avoid breathing in the "toxic fumes" of a Reese's Peanut Butter cup. Maybe they themselves have an allergy, or maybe it is their brother, sister, mother, or neighbor who are the ones limited in what they can safely eat for lunch. Either way, allergies are a commonly known phenomenon throughout society. They are a widespread issue, affecting people's lives around the globe.

Sufferers of food allergies face difficulties and dangers every day. They must take great care to avoid foods that are often necessary in the most basic recipes, such as dairy, nuts, fish, and eggs. For some, it is enough to avoid ingesting the food; however, for many it is dangerous, or even fatal, to touch or smell them. Reactions can include difficulty breathing or swallowing, swelling, cramps, and vomiting, and range from painful to deadly (1). More often than not, it is possible to live a normal and healthy life despite these issues. However, a large collection of patient reports show that allergies are not merely an annoyance in the patient's day. They are a chronic burden which causes both practical and emotional difficulty. Data show that the constant medication and necessary lifestyle changes resulting from food allergies can lead to "anxiety, tension, irritability, and an unsatisfactory social life" (5).

Epidemiologists (public health experts) have strived to find ways to approach this global issue, but it has not been simple. First they needed to answer some basic questions in order to find out what they were dealing with. For example, how many people had allergies? How did these allergies differ across numerous regions? Were the number of allergies rising? Certain factors made this data difficult to collect.

One problem was the lack of a consistently correct social perception of allergies. Many opinions reflect the ignorant belief that food allergies are closer to food preferences than medical conditions. Others associate metabolic conditions, such as lactose intolerance and celiac disease, with food allergies and include them under their definition. Both of these assumptions are unfounded (1). Food allergies are an immune system response to an allergen, which is usually a food protein.



When a normal infection occurs in the body, mast cells alert the immune system, responding with an inflammatory reaction. When an allergy occurs, the mast cells are activated by a harmless antigen despite the fact that no infections are present. This is called an immunoglobulin (IgE) mediated mast-cell activation, and the severity of the consequences of this activation depend on how the antigen entered the body. It can range from a bit of a sniffle from inhaling pollen to a deadly circulatory collapse from the ingestion of peanuts (10).

Since people did not always understand what exactly constituted an allergy, some worried that there would be over-reporting for things like lactose intolerance, celiac, or hypersensitivity. However, the opposite was true. The FAAN (Food Allergy and Anaphylaxis Network) concluded that under- reporting was actually a far greater issue. They collected data by random phone surveys and found that four percent of the United States population, or about 12 million people, are allergic to peanuts, tree nuts, fish, or shellfish. But "we are probably still under-reporting," said Anna Munoz-Furlong, the founder and CEO of FAAN. For every case reported, they theorize two or three go unrecorded. Additionally, many records of allergy prevalence are only based on allergy related hospital visits, therefore excluding anyone whose allergies were not severe enough to require hospitalization. Even though the numbers of reported allergies were high, the actual numbers were even higher (1).

The research collected not only consistently showed that the number of people with allergies was extremely high, but that they were notably rising. In the United States, there has been an 18 percent increase between 1997 and 2007 (6). In the UK, food allergy related hospital visits have increased by 500 percent since 1990 (1). The tremendous amount of people suffering from allergies and the dramatic rate they are increasing further spurred public health officials to search for answers. They investigated many different factors and how they affected the prevalence of food allergies (6). "Allergy rates might have as much to do with how and when the food is introduced as with the food itself (1)".

One factor that was investigated was at what point a typical allergen, such as peanuts, was introduced into the child's diet. Up until recently, the advice of doctors was to keep all potential allergens away from a child as soon as they are born. New research proves this theory wrong. Gideon Lack, a pediatric allergist from England working in King's College, worked with his team to conduct an experiment using hundreds of babies that were four to eleven months old. They all had displayed signs of a developing peanut allergy, such as severe eczema (rashes), or egg allergies, which are often early signs of peanut allergies. Doctors gave each baby a skin test, which involved injecting each baby with traces of peanut. If the baby reacted strongly, the baby was removed from the trial. After the tests, 530 babies remained and each baby was randomly assigned either to ingest small amounts of peanut butter three times a week, or to have none at all. The doctors monitored the children for about four years. For those who were given peanut butter three times a week, less than two percent had peanut allergies. For those who had no peanut butter at all, the rate was almost fourteen percent—more than seven times the other rate (4).

Another study called the Learning Early About Peanut (LEAP) study also concluded that early introduction of the allergen could dramatically lower the risk of developing childhood allergies, especially in high-risk children. They found that the risk was reduced by as much as 80 percent. Like the other study, they were sure to emphasize first testing the child for allergies before introducing the food (6). Early exposure can help prevent childhood allergies, but can of course be extremely dangerous if the child already has the allergy and reacts to it. Therefore it is crucial that the child is tested for allergies before the early exposure technique is utilized.

This research about early exposure is especially important for children whose parents have allergies because they are particularly at risk for allergies and

often have an increased predisposition to allergies (3). It is crucial that they get early exposure to reduce their high risk. However, often the odds are stacked further against them because their parents, who have suffered with allergies their whole lives, will be extra careful to avoid giving their child any exposure to the allergen in fear that the child will have an adverse reaction. It is very important that they have access to updated advice so that their children can receive the exposure they need.

Studies comparing the allergy rates in different countries further strengthened the early exposure theory. Allergist George Du Toit co-authored a study that he started after noticing the striking differences in the allergy rates between Jewish children in the United Kingdom and in Israel; the British children had peanut allergy rates that were ten times higher. He suspected the reason was connected to the early exposure methodology. Sure enough, his team found that the British children started eating peanuts significantly later than the Israeli children did (4).

…a striking difference in the allergy rates between Jewish children in the United Kingdom and Israel.

The studies done in regards to peanut allergies consistently proved the early exposure theory. However, there seemed to be a contradiction in the data collected by researchers studying allergy trends in Asia. Countries in this eastern continent had unusually high rates of shellfish allergies, which were attributed to the abundance of crustaceans and mollusks in the region. This seemed to imply that increased exposure led to increased allergies, despite the fact that all other evidence pointed in the opposite direction. However, further findings clarified the truth. Although regular fish was extremely abundant in the area, the rates for fish allergies were extremely low-much lower than the rates among American children. This was because Asian children were weaned at a young age and fed these kinds of fish. Since they were commonly fed regular fish at a very young age, the early exposure helped create extremely low regular fish allergy rates. The case was not the same for the shellfish and the rates of that kind of allergy were very high. This proved that exposure was not enough; it was key that exposure was early enough in the child's development, if it would help prevent allergies (14).

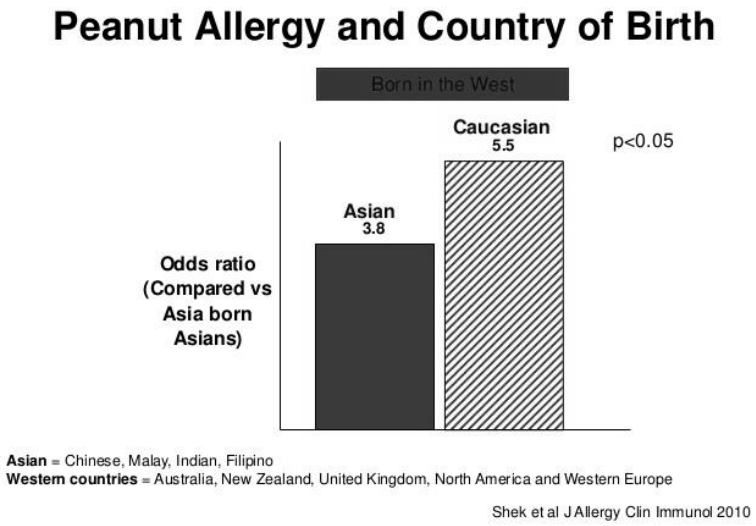
Groups like the American Academy of Allergy, Asthma, and Immunology, the American Academy of Pediatrics, and the Canadian Society of Allergy and Clinical Immunology recommend that children at high risk of allergies be exposed within the time frame of four to eleven months. They recommend introducing a new food every 3-5 days, and to introduce potentially allergenic foods—such as eggs, fish, milk, and nuts—in small amounts, slowly increasing the quantities as days go by. Previous guidelines supported avoiding potentially allergenic foods until later times, like 12-36 months. However, extensive research has shown these guidelines to be ineffective, and prove that having these foods introduced early enough is crucial to help prevent allergies (6). American and European doctors are working together to develop new formal guidelines for the best way to implement exposure of these foods for children. The American Academy of Pediatrics (AAP) has endorsed the creation of these guidelines and published a document titled, "Consensus communication on early peanut introduction and the prevention of peanut allergy in high-risk infants," in September 2013 (9).

By observing the different allergy trends in certain regions, researchers were able to conclude that early exposure can be highly beneficial in preventing allergies. They found a cultural difference between the lands and saw how these conditions were connected to the trends in allergy rates. Based on this, they were able learn what should be done or avoided to help reduce allergies worldwide (6).

Researchers use this method of comparing allergy demographics in different regions in order to identify additional factors, besides early exposure, that were also used to figure out how to help minimize allergies. For example, some studies examine how certain cultures' way of preparing a food can affect the allergy rates in the region. This phenomenon is seen in research printed about allergies in Asian children. Tables of data showed a great disparity in the wheat allergy rates among different Asian countries, and researchers attributed it to the varying cooking methods used with wheat throughout the continent (14).

Peanut allergies are another prime example of allergy rates in different regions affected by cooking method. Peanut allergies represent 28 percent of all food allergies (11). Since 2010, two percent of the population in the United States has peanut allergies (4). That makes up around 50 percent of all allergies in the US, according to studies showing that around four percent of the population has allergies in general (1). Peanuts are just as much a staple in Asian diets as they are in American cuisine. However, in Asia nut allergies are considered to be much less prevalent than other food allergies. Far less than one percent of the population exhibits food allergies in Korean and Singaporean children and there have been almost no cases reported in China and Thailand (14).

This phenomenon has been explained by the different preparation methods in Asian and American regions. In America, peanut allergy rates nearly doubled from 1997 to 2002, despite the fact that peanut consumption had not greatly increased. This was attributed to manufacturing methods; dry roasting the peanuts became a prominent method during this time in America. Dry roasting peanuts gives them a very high allergenicity (1). In contrast, peanuts are usually first introduced into a child diet in a boiled or fried form. Research published in the "Journal of Allergy and Clinical Immunology" in 2001 shows that boiled or fried peanuts are much less likely to lead to allergic reactions (13).



When one has an allergic reaction to peanuts, they are reacting to one of the three peanut allergens: AraH 1, 2, and 3. The most common reactions are reacting to the AraH 2. The different forms of processing change how the body is able to handle the allergen. Roasting the peanut increases the immunoglobulin (IgE) antibodies response, while boiling or frying them reduces the reaction. A recent study even suggest that eating boiled peanuts can increase peanut tolerance in someone who has already developed an allergy. Four subjects with an allergy to peanuts were fed boiled peanuts every day

in increasing amounts. They were able to safely eat boiled peanuts, since the boiling reduces the immunoglobulin response, but could not handle other forms of peanuts. After many months, some of the children were able to tolerate orally ingesting raw peanuts (12).

After examining the library of research and guidelines about allergies, it is clear that there is an abundance of facts that could be used to dramatically minimize and prevent allergies. Until recently, the public was given incorrect information about how to approach allergy prevention for their children. Doctors were giving advice and guidelines based on the premise that keeping your child away from any potential allergenic foods will keep them safe from harm and to avoid them at all costs until later in development. The new consistent and compelling consensus shows that this could not be further than the truth. All the evidence now shows that it is crucial to introduce foods into a child's diet in the right way, and the answers of as to when and how to introduce the foods are in ample evidence.

But it is not enough that this information has been gathered, tested, and confirmed in medical journals, health organizations, and research articles. These methods are not being translated into public knowledge and practice. There are plenty of reactive policies and knowledge to help schools handle allergic reactions, to show parents how to handle children with allergies, and to advance medical care for those with allergies. But there is a serious lack in proactivity when it comes to actually preventing these allergies in the first place.

Rather than the wholesale distribution of epi-pens, perhaps the public would be better served by wholesale distribution of information, to retrain perception on how to best prevent allergies in the first place.

Bring on the Bamba.

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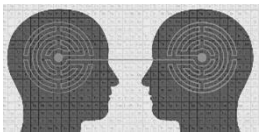


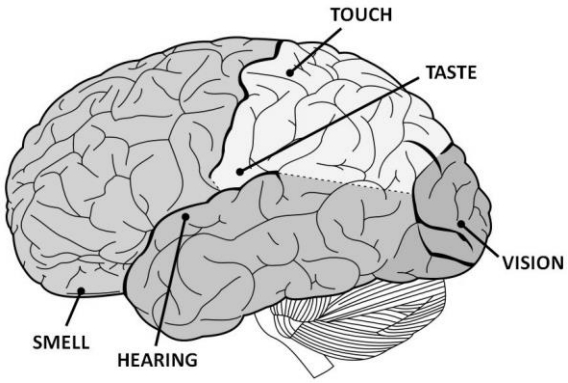
Kayla Samet

SYNESTHESIA: THE SOUND OF COLOR

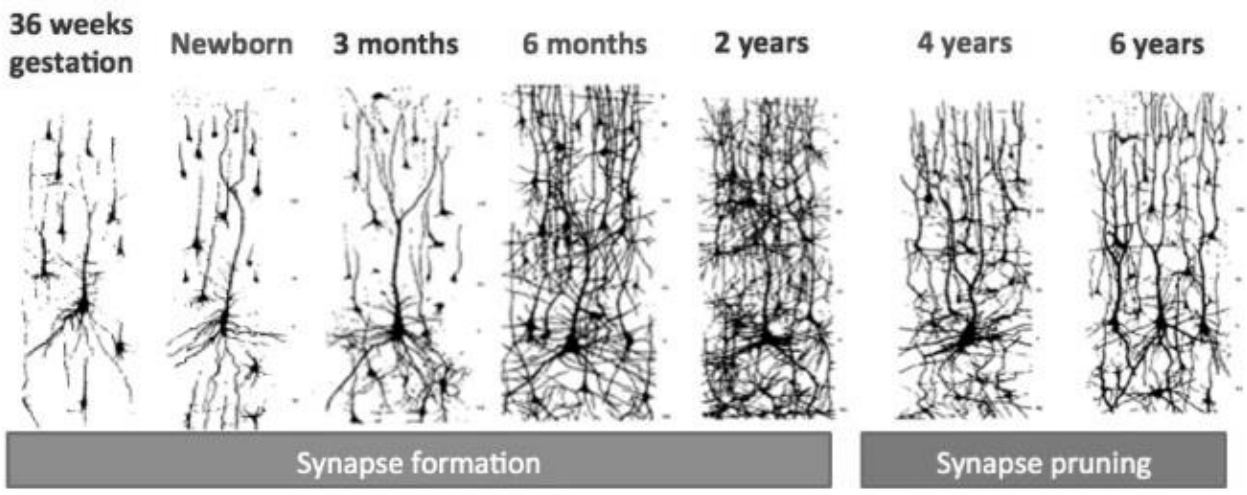
Those who have this mysterious condition often do not realize they have it until their friend mentions that no one else in the room is hearing purple. For the synesthetes, this is not a handicap. It is a gift, or a sixth sense. Jane Mickay, for example, is an exceptional artist who uses her synesthesia for income. She lives near the sea and often takes walks along the beach for inspiration. She hears the waves crashing and the rocks being pulled towards the ocean and an influx of colors appears before her. She is suddenly bombarded with inspiration of what to paint and she says, "I can't even breathe!" For her, synesthesia is bliss because she can merely listen to music and produce a masterpiece (4).

What exactly is this odd condition? Synesthesia is when there is a crossover in the brain's different areas that affect different senses. One sense is perceived through another. The perception is unique for each synesthete. Some can hear colors, some can taste names, and some can smell sounds. It is a form of conditioned reflex; it just happens. Those who have it have excellent memories. The reason for this is because they associate words or concepts with colors or tastes, so two senses simultaneously trigger a memory and they can recall things more easily (1). The prevalence of synesthesia in the adult population has been estimated at 1 in 2,000-25,000 and could be higher in children. The reason estimates vary is because many synesthetes don't realize they have it and don't realize they are different—it is a part of their lives. About six times as many females report having synesthesia, and it seems to run in families, which seems to hint at X-linkage, but that could be because women might be more in tune to their senses (2).

When a child is born and their brains are developing, they have many connections throughout their brain. As they get older, the brain prunes away any unnecessary connections. For synesthetes, those connections never get pruned away, and so, since their birth, the auditory and visual areas in the brain will forever have a connection. This is one cause of synesthesia. Another cause is the sprouting of additional synaptic connections. Researchers have found that these two causes are genetic, so a baby's brain will not leave behind unnecessary connections unless their parents passed it down to them (5).



For years, scientists refused to look deeper into this condition because they thought that it was merely the result of drugs, hallucination, or just a person going



mad. Dr. Ramachandran was convinced that there was something more. He did tests where he found out that synesthesia was real and that those who have it are not crazy; they are actually physically mixing up their senses. He proved that synesthesia is real and his studies sparked a new search for the physical cause. Positron Emission Spectroscopy (PET) was used to examine the patterns of brain activity of six color/phoneme female synesthetes and six non-synesthetes as controls. Participants either listened to pure tones which did not elicit synesthesia or to words spoken over headphones. Patterns of activity markedly differed between the two groups for spoken word only (2).

One of the major lines of inquiry when trying to understand the foundations of a condition, is to go back to the foundations and investigate if the causes are genetic in nature. It has been found that synesthesia clusters in families. Genetic samples were taken from 196 individuals from 43 families. Of these, 121 exhibited sound-color synesthesia. Genetic analysis tracked number and location of repeat markers and identified regions of DNA associated with this condition. A region on chromosome 2 was strongly linked, which is intriguing because this region is also implicated in autistic savants, leading to the speculation that these conditions share neurological underpinnings. Three other areas on chromosomes 5, 6, and 12 were also identified. These regions are known to be involved in regulating neuronal activity. More research is necessary to pinpoint the exact gene affected, and to identify the protein product of these genes (31).

James Wannerton, a synesthete, tastes colors. When he hears the name "Derek," he tastes ear wax. He has no control over which taste is linked with which word. Throughout his day, he is bombarded with a vast array of flavors. He works in a cafe, and can smell the fried eggs and bacon while tasting steak, if he hears the name that brings that taste to his mouth. When Dr. Ward tested James, he found that all the food he was tasting was food he ate in his childhood. When it came to food that James at recently, like olives or curry, he had no association with those tastes and the names he heard. This showed that early childhood plays a vital role with synesthetes. James said that sometimes his synesthesia can be hard. He'll be driving and notice a road sign, but he cannot comprehend it due to the influx of tastes his mouth experiences. However, when asked if he would want

to give it up, he furrowed his brow and mentioned that he never even thought about it. His synesthesia was a part of him, and he couldn't imagine life without it (6)

John Fullwood, another synesthete, sees words as colors, but only sequenced words such as Monday, or May. The words have to be a part of a greater whole, a sequence. He likes his synesthesia because it helps him distinguish between days of the week or which month it is. Here is why he is unique: John Fullwood is blind. His synesthesia cannot possibly be influenced from signals in his eyes. His ability to see colors is triggered deep inside his brain. Meghan Steven put Fullwood under a scanner at Oxford University to see what was going on. When he heard random words, such as "master," or "exquisite," the auditory areas in his brain lit up. When she said words such as "Tuesday," or "December," not only did the auditory area light up, but the visual area in his brain lit up. This proved that he was seeing colors when he heard those words, and he is blind (6).

He'll be driving and notice a road sign but cannot comprehend it due to the influx of taste experiences.

Dr. Ward mentioned that about 1 in 100 people have synesthesia, so if you start looking amongst your family and friends, it may not take long to find it. Many have it but they do not realize they have it. Synesthesia is a gift. It is a portal to a world that those of us with "normal" sensory connections do not even realize exists. Who knows how many other worlds are out there that we are missing because we lack the neural connections.

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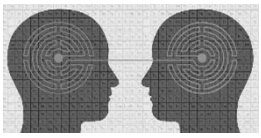


Chani Weiner

PHOOD PHARMACOLOGY

He sits on the bus with all the other children, bouncing up and down in their seats like the blue and green marbles in his jar at home. The four solid color notebooks are all lined up in his backpack like soldiers. The sharp edges of their crisp covers and starchy papers scare him. He thinks about his sandwich with the smooth peanut butter that has no peanut chunks because they scratch his tongue. He loves his sandwich and he has had it for lunch every day for as long as he can remember. He looks out the window at all the houses each with their windows like eyes and doors like mouths. He does not recognize them and he wishes to be back home with Mama. He wanted to bring Mr. Snuggles but Mama said that bears do not go to school. The voices of the little children sound like screeching tires in his ears so he squeezes his eyes shut in protest and cover his ears.

What if there was another route that would improve his symptoms and not yield terrible side effects?

Finally he sees the school and the relief washes over him like friendly hug. All the children line up and file off the bus. He walks off the bus and starts toward the building. So many children in their bright colored clothing and shiny shoes head toward the school doors. The little boy is overwhelmed and confused. He does not know where to look and everywhere there is color and noise and no one sees him. He knows where Mrs. Casey's classroom is but he knows that he will not learn from her this year. He will have a new teacher but where is the classroom? The principal stands waving at all the children. Her shirt is nice. It's a light purple that's not too dark with small white circles on it. Her hand moves back and forth and her smile looks like she stuck it to her face with the slimy white glue that the boy uses to make pictures for Mama.

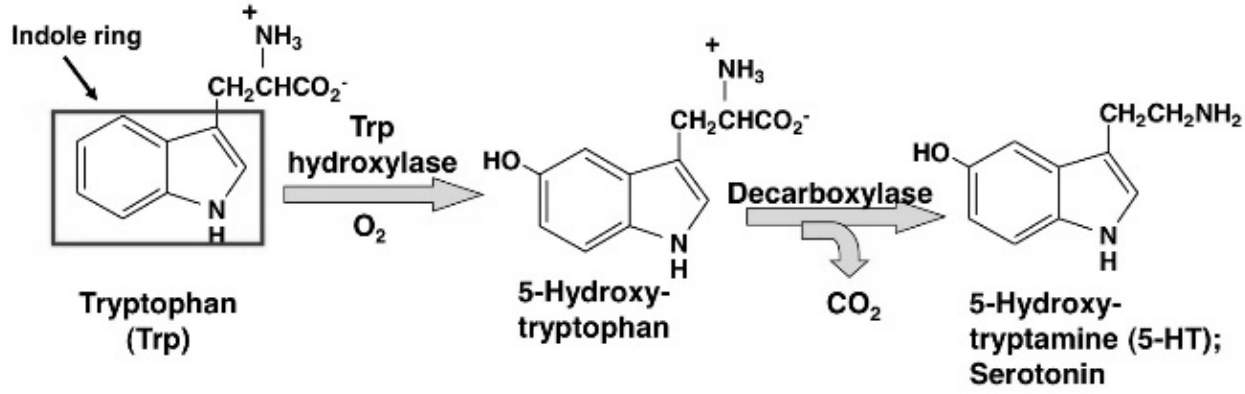
The children all walk down the hallway, and enter their given classrooms like the loud, angry train that deposits everyone right by their houses. The boy feels like he is in a box that keeps getting smaller and when children talk to him he doesn't understand. He just sees their mouths moving but only air comes out. The hallways start growing smaller and soon the boy will be squished. He wants to run but there are too many children. He runs to the corner and rocks back and forth with his head on his knees. He wishes that he could take the little white circles again. With them everything was quieter and the boy could concentrate. But Mama said no more. She said that they were the reason the boy could never fall asleep at night or why he sometimes was not hungry for dinner. The boy wishes that he could feel the quiet again and the calm.

What if there was another route for the boy that would improve his symptoms and not yield terrible side effects? Then the boy could go to school and not become overwhelmed by all the noise and commotion. There may be another alternative in the form of a controlled diet. The restricted, stereotyped, and repetitive behavior (RSRB), commonly found in people with autism, is caused by insufficient inhibitory control. The scientific basis for this is unknown, but may be regulated by the neurotransmitter, serotonin. Previous research has shown that people with ASD, autism spectrum

disorder, have significantly lower amounts of serotonin in their brain compared to control subjects (2). This finding has led to the belief that irregularities in brain function of people with ASD can be a result of abnormalities in serotonin levels. Tryptophan, a dietary amino acid, is a precursor to serotonin. Therefore, decreasing it in the blood stream can have an effect on the production of serotonin in the brain (3). Studies using fMRI have shown that serotonin increases the function of cerebellum, parietal and frontal lobes which regulate behavior, memory, language, sensation, reading, balance and coordination (2).

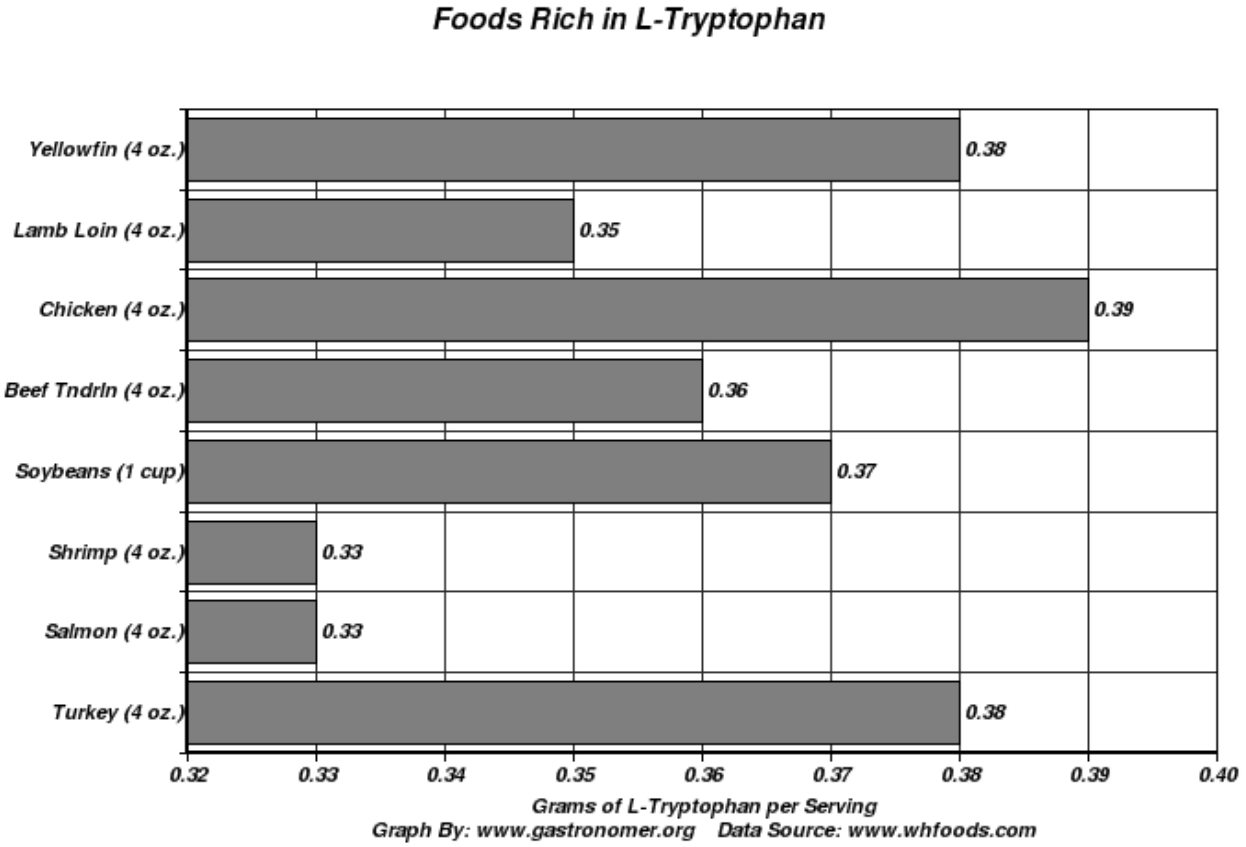
Subjects with ASD and a control group of healthy individuals, were given both a mixture of amino acids lacking tryptophan and a sham mixture with high tryptophan levels. They were put through a Go/No-Go Test, measuring their response inhibition. Scientists found that subjects with ASD had baseline scores significantly higher than the control group (2). The control subjects themselves scored within the normal range. After the sham mixture, subjects with autism showed reduced activity in right inferior frontal cortex. In control subjects, tryptophan depletion led to reduced activation in right inferior cortex, while in subjects with autism, tryptophan depletion enhanced activation in right inferior cortex. These results demonstrate that serotonin has an opposite effect on those with autism and without (5).

Further research has been done on tryptophan depletion and its effects on facial emotional processing. Neural responses were measured during incidental processing of happy, sad, fearful, and disgusted faces. They hypothesized that the lack of serotonin would have an impact on neural activity within the networks of facial expression recognition. They concluded that serotonin does impact brain function during facial emotion processing, but only on the networks of fearful, happy, and disgusted expressions, not sad faces (5).



Research has found that children born with autism exhibit high levels of serotonin in their bloodstream. Since serotonin is known to stimulate the growth of nerve cells, it would be understood that children with ASD, who have higher levels of serotonin, would have more neurons, therefore bigger brains, than children without ASD. Upon further research, it was found that children with ASD exhibit sensory responses earlier than regular children, in addition to increase in brain size. Analysis of the size of the axons shows that children with ASD exhibit increases of serotonin in the superior temporal cortex (4). However, fMRI has shown that after being administered a mixture containing tryptophan, activity of serotonin creation was decreased in children. Second, RSRB, is associated with the decrease of serotonin. By giving autistic children meals that are heavy with tryptophan, serotonin synthesis can increase and lessen the symptoms of autism and allow autistic children to learn easier and recognize facial emotions. The little boy would no longer be afraid of unfamiliar houses and think that his principal's smile is fake. With increased serotonin levels, the boy may understand that he can ask the principal for help. Children with autism have a hard time understanding the meaning behind their teachers' words and they find it difficult to express their thoughts. In order to alleviate these symptoms, children with autism should be placed on diets consisting of turkey, eggs, tofu, nuts and other foods rich in tryptophan.

The concept of treating genetic disease through food intake alteration is not novel and not without precedence; it has been successfully utilized with Familial Dysautonomia (FD). Dr. Beirish Rubin of



Fordham University, working at the request of Dor Yesharim, uncovered a blood test for carriers of FD, which is a disease of the Ashkenazi Jewish population. Dor Yesharim has since added this test to their screening panel. This disease had tragic outcomes until his new research discovered that foods rich in tocotrienols, a form of vitamin E, and a chemical component of green tea called epigallocatechingallate (EGCG), if started early, dramatically reversed the symptoms of patients afflicted with this terrible disease and improved their quality of life and longevity (1).

It is with profound amazement and wonder to realize that cures for what ails us can be found in our food. Just as doctors and pharmacists study which drug to administer for which condition, in the proper dosage and with proper timing, the "master pharmacist" above has also carefully measured out, incorporated and tastefully packaged into our food what our body needs to stay healthy. The Eat Real Food movement is starting to look more mainstream. Imagine going food shopping to stock the refrigerator and pantry instead of the medicine cabinet. The cornucopia is also the pharmacopeia.

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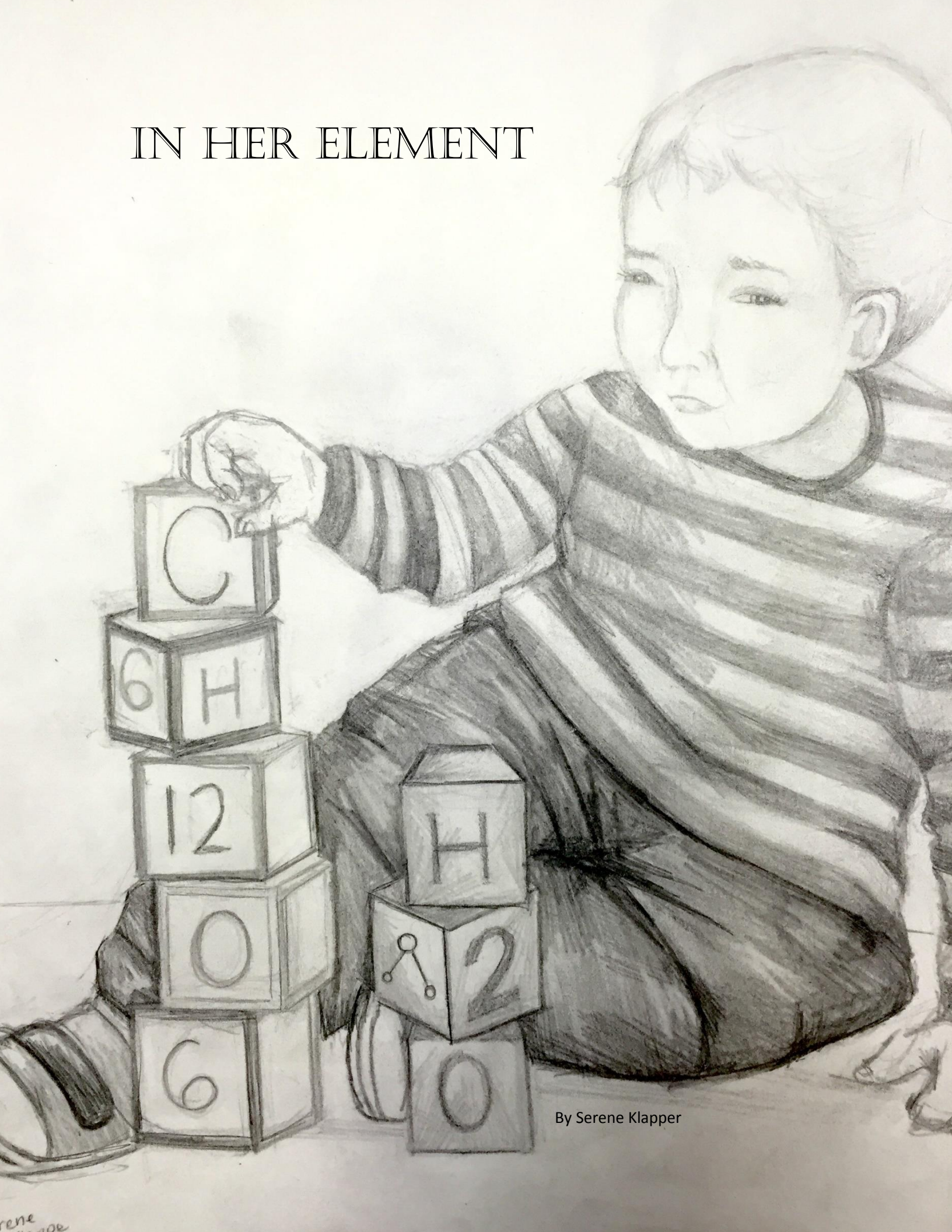
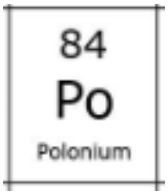
IN HER ELEMENT



By Serene Klapper



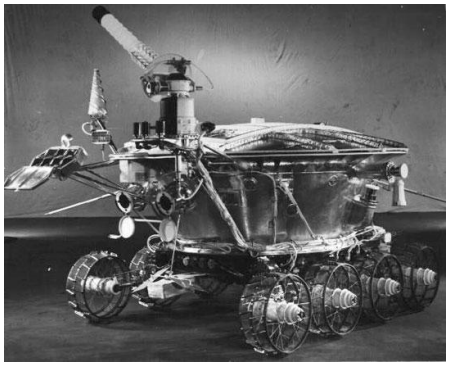
Devorah Amsel

THE STEALTH BOMB

There are not many that can boast they have had experiences that match those of polonium. Polonium has successfully ventured to the moon, helped machinery function, and defended America in war. It has also been a conduit for some of the most evil acts in history. Its usage in nuclear bombs have killed and injured hundreds of thousands. It has been used to assassinate in secret and it lurks to kill in unexpected places. How can something that has advanced our society so much also be used for such extreme chaos? In order to understand this fascinating element, we need to start from the beginning.

Polonium was discovered in 1898 by Marie Curie while she was working in France. Curie was a two time Nobel Prize winner, one for her work in physics and one for her work in chemistry. She and her husband Pierre successfully isolated polonium, and then later radium (9). Polonium was the first element discovered by Curie so it was named after her birthplace, Poland. It is a radioactive element that occurs naturally in very low concentrations in the earth's crust (11), belongs to the group 16 elements, forms compounds that are ionic and has no stable isotopes (3). However, it forms 33 unstable ones, with half-lives ranging from 300 nanoseconds to 102 years. Only 3 isotopes have an appreciable half-life: polonium-210, polonium-209, and polonium-208. The half-life of polonium-209 is 102 years, making it the most stable isotope. It emits alpha particles and decays into lead-205. Polonium-210 is the most used isotope, used as an atomic heat source, a neutron source and a static remover generated in machinery caused by processes such as rolling of paper, wire or sheet metal. Polonium is also used in brushes for removing dust from photographic films (12). It is also highly toxic. Polonium does not exist in nature in compounds, but can form synthetic compounds in the laboratory. It is used as an alloy with beryllium to act as a neutron source for nuclear weapons (10).

Polonium played a huge role in the first successful robotic lunar rover—Lunokhod 1. Po-210 was used to heat this Soviet Union controlled rover for ten months while it successfully sent vital information back to earth. Because it can reach temperatures up to 1500° F, polonium is a great candidate for a heat source in space where it will need to generate temperatures of that level.



Lunokhod rover (5).

Polonium exerts its toxic effects due to its radioactivity. The first thing we must establish is the effects of radioactive illness and how it is contracted. Po-210 is the most harmful isotope of Po, and an interesting radioactive substance because external contamination does not cause radiation sickness. Therefore, it can be carried around with impunity; it only presents a radiation hazard if taken into the body (ex. by ingestion or inhalation). If it enters the body, Po-210 can cause

Acute Radiation Syndrome (ARS). It is an illness caused by irradiation of the entire body by a high dose of radiation in a very short period of time (usually minutes). If the dose is greater than .7gy (gy=gray, the measure of absorption of one joule of radiation energy per one kilogram of matter), then ARS can cause one or more of its three deadly syndromes; bone marrow syndrome (BM), gastrointestinal syndrome (GI), and cardiovascular (CV)/ central nervous system syndrome (CNS). Most of these are deadly and if untreated, can cause death in as little as three days. There are four stages of ARS. The first stage can occur minutes from exposure and includes nausea, vomiting, anorexia and diarrhea. In the second stage, the latent stage, the patient looks and feels generally healthy. The third stage is when the illness manifests itself, and its symptoms depend on the type of syndrome contracted. Each has different effects on the body and has different recovery expectations. For example; BM syndrome has the largest chance of recovery because the bone marrow cells will most likely begin to repopulate the infected marrow. In CV/CNS no recovery is expected, making it the deadliest syndrome. In the fourth stage, if the patient has not begun treatment, s/he will die (13).

Even before the outbreak of World War II in 1939, a group of American scientists—many of them refugees from fascist regimes in Europe—became concerned with nuclear weapons research conducted in Nazi Germany. In 1940, the U.S. government began funding its own atomic weapons development program, and The U.S. Army Corps of Engineers was tasked with spearheading the construction of the vast facilities necessary for the top-secret program, code-named "The Manhattan Project." Polonium-210 was vital to this program, because it was to be used in a neutron source that would ensure initiation of a chain reaction. President Truman wanted to end the war fast, and without American casualties. He then did something that remains one of the most ethically debated decisions in history. He chose to ignore the moral reservations of Secretary of War Henry Stimson, General Dwight Eisenhower and a number of the Manhattan Project scientists, and decided to use the atomic bomb in the hopes of bringing the war to a quick end. They dropped the bomb known as "little boy" over Hiroshima and then the "fat man" over Nagasaki. Although this did ultimately lead to Japan's surrender, the results were horrifying (2). Over 100,000 were killed instantly and about the same number were severely injured. The injured suffered immensely from ARS and many eventually died from it weeks to months after the bomb was dropped.

He then did something that remains one of the most ethically debated decisions in history.

Timeline 4-6 gy (13)

There is one other area where Po has been used not just once, but twice in the past 10 years as an assassinating poison. The most famous cases are the assassination of Aleksandr Litvinenko and later former Palestinian politician Yasser Arafat. The isotope Po-210 is used as a poison and is especially unique. It poses no danger outside the body, but once ingested can cause major organs to shut down and almost guarantees death. It's also unique because its presence in the body is very hard for doctors to identify unless they are looking specifically for it. It is easy to conceal and transport across borders, because unlike most common radiation sources, polonium-210 does not set off standard radiation detectors because it emits only alpha particles that do not penetrate even a sheet of paper. It can be carried in crystallized or powdered form or diluted in a bottle of liquid. Identifying it in any of these forms with current methods is both time-consuming and requires an experienced analyst.

Polonium has one significant drawback. If investigators are alert enough to detect it has been used, they can follow the radioactive trail it leaves on everything it has come into contact with before the killing to find and identify a suspect. This is what happened in the Litvinenko case. Investigators found traces of polonium in the hotel room where the tea was served and followed the trail backward (6). In 2012, Arafat's widow let toxicologists test some of his belongings and they found traces of polonium in his underwear. Although it is not confirmed that Arafat was poisoned by Po-210, the evidence we have certainly points in that direction (7).

As illustrated, polonium has a huge spectrum of uses and is currently being researched in many different fields. For example, around the Kanyakumari coast in India various levels of polonium concentration were found. Scientists had to calculate the amount of Po-210 ingested by the people living there to asses if it was becoming a health hazard. This lead scientists to do research in many other areas that also have natural high background radiation areas (HBRAs) (8).

Another way Po has and still is affecting hundreds of thousands of people is its presence in tobacco. A new study reported in the Independent and to be published in the American Journal of Public Health suggests that tobacco companies have known about the danger of polonium in cigarette smoke for over 40 years, yet have managed to keep this information pretty much under the radar. Studies have detected polonium-210 in the airways of smokers, where they are concentrated in hotspots. They remain there because other chemicals in cigarette smoke damage the body's cleaning systems, which would normally get rid of gunk in our airways. As a result, polonium builds up and subjects nearby cells to higher doses of alpha-radiation. These build-ups lead to far greater and longer exposures to radiation than people would usually get from natural sources.

For example, one study found that a person smoking two packs a day is exposed to about 5 times as much polonium as a non-smoker but specific parts of their lungs could be exposed to hundreds of times more radiation. Another study estimated that smoking a pack-and-a-half every day exposes a smoker to a dose of radiation equivalent to 300 chest X-rays a year. It's hard to say if the Po specifically causes lung cancer, especially since the effects of polonium are only part of a wider range of damaging consequences caused by inhaling cigarette smoke. But animal studies certainly give us cause for concern. Absorbed doses of radiation can be measured using units called rads, and experiments have shown that as little as 15 rads of

polonium can induce lung cancers in mice. That's only about a fifth of what a smoker would get if they averaged 2 packs a day for 25 years. Indeed, the lung tissues of smokers who have died of lung cancer have absorbed about 80-100 rads of radiation (15). These examples are just some of the damaging effects Po can have.

The most recent polonium concern is not assassinations or coastal contamination; it's about people knowingly inhaling this extremely toxic and radioactive element and allowing it to destroy their bodies. Now people are increasingly becoming more aware of the Po-210 found in tobacco and many anti-smoking organizations are using this knowledge to get people, especially teenagers, to stop smoking. According to the World Health Organization, tobacco kills around 6 million people each year (14).

Probably the most frightening lesson to internalize from this project is that the same element that was used to assassinate two men is found in every cigarette; yet people still smoke several a day! After all the internal havoc that Polonium can wreak, it is incomprehensible how some can ignore the dangers and continue to play the game of Russian Roulette and pick up that smoking gun on a daily basis. I know this changed my view on smoking and I hope it will change yours.

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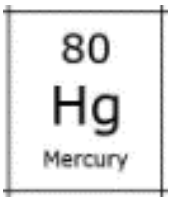


Nechi Bertram

GO ASK ALICE

In the ancient cultures of India and Tibet, a silvery liquid was believed by mystics and alchemists to be the primordial element; the source from which all other matter was formed. The early civilizations of Egypt, China, Greece, and Rome knew of this substance as well and treated it with both respect and fascination (13). This material which the ancient world was so captivated by is now known as mercury, one of two of the elements found as a liquid in its natural state. Described as "the most potent and poetic substance in the universe" (19), truly mercury is a fascinating element. Its Latin name Hydrargyrum, hence its chemical symbol Hg, means "Water Silver" a simple description of its mesmerizing appearance and behavior. Since its discovery around 1500 BC, over the centuries mercury has successfully captured the hearts and minds of humanity(6).

Mercury is most commonly used in the thermometer, barometer, batteries, anti-fouling paint, diffusion pumps and dental fillings (14). The reason for mercury's function in tools such as the thermometer and barometer is because of mercury's clear response to temperature and pressure changes respectively. When the temperature rises, atoms of mercury are activated by kinetic energy causing them to collide with one another with greater frequency and impact. This causes them to spread out and rise higher in the glass tube in which they are contained and vice-versa. Since the density of mercury is quite high, only a small volume is needed and instruments can be small (9). Although Mercury is silver colored, thermometers today will often contain a red liquid, usually alcohol and red coloring, not mercury at all. This is because mercury is toxic and glass thermometers are easily broken, releasing the mercury contents (15). Another common use of mercury is mercury amalgams used in "silver" dental fillings. This filling is an alloy of mercury, silver, tin and copper. However, 50% of its weight is mercury, which may make one wonder why we call these "silver" fillings instead of "mercury" fillings. The answer is simple—the fillings are known as "silver" not because of their elemental name, but because of their color. As stated previously mercury is toxic, but through scientific research the FDA has concluded that it is safe to place mercury amalgam fillings in mouths of adults and children aged 6 years and above (17).

Mercury is naturally found in air, water, and soil. The Mercury found in the air is a result of volcanic eruptions, erosion of rocks and decomposition of soil. This is the elemental form of mercury. Elemental mercury becomes an environmental toxin when power plants burn fossil fuel. Greater burning of fossil fuels accounts for higher rates of mercury in the more industrialized northern hemisphere than the arguably lesser developed southern hemisphere. Excessive exposure to mercury can be life threatening.

Two common forms of mercury include: methylmercury and inorganic mercury (17). Methyl mercury is an organic form of mercury found in fish and inorganic mercury is used in cosmetic creams outside of the US (3). When mercury enters water, it combines with organic substances found in water and forms methyl mercury (CH_3Hg). Methyl mercury is not broken down and climbs up the food chain, concentrating as it goes along in a process called biomagnification (3, 16). This is the reason to limit weekly consumption of fish such as tuna. In 1958, a mysterious and often fatal sickness began to spread on the island of Kyushu, commonly affecting fishermen and their families. It was discovered that this sickness was caused by methyl mercury, which was consumed by fish and shellfish, and later eaten by humans, thereby contaminating people with mercury poisoning. Other examples include incidents in Honshu, Japan (1965) and Quebec, Canada. Additional organic compounds of mercury such as Thimerosal and Phenylmercury are made in small quantities for use as preservatives. Thimerosal is used as preservatives in vaccines, providing more ammunition for the anti-vaccination movement (12, 1).

Mercury's weak metallic bond is a factor in mercury's state at Standard Temperature and Pressure (STP). Mercury has 80 protons giving it a large dense nucleus allowing it to hold onto its valence electrons relatively strongly. Metallic bonding occurs when atoms of a metal form a lattice, allowing their valence electrons to delocalize and hop skip and jump around the crystal. A metallic bond's strength is determined by how tightly the electrons are held; the tighter held, the weaker the metallic bond. Mercury's nucleus has a strong grip on its valence electrons, which results in a weak metallic bond that heat can easily break. Since very little is energy required to separate the atoms of Mercury, its melting point is a low 234k (-44C), resulting in a liquid state at STP. Even though its metallic bonds are not strong enough to keep it in the solid state, they are still significant, causing mercury to have high surface tension. Surface tension is what causes water to bead up on a waxy surface and in a similar fashion, mercury will bead up on any surface. Not only that, but the beads of mercury will join together to form a larger bead similar to the way the circles of fat join together on the surface of your chicken soup (11, 7). *See figure below.*

Mercury's melting point is one of its physical properties but because of its chemical property of only 2 valence electrons, mercury has the ability to form different compounds. Because of mercury's 2 electrons in its valence shell it can form a compound with two chlorines called mercuric chloride ($HgCl_2$), and mercurous chloride, or calomel, (Hg_2Cl_2), both of which are used as antiseptic. An additional compound of mercury is mercuric sulfide (HgS). Because of its bright red color, it is contained in pigments called Vermillion

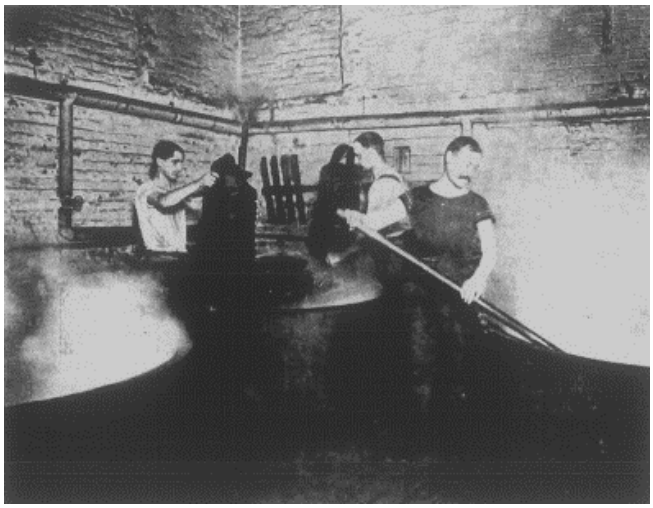
and used for jewelry and ornamentation (2, 5, 10). Despite its beauty, mercuric sulfide is toxic and its use has been discontinued. It is fascinating to see how compounds formed from the same basic element can be both healing and lethal.

Mercury is an element and therefore indestructible. This becomes complicated as a result of mercury's toxicity. As it is both indestructible and toxic, people do not know how to dispose of their possessions containing mercury. There are websites providing a detailed list of common items containing mercury, along with clear instructions on what to do if you own a product containing mercury and would like to get rid of it (15.) There is also guidance on what to do if that object cracks, such as using an eyedropper to gather up mercury that may have spilled and sealing it in a plastic container. The container should then be clearly labeled "mercury recycling" and brought to a mercury recycling site. Since mercury is a liquid, spills can vaporize and the vapor can be inhaled, offering another route to enter the body.

Camel hairs were commonly treated with camel urine to speed up the felting process.

In earlier generations humanity was not afforded the knowledge to protect itself, resulting in many mistaken and interesting uses of mercury. In 18th and 19th century England, mercury was used in the production of felt, which was commonly used in manufacturing hats. Mercury vapor interferes with the functioning of the nervous system leading to dementia in cases of severe exposure known as "Mad Hatter Syndrome" and thus the phrase became the popular way to refer to someone insane. The story of mad hatters in the UK actually began in Turkey where hat companies used camel hair for the felt material, and camel hairs were commonly treated with camel urine to speed up the felting process. This concept was passed to hat industries around the world. However, instead of using camel urine manufacturers began using human urine. One particular sample was producing better felt and so they traced it back to the workman who they discovered was afflicted with a communicable infection and was therefore taking a mercury compound pill. The manufacturers linked the mercury to the improved felting process. This insight led to the widespread use of mercuric nitrate in many felt hat companies. Mercuric nitrate, $Hg(NO_3)_2$, was used during the Industrial Revolution to improve the process of making felt hats. The concept of "mad as a hatter" has been popularized through the character The Mad Hatter in Lewis Carroll's *Alice in Wonderland*

Hat-makers dip felt hats into nitrate of mercury solution. From W. Gilman Thompson, MD, The Occupational Diseases, D. Appleton and Company, 1914



(6, 12).

There is a mysterious compound of mercury known as Red Mercury, the "properties [of which are] unmatched by any compound known to science." Red mercury is actually deadly and

purportedly can be used in nuclear weapons and bombs and is not the substance found at the bottom of your thermometer; "a famous nuclear scientist once suggested [red mercury] could be used as a component in a neutron bomb small enough to fit in a sandwich-size paper bag." Red mercury is extremely rare, and some even argue that it does not exist. Yet throughout the generations, men have been searching everywhere to get hold of this deadly compound. There is much unsupported lore surrounding red mercury, which has spawned ISIS attempts to obtain it. Red mercury can supposedly create a blast powerful enough to flatten a city. A red mercury bomb could potentially change the face of warfare by adding yet another weapon in our arsenal with the power to create massive destruction. The search for red mercury can be traced back to the Cold War of the 1990s, during which the threat of nuclear weapons was growing ever more frightening. Samuel T Cohen, a physicist and veteran of the Manhattan project, was involved with red mercury and said people should be more afraid of this compound's power. It is indescribable, can be slipped into the tiniest of bombs and can create a very large and destructive nuclear bomb. Despite the warning, people continue to doubt its existence since few have witnessed the lethal compound (4). While western physicists continue to write red mercury off as a scam and a myth, there is evidence that ISIS officials have been obtaining a dangerous quantity of this compound.

This silvery element is a poison we voluntarily place in mouths, and in its differing forms can clean wounds, cause madness, and kill. Studying mercury's past and present gives one a sense of what the future might hold. There is a distinct pattern with mercury's use; it was constantly placed in household objects, such as hats and jewelry and then removed due to its toxicity. Our "safe" silver fillings of today could soon be replaced with a safer substitute. This seemingly magical element has equal potential for good and for evil; let us hope that its power does not fall into the wrong hands.

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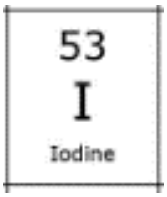


Ruchama Biderman

I-53 Think Therefore I-53 Am

The human mind is what elevates mankind from the animal. Without the ability to rationalize and develop ideas it would be impossible to tell the difference between humans and other living things. However, there is a significant and commonly overlooked factor to one's life which allows for such developments. Element number fifty three, iodine, is an essential factor in ensuring that one has a healthy bodily function. An English philosopher, Bertrand Russell stated, "The energy used in thinking seems to have a chemical origin...For instance, a deficiency of iodine will turn a clever man into an idiot. Mental phenomena seem to be bound up with material structure." Iodine allowed Russell to understand how emotions and memory depend on the material condition of the brain (1). Without iodine, one's mental capacity would be close to the animal.

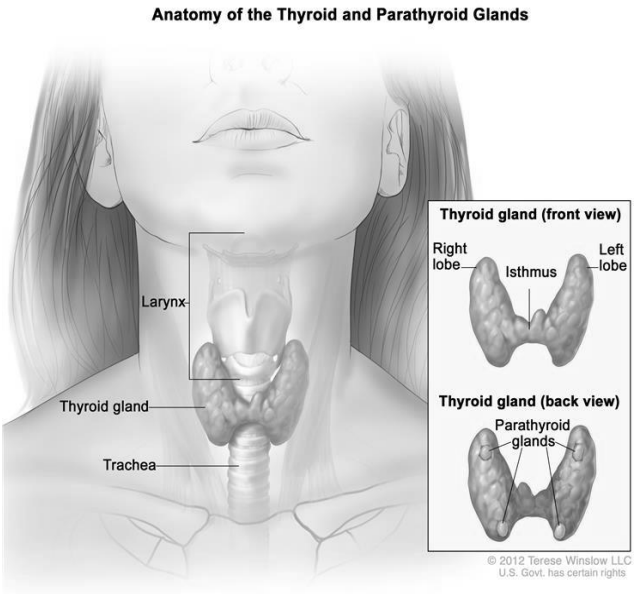
For instance, a deficiency in iodine will turn a clever man into an idiot.

The history of this important element was first developed by Bernard Courtois. In the early 1800s, Bernard Courtois of Paris manufactured saltpetre (potassium nitrate- KNO3), using seaweed ash as a source of potassium. Sometime later, in 1811, Courtois decided to add sulfuric acid resulting in a scene of purple fumes that had condensed to form crystals with a metallic lustre. Courtois hypothesized that this must be a new element and derived the name iodine from the Greek word "iodes" which means violet, due to iodine's purplish color. In order to confirm his new finding, Courtois offered a quantity of the element to Charles-Bernard Desormes, a French physics and chemist, and some to Nicolas Clément, an industrialist who was an owner and a partner in several chemical companies. Desormes and Clement carried out a systematic investigation and confirmed Courtois's prediction to be true. In November 1813, the new element of iodine was exhibited at the Imperial Institute in Paris. Joseph Gay-Lussac, a chemist and physicist, verified that this discovery was indeed a new element, and was then further confirmed by Humphry Davy, a chemist and inventor. Davy had then sent a report to the Royal Institution in London generating a false assumption that Davy was the discoverer, a belief that lasted for over 50 years (2).

Iodine plays a significant role in one's thyroid development. The thyroid is an important hormonal gland which is critical for the metabolism, growth, and maturation of one's body. The thyroid is located below the voice box in the front part of one's neck and is shaped like a butterfly. This gland produces three hormones known as triiodothyronine (T3), tetraiodothyronine (thyroxine or T4), and calcitonin. T3 and T4 both contain iodine as their main component. This portrays iodine's significant role in thyroid metabolism. However, the body cannot produce it on its own and it therefore must be acquired through food (3).

After iodine enters the intestine it is extracted from the food, begins to enter the blood stream and is delivered to the thyroid gland where it is incorporated into the hormones. T3 and T4 increase the basal metabolic rate and so all the body cells will then work harder providing a need for more energy. This strengthen the heartbeat, promote brain maturation in children, advance child growth, and activate of the nervous system

(which allows high levels of attention and quick reflexes) (3).



There are several consequences if the thyroid were to produce an overabundance or an insufficient amount of hormones. An overactive thyroid, known as hyperthyroidism, can cause tachycardia (racing heart), insomnia, emotional instability, hair loss, and weight loss. An overactive thyroid is often caused by an autoimmune disease of the thyroid tissue, called Graves or Basedow's disease. The over- activity is frequently generated by problems in the thyroid axis, which is accountable for the regulation of metabolism. This is dependent on the hypothalamus, the pituitary gland, and the thyroid gland. The thyroid function is usually regulated by a hormone produced in the pituitary gland (thyroid-stimulating hormone-TSH) which ensures that neither too much nor too little thyroid hormone is produced (3).

Hypothyroidism is when too little thyroid hormone is produced, which can either be genetic or developed in the course of life. Lack of iodine is a common cause of hypothyroidism, which proves that an adequate amount of iodine is vital for normal thyroid function. A child that lacks the right amount of thyroid hormones can often be affected both physically and emotionally. Iodine deficiency during pregnancy can cause maternal and fetal hypothyroidism (3). Also, hypothyroidism can lead to mental slowness, loss of energy, dry skin, slow metabolism, and depression. Hypothyroidism is often confused with the normal signs of aging. Due to hypothyroidism, the thyroid gland can grow and become visible as a goiter, which is a swelling of the neck. A goiter can bring difficulty when swallowing or breathing (4). For example, in 1800, the Napoleonic census of the canton of Valais found that 4,000 out of a population of 70,000 had people deformed or medically handicapped because of congenital thyroid deficiency (2).

Iodine is found in minute amounts in the upper crust of the earth. The effects of flooding, glaciation, and leaching into the soil during the Ice Age have caused the geographic distribution of iodine. Resulting from these natural forces, iodine

is frequently found in coastal areas in the seaweed and other seafood (5, 6). A lack of iodine is more common in places that are located far from the sea. For example, in Derbyshire and Nottinghamshire many people had developed a goiter, known then as Derbyshire neck. This was a consequence of the lack of iodine in their diet due to their distance from the ocean (7). Also, the iodine content of food that is grown or raised on a particular soil depends on the iodine content of this soil.

In the US, dairy products contribute up to 90% of total estimated iodine intakes in infants, at least 70% in children from ages 2 through 10, 53%-63% in teens from ages 14 through 16, and about 50% in adults. However, in England and northern Europe, iodine levels in dairy products are often quite low in the summer time when the cattle is allowed to graze in pastures that have a low soil iodine content. Additionally, dietary iodine can be found in eggs, fruit, poultry, and grain products. Processed foods often contain iodized salt or food additives, such as calcium iodate and potassium iodate (8). Iodine is added to salt in order to ensure that one has a sufficient amount in one's diet. When one has an inadequate intake of iodine, the resulting meager development of thyroid hormone can lead to mental retardation, dwarfism, and hearing loss. The fortification of salt with iodine is an effective, inexpensive route for one to guarantee a well suited intake of iodine. In some regions of the world where salt iodization is not ideal, iodization of other common foods for example, bread, is targeted. One can also receive oral or intramuscular iodized oil supplements. In the US, iodized salt is not used in the manufacturing of processed foods and fast food products, and the food industry is not obligated to list the iodine content on food packaging (5).

It is interesting to note how one form of iodine can be effective in helping one's body while exposure to another form can be extremely harmful. If too much radioactive iodine enters one's body, the radioactive iodine will accumulate in the thyroid gland and destroy the cells that manufacture the hormone. Too much radioactive iodine in one's body can also cause thyroid nodules (swelling) or cancer (9). For example, the 1986 nuclear accident in Chornobyl exposed many people to 131I (a radioactive isotope of iodine), and reports of radiation epidemiology studies indicate that years later, exposure generated cases of radiation induced thyroid cancer. Nuclear power plants in the United States contain a source of radioactive iodine that can possibly impose risks of exposure, which could lead to thyroid cancers (10).

KI, potassium iodide, is effective in protecting against potential thyroid cancer. The use of KI during the Chornobyl incident can likely explain the lack of a significant increase in childhood thyroid cancer. In the US, the Nuclear Regulatory Commission (NRC) requires the consideration of potassium iodide distribution as a measure to protect the general public in the case of a major release of radioactivity from a nuclear power plant (8). Potassium iodide (KI), a salt of stable iodine, is formed when potassium (K) donates its single valence electron to iodine, and form an ionic bond. Potassium iodide helps to block radioactive iodine from being absorbed by the thyroid gland which protects the thyroid from radiation injury (5, 11).

Potassium iodide has also been used as an ingredient in cough medicine (12).

Silver iodide, another ionic compound is used in cloud seeding and in antiseptics (13). Iodine accepts the single valence electron that silver donates, allowing itself, as well as the silver atom, to achieve stability. It was instrumental in the first commercial use of film photography. In 1839, Louis Daguerre invented a technique for producing images on silver plated copper called daguerreotypes. Daguerre understood how iodine was sensitive to light and could be used to produce images. The silver plate became exposed to iodine fumes from a box which contained iodine crystals on the bottom. The iodine fumes touch the silvered surface creating a thin layer of silver iodide on the plate. When the layer of silver iodide was exposed to light by the camera, its color began to darken and a negative image was formed on the plate (14).

Iodine is also used for purifying water, skin soaps, bandages, and as a disinfectant for cleaning surfaces and storage containers (15). Povidone-iodine (chemical complex of polyvinylpyrrolidone [povidone, PVP] and elemental iodine), also known as Betadine, is frequently used to clean one's wounds (16). Ironically, because of iodine's redish, purplish color it often will make a cut look even worse (17).

In the realm of technology and medical imaging, Iodine is a component used in the process to create LCD (liquid crystal display) screens that are ubiquitous in our modern gadgets such as digital watches, laptops, TV screens, digital cameras, and

calculators. Organic iodine derivatives are used to make soft tissue visible during x-ray examination. They block the x rays power to pass through and temporarily change the appearance of body tissue, blood vessels, and organs (18).

Iodine is important for the bodily and thyroid functions of a human while it is also a component in commonly used day to day items. For future safety, iodine is likely to play a significant role in the case of a terrorist attack either at a nuclear power plant or with a "dirty" bomb. If radioactive iodine was to be released, then potassium iodide will be needed to help prevent any internal bodily issues (19). Iodine's duel ability allows for it to be man's savior while potentially having the ability to destroy through its radioactive state. However without this possibly destructive element, development of man's capabilities and mental capacity would be almost nonexistent.

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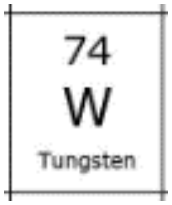


Racheli Brunner

SEEING THE LIGHT

Like Manhattan, the Periodic Table of the Element is organized as a grid. While the intersection of Sixth Avenue and Sixth Street technically does not exist, we can predict in which neighborhood it would land: Greenwich Village. The Periodic Table of Elements is composed of 118 natural and synthesized elements, with the synthesis of element 119 to be confirmed, and because it is a grid of vertical groups and horizontal periods, we could predict the properties of the element based upon the "neighborhood" in which it is found. The intersection of sixth and sixth lands squarely on the square of the 74th element, Tungsten.

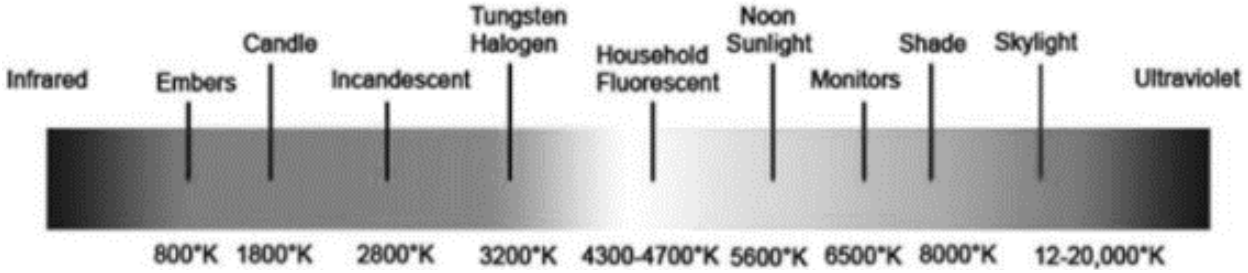
It could be said that the history of chemistry is bound to the quest for light.

The discovery of tungsten was a long bumpy road. It began in the year 1779 when Peter Wolfe examined the mineral wolframite. He concluded that it contained a new metal, however he could not separate it (3). Two years later, in 1781, Wilhelm Scheele investigated the same mineral and succeeded in separating an acidic white oxide which he said was an oxide of the new metal. However, the real credit for the discovery of tungsten is given to the Elhuyar brothers Juan and Fausto. In 1783, at a Seminary in Vergara, Spain, the Elhuyar brothers produced the same acidic white oxide as Scheele, and even succeeded further in reducing it to the tungsten metal itself by heating the oxide with carbon (2). It was given the chemical symbol W after the ore in which it was found. The name Tungsten comes from the Swedish, which means heavy stone, because it has a whopping density of 19.6 g/cm^3, exceeding that of gold (9).

It could be said without hyperbole that the history of chemistry is inextricably bound to the quest for light and the vanquishing of darkness. Due to its properties, Tungsten has varied uses and contributed largely to the development of the lighting industry. In the late nineteenth century Thomas Edison, the wizard of Menlo Park, NJ, had a vision of lighting the masses. Up until his discovery of the incandescent light bulb, burning candles, simple oil lamps, and gas lights were used. Their light was feeble and flickering; streetlamps had to be lit one by one by carrying a flame. The incandescent bulb has arguably done more to alter social habits and the establishment of our electrical grid system than any other single invention. It brought safe, bright light into homes and streets at night and tungsten played a starring role in the drama (7).

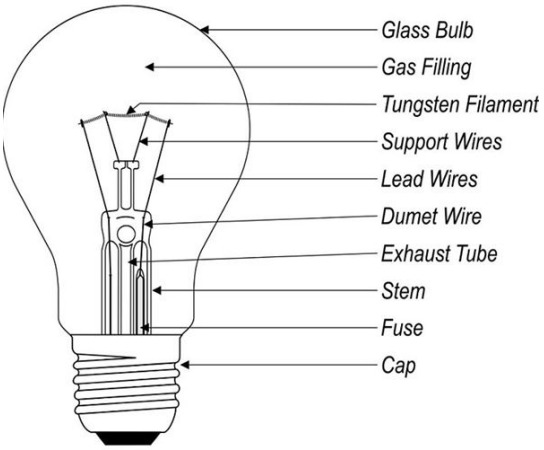
Tungsten is a natural element and of all the metals on the periodic table, it holds the prize for the highest melting point. Of all elements, tungsten comes second only to carbon. Tungsten's high melting point makes it suitable to make up the filaments of light bulbs. Light bulbs emit light through black body radiation; the higher the temperature, the shorter the wavelength of light. At lower temperatures, wavelengths fall within the infrared region, which are not visible to the human eye. This is the origin of the phrases "red-hot" and "white-hot." The human eye can register wavelengths of 400-700 nm (10^{-9} m) and in order for people to see the light emitted by a light bulb, the filament needs to be close to 3000 degrees

Celsius. Of all metals, only tungsten can reach that high a temperature without melting (1).



http://www.hoveyelectric.com/Portals/47330/images/lighting-sources-color-temperature-led-lighting-hid-incandescent-resized-600.png

Disappointingly, after a short time, the blackened tungsten would vaporize and deposit on the inner surface of the bulb making it unusable. Irving Langmuir, winner of the 1932 Nobel Prize in Chemistry, introduced the unreactive gas Argon into the bulb to exert a positive pressure on the filament and solve the problem (7). Twenty first century lighting technology has since advanced to fluorescence and now with the Light Emitting Diode (LED) making inroads, the tungsten incandescent light bulb has pretty much gone the way of the Model T.



During World War I, tungsten proved invaluable. Nearly as hard as diamond, a small addition of tungsten to steel made shields much more resistant. The British used tungsten steel for ships. Belgium and France used it for steel and concrete fortresses. Tungsten became so valuable that when gold was found in the mines, it was discarded as a contaminant (6). Presently, tungsten carbide is used to make cutting tools for a variety of uses, some of which are drilling, mining, and construction (10). Tungsten is also used to form the tips of electron guns that allow electron microscopes to examine singular molecules of different objects. Spikes in the tracks of snowmobiles and vibrators of cell phones are made of tungsten too. Tungsten can also add incredible strength to missiles and bullets. Military personnel are attempting to add tungsten to their armor as well, so it can help protect from the tungsten bullets (11).

Personnel wounded with shrapnel from tungsten alloyed (WA) munitions used during the 1991 Persian Gulf War were found years later to suffer from metastatic tumors surrounding the embedded shrapnel. Rats implanted intramuscularly with WA weapons grade pellets developed extremely active tumors within 4-5 months after implantation. Rats implanted with Tantalum pellets, used as a control, did not develop tumors. These results should serve as a warning signal that tungsten is not without its health concerns (4, 8).

The largest producer of the world's tungsten is China, accounting for about 75-80% of the world's total supply. Vietnam, Russia, and Canada also

possess nice supplies of tungsten. Maintaining friendly relations with our trading partners is crucial to keep the supply lines flowing and, unfortunately, sometimes these considerations trump human rights violations. Most of the world's tungsten is actually acquired through the recycling of wastes from tungsten products. In the United States, nearly one third of our tungsten is acquired through this recycling process (2). If we could ramp up this process, perhaps we could achieve tungsten self-sufficiency.

Up until now, we have used the disciplines of physics and chemistry to learn how to utilize the unique properties of tungsten to our advantage. The study of biology has also lent itself to adding to the list of uses for element 74. Recently, researchers have discovered new species of primitive bacteria called hyperthermophiles that metabolize sulfur instead of oxygen and are capable of surviving the high temperatures of the hydrothermal vents of the ocean depths. It is thought that these hydrothermal vents provided the right conditions necessary for the origin of life. These life forms are puzzling because proteins normally denature at high temperatures but researchers isolated and purified tungsten containing enzymes in all five of the genera examined. This finding has potential applications for catalyzing industrial reactions at temperatures where no synthetic catalyst is known (5).

Of the 118 confirmed elements on the Periodic Table, with number 119 waiting in the wings, most people can tick off an average of only 10-20. When most people look around at the world, they do not see things for what they truly are. There is science behind every single substance in the world and people just do not realize it. Many of the elements on the periodic table are unfamiliar to most, yet they make up such important parts of our lives. The element tungsten may be unheard of to many and yet without this vital element it would be nearly impossible to have a simple light bulb, to safely shield ourselves in war, or to understand basic biology. It is essential to realize that when looking at the world, there is so much more to understand than what simply meets the eye, so that we do not squander our resources for lack of knowledge.

David HaMelech learned the hard way that every creature was placed here in the world with a plan and with a purpose. One could argue the same of the elements.

Meet me at sixth and sixth.

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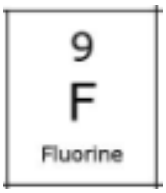


Leora Mause

THE CANARY IN THE KITCHEN

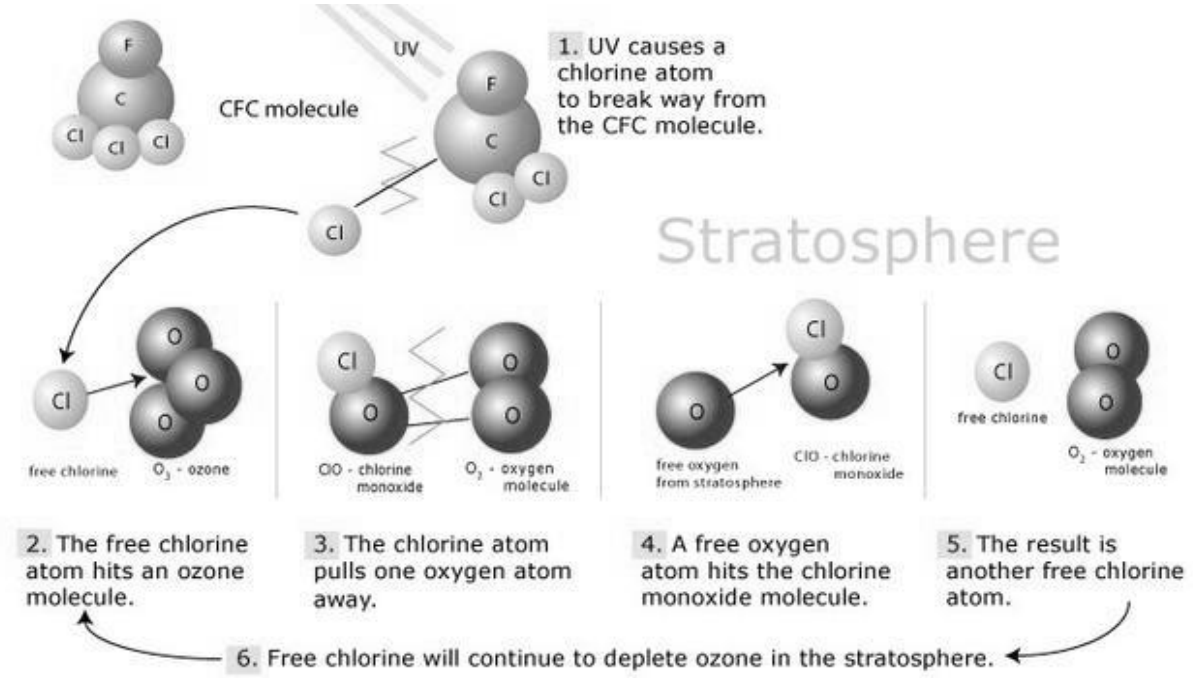
She placed the non-stick frying pan on the burner, getting ready to fry some fish for dinner but was distracted by the phone. The friendly voice on the other end was someone she hadn't spoken to in a while and she settled down to catch up. When she returned to the kitchen, the frying pan was smoking and her canary lay dead at the bottom of the cage. Unbeknownst to her, the bird succumbed to Polytetrafluoroethylene (more commonly known by its trade name, Teflon) Toxicosis. Birds have a highly efficient respiratory system and are particularly sensitive to airborne toxins. That is why canaries are sent down to coal mines in advance of the miners to ensure that the air quality is safe. Teflon was introduced in 1946 by DuPont and is still one of their signature products. Fluorine is one of the key elements in Teflon (8).

Fluorine, a pale yellow gas, is the most reactive of all elements, and it is impossible for a substance to release fluorine from its compounds without any outside intervention. Since fluorine is so reactive, it does not occur freely in nature and was hard for scientists to isolate. In 1670 Bohemian emerald (calcium fluoride CaF_2) was used to etch glass. Chemists wondered what was in it that had the ability to etch glass. Many attempts were made to free fluorine but were unsuccessful until 1886 when Ferdinand Frederic Henri Moissan, a French chemist, isolated fluorine. He did this through the electrolysis of potassium fluoride and hydrofluoric acid, and this method is still used commercially to this day. Electrolysis is a way of separating elements by pushing an electric current through a compound. Moissan's work was so impressive that he was awarded the Nobel Prize for Chemistry in 1906 (9). Fluorine is found in nature in minerals like fluorspar, fluorapatite, and cryolite. These minerals are found in China, Mexico, Mongolia, and South Africa. In its elemental state, fluorine forms a diatomic gas (3).

The reason for fluorine's high reactivity can be explained by its atomic structure. Its seven valence electrons are in the second energy level, held tightly by its nine proton nucleus. Fluorine needs one more electron to complete its stable octet and will figuratively vacuum up more loosely held electrons from other atoms. Given that fluorine has the highest electronegativity of all the elements, not even the normally inert Noble gases withstand fluorine's allure (1). Neil Bartlett, a chemist wanted to make the first noble gas compound and the element capable of reacting with xenon was fluorine. When he "broke the seal between the red PtF_6 gas and the colorless xenon gas, there was an immediate interaction, causing an orange-yellow solid to precipitate" (7).

As a gas in its elemental state, fluorine doesn't have so many uses since it is so reactive, but it is used in rocket fuels (10). With most compounds fluorine reacts violently, and with water explosively. Fluorine even makes glass flammable (1). Because of fluorine's reactivity, many useful compounds are made that we benefit from daily. Fluoride compounds such as sodium fluoride, stannous (II) fluoride, and sodium monofluorophosphate are added to toothpastes to prevent tooth decay. Some municipalities even add it to drinking water. Without fluoride, the tooth decay and cavities can lead to formidable infections that can spread into the jaw (2). However, as with most things, excessive use does have its downside.

CFCs (chloro-fluoro-carbons) are organic compounds containing fluorine. They were used in air conditioning, refrigeration systems, and aerosol spray cans, but they were since banned because they cause damage to the ozone layer by catalyzing the reaction $2\ O_3 \rightarrow 3\ O_2$ (9). *See graphic below for details of chemical reaction.*

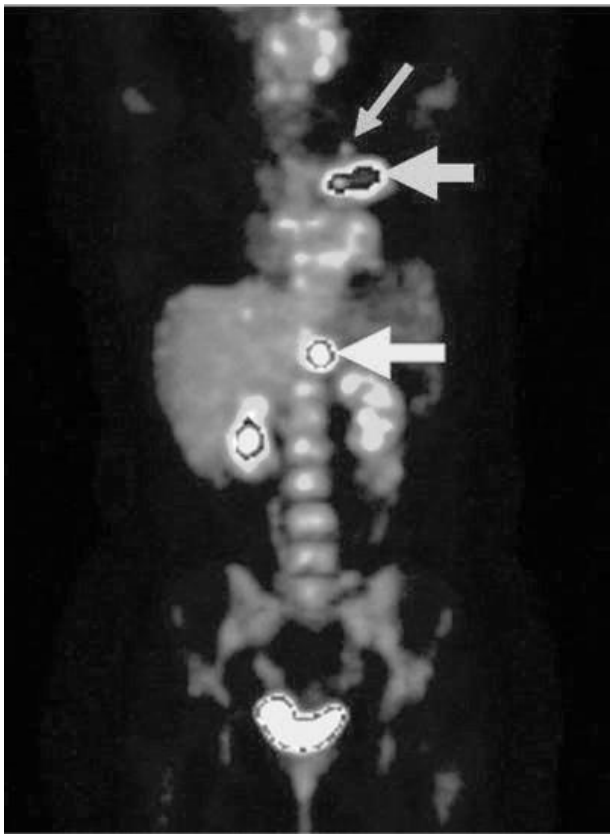


While working at Dupont on the new CFC refrigerants, Roy J. Plunket discovered Teflon by accident in 1938. When he opened the gas cylinders to investigate why they had stopped flowing, he found a white powder clogging the nozzle. Plunkett had the presence of mind to characterize its properties for other than refrigeration potential. He found the substance to be heat resistant and chemically inert, and to have very low surface friction so that most other substances would not adhere to it. The CFC's had polymerized to form Teflon. Plunkett often told student audiences his mind was prepared by education and training to recognize potential in lucky accidents (6).

One of fluorine's isotopes, F-18, is radioactive and can therefore be used to detect problems in the body by using Positron Emission Tomography (PET). Fluorodeoxyglucose (FDG), a version of sugar glucose, is prepared with F-18 and administered to the patient, where it will concentrate in places where glucose is used for energy. The PET scanner detects the radiation that is being emitted by the radioactive drug in the patient, and takes images of the places where the FDG is localized. The brain is a high consumer of

His mind was prepared by education and training to recognize potential in lucky accidents.

glucose and also cancer cells so it is helpful in detecting tumors (11).



FDG activity is highlighted by the bold arrows. Low-grade FDG activity is shown by the thinner arrow, indicating nonspecific inflammation or resolving infection.
http://www.medscape.com/viewarticle/477469)

Despite all the benefits, fluorine can have negative effects as well. When in contact with our skin it can leave destructive burns. Studies show that drinking a lot of fluoride leads to negative health effects like bone fractures, thyroid disorders, impaired brain development and function, and dental fluorosis. Dental fluorosis is when white streaks appear on your teeth. When severe, there can be brown stains, pits, and broken enamel on your teeth (2). Fluoride is known to have large neurological effects, either lowering IQ's or causing memory loss, rendering it a dangerous tool. The account below shows us the dangers of fluorine and why it is necessary to be cautious with it.

At the end of WWII, Charles Eliot Perkins, a noted scientist, was sent to take over the I.G. Farben plants, one of the largest German chemical manufacturers. It produced Zyklon B, the poisonous gas used to exterminate inmates of the concentration camps. Perkins wrote a letter on October 2, 1954 to the Lee Foundation for Nutritional Research. He reported that the German General Staff approved a control plan to use on subject populations. It was going to control their minds by medicating the water using sodium fluoride. In the letter, Eliot Perkins wrote: "However, I want to make this very definite and very positive—the real reason behind water fluoridation is not to benefit children's teeth…The real purpose is to reduce the resistance of the masses to domination and control and loss of liberty." He also stated "…any person who drinks fluoridated water for a period of one year or more will never again be the same person, mentally or physically." Studies in China in the 1990s showed a drop in IQ of people exposed to fluoride in their drinking water (4). The dangers that come from fluorine are generating controversies world-wide over fluoridation of drinking water.

Not only are there mental effects caused by fluorine, there are also many diseases that are caused by fluoropolymers. Fluoropolymers are fluorinated carbon chain polymers. Fluoropolymers are used in products as water and soil repelling agents, lubricants, sealants, and leather conditioners. With these products, there have been outbreaks of respiratory disease, including a cough, shortness of breath, and chest pain. Sometimes this leads to hospitalization, respiratory failure, acute respiratory distress syndrome (ARDS) and death. In Switzerland in

2002, there was an outbreak of a disease in a tiling company. There were three workers who became ill with dyspnea and a cough. The product was investigated and they found that the ingredients of the product had changed. The change involved the solvent and the water-repelling agent. Later, 150 people exposed to waterproofing agents had similar respiratory outbreaks to these three people. In all cases the same fluoropolymer was evident (5). As stated before, Teflon is a fluoropolymer, hence the death of the canary with the sensitive respiratory system. From all of these accounts, it is evident that fluorine has a vast amount of dangers which must be handled with extra protection and precautions.

Fluorine's many dangers must not be dealt with haphazardly. Fluorine can be to our benefit or to our detriment; which way it will go is determined by us. It depends on how it is used. If it is used properly fluorine products can be helpful tools. Fluorine is a unique and interesting element, and while so much is already known of fluorine, there is always more to research and discover. In the future, fluorine may be banned from drinking water or perhaps put to use as a pharmaceutical and save someone's life. There are two sides to every debate and hopefully more research will be done and only good things will come from it.

Too bad about the canary, though.

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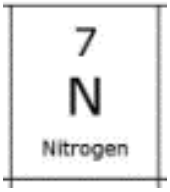


Avigail Ovitsh

GUNS AND BUTTER

Living in today's fast-paced, demanding society, it is very easy to forget about the things behind the scenes that really make our world run. No one ever stops to think about how our electricity turns on, how the atmosphere regulates our ecosystems, or even how our body digests a slice of pizza. Many people don't realize that behind all these processes are 118 confirmed (with 119 waiting in the wings) little substances called elements that make up our universe and everything in it. One of these elements, nitrogen, is especially useful to our atmosphere, the human body, our ecosystem, and industrial and technological systems.

Nitrogen is a very common element in the universe, estimated at about seventh in total abundance in the Milky Way Galaxy and our Solar System. On Earth, the element forms about 78% of the Earth's atmosphere. Nitrogen, a stable diatomic molecule as a gas in its elemental state, has many uses. Nitrogen gas is used as an inert replacement for air where oxidation is undesirable. Nitrogen can be introduced as a component of a modified atmosphere. Pure or mixed with carbon dioxide, it preserves the freshness of packaged or bulk foods. It is also used in incandescent light bulbs as an inexpensive alternative to argon (*See Racheli Brunner "Seeing the Light" in this publication*). It can be used for the manufacturing of stainless steel, and in some aircraft fuel systems to reduce fire hazard. Interesting for paintball enthusiasts, nitrogen tanks are replacing carbon dioxide as the main power source for the guns. As a liquid, nitrogen is used as a refrigerant in the cryopreservation of blood, reproductive cells, and other biological samples and materials. Cryopreservation is a process where cells, whole tissues, and any other substances that can damage over time are preserved by cooling to subzero temperatures (10).

The Discovery of Nitrogen

Nitrogen is an element that is found in Earth's atmosphere. It was not synthesized, but was discovered by Scottish chemist and physician Daniel Rutherford in 1772. He called nitrogen *noxious air*. Although at first he did not recognize it as a new chemical substance, he distinguished it from carbon dioxide that was also found in the air, discovered by Joseph Black. When Joseph Black was studying the properties of carbon dioxide, he saw that a candle would not burn in it, it would just be extinguished in the carbon dioxide. As his student, Rutherford continued Black's research. He kept a mouse in a space with a confined amount of air until it died. He then burned a candle in the remaining air until it went out. He then burned phosphorus in that same air until it would not burn anymore. The mouse, the burning candle, and burning phosphorus consumed all the oxygen from the air and produced carbon dioxide instead. The air was passed through a carbon dioxide absorbing solution. The remaining component of air, which contained what we know today as nitrogen, did not support life, and a new mouse died. As a result of this experiment, Rutherford saw that there was a component of the air which was not carbon dioxide, and it did not support fire or life. It was then that he first observed the element nitrogen and called it *noxious air*.

The English word "nitrogen" entered the English language in 1794, from the French word *nitrogene* coined in 1790 by French chemist Jean-Antoine Chaptal. It comes from the Greek word *nitron* which means sodium carbonate and the French

word *gene*, which means better, or producing. He named it nitrogen because it is the essential part of nitric acid (HNO_3), which is formed from potassium nitrate (KNO_3), also known as saltpeter. By the Middle Ages, nitrogen compounds were very well known. Alchemists knew nitric acid as strong water called *aqua fortis*. The mixture of nitric and hydrochloric acid was known as *agua regia* (royal water), because it was able to dissolve gold (10).

Nitrogen Compounds

Nitrogen, with five valence electrons and fairly high electronegativity, tends to form three covalent bonds in its varied compounds. These compounds have many important uses. Many are industrially important, such as ammonia and nitric acid. Synthetically produced ammonia (NH_3) and nitrates are key industrial fertilizers. Nitric acid (HNO_3), is a highly corrosive mineral acid that will destroy and damage other substances it comes into contact with. Some of these compounds are thermally sensitive explosives (think of trinitrotoluene, more commonly known as TNT). Alfred Nobel was an industrialist who created dynamite using TNT. He established the Nobel Prize to assuage his guilt over development of this explosive. A few of these are stable enough to be used in pigments, inks, and dyes. Nitrogen is also a part of molecules in every major pharmacological drug class, including antibiotics (10).

Sodium Nitrite ($NaNO_2$) is another important compound that has a unique ability to be used as a food additive. Food additives are substances added to food to preserve flavor or to enhance its taste or appearance. Sodium nitrite is used as an additive but has the potential to cause cancer. During digestion, sodium nitrite found in the stomach can transform some of the digestive and metabolic products of proteins into a class of compounds called nitrosamines. Nitrosamines are among the most powerful carcinogens, which are cancer-causing agents, known in the world. They have been found to cause cancer in every species of laboratory animal tested. It is uncertain, however, whether sodium nitrite does actually generate nitrosamines in the stomach which can cause cancer, but the risks are very high. On the other hand, the benefit of using sodium nitrite is that it protects processed meat against one of the deadliest of all poisons, botulism. Botulism is responsible for a lethal kind of food poisoning. Because of its potential carcinogenic effects, there is current debate regarding its value as a food additive in meats. While removing sodium nitrite from meats can reduce the risk of cancer, removing it would also increase the risk of a very lethal form of food poisoning (9).

Nitrogen in the Atmosphere

In addition to its use in numerous compounds, nitrogen also makes an essential contribution to Earth's atmosphere. As previously stated, it makes up 78.1 % of the Earth's atmosphere, while oxygen makes up 21% (8). Scientists believe that most of the nitrogen in our air was carried out from deep inside the Earth by volcanoes. The nitrogen molecule is heavier than most other molecules in the atmosphere, so it tends to settle to the bottom of the atmosphere, and therefore takes up so much of our atmosphere. On the other hand, hydrogen and helium are much lighter gasses so they tend to stay on top of the atmosphere and become diffused in space, constituting less of Earth's atmosphere (4).

Nitrogen abundance in the atmosphere allows for numerous social and technological contributions. However, it can also produce negative consequences, such as being a part of air pollutants and climate alterations. Nitrogen oxides are one form of air pollutants along with sulfur oxides and

carbon monoxide. Unlike in sulfur oxides, the nitrogen of air pollutants comes directly from the air itself and not impurities in fuel. Nitric oxide (NO) is a colorless gas that is formed when molecules of nitrogen and oxygen combine at very high temperatures in engines. Once it is in the atmosphere, NO reacts with more oxygen to form nitrogen dioxide, a reddish-brown toxic gas that causes irritation to the eyes and respiratory system. Nitrogen dioxide (NO_2), can produce an inflammation of the lungs that can become fatal if not treated, but fortunately, nitrogen dioxide is not a major air pollutant nationally (9).

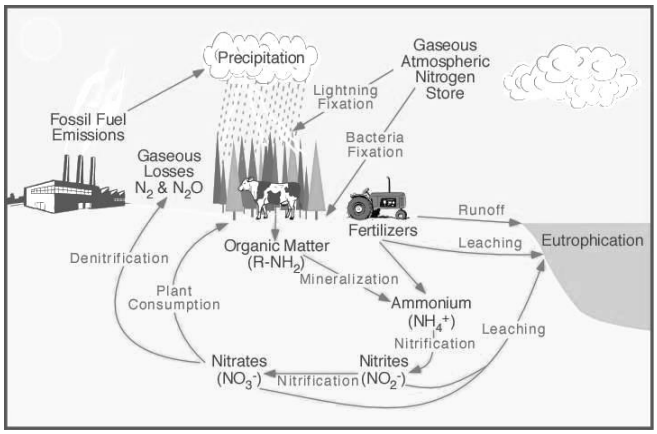
Reactive nitrogen (Nr) emissions alter the climate in many ways. Excess nitrogen can change the emission of three of the most important greenhouse gasses produced by humans—carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Nr affects the production and lifetime of greenhouse gases such as ozone (O_3) and methane. The most direct effect of nitrogen on the climate is through N_2O production, which contributes to 6% of total human induced global warming. Globally, natural ecosystems release approximately 10 Tg (teragram, = 10^{12} grams or 10^9 kilograms) N_2O per year. Anthropogenic sources are dominated by the widespread use and processing of fertilizer in agricultural soils. Atmospheric concentrations of N_2O have increased rapidly since the Industrial Revolution in the late 1800s, as livestock herds increased worldwide and use of synthetic nitrogen fertilizers increased after WWII. The current rate of increase in the concentration of N_2O is about 0.3 % per year. The United States Environmental Protection Agency's Office of Atmospheric Programs estimated that agricultural activities in the US are directly responsible for emissions of about 0.48 million tons of N_2O-N per year, which is about 80 % of total US N_2O production (the remainder from energy and industrial sources), and about 10 % of the global N_2O emissions from agriculture (1). Ammonia fertilizers, a major use of nitrogen in the agricultural system, now helps feeds a third of the world, the rest of whom are fed by phosphate fertilizers (6).

Although nitrogen sounds terrible for the environment, it is actually really important in our atmosphere. All the gasses in the air combined have a great mass and great weight, and because of this mass and weight, there is a specific air pressure. The air pressure is highest at sea level where the weight of the gasses press down the most. As one moves up from sea level, air pressure decreases, and eventually one cannot breathe. Without the significant amount of nitrogen in the atmosphere, air pressure at sea level would not suffice for human respiration. If a reactive gas such as oxygen replaced the 78% of nitrogen in the atmosphere, Earth would be unable to properly support life, so it is beneficial that nitrogen is not very reactive yet so abundant in our atmosphere (3).

Nitrogen Cycles and Environmental Role

In addition to its essential role in the atmosphere, nitrogen has vital biological and environmental uses as well. Nitrogen exists in all organisms, primarily in amino acids and proteins, in the nucleic acids (DNA and RNA), and in the molecule adenosine triphosphate, which is involved in energy transfer and cellular respiration. The human body contains about 3% nitrogen by mass, the fourth most abundant element in the body after oxygen, carbon, and hydrogen (10).

The nitrogen cycle is the process by which nitrogen is converted between its various chemical forms. This can be carried out through biological and physical processes. The nitrogen cycle is one of the most important nutrient cycles in ecosystems. *See graphic below for details.*

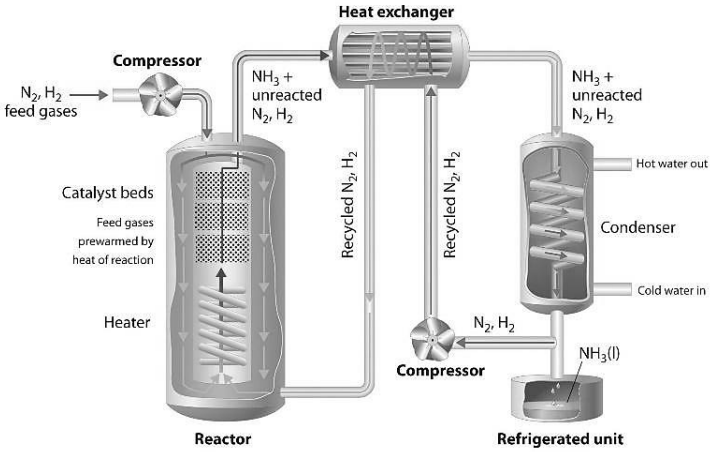


Living organisms use nitrogen to produce a lot of complex organic molecules like amino acids, proteins and nucleic acids. Organic matter in soil and the oceans are other major stores of nitrogen. Despite its abundance in the atmosphere, nitrogen is a very limiting nutrient for plant growth. This occurs because most plants can only use nitrogen in its two solid forms of ammonium ion and the nitrate ion. In order to be able to use the nitrogen for plant growth, reproduction and metabolism, plants require "fixed" nitrogen within the soil by specialized microorganisms like bacteria, actinomycetes, cyanobacteria, and legume plants (2). Nitrogen fixation is a step in the nitrogen cycle and is the process in which nitrogen in the air is converted into ammonium (NH_4^+), a nitrogen ion which plants can use. Nitrogen fixation also helps fertilize the soil. Legumes contribute to nitrogen fixation by hosting symbiont micro-organisms and include kudzu, clovers, soybeans, alfalfa, lupines, and peanuts. They contain a bacteria called *rhizobia* within their root systems that helps the plant grow. When the plant dies, the fixed nitrogen is released and available to other plants which help fertilize the soil (11). Scientists estimate that biological fixation globally adds approximately 140 million metric tons of nitrogen to ecosystems every year (1).

Despite being great fertilizers, synthetically produced ammonia and nitrates are key pollutants in causing the eutrophication of water systems (10). Eutrophication is a form of water pollution in which plants who are well nourished by fertilizer runoff, thrive at the expense of aquatic animals. When chemical fertilizers like nitrates and phosphates are overused, the excess enters the water of lakes and streams. They produce a rapid growth of surface plant life, especially algae that forms a mat to cover the surface of the water. Fish and other aquatic animals disappear from the waters because of the oxygen deprivation and plant life thrives at the expense of animal life (9).

Nitrogen Fixation Discovery

The nitrogen cycle has existed since the beginning of creation, but not many people know the amazing stories behind the discovery of nitrogen fixation as an industrial process. Nitrogen can be "fixed" in two ways, biologically and through an industrial process. Biologically, it is fixed through the nitrogen cycle, as discussed above, and was discovered by German agronomist Hermann Hellriegel and Dutch microbiologist Martinus Beijernick. Another way to "fix" nitrogen is through industrial nitrogen fixation. The possibility that nitrogen in the atmosphere responds to certain chemicals was first observed by Desfosses in 1828. He saw that mixtures of alkali metal oxides and carbon react at high temperatures with nitrogen. In 1898, Adolph Frank and Nikodem Caro discovered calcium cyanamide that is also used as a major fertilizer. In 1902, the Ostwald Process for the production of nitric acid was discovered. The Ostwald and Frank-Caro processes dominated the industrial fixation of nitrogen until the discovery of the Haber process in 1909 (11).



The Haber-Bosch process (see above) was developed in the first half of the 19th century by German inventors Fritz Haber and Carl Bosch. Throughout the 19th century, the demand for nitrates and ammonia for use as fertilizers and industrial feedstocks had been steadily increasing. The main source was mining niter deposits. At the beginning of the 20th century these sources were not sufficient. Therefore, research into new potential sources of ammonia became more important. Haber, with his assistant Robert Le Rossignol, developed the high-pressure devices and chemical reactions to demonstrate the Haber process at laboratory scale. They demonstrated their process in the summer of 1909 by producing ammonia from air drop by drop, at the rate of about 125 ml per hour. The process was purchased by the German chemical company BASF, who then gave Carl Bosch the job to elevate Haber's process to the level of industrial production. He succeeded in 1910. Haber and Bosch were later awarded Nobel prizes, in 1918 and 1931 respectively (12).

Fritz Haber and the Jewish Connection

Fritz Haber was one of the greatest minds in the history of chemistry. Haber was a Jew who converted to Lutheranism at the age of 46 because he thought he could advance further in German society. He discovered how to chemically "fix" nitrogen, or convert it to its compound ammonia. Haber invented an industrializing process that can "capture" nitrogen. He heated nitrogen to hundreds of degrees, injected some hydrogen gas, turned up the pressure, added some osmium as a catalyst to start the reaction, and got ammonia. Since ammonia is used as a major fertilizer, with Haber's discovery, cheap industrial fertilizers were now available and Haber had likely saved millions of starving people by the time World War I broke out.

Haber didn't really care about fertilizers. He pursued cheap ammonia to help Germany build nitrogen explosives. During World War I, the Allies' blockade of Germany prevented the import of sources of nitrogen and the armaments efforts stalled. At the beginning of the war, Germany was more behind in warfare than France, so German military leaders recruited Haber to modernize their warfare. Haber was the first to develop gas warfare using chlorine. The Germans first tested Haber's new gas technology on the British army who had no gas. Haber directed the first successful gas attack in history which left 5,000 Frenchmen burned and scarred. As a result of his success, the military promoted Haber to captain during the war. Haber's wife Clara Immerwahr was also a chemical genius equal to her husband who had the bad luck in her choice of spouse. Horrified by the gas projects, Clara killed herself with Haber's army pistol.

Despite Haber's gas weapons, Germany lost the war and owed a great debt to the Allies. In 1919, Haber won the Nobel Prize for his discovery of the conversion of nitrogen to ammonia and the initiation of the Green Revolution. A year later he was charged with being an international war criminal, and humiliated by the huge reparations Germany had to pay to the allies, Haber spent 6 years trying to extract gold from the Oceans to pay

the money himself. Haber had invented a gas called Zyklon A before the war, and a German company created a second generation gas called Zyklon B to use on Jews. The Nazis exiled Haber for his Jewish roots. The fact that he renounced his Jewish heritage for the sake of the Fatherland or that he had brought Germany pride by winning the Nobel Prize meant nothing to them. The only consideration they gave him was that he was not sent to the concentration camps. He led a nomadic life traveling through Europe. Einstein tried to convince him to go to Palestine but he died a broken man in 1934 on his way to England before he could make a decision. Meanwhile, in the epitome of irony, the Nazis were gassing many Jews, including Haber's relatives, with the second generation Zyklon B gas he helped create (7). An article in the New York Times entitled "Nobel Award to Haber" published in January of 1920, stated that nitrates are one of the main sources for explosives, and without the Haber process, it is doubtful if Germany would have even started the war (5). Nitrogen is such an essential element that it might even be considered the catalyst for causing both World Wars!

The fact that he renounced his Jewish heritage meant nothing to them.

Nitrogen is an element that many of us are not even aware of in our daily lives, but contributes so much to our environment, bodies and atmosphere. Without it, we would not be able to survive. It has a fascinating history and many amazing stories behind its evolution as one of the most important elements in the universe. Research on nitrogen and its agricultural use as a major fertilizer, as well as a dangerous environmental pollutant is constantly being conducted and written about extensively in science and medical journals. Although scientists know so much about this fascinating element, there is always more to learn. The ever-evolving nature of scientific knowledge beckons us to dive in, explore, and continue to discover.

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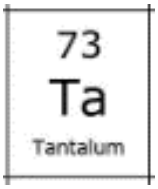


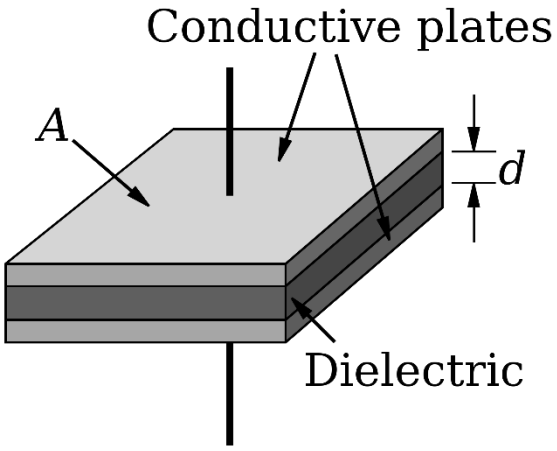
Bassy Reissman

TANTALIZING TANTALUM

Most people reflexively reach for their iPhones with nary a thought to the possibility that it was manufactured with minerals from a country where warlords and mass murders benefit from the profits of those mines. Recently, civil rights groups have strongly been calling for transparency from tech companies including Apple that use foreign sourced minerals in their tech products. A year ago, Apple made a claim: It had audited smelters in its supply chain and none of them were still using tantalum, which has been known to be sourced from wartorn corrupt regions in the Democratic Republic of Congo (DRC) (4).

Tantalum (Ta), atomic number 73 on the periodic table, is a transition metal. Anders Gustaf Ekenberg, a Swedish chemist, discovered tantalum in 1802 in minerals obtained from Ytterby, Sweden. At the time scientists believed that they had discovered an allotrope of niobium, an element that is chemically similar to tantalum. The allotrope issue was settled in 1866 when Jean Charles Galissard de Marignac, a Swiss chemist, proved that tantalum and niobium were two distinct elements. The first relatively pure samples of tantalum were first produced in 1907 (1, 2, 7, 17).

The history of Tantalum closely parallels the history of technological growth in America. Tantalum is widely used in the manufacture of electronic components. More than 70% of the global tantalum production is consumed by the electronics industry (*See figure next page*). It can be used as a thin-layer coating for other metals, making Tantalum ideal for devices such as mobile phones and other portable electronics. The main development in the technical use of tantalum began with the discovery that the tantalum oxide film on the surface of the metal, when submerged in an electrolyte allows current to pass in one direction but not in the other. This discovery led to both the direct current (DC) rectifier and the tantalum capacitor, which temporarily stores current. Inside capacitors are two conducting metal plates connected to terminals with an insulator (dielectric) between the two. One of the plates is charged, creating a charge separation (charge storage). The charge will then slowly dissipate across the insulating layer to the other side. In the 1920s, DC rectifiers were extensively used in radio receivers. But, by the mid-1930s, this application had become irrelevant. At the same time, only a small demand for tantalum capacitors was reported.



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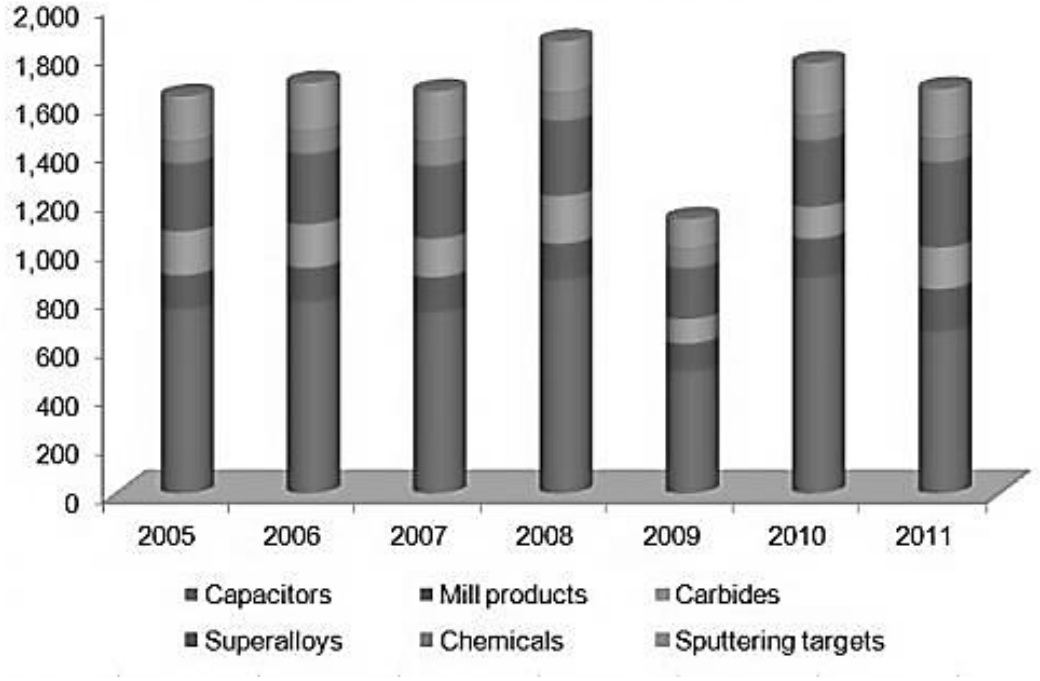

The small tantalum electrolytic capacitors used today were first developed in the 1950s and their demand rose quickly; their use in electronic components became the single most important use for tantalum in the US in the 1960s. The use of tantalum for electronic components already dominated tantalum demand by the mid-1970s and its share remained fairly stable at least until 2000. The construction of tantalum capacitors is reported to account for more than 60% of tantalum demand in the US today. The quantity required for this purpose remained stable between 2005 and 2008 and decreased sharply as a result of the worldwide economic crisis in 2009. Tantalum has two key advantages: it has a higher dielectric constant allowing capacitors to be smaller, important in reducing the size of electronic devices and its oxide layer is more stable, giving tantalum capacitors an advantage in applications requiring high reliability.

Tantalum metal is used in the electronics industry as a barricade to prevent copper from polluting silicon in products such as computer chips and storage devices. This separation is necessary because the presence of copper in silicon leads to device degradation and failure. Tantalum is suitable for this purpose because it, and its nitrides, does not form any compounds with copper.

Tantalum is used in the medical field extensively due to the fact that it causes no immune response in people and therefore can be safely used in surgical implants. Tantalum can be used to replace bone and skull plates and can even be used as wire to connect torn nerves. It can also bind abdominal muscles in surgical procedures. The use of tantalum in surgical and biomedical applications is based on its bio-inertness that in turn is due to the adherent oxide layer, which forms spontaneously on the surface of tantalum metal when exposed to air. Tantalum is inert in bodily fluids and has good mechanical properties. Tantalum applications for example are surgical clips, bone grafts, plates for

cranioplasty, mesh for abdominal wall reconstruction and dental implants.

Bobyn et al studied the characteristics of a new porous tantalum biomaterial in a simple transcortical canine model using cylindrical implants. After they performed histological studies on two types of material, one with a bigger pore size than the other, they discovered that when filling the pores with tantalum the material with new bone increased. They concluded that porous tantalum biomaterial has desirable characteristics for bone ingrowth. Alkali- and heat-treated tantalum has been shown to bond to bone. A study was done to investigate the effects of chemical treatments on the bone-bonding ability of tantalum implants in rabbit tibiae. Miyazaki et al. reported in vitro that alkali- and heat-treated tantalum had an ability to form apatite (in important constituent of bone) in a body fluid. In this experiment, smooth-surfaced rectangular plates were prepared. One plate of pure tantalum and one of treated tantalum were prepared. Then the plates were inserted into the proximal metaphyses of joint rabbit tibiae. In one limb, alkali- and heat-treated plates were injected and untreated plates were put in for the other limb, which served as a paired control. Bone bonding, at the bone/implant interface, was evaluated at 8 and 16 weeks after implantation. The information they derived from the test results was that the treated implant showed weak bonding to bone, compared to the untreated tantalum implants. The untreated implants showed almost no bonding, even at 16 weeks. These results clearly show that alkali and heat treatment induce the bone-bonding ability of tantalum. This new bioactive tantalum is an effective material for bone-bonding orthopedic devices (3, 7, 11).

The tantalum coming from this part of the world is called "blood tantalum."

Returning to our iPhones and the other devices we rely on, it is important for the consumer to understand the production chain so they can make a good choice to support companies that care about global human rights. Production of tantalum is widespread, whether through industrial mining, artisanal mining, as a secondary mineral or as a mining byproduct. Brazil is currently its major producer. Large quantities of tantalum are also produced in China, the Democratic Republic of Congo, Russia and Rwanda.

For much of the past decade, cheap supplies of tantalum derived from mines under the control of various rebel groups based in the north-eastern regions of the DRC have flowed into a complex politically charged supply chain. The International Rescue Committee refugee action group says the conflict has resulted in the death of over 5.4 million Congolese over the past decade. The tantalum coming from this part of the world is called "blood tantalum." Among those groups profiting from this trade are Hutu militia associated with the 1994 Rwandan genocide. In central Africa, tantalum is extracted from an ore called Coltan, short for Columbite-tantalite. Coltan is found in alluvial deposits on river banks or mined in primitive open-cut pits by enslaved or indentured workers—some of whom are children—using the most basic of hand-held tools.

Children as young as two, join their parents in the mines where, using the most rudimentary of tools, they transport, wash, crush minerals for half a dollar a

In the same way that the Taliban uses opium to fund its war in Afghanistan, or the rebel groups in Colombia thrive off the proceeds of cocaine sales, the civil war in Congo is bankrolled by the sale of illegally mined "conflict resources" such as tantalum. The Congo Conflict Minerals Act calls on the United States to support efforts to "investigate, monitor, and stop activities involving natural resources that contribute to illegally armed groups and human rights violations in eastern Congo" (3, 7).

Ultimately everything comes down to economics and the U.S. has an economic plan when it comes to Tantalum. In order to reduce our debt with China and other countries, America plans to buy tantalum from the countries listed above and stockpile this element to sell to other countries for a higher price. (7)

To follow the path of Tantalum from discovery in the 1800's all the way to today we can see that everything in this world can be used for good or bad. Many times it's hard to see that something used for good can also cause pain. We as citizens and consumers must not take for granted that our choices seemingly so small and insignificant are not part of a something greater that we can impact in a big way. Studying this obscure element taught me this lesson and I now ask bigger questions and chose to look at the bigger picture of how my choices make a difference.

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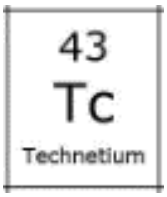


Nechama Weiner

TECHNETIUM'S TENUOUS SUPPLY LINE

To the uninitiated, chemists are often mistakenly thought of as the mad-scientist type in white lab coats and bulky goggles, who spend their time in labs mixing different colored solutions together and watching them explode and blow up. The real truth is, we are all chemists down to our core. Chemistry is the study of matter, its properties, how and why substances combine or separate to form other substances, and how substances interact with energy. Chemistry is part of everything in our lives, inside our bodies and outside in our environments, and it helps explain why things happen and work the way they do. Recently, chemistry played a starring role on the world political stage during contentious negotiations over the approval of the treaty with Iran.

Dmitri Mendeleev, a mid-nineteenth century Russian chemistry professor, predicted element forty-three in his periodic table almost seventy years before technetium was actually discovered. He thought it would have properties very close to manganese (because they are in the same group), and even named it ekamanganese. Scientists in 1846, 1847, 1877, 1896, 1908, and 1925 published reports claiming that they had discovered element 43. All of those reports turned out to be false. Instead, they discovered different elements. It wasn't until 1937 that technetium was discovered in Italy by Emilio Segre and Carlo Perrier. Technetium is named after the Greek technetos, meaning artificial. They published the results of their experiment, in which they isolated technetium from a sample of molybdenum which was bombarded by deuterons (12).

Technetium is a transition metal that is produced synthetically either in a nuclear reactor or in a particle accelerator and only exists in minute amounts in nature. Naturally occurring technetium occurs as a spontaneous fission product in uranium ore or by neutron capture in molybdenum ores (1). All technetium's isotopes are radioactive. Thirty-six known isotopes of technetium have been created. The most stable of these technetium radioisotopes have half-lives ranging from over 200,000 years to over four million years. Twenty-nine of the radioisotopes have half-lives of under an hour (1). Technetium is radioactive because of the unstable arrangement of its protons and neutrons in the "shells" of the nucleus (similar to the way the electrons are arranged). Elements with odd proton and neutron numbers have far fewer stable isotopes than even elements, for reasons of the stability of pairing. Technetium is an odd element; its atomic number is 43. Isotopes with an even number of protons and an even number of neutrons are more stable, and isotopes with odd numbers of both protons and neutrons are unstable. This is because protons and neutrons like to form pairs of "spin up" and "spin down" - an odd number means there is an unpaired spin (7).

Technetium-99 serves a key role in nuclear medicine. It is used in finding out about diseases and health problems. Molybdenum-98 becomes molybdenum-99 when it captures a neutron.

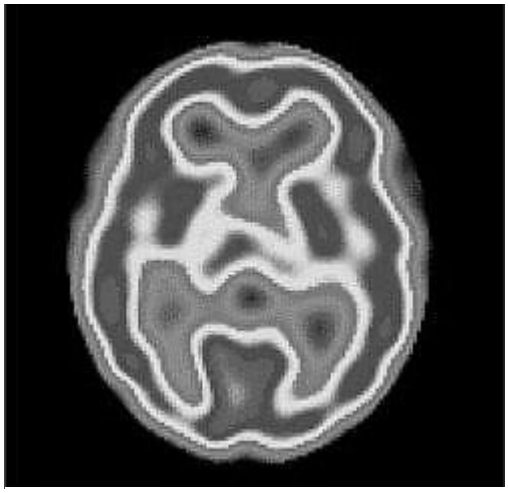
The two step reaction to produce technetium beginning with the capture of neutron by Molybdenum 98 and the subsequent beta emission.

$$^{98}_{42}Mo + {}^{1}_{0}n \rightarrow {}^{99}_{42}Mo$$

$$^{99}_{42}Mo \rightarrow {}^{99m}_{43}Tc + {}^{0}_{-1}e$$

Molybdenum-99, with a half-life of 65.94 hours, decays into technetium-99 through beta decay.

About 35 million procedures per year are done with the use of technetium-99. Technetium-99 is injected into the patient's blood stream for the purpose of viewing a small part of the body. Technetium-99 emits gamma rays which are used to view internal organs. Photons are detected by a gamma camera which is able to view the organs from multiple different angles. The camera builds up an image from the points where the radiation is emitted. The image is then enhanced by a computer and viewed by a physician on a monitor for any signs of abnormal conditions (4).



Healthy brain scan using technetium-99m. Here the brain activity is color-coded, from red (most active) through yellow to green and blue (least active).

Technetium is well suited to be used in nuclear medicine because the gamma photon it emits has energy of 140 keV which is easily detectable and provides a high resolution. Additionally, the gamma emission is accompanied by beta emission, which makes alignment of imaging detectors much more precise. Since its half-life is about six hours, it emits a considerable amount of radiation in a short time, making the capturing of an image a relatively short procedure. Because of these unique characteristics, it gained dominance in the field (4).

After injection with techtenium-99, the patient must be monitored. Since it is constantly decaying, it is important to check that it is still sufficiently radioactive to produce an image, but not enough to be harmful. Each radioactive atom is attached to a "ligand"—a chemical that ensures that the technetium reaches the right part of the patient's body. If the technetium was injected without the ligand, it would probably end up in the patient's thyroid and stomach. After injection, the patient has to wait four hours before performing the scan, to wait for the technetium to reach the designated body part. After the four hours, there is a short window during which the scan can be done before the technetium decays away.

In the case of a spinal scan, the patient is put through a full-body scanner that detects the gamma-ray emissions and uses that data to create a three-dimensional image of what is happening in the spine. The scan reveals where there is high activity where the bone may be repairing itself, or cold spots where the bone may be dead (6). Bone is just one material that technetium can be used to peer at. By attaching it to other chemical ligands, this radioactive marker can be towed through the body's metabolic pathways to other organs—the spleen, lungs, liver, lymph glands, and heart. For example, the technetium-99 heart scan is used to evaluate the heart after a heart attack. It can confirm that the patient had a heart attack, even when the pain and symptoms usually associated with a heart attack aren't present. It can also identify the size and location of the heart attack and provide information of what the patient's post-heart attack prognosis will be. Technetium-99 is injected into a vein and absorbed by healthy tissue. Then it accumulates in hearttissu

e that has been damaged, leaving "hot spots" that can be detected by the camera. The detector picks up the gamma rays emitted by technetium-99 (5).

Despite its importance in nuclear medicine, the supply chain of technetium is surprisingly fragile for multiple reasons. The reactors which make it are aging and in need of repair. Technetium-99m was mainly made at a plant at Chalk River, Ontario, Canada; however in 2009, two nuclear research reactors shut down for repairs and maintenance. These reactors produced most of the world's supply of technetium-99m. Hospitals around the world went into a panic, because they had a shortage of the crucial isotope; doctors cancelled scans, postponed operations or switched to older diagnostic techniques that exposed patients to higher doses of radiation. Many hospitals didn't receive technetium for weeks. The crash made it clear that the world's medical-isotope supply chain was in danger, relying on government-subsidized reactors built in the 1950s and 1960s. The Chalk River reactor, which produces close to one-third of current global supplies, is stopping the production of isotopes in 2016 (10).

Hospitals around the world went into a panic because they had a shortage of this crucial isotope.

Nuclear engineers figured out a way to use particle accelerators rather than nuclear reactors to transform uranium into technetium. Both methods require highly enriched uranium (HEU) as a starting material. Shipments of HEU require tight security so that they don't fall into rogue hands, as they contain material that could potentially be turned into nuclear weapons. While isotopes that are used for nuclear medicine are enriched at a 20 percent level, there is general agreement that enrichment levels of 90 percent or higher are considered weapons grade, ready to be loaded into a bomb. But that does not mean that material enriched to a level of 20 percent or below could never be used in a nuclear weapon. This presents a conundrum and highlights the conflict in US policy on nuclear material: medical necessity vs. non-proliferation concerns. This conflict was in particularly stark relief during the negotiations with Iran on lifting sanctions and allowing their reactors to operate under monitored supervision. While they claimed their reactors are exclusively for energy, medicinal and researches purposes only, skepticism remains (8).

Facilities and institutes are working to produce an alternative to technetium-99. Now, they are producing rubidium-82 for use in Positron Emission Tomography (PET) scans, which use traceable isotopes that light up organs or areas of disease. It is considered accurate and safe because it exposes patients to less radiation. However, the situation is not ideal because there are insufficient PET scanners due to expensive cameras required—about $3 million each—rubidium is much more expensive and it's more labor intensive. It is highly unlikely that rubidium 82 will ever replace the popular technetium 99 m, which for decades has been the mainstay of millions of procedures. Medical practitioners will stick with the known and resist the unknown. However, there are many other radioisotopes that are possible candidates for medical use. It is important that research continues into the use of alternatives, including forms of diagnostic testing that do not involve the use of radioisotopes at all (10).

We are all essentially chemists in our own individual ways. Chemistry is in the world around us and with a little awareness we can discover great things.

Chemistry is truly the "central science," bridging the worlds of physics and biology.

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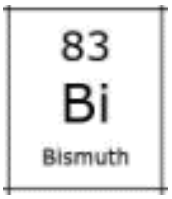


Yael Weinroth

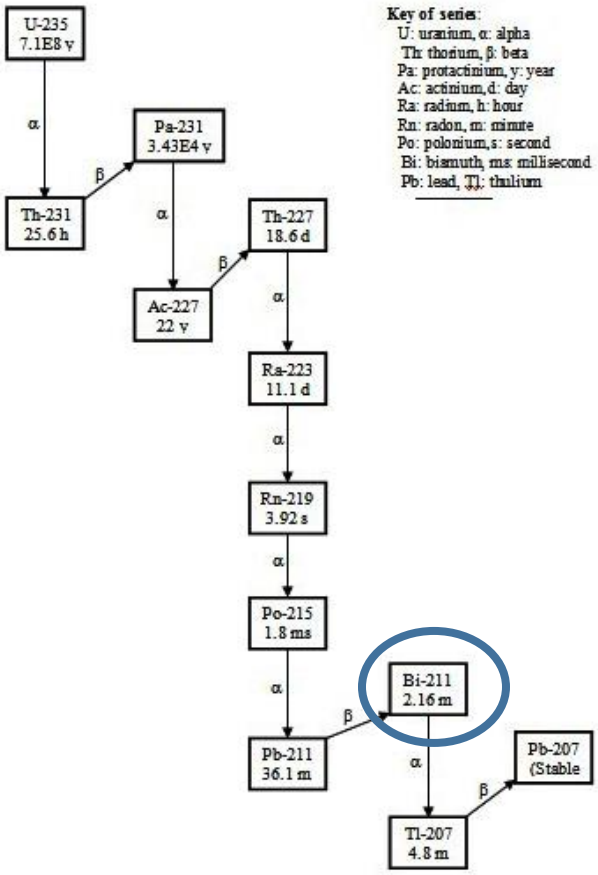
PRETTY IN PINK

Popular wisdom aside, it is actually Bismuth that is a girl's best friend. The element Bismuth, atomic number 83, is naturally found, useful, pretty, and unique. Bismuth stands apart from all the other elements surrounding it on the periodic table. It is dangerously located in the "poisoner's corridor," as it is stuck between sets of lethal elements. Its neighbors, Antimony, Thallium, Radium, and Arsenic, can effectively eliminate a person in various different ways. Naturally, it would be expected that Bismuth would be a painful weapon or would function as a terrible torture device, since it hangs out with the "bad guys." Surprisingly, despite the company that it keeps, Bismuth is actually harmless. In fact, it is even medicinal. It is used to treat stomach problems and is the "bism" in the well-known bright pink medicine Pepto-Bismol (Bismuth subsalicylate). This fact gave Bismuth the status of a "gentleman among scoundrels" because of its position on the periodic table despite its harmless properties (7).

This fact gave Bismuth the status of a "gentleman among scoundrels."

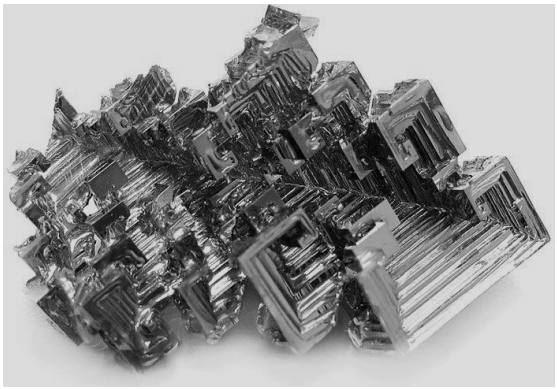
Aside for Bismuth's ability to treat stomach problems, Bismuth has recently been discovered to help treat cancer. The Memorial Sloan Kettering Cancer center in New York has identified an alpha-emitting radioisotope of Bismuth, Bi-213, that can be very useful for eliminating cancer cells. An alpha-particle is a fast moving ray particle, containing two protons and two neutrons. Alpha-particles are perfect for radio immunotherapy (therapy using radioisotpes to treat cancer) applications because when they deliver high energy particles into a soft tissue it is limited to just a few cell diameters. Since this particle will only destroy a few cells, it is perfect for targeting tumor cells such as leukemia and won't destroy any healthy cells surrounding the cancer. Bismuth-213 is unique in its nuclear properties, as it has a short 45 minute half-life (the time required for the radioactivity of a substance to decrease by a half) and high energy alpha-particle emission. Therefore, it is of special interest for this type of therapy. Bismuth-213 is acquired through a very unique multistep process of a lengthy decay series, where the product of one step is converted sequentially to the final product. It is obtained from the radioactive decay of actinium-225, the decay product of radium-225. Radium-225 is formed from the decay of thorium-229 which is obtained from the decay of uranium-223 (*See graphic below).*

The very short half-life of Bismuth limits its use, but when it is attached to a carrier molecule it can quickly target the leukemia and will produce significant damage to the leukemia cells (5, 1).



Additionally, Bismuth is frequently used in cosmetic applications. Since Bismuth is silver-white when it is freshly produced, it is used to give a pearly effect in makeup. For example, Bismuth oxychloride (BiOCl) is a mineral used as a makeup colorant that provides an iridescent (shiny) effect. It is an inorganic compound and is manufactured by combining Bismuth with chlorine and water. It is used in cosmetics because it has a distinct shimmery, pearl-like appearance and a fine white powder texture that adheres well to the skin. The shimmering glow that bismuth oxychloride imparts is a big selling point in makeup, and for that reason it is found in bronzers, blush, and eyeshadows (4, 8). Also, bismuth oxychloride is oil-absorbent and gives a silky feeling to the powders it is used in. Other examples of Bismuth's use in makeup are Bismuth subcarbonate and Bismuth subnitrate, which are also pearly-white powders that are used in lipstick and eyeshadow. Bismuth subcarbonate is a dermatological agent and is typically used in lotions and ointments. Also, Bismuth oxide is used as a yellow pigment for cosmetics and is one of the most industrially important compounds of Bismuth (3, 9).

Aside from all the helpful uses of Bismuth, Bismuth also has a very unique and beautiful shape. Bismuth is a white, crystalline, brittle metal with a pinkish tinge. High purity bismuth can form into distinctive beautiful hopper crystals. These crystals are laboratory grown and do not grow naturally. They normally are made from pure bismuth pellets. These crystals are formed with a stair shaped structure which is a result of higher growth rates on the outside edges than on the inside edges. This stair shape that Bismuth forms is called a rhombohedral. Bismuth crystals also have many different iridescent colors as a result of surface oxidation (the combination of a surface with oxygen). The variations in the thickness of the oxide layer that forms on the surface of the crystal causes different wavelengths of light to interfere upon reflection, thereby displaying a rainbow of colors. This is actually interference coloring, similar



A laboratory grown crystal in its stair shaped form, including its iridescent oxide layer.

to the coloring you see on soap bubbles (and is based on how thick the oxide grows). Some labs report that adding voltage from a small battery helps control the coloring during its formation. Since Bismuth is relatively nontoxic and has a low melting point just above 271 °C, crystals may be grown using a household stove (6).

In conclusion, Bismuth is a very helpful and unique group 15 metal. It can calm an upset stomach, help save lives and can even make a person feel beautiful. Bismuth is a true gentleman and unlike any other element.

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Chavi Zelefsky

CHIPS, GRAINS AND BLESSINGS

Number 14 on the Periodic Table lies just south of carbon. While carbon is known as the element of life, silicon is known as the element of technology. In fact, there is a valley in California named after it. The origin of Silicon's name came from a chemist, Thomas Thomson, in 1817 who based the name on the Latin word *silen* meaning "flint." The "on" part of the word came because of the similarities seen between bor*on* and carb*on* (9).

The element Silicon is found in two allotropic states: a shiny, gray crystal or one without the crystal-like structure and instead looks like a brown powder. Silicon also has three natural isotopes: Silicon-28, Silicon-29, and Silicon-30. Radioactive isotopes for Silicon have also been discovered, but since they have no known use, they are not considered when referring to the isotopes of Silicon (6, 7, 8).

Silicon also has many useful alloys which contribute to making "stuff" stronger and resistant to corrosion. Some of Silicon's most important alloys include those made with iron, steel, aluminum and copper. The alloy made with iron reacts quickly with sand and forms a substance called Ferrosilicon. Ferrosilicon offers two advancements when added to steel. First, it improves the strength and toughness of the steel and the other advantage is that when added during the steel-making process the ferrosilicon removes any impurities from the steel. Silicon alloys with Aluminum and Magnesium, resulting in extreme corrosion resistance. It is used in buildings, bridges and transportation vehicles like ships and trains to improve their longevity (11).

Silicon is also the second most abundant element found in the Earth's crust, coming second to Oxygen, and the top eighth in the world. Many rocks and minerals found actually contain Silicon including sand, quartz, clays, flint, opal, mica, feldspar, garnet, tourmaline, asbestos, zircon, emerald, and aquamarine. Although Silicon is found in many different places, Silicon does not exist alone in its natural state, making separation methods necessary. Isolating silicon from its oxide is very difficult since its bond to oxygen is very strong. However, in 1823, a Swedish chemist named Jons Jacob Berzelius accomplished this feat by mixing molten Potassium with the compound Potassium Silicon Fluoride (K_2SiF_6) resulting in the separation of silicon and the formation of potassium fluoride (KF) (6, 7, 8).

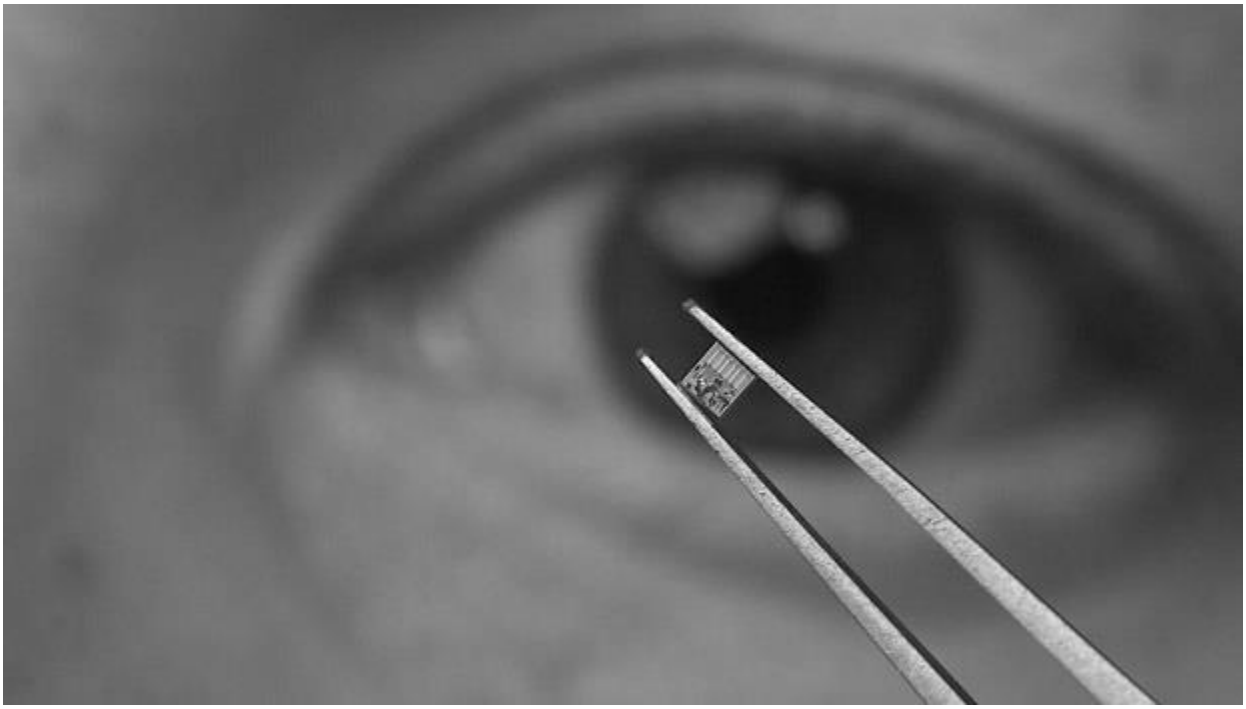
Another way that Silicon is prepared is by heating silicon dioxide with carbon. The carbon, through heat, will replace the silicon, subsequently producing carbon dioxide, and in effect leaving the silicon separated from the compound with 96-98% purity. Because many different applications require a very pure Silicon, numerous other methods have been created to separate Silicon. The purest Silicon made, called hyper pure Silicon, is 99.97% pure (6, 7, 8).

As a metalloid, silicon exhibits properties intermediate between metals and non-metals. For instance, it is a semiconductor; although Silicon can conduct some electricity it does not conduct it as well as Copper or Aluminum which are full-fledged metals (6, 7, 8). This property is what lends silicon one of its best known uses as the "chip" in electronic devices.

One of the many reasons why silicon is used in this application is because electronics require semiconductors. Electronics operate by controlling the flow of electricity through tiny circuits by opening or closing transistors, or switches, somewhat analogous to the control of train traffic on the network of tracks by opening and closing gates. Fine control is lost using conductors, since they allow an unimpeded flow of current which would quickly swamp the transistors. Insulators would slow the flow of current to a crawl. Semiconductors offer control of current while still maintaining appreciable speed. The fact that silicon is both cheap and abundant is an added bonus. Silicon is also a material which has been used for electronics for a while and therefore the process to perfect it is known; to figure out the way to make another flawless material would take both time and money.

Unlike other materials, no matter how reduced in size, silicon still retains all of its properties. Computers have shrunk in size because of this. There are about a billion resistors on a computer chip that is about one inch square. This is in accordance with Moore's Law that states the number of transistors in an integrated circuit double every two years, and that is what we have been seeing. An important note though is that the resistors cannot be shrunken too small and be too tightly compacted otherwise a short circuit can occur from electricity leakage. To solve this problem, nanowires are being created and stacked vertically. Scientists are trying to push the envelope of Moore's Law (1, 2, 5).

Silicon dioxide, known as quartz, is what makes today's timepieces "tick." Ever since Galileo recognized that the regular repetition of a swinging pendulum could be used to incrementize the passage of time, clockmakers have been searching ways to divide the basic unit of time to smaller and smaller subdivisions. In early times, mechanical mechanisms such as springs and gears were needed, but these were relatively large and bulky. In the 1900's, it was discovered that by heating up quartz, the vibrations could reliably divide the second into



smaller and smaller subunits. Today, the element Cesium is used as the standard atomic clock (5).

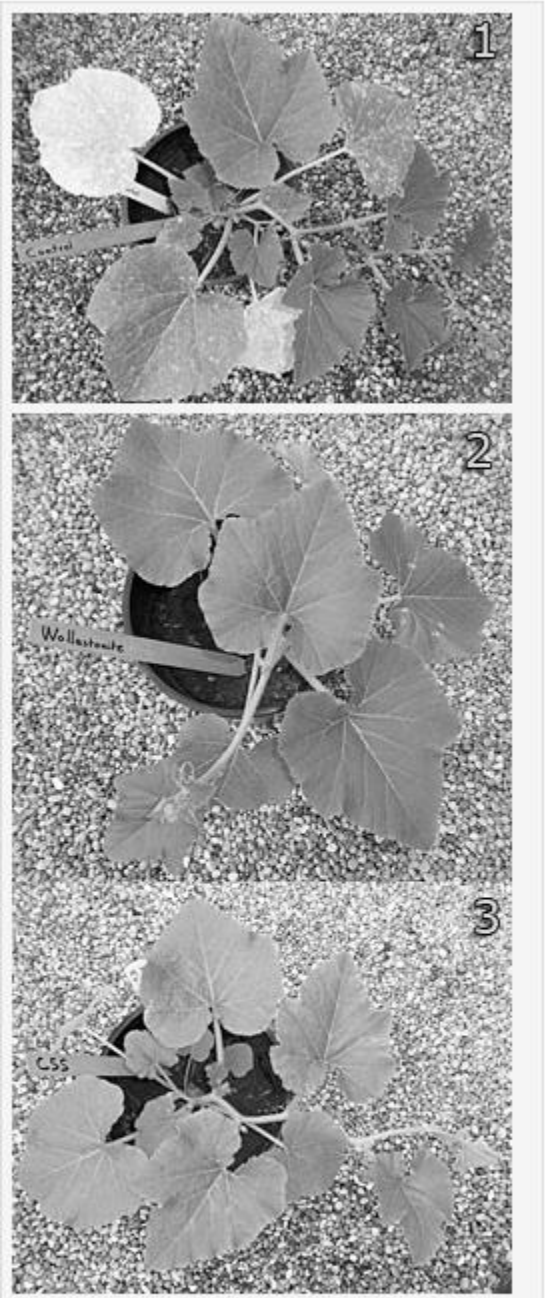
There are many different places where silicon dioxide can be found. One of them is a particularly common item, found in abundance especially on the beach. Beyond its "magical" annoying propensity to find its way into every crevice, sand does have some other "magical" properties. Heated to 1000 degrees, ordinary sand fuses and transforms into glass. Archeological excavation in several locations in Israel, particularly in the Haifa region, have uncovered large facilities for its production in times of antiquity, making that area a major regional exporter of glass. It would be hard to envision a world without glass. Our homes would be dark even in the daytime, we would be driving cars with the wind in our eyes, we would have no microscopes, our chandeliers would not be accompanied by dancing rainbows, and we would lose an important *milchig/fleishig* bridge.

Beyond its "magical" propensity to find its way into every crevice, sand does have some other "magical" properties.

In addition to ushering advances in the world of technology, Silicon has demonstrated benefits to the world of biology. The skeletons of most sea sponges are made up of either silica or calcium carbonate which provide the small structure for the otherwise unformed creature. It is said that silicon is similarly important for the bone structure of humans. However, at the moment it is still undetermined as to why it has such a great importance. Even though a small amount of silicon is required in the human body, too much is detrimental. Asbestos is a soft fibrous silicate mineral that has gained notoriety for its carcinogenic properties. On the flip side though, silicone polymers (made up of repeating units of alternating silicon and oxygen atoms) are known to be beneficial in treating both burns and the reduction of scars. Silicone gel is known to also help already closed wounds like scars from both becoming red, raised and inflamed and from enlarging over its normal tissue. With other silicone treatments, the healing process can be decreased from a year to weeks (1, 4, 9).

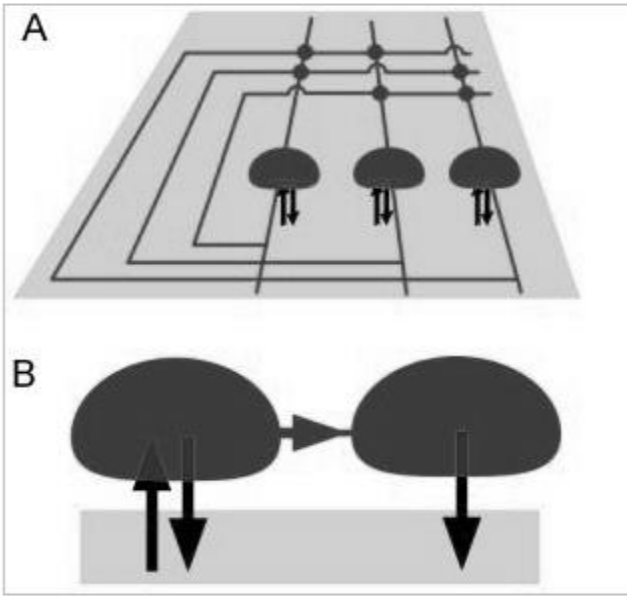
Joseph Heckman, a specialist in soil fertility, studied the role silicon can have in the reduction of a powdery mildew disease by using calcium silicate as an additive to the soil. Usually lime, calcium oxide, alone is used to neutralize acidic soils but with the addition of silicon, there is an increased benefit such as the prevention of the mildew disease. The first experiment that Heckman did was with pumpkins, and indeed there was seen to be a resistance to the powdery mildew disease. Corn, oats, winter wheat, red clover, orchard grass hay, and cabbage were the next vegetables to go through with the experiment. Other benefits that Heckman discovered from the examinations were that there was a larger crop yield, corn plants had less stem damage, and cabbage had an overall increase in its production. Additionally, all these benefits were still exhibited three to four years later. Heckman had stated that with all the benefits that silicon provides for plants, he believes that there is a possibility this can lead to less usage of pesticide (3).

The most complex organ in the human body is the brain and scientists and doctors are always trying to find new ways to understand it. In recent research, bordering on the realm of science fiction, neurons from a snail were interfaced with silicon chips. The



1: Pumpkin plant growing in untreated soil exhibiting symptoms of powdery mildew disease.
2: A healthy pumpkin plant growing in soil amended with, Wollastinite, a naturally occurring mineral source of silicon.
3: A healthy pumpkin plant growing in soil amended with a commercial silicon fertilizer.

neurons were stimulated via voltage applied to the computer chip and the neurons responded by generating neurotransmitters across the synapse, generating an action potential in the post synaptic neurons, which in turn modulated the voltage on the second computer chip. This proof of principal experiment could possibly pave the way for development of neuroprosthetics. This is one example of how Silicon is being implemented in modern technology to better understand the workings of the brain. Although this experiment failed in its replicability and requires improvement, it is a step in the direction of advancing future medical scientific understanding of the brain (10).



(A) Network of nerve cells (red) with controlled connections of axons, synapses, and dendrites supervised from a semiconductor chip (blue) by two-way interfacing (black). (B) Elementary silicon-neuron-neuron-silicon circuit with presynaptic stimulation and recording, synaptic

Hashem promised to *Avraham Avinu* that we, his descendants, would be just as abundant as grains of sand. Additionally, we have managed to find our way to just about every crevice on the face of this earth. By studying silicon, the major component of sand, we can truly appreciate what a blessing that truly is.

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