Foreword

Paradise Valley Community College is proud to present this 3-volume set of the 23rd Annual Mancini Science Symposium. This symposium was held on May 11, 2017 in the Center for Performing Arts (CPA).

Dr. Hank Mancini started the Annual Science Symposium in 1995. The first publication contained papers from his Organic Chemistry class. This annual symposium has since grown to include papers from Physics, Engineering, Astronomy, Chemistry, Biology, and Math. What began with 9 research papers in the first year has evolved into a record number of 105 papers this year. Dr. Mancini retired in 2012. After his retirement, the symposium was renamed the Annual Mancini Science Symposium.

Students enrolled in Astronomy, Biology, Chemistry, and Physics classes from PVCC participated in the event this year. Each contributor was responsible for selecting and researching his/her topic and preparing a paper. This 3-volume set contains all 105 papers (4 in Astronomy, 25 in Biology, 18 in Chemistry, and 58 in Physics). A few students gave oral presentations of their project to their peers. Students chose the oral presentation topics.

I would like to thank the following faculty members for participating in this event:
Darra Browning, DVM – Biology
Scott Massey, PhD – Chemistry
Julie Olander, MS – Chemistry
Lori Prause, MS – Astronomy
Mike Swingler, MS – Physics

As instructors and faculty advisors for these students, we want to thank and congratulate each participant for his/her effort, courage, and dedication. By participating, these individuals perpetuate this event annually. We are proud and honored to present the work of these individuals.

Casey Durandet, PhD – Physics
Symposium Coordinator
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The Chemistry Behind Depression

Rita Oliverius

April 16, 2017

General Chemistry II, CHM 152

Professor Olander
ABSTRACT

Everyone has experienced times in their life when they have felt down, having little motivation, sad or numb emotions, overwhelmed by factors of everyday life, and even feelings of helplessness. Usually these feelings fade away naturally and fairly quickly, but what happens when they don’t? Is there a name for this prolonged state of mind and who is affected by it? It is called depression and affects more than 25 million people every year in the U.S. alone. The human brain is an emotional and complicated machine. Modern neuroscience offers some explanation as to how the brain functions, causes and symptoms of depression, and ways to treat the underlying factors that lead to chemical imbalances in the brain.

Different people experience symptoms of depression in different ways. Symptoms often include persistent feelings of sadness, loss of interest or pleasure in activities, anxiety, hopelessness, and social isolation. Depression manifests itself physically in many ways as well. Disrupted sleep patterns such as insomnia or excessive sleep are common. Chronic fatigue, restlessness, excessive hunger followed by weight gain, loss of appetite followed by weight loss, lack of concentration, repeatedly going over unpleasant thoughts or thoughts of suicide are all warning signs of a more serious problem. Depression often hinders a person’s ability to meet their personal, social and occupational responsibilities. If waking up and getting out of bed becomes challenging for one to do, then going to social events, taking care of family and self, and going to school or work may seem like tasks that are nearly impossible to accomplish. In today’s society it is not uncommon to hear about mental illness and the struggles that accompany it. Social media has opened a gateway for anyone and everyone to express their mood in a public forum while allowing the whole world to see a side of the human psyche that was once considered intimate. This begs the question, was depression as common in the past and just well hidden from historical records? Or is there a factor in modern day society that is prone to triggering depression in more people?

Although the term “depression” wasn’t coined until more recently, the plaguing feelings of prolonged sadness have been a noticeable part of human history since the beginning. The ability for the human brain to feel immense emotion is what makes it so fascinating to some and a curse to many than others. Depression has always been a health problem for human beings. The first historical concept of depression was that it was a spiritual or demonic illness of the mind, called “melancholia”. Earliest accounts date back to the second millennium B.C. where Ancient Greeks and Romans were in disagreement about the cause and cures of melancholia. Other early civilizations in China, Egypt and Babylonia also viewed mental illness as demonic possession. If demonic possession was the cause of this illness, then any sort of cure must be to exorcise the evil spirits out of the victim. Barbaric techniques for exorcism included locking the patient up in asylums so as not to infect others with their madness. Patients were restrained, forced to take ice baths, beaten and starved. It was believed that if the environment and body became unpleasant enough, the demon would leave. Even more horrific events, which began during the Renaissance Era and continued on throughout history, were the popular witch hunts. The mentally ill were considered possessed by the devil, demons or witches and forcibly drowned or burned alive. On the other side of the spectrum, there were many Roman and Greek doctors who believed the Hippocrates philosophy of mental illness to be true. Hippocrates was a Greek physician whom viewed depression as a biological and physical disease caused by an imbalance in bodily fluids, poor diet and grief. Afflicted patients were engaged in a rigorous and pleasant
schedule filled with music, massage, exercise and baths. Patients were put on a healthy diet which included goat milk mixed with poppy extract, medicating them with opiates to induce a euphoric state of mind (National Institutes of Health. National Institutes of Health. [accessed 2017 Apr 16]. https://science.education.nih.gov/).

New therapies for depression were developed in the 1800s; water immersion involving submerging the patient under water for as long as possible without drowning them, spinning tools that spun patients in order to rearrange the contents of the brain back to their correct position, and earliest forms of electroshock therapy introduced by Benjamin Franklin. For those with more severe depression, lobotomy was the common treatment and cure. Lobotomy is a surgery in which the frontal lobe of one’s brain is destroyed, having a ‘calming’ effect. Seemingly obvious side effects include personality changes, loss of memory and loss of ability to make decisions, coma, and often death. Still other doctors viewed depression as a mix of body imbalance and grief. Sigmund Freud discussed Psychoanalysis, the psychotherapy based on psychodynamic theory where means of treatment were “talk therapy”, in a 1917 essay. He explained melancholia as a response to loss, whether it be the loss of a loved one or failure to achieve a certain goal. Freud believed that a person’s subconscious anger over their loss resulted in self-hate, destructive behavior, and a blow to the ego. He recommended counseling as a means of therapy to resolve internal conflict (National Institutes of Health. National Institutes of Health. [accessed 2017 Apr 16]. https://science.education.nih.gov/).

It wasn’t until recently, around 1950, that mental illness was clearly divided into separate classifications divided by subtypes in terms of symptom degree. Organic causes for mental illness were finally accepted and almost by accident, medication was discovered. In 1952, doctors discovered that a medication for tuberculosis (isoniazid) was also able to treat symptoms of depression. Thus the industry for pharmaceuticals and psychiatry, emphasizing the use of medication for mental illness, was born. Currently, scientists and mental health professionals agree that depression can have both physical and mental causes including biological, psychological and social, and multiple treatments are necessary to those afflicted. The very word itself can help define depression which is literally, the state of being pushed down. Depression often hinders a person’s ability to meet their personal, social and occupational responsibilities. If waking up and getting out of bed becomes challenging for one to do, then going to social events, taking care of family and self, and going to school or work may seem like tasks that are nearly impossible to accomplish (An Overview of Psychotic Disorders. Psychotic Disorders in Children and Adolescents.:1–15.).

The most tragic consequence of major depression is suicide. Every year, over 850,000 people attempt suicide, making it the second-leading cause of death among ages 15 to 34. There are more than 1,000 suicides on college campuses every year in the U.S. and the rate continues to rise. There is a new and disturbing term among teen and young adult communities across the Nation called “suicide cluster”, a group of suicides in which one seems to set off others. That is, “a chain of completed suicides, usually among adolescents, in a discrete period of time and era, which have a ‘contagious’ element.” Even more disturbing is the fact that writers, television and movie producers are literally banking on the growing popularity of suicide among the youth today. Media is creating stories that seem to glorify the tragedy of suicide and the popularity a person gains after their death, while making light of the reality of pain and struggle major depression inflicts on the person suffering and their loved ones. “13 Reasons Why” (based on the novel “Thirteen Reasons Why”, by Jay Asher) on Netflix is one of the most popular and talked about series to ever have been produced in television. It is a very sad and graphic
depiction of one girl’s high school drama including issues of bullying and rape that ultimately led her to end her own life.

Social media is a modern day marvel. Online social networking has changed the way people communicate and interact in a profound way. In less than a second, numerous people located across the globe from one another are able to see and talk to each other via video chat. At the push of a button one can share pictures, instant messages, make a new friend, even a love connection through social media platforms including Facebook, Instagram, Twitter, Snapchat, or Tinder just to name a few. Recent research has proven the association between online social networking and the rise in psychiatric disorders and symptoms such as depression, anxiety, and severe low self-esteem which poses serious concern for the future of public health. These effects are especially damaging to the young impressionable minds of children and adolescents. The youth today has another aspect to add to the awkward phase of puberty that no preceding generation can relate to – the ever-growing popularity of social media. Studies have proven time and time again that social media has taken the place of face-to-face social interaction, causing strain on meaningful relationships and intimacy for every age, gender and race. Today, social media is not only used to connect with loved ones, it is also used as a weapon. False news, threats, insults, and rumors are easy to post anonymously online where one will never be held accountable or traced. Damaging photos or videos are commonly posted by others in a form of cyber-bullying. Thus it is expected that the ones most affected by this phenomena are the impressionable young minds that have one of the most powerful weapons ever created in the palm of their hands. Adolescents are often ill-equipped to handle these situations in a healthy manner; their self-worth becomes associated with how many ‘likes’ and ‘followers’ they have. Most adolescents are very aware of these amplified negative feelings but remain incapable of understanding what those feelings are or why they have them at all and too embarrassed to seek help.

In order to help people with serious mental illness, it is first important to have an understanding of how the human brain works. Despite all of the remarkable advances in science and technology today, the brain remains mostly a mystery. The fairly recent development of brain imaging technology has equipped scientists with tools to more accurately study the brain and how it functions. Scientists can now watch different parts of the brain light up in the process of firing a neuron with the help of brain imaging. Modern science allows scientists and physicians to alter certain neural functions with chemicals or surgeries.

The neuron is the basic signaling unit of the nervous system in the brain, which contains billions of them. The interactions between these networks of neurons enable people to think, move, and feel emotion. There are two main types of signaling in the brain; electrical signals and chemical messengers. When stimulated, the neuron sends an electrical signal, triggering a chemical message to release neurotransmitters. Neurotransmitters are chemical substances that control and create signals in the brain within neurons, allowing them to send information to another cell. Each chemical communicates with its own specific neuron, and each neuron has a unique function for the brain as a whole. An upset or imbalance in this intricate system can harm the way neurons send and receive information, thereby affecting behavior. Research shows a strong connection between mental illness/mood disorders and abnormal amounts of neurotransmitters present in the blood.

A neurotransmitter’s effect depends on its receptor and can be excitatory or inhibitory. Excitatory neurotransmitters are called this because they start an ‘action potential’ in the responding neuron, thereby activating the receiving cell. Inhibitory neurotransmitters block the
‘action potential’ from happening in the responding cell. Sometimes neurotransmitters stop functioning properly and cause problems, such as chemical imbalance, throughout the brain’s communication system. The neurotransmitters most associated with chemical imbalance in patients with major depression are dopamine, norepinephrine and serotonin. These neurotransmitters are generally inhibitory and when concentrations are too low, symptoms of depression appear.

Dopamine (figure 1), C₈H₁¹NO₂, is an organic chemical and the main neurotransmitter involved in the brain’s reward system. It controls habit learning and is studied in addiction. The chemical classification of dopamine is catecholamine which means it is derived from tyrosine and is the precursor to norepinephrine. Its structure is made of two hydroxyl groups and one amine group attached to a benzene ring. Although dopamine is an amino acid and can be found in almost any protein, it cannot pass the blood brain barrier on its own. Therefore to be able to function properly it must be made naturally inside the brain or artificially manufactured in the lab. This is true for all neurotransmitters. Dopamine is linked to motor and movement disorders such as Parkinson’s disease, ADHD, addictions, paranoia, and schizophrenia. Very low levels can impair a person’s motivation, making concentration and focus very difficult. On the other hand, high levels of dopamine make one hyper stimulated, their focus becomes too narrowed causing paranoia and delusions (The PubChem Project. National Center for Biotechnology Information. PubChem Compound Database. [accessed 2017 Apr 16]. https://pubchem.ncbi.nlm.nih.gov/).

With the aid of specific enzymes and oxygen, dopamine is converted into another catecholamine called norepinephrine (or noradrenalin) (figure 2), C₈H₁¹NO₃. It is a naturally occurring stress hormone that directly stimulates adrenergic receptors, increasing action and energy in the brain and helping the body respond to danger and stressful situations. It is the “fight-or-flight” neurotransmitter. For this reason, the amount of norepinephrine released during sleep is much less than the amount released during wakefulness, if functioning properly. The base structure of a norepinephrine molecule is nearly identical to that of dopamine. It works by binding to receptors on cells and activating them, and then is absorbed back into the original neuron via reuptake. Stress is the most common environmental factor that causes the release of norepinephrine. Chronic stress, if continued for a long time, causes damage to the body and neurons in the brain. Signs of low levels of norepinephrine include poor memory, loss of alertness, ADHD and depression. Medications for depression and ADHD can often target dopamine and norepinephrine levels in the brain in order to restore them to a normal level. Sudden increases in norepinephrine are associated with panic attacks which are a severe physical and chemical fight-or-flight episode that happen unexpectedly, without any apparent danger (The PubChem Project. National Center for Biotechnology Information. PubChem Compound Database. [accessed 2017 Apr 16]. https://pubchem.ncbi.nlm.nih.gov/).

A third monoamine culprit associated with depression is serotonin (figure 3), C₁₀H₁₂N₂O, made from the amino acid L-Tryptophan. Serotonin is a biochemical messenger and regulator of behavioral response such as mood, appetite and sleep. It was first isolated in 1933 and has also been identified in other psychiatric disorders including phobias, social anxiety, eating disorders, and obsessive-compulsive disorder. When serotonin levels are low, problems with concentration and organization arise, routine responsibilities become overwhelming, forgetfulness is more common, chronic fatigue due to lack of sleep caused by racing thoughts, changes in appetite causing rapid weight loss or weight gain, social withdrawal, emotional sadness with frequent spells of crying, low self-esteem and low self-confidence. Over time these symptoms can become an overwhelming torture leading to impulsive lifestyle changes such as

Depression is the most common mental health problem seen in medical practice today. Medications for major depressive disorder are called antidepressants and they work by improving the effects of neurotransmitters in the brain. Most treatments involve medications that specifically target and increase the levels of serotonin in the brain. These medications are known as Selective Serotonin Reuptake Inhibitors (SSRI’s) and Serotonin-Norepinephrine Reuptake Inhibitors (SNRI’s). The exact mechanism of SSRI’s is not yet completely understood but scientists have a theory on how they work chemically in the brain. The Reuptake Inhibitors block the ability for reuptake of serotonin and/or norepinephrine into the presynaptic cell which leaves the excess molecules more accessible to the postsynaptic receptor and brain cells that use it. What is known is when neurotransmitter functions return to normal, the brain sends and receives signals well and mood improves.

Manufactured drugs designed for serotonin receptors have only recently been discovered however many of them are still not ready to be tested on humans. There are numerous subtypes for serotonin receptors and ongoing research is attempting to prove scientific theory that serotonin is actually functioning on specific receptors in the way it is believed. Based on the existing facts so far, it has been concluded that serotonin mediates different physiological factors through different receptors specific to each action. For example, studies have led to the hypothesis that post-synaptic 5HT serotonin receptors are responsible for mediating mood, anxiety and body temperature. More clarification is needed to determine the absolute pathways for serotonin in the central nervous system. In the same respect, therapeutic actions of manufactured drugs that are designed to affect serotonin may also be site and receptor specific, or designed to behave in such a way. Currently the experiments utilizing drug administration show affects to all receptors in all locations equally.

Serotonin inhibition has long been used in antidepressants. It has only been recently that more serotonin specific agents have been introduced into the industry of treatment for mental health. This well known class of antidepressants is called SSRI’s and includes household names like Prozac, Paxil, Zoloft and Celexa among many others. Scientists termed the effects of psychotropic drugs as “initiating”, since the drugs initiate a molecular chain of events that eventually result in “adaptations” to continuous use of the drug. In regards to SSRI’s, the drugs are able to selectively act on serotonin receptors and transport without affecting norepinephrine or dopamine functions. The serotonin transporter is a compound which includes the energy-producing enzyme, sodium-potassium adenosine triphosphatase (Na⁺/K⁺ ATPase), and multiple binding sites specific only for serotonin, sodium ion, or the SSRI. Na⁺/K⁺ ATPase is an electrogenic transmembrane ATPase found in the plasma membrane of all animal cells which acts as a pump, allowing the flow of sodium ions out of the cell and potassium ions into the cell, both against their concentration gradient (meaning the flow of ions is moving from lower concentration to higher concentration forcibly by the cell membrane). The sodium binding site is designed to increase serotonin binding while the function of the SSRI binding site decreases binding, thus inhibiting it. Although a naturally occurring substance such as a ligand that acts in the same way as an SSRI has yet to be found, the fact that synthetic drugs can bind to a natural receptor suggests that one in nature could exist. Serotonin transporters immediately recapture the unused serotonin molecules and store them until another message is sent to release again. The binding of an SSRI (figure 4) inhibits the transporter from recapturing the molecules and these
events are an immediate response after the patient has been administered the SSRI (Stahl SM. Mechanism of action of serotonin selective reuptake inhibitors. Journal of Affective Disorders. 1998; 51(3):215–235.).

A more simplified illustration of brain chemistry and neuronal function can be described as similar to a game of baseball (Brain Chemistry. Brain Chemistry. [accessed 2017 Apr 16]. http://www.beatcfsandfms.org/html/BrainChem.html). Each neurotransmitter molecule is a baseball, the transmitting nerve cell is the pitcher, the receiving nerve cell is the catcher, and the receptor is the catcher’s mitt. The action of the ball being thrown and caught is equivalent to a transmitted message. The catcher catches the ball and throws it back to the pitcher in order for it to be thrown again. Problems can arise causing trouble in communication. If the mitt (receptor) is clogged, the ball is missing, if there is no leather to make the ball, or the ball factory breaks, the catcher cannot catch the ball. There are different types of baseballs in this game, each playing for its specific team; dopamine, norepinephrine and serotonin. Each team has its own pitchers and catchers who are trained in throwing and catching their team specific baseballs. Each team also has different types of catchers for each baseball, meaning each catcher is designated to throw each baseball to a specific pitcher, sending the correct message (like a plan of action for the team’s next play). There is a class of drug called the reuptake inhibitors (SSRI’s and SNRI’s), which clog the pitchers glove, making it difficult to catch the ball thrown back by the catcher. When this occurs, the ball bounces off the back wall and lands with the catcher again. Of course there are many other players on the field such as enzymes and ligands, as well as agonists. Agonists are another class of drug that act as the catcher’s glove stimulator by stimulating specific receptors, making them think they just received a neurotransmitter molecule (or caught a ball). This type of stimulating initiates the action of sending a message (throwing the ball), and unclogging the receptor.

By inhibiting the reuptake of serotonin in the brain as a result of SSRI’s, the neurotransmitter molecules stay in the gap between the nerves keeping levels high and improving communication between the nerve cells. Prolonged improvement of communication can strengthen circuits in the brain which regulate mood and ease symptoms of depression with fewer side effects than most other types of antidepressants. Although serotonin receptors such as 5-HT2 are considered the addictive receptors, SSRI medications are not considered addictive. Although antidepressants are known as effective treatments for depression, they should not be the only means of treatment considered. Doctors and scientists across the board and throughout history have agreed that a healthy diet accompanied by regular exercise and adequate sleep is a good remedy for many ailments. Keeping the body and mind in a healthy state can improve many symptoms of mental illness, but not all. Other over-the-counter suggestions to help treat depression include taking vitamins such as B6, incorporation more protein in one’s diet to elevate levels of tyrosine, and spending 30 minutes a day in direct sunlight for pure vitamin D absorption.

CONCLUSION:

Severe disabling mental illness has increased at an alarming rate in the U.S. It seems that we may be in the midst of an epidemic of depression with major depressive disorder becoming the ‘common cold’ of psychiatric diagnosis. The percentage of individuals seeking help for depression has doubled in only the last 20 years and continues to rise. Meanwhile, the age of those afflicted with major depression is plummeting. Only 20 years ago the average age in which first onset depression occurred was 30 years old. Now the average is 14 years old and we
are seeing thousands of college and high school students committing suicide every year. It seems that modern society is breeding anxiety, depression and social isolation.

It is helpful to understand the science behind what causes mental illness and how it manifests itself in everyday life. Living with mental illness or caring for someone who is ill is a constant lifelong battle. Unfortunately many mentally ill people discontinue treatment on their own and the available healthcare in the U.S. is poor. Treatments available are proven to be effective when taken as prescribed and followed diligently. Currently there is no cure for mental illness, however scientists are closer to finding cures than ever before with new brain imaging and scan techniques along with technological advances in manipulation of electric and magnetic fields. Breakthroughs in the medical field have allowed us to study the living functions of human anatomy without harming the individual being studied. These massive strides in scientific advancement are a bright light at the end of the very dark and long tunnel called depression.
FIGURES:

Figure 1: Dopamine molecule in 1D
Chemical formula: \( \text{C}_8\text{H}_{11}\text{NO}_2 \)
Molecular Weight: 153.181 g/mol

Figure 2: Norepinephrine molecule in 1D
Chemical formula: \( \text{C}_8\text{H}_{11}\text{NO}_3 \)
Molecular weight: 169.18 g/mol

Figure 3: Serotonin molecule in 1D
Chemical formula: \( \text{C}_{10}\text{H}_{12}\text{N}_2\text{O} \)
Molecular weight: 176.219 g/mol

Figure 4: Illustration of mechanism of action of serotonin selective reuptake inhibitors.
REFERENCES:


Your Brain on Magnets

Rita Oliverius

April 20, 2017

Physics112

Dr. Durandet
ABSTRACT:

The word “schizophrenia” sparks reactions of misunderstanding and fear. The illness has been associated with violence and criminals, but people who suffer from schizophrenia are not more likely to be violent criminals than everyone else unless they possess a history of violence prior to becoming sick. Schizophrenia causes psychological distress incomparable to other mental illnesses due to factors like hallucinations and an inability to distinguish between reality and fiction. Voices in one’s head are hard to ignore. Although the history of schizophrenia is long, not much is known about the illness and even less is known about effective treatment outside of a handful of antipsychotic medication. New research uses elements of nature such as electricity and magnetism as a way of manipulating the already-occurring electric and magnetic properties of cells in the human brain. Imaging of brain tissue combined with pulses of electromagnetism has open doors for research on the human brain and schizophrenia.

Mental illness has long been thought of as different types of psychiatric disorders that affect a person’s ability to behave, think and feel in the “normal” realm of societal expectations. Progression in the world of mental health has given scientists and physicians new perspective as to the causes and possible treatments for those affected by mental illness. Schizophrenia is labeled one of the most severe of all psychiatric disorders however little has been known about the physical signs and symptoms of a schizophrenic brain until more recently. Modern day scientists refer to schizophrenia as a chronic brain disorder; an active disease characterized by episodes of psychotics symptoms throughout the person’s life. Only about 1% of the population is affected by schizophrenia and symptoms can often be controlled with the correct medication and care. Unfortunately, nearly all schizophrenic patients chose to terminate treatment more than once, believing that they can “beat” the disease on their own without medication.

Schizophrenia is an unusual and mostly silent illness that most people will never understand. Schizophrenia is a disease, something a person is born with. It is already mapped out in their DNA, all the genetic precursors are set in place. Unlike other genetic diseases, however, schizophrenia gives no warning. There is no early “tell” to distinguish a mentally healthy child from one that will develop schizophrenia. And not every child with the genetic makeup and DNA in place will ultimately become schizophrenic or schizoaffective. Although research shows many possible factors involved with the risk of developing the illness, there is not consistency. It seems more like a gamble than a science. For someone to actually develop schizophrenia, they must have the genetic heredity and DNA sequencing in place, they must have dysfunctional neuron communication, they must exhibit abnormally high amounts of loss of grey matter in their brain, and they must reach a certain age before symptoms appear. It’s like a ticking time bomb and when it blows, no one knows what hit them. Loving and caring for someone who is suffering from schizophrenia is a constant battle, often unrewarding as well. The person who is being cared for is sick, and doesn’t understand what is so hard about giving them what they want at all times, no matter the cost. “But they’re sick.” Too sick to ever hold a job and at times too sick to complete even a couple hours of work. So they don’t understand the concept of having to work hard to earn everything that family’s need. Schizophrenic episodes and outbursts often coupled with the random mumbling conversation to themselves, and loved ones know what’s coming next… another bomb. They say and do hurtful things that are unnerving and even scary when they’re not well, screaming at everyone to disappear or
threatening to disappear themselves. “But they’re sick.” They are confused, delusional, scared themselves. Remember that symptoms of schizophrenia include the inability to process information or even remember information directly after having learned it. Schizophrenia leaves loved ones unsure of what the future holds or even who they are as an individual because their life becomes consumed with the one they are caring for. For a parent it is hard to relinquish the feelings of self-guilt For a sibling it is difficult to accept the idea that it is not their loved one’s fault, they are sick. Mental illness is not something one can beat on their own. As schizophrenia progresses with age and more grey matter in the brain is lost, it becomes more and more apparent – they are losing their mind, literally and figuratively. It’s a very sad reality, like trying to cope with the loss of that loved one, however there is no time to heal. Looking into their eyes, loved ones are constantly reminded of the person that once was their child, sibling, or grandchild, … that person is gone.

The onset of schizophrenia usually begins between ages 16 (mostly male) and 30 (mostly female). It is rare to find a child showing early schizophrenic symptoms. There are three classifications in which the symptoms of schizophrenia fall; cognitive, negative, and positive. Severity of cognitive symptoms can vary between patients and include trouble focusing, disorganized thinking and speech, unable to recall memories, and little ability to understand information or to use information immediately after learning it. Negative symptoms are associated with emotional behavior such as loss of enjoyment in everyday activities and life, reduced speaking along with reduced expression of emotion while speaking, lack of facial expression when speaking and monotone voice. Positive symptoms are by far the most alarming to the person affected and surrounding people. They include the ‘psychotic’ behaviors; smelling, seeing and hearing hallucinations, paranoid delusions of self and environment, agitated body movements and disorders, distorted ways of thinking and responding. Often times, these hallucinations and delusions involve threatening messages and images to the person suffering, which can be a terrifying reality they are facing every day.

More than 100 genomes have been associated with the risk of developing schizophrenia. Currently some known contributing factors to the risk of developing schizophrenia are genetics (schizophrenia is hereditary), environmental factors (abuse or exposure to viruses), prenatal malnutrition, autoimmune disease, imbalanced brain chemistry and neuronal malfunction, exposure to mind-altering drugs (especially during adolescence). Schizophrenia runs in the family and the disorder is likely to be inherited, although genetics are not the sole factor. If it was purely genetics, then the likelihood of identical twins both having the illness would be much greater than it currently is. Child abuse and acute stress caused by traumatic events increases the risk of schizophrenic symptoms as well as malnutrition during pregnancy or viral infection. Severely abnormal functioning of neurotransmitters, mostly dopamine and glutamate, largely contribute to the more psychotic symptoms of schizophrenia. Schizophrenia is linked to over-excitability in parts of the brain, therefore changing brain structure and affecting neuron activity that evolves progressively with age.

Along with symptoms and factors, there are different types of schizophrenia that a person can be suffering from. Catatonic schizophrenia impairs the ability of controlling one’s own movement, often mimicking the movement of others and either severely quick or slowed reactions. Disorganized schizophrenia impairs one’s ability to do daily activities or exhibit appropriate emotions. Paranoid schizophrenia seems to affect cognitive behavior less than other forms, however visual and auditory hallucinations are prevalent, followed by delusions and conspiracy. Undifferentiated schizophrenia includes several different forms of the schizophrenic
types mentioned above. Residual schizophrenia is the diagnoses when a person whom was once experiencing schizophrenic symptoms no longer exhibits them. There is also a schizophrenic-type symptom of other mental illnesses called schizoaffective disorders. One example is schizoaffective major depressive in which a person suffering from major depression and manic highs and lows also experiences schizophrenic manic episodes.

The name “schizophrenia” was given to the disease around 100 years ago, however historical documentation of the illness has been traced back to the second millennium B.C. It was believed that all mental illnesses were caused by evil spirits and demonic possession, and the only treatments were barbaric means to exorcise the demons out of the patients. Originally, all mental illness, physical illness, and disability was lumped into the same category and treated in the same manner. In fact, most treatment for the mentally ill throughout history has always had torturous aspects until the late 1800s. In the early 1900s, schizophrenia was distinguished apart from depression and dementia. The turn of the century brought about new discoveries for the treatment of mental illness including the accidental birth of pharmacology and the pharmaceutical industry and the beginning of electricity and electroconvulsive therapy (ECT).

ECT is the most historical brain stimulation therapy studied and is still in use today. Treatment procedure involves an electric current that is administered to electrodes placed in precise unilateral position on the patient’s head. The patient is placed under anesthesia during the procedure so as to avoid movement and discomfort. A seizure is induced by the electric current as it passes through the brain. This type of treatment is generally administered to those suffering from serious depression that is unresponsive to medication or psychotherapy. Normally a patient will undergo sessions at least three times a week for two to four months, or until depression symptoms improve. Maintenance sessions are required to reduce the chances of symptoms returning. The original, traditional form of ECT was known as bilateral ECT⁹, in which the electrodes were placed on either side of the head bilaterally. This type of treatment was known to have many more side effects and generally unsafe for the patient’s ability to learn and recall memory. It wasn’t until 1985 that a much safer technology with fewer side effects and less chance for regression had been developed, repetitive transcranial magnetic stimulation (rTMS) was developed.

Advances in medical equipment today use electric and magnetic forces to diagnose and treat various illnesses. Electric charges can either be positive or negative. Opposite charges attract one another while like charges repel, creating a force between each charge. Units of charge are given in coulombs where the basic unit of charge, \( e = 1.6 \times 10^{-19} \text{C} \). Protons are the basic unit of positive charge and are located within the nucleus of an atom. An electron is the basic unit of a negative charge which is opposite to that of a proton, but equal in magnitude. Electric charge can be transferred between objects but it is never destroyed; conservation of charge is an important concept used when working with electricity. The magnitude of electric force between charged particles can be calculated using Coulomb’s equation: \( F = k_e \frac{q_1 q_2}{r^2} \), where charges \( q_1 \) and \( q_2 \) are separated at a distance \( r \), and \( k_e \) is the Coulomb constant \((8.9875 \times 10^9 \text{N} \cdot \text{m}^2/\text{C}^2)\) given in units of Newton. Electric fields also produce a force on any charged object within its field lines as demonstrated by the equation: \( E = k_e \frac{q}{r^2} \), also given in units of Newton. Magnetic force is a resultant of the electric force that happens when charged objects are in motion. Charged objects moving in the same direction experience an attractive magnetic force between them. If they are moving in opposite directions, the magnetic force between them is repulsive. The magnetic force’s magnitude is proportional to the amount of charge between the objects, their velocity, and the distance between them. Magnetic force can be found using
the equation $F = qvB\sin\theta$, where $q$ is the amount of charge, $v$ is velocity in which the charged particles are moving, $B$ is the magnetic field, and $\sin\theta$ is the angle between the magnetic field vector and the velocity vector. Magnetic fields are often used to describe how magnetic force manipulates the space surrounding it. Electricity and magnetism are two aspects of the science of charge and the forces and fields associated with charge, called electromagnetism (encyclopedia Britannica). Information known today about electromagnetism is used in particle physics which allows for some incredible advances in medical technology.

The human brain can be viewed as a complicated and magnificent machine that is not yet fully understood. One specific type of cell that uses electrical signals as a means of communication is neurons. The neuron is the most basic signaling unit of the nervous system and the human brain contains billions of them. All living cells are surrounded by a cell membrane which mediates the passing of electrically charged ions into or out of the cell. This action creates an interior and exterior electric potential across the cell membrane, making it a great conductor and insulator for electricity. A capacitor is a device that stores electric charge and is made up of parallel plates of conducting material separated by a layer of insulation. The lipid bilayer of the cell membrane forms the insulation (separation layer of conducting material) between the electrically conductive solution of charged ions inside and outside of the cell (two conductors), thus storing charge and acting as the capacitor. The amount of charge stored by the membrane can be given by the equation $q = CV$, where $C$ is the capacitance of the membrane and $V$ is the amount of voltage across the capacitor. The capacitance of a cell membrane is approximately $10^6$ farads per square centimeter and its thickness is approximately $6.0 \times 10^{-9}$ meters (roughly the size of two molecules). Electrical signals occur when there is a flow of electrical current. In nerve cells this occurs when ion channels in the membrane open and allow the electrically charged ions to flow into or out of the cell, creating a membrane potential. If this current ($I$) is constant, then it can be calculated using $I = C \frac{V}{t}$ given in units of amperes, where $C$ is capacitance and $V/t$ is the amount of voltage passing per unit time. These open ion channels act as resistors in which they resist the flow of ions that cross the cell membrane, measured in ohms (1 ohm = 1 volt/1 ampere). Magnetic fields in the human body are created by this electrically charged activity. More specifically, magnetic fields are created by the current produced from the flow of charged ions across the cell membrane through open ion channels. Membrane potential across the cell membrane increases as more ion channels open. When increased enough, the polarity of the membrane will change, reversing the direction on both magnetic and electric field line vectors, thus causing ion channels to close. The electric and magnetic fields in the brain help synchronize neuronal communication and regulate their activity. Being able to safely manipulate and change these fields could possibly change what happens in neuronal activity, changing what happens in the brain.

Research in schizophrenia has shown that the disease causes disconnect between the prefrontal cortex and the auditory cortex. This discovery was possible due to the modern technology of functional magnetic resonance imagery (fMRI)³. Using MRI technology, fMRI measures a functioning brain’s activity through neuroimaging by detecting blood circulation and responses in active parts of the brain (figure 2). Coils in the machine carry an electric current that creates electric fields parallel to the coil plane, and magnetic fields perpendicular to the coil plane. Radio waves are then directed toward the protons in the magnetic field and sent in pulsed waves. The protons, in turn, fire off electric signals that are detected by the machine’s coils. Blood flow and oxygenation is directly related to neuron activity in the brain. Deoxygenated blood is much more magnetic than oxygenated blood, a contrast between more active blood flow
as opposed to less active is made by activating neurons, allowing magnetic imaging to show
differentiation in the brain region being studied. It is now possible to not only diagnose
schizophrenia through this noninvasive procedure; researchers are able to detect schizophrenia
early on in life as well. People with schizophrenia exhibit different brain structures starting as
early as infancy. Years before symptoms manifest themselves, the auditory and prefrontal
cortices are already malfunctioning; neurons in the auditory cortex fail to send the correct signals
to the prefrontal cortex. Early detection of the disease is currently the best means for treatment.
Two-dimensional and three-dimensional magnetic resonance imaging has also proven that those
suffering from schizophrenia have less grey matter than healthy subjects (Figure 1). This loss
becomes more predominate with age and is caused by a protein that everyone has in their brain.
The protein is considered a ‘house-keeping’ protein that eats away at unnecessary neuronal
synapses as the brain ages. This protein is found in more abundance in the blood of
schizophrenic patients. Neural ventricles tend to have a much greater diameter in patients with
the disease as opposed to the healthy participants. These malfunctioning structural abnormalities
create chemical irregularities with an abundance of glutamate and dopamine neurotransmitter
levels also found in the blood, which create the psychotic positive symptoms of schizophrenia.
The ability to detect schizophrenia at an early age, before excessive grey matter is destroyed and
structural abnormalities are exaggerated, is possibly the greatest advancement in mental health
today. In the earliest years of life, human tissue, organs, brain and neurons are most malleable
and can be taught normal electrical patterns and rewired in a noninvasive way that will carry on
through adulthood.

Effective treatment for mental illness beyond medication has yet to be released to the
masses. Until recently, tools and technology that allowed scientists to study how the living
human brain functions have been obsolete. Progression is well underway now that functional
brain scanning is available. One promising treatment for patients with schizophrenia involves
stimulation of neuron activity with magnetic and electric pulses that travel through the skull,
called transcranial stimulation (“trans” meaning “through” and “cranial” meaning “the skull”).
Transcranial stimulation affects neuron activity and behavior by creating different
electromagnetic fields and current in the brain. Transcranial magnetic stimulation (TMS)
generates an electric current along the scalp without any real physical contact by means of an
electric coil and magnetic flux. A coil of wire is enveloped by a plastic coating and held next to
the skull (Figure 3). Once the procedure begins current travels through the coil wire and produces
a magnetic field around the wire that is perpendicular to the coil plane. The magnetic field is what
passes through the skull and enters into the brain. This creates a current which flows opposite of
that already produced by the neurons in the brain and affects surrounding nerve cells. Magnetic
fields affect moving charges and moving charges produce magnetic fields. All living cells have
a membrane potential created by the exchange of electrically charged ions, including the neurons
in the brain. Deep TMS can penetrate as far as 6 centimeters into the brain tissue, depending on
how strong the pulse generated by TMS is made to be (1).

An easier way to envision the way that magnetic fields work in TMS is to understand
how charged particles, like neuron cells, achieve magnetic force. As mentioned before, protons
are positively charged particles found in the nucleus, and electrons are negatively charged
particles orbiting the nucleus. Electrons are constantly spinning in one of two directions, either
upwards or downwards. Normally half of the number of electrons spins in one direction while
the other half spins the opposite way. This is known as equilibrium and is not magnetic.
Magnetism happens when a lot of these charged particles in one specific area are spinning in the

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same direction. Once the particles have achieved this and become magnetically charged, they create a surrounding area filled with magnetic field lines that influences other charged particles. This influence can either be attractive or repulsive. Neurons communicate with each other through bursts of electricity, like a light’s on/off switch. Movement of electrons creates electricity. Thus magnetism and electricity both result from the behavior of neurons. Just as magnets are surrounded by magnetic fields, electrically charged objects are surrounded by electric fields. Magnetic and electric fields can interact with each other and influence or disrupt the behavior of each other. TMS works in this way, disrupting the coordinated electrical and magnetic activity of neurons. The brain manages thought processes by creating neuronal pathways for neurons to communicate via electrical and chemical messengers. Communication between neurons exhibits a type of muscle memory along pathways in the brain over time, thus leading to the hypothesis that an alternate way of communication can be learned over time as well.

Suppression of the positive symptoms of schizophrenia has already been achieved through TMS. By placing the TMS coil over the temporal parietal region and using a low frequency, an inhibitory affect is produced (higher frequencies are used for an excitatory effect on patients with other disorders such as major depressive disorder). Although the results of treatment thus far have been promising and it would seem that receiving such an effective and noninvasive treatment is an obvious benefit, TMS treatment for schizophrenic patients can be very tedious. In order to be effective and achieve long-term results, treatment must be administered in a lab or clinical setting five days per week, with each session taking two to three hours. This proves to be an intense process commanding serious commitment which would be difficult for any healthy person. To someone suffering from schizophrenia, this would seem like an eternity spent in a long dark tunnel with no light and no end. Fortunately there is another form of transcranial stimulation called deep brain stimulation (DBS) (11). One would have to undergo a series of tests prior to this type of treatment to see if they could be considered a candidate, as DBS is not a noninvasive procedure. DBS consists of a simulator that is surgically implanted in the patient’s head, above the Dura (the outermost membrane enveloping the brain). The stimulator is battery operated and performs the same process that is involved in TMS. The patient receiving treatment would experience relief from auditory and visual hallucinations without having to endure the inconvenience of the laboratory setting and schedule.

CONCLUSION:

Schizophrenia is a disease that deteriorates the brain and brain functions as it progresses. If there is a way to catch the disease before symptoms begin, then there is a way to slow the progression and even more promise to finding means of treatment to cure and demolish schizophrenia for good. Schizophrenia has affected the minds of extremely talented historical figures. A list of some beautiful minds in history that suffered from schizophrenia include Eduard Einstein (Albert Einstein’s son), Peter Green (of Fleetwood Mac), Syd Barrett (of Pink Floyd), Charles “Buddy” Bolden (jazz musician), Mary Todd Lincoln (wife of Abraham Lincoln and first lady), Jack Kerouac (author), Vincent van Gogh (painter and artist), Zelda Fitzgerald (novelist and wife of author F. Scott Fitzgerald), Lionel Aldridge (former NFL player), and John Forbes, Nash, Jr. (mathematician) just to name a few. Particle physics with electromagnetism and transcranial stimulation holds the perfect formula for perfect mental health. After all, a beautiful mind is a terrible thing to waste.
FIGURES:


Figure 2: Images as seen on an fMRI of a functioning schizophrenic brain showing abnormal levels in brain function on the subject early on and 5 years later. (Magnetic resonance brain imaging studies in schizophrenia. Magnetic Resonance Imaging. 1985;3(2):185.)
Figure 3: Mechanism of action for TMS. (Vernet M, Thut G. Electroencephalography During Transcranial Magnetic Stimulation: Current Modus Operandi. Transcranial Magnetic Stimulation Neuromethods. 2014:197–232.

Figure 4: Mechanism of action and intended results for TMS. (Rapid Transcranial Magnetic Stimulation/Repetitive Transcranial Magnetic Stimulation. Encyclopedia of Clinical Neuropsychology. 2011:2113–2113.)
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Why Nerves of Steel?

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ABSTRACT

The human body has about 100 billion nerve cells serving some of the most important parts such as the brain, spinal cord, sensory organs, and every nerve connecting to ever other nerve. The whole of the nervous system is what people use every day to greet friends, play sports, avoid pain, and many other views on life. Without the sense of touch to connect with the world as we know it, then people could distance themselves or worse. Soldiers fighting overseas lose limbs or other vital organs. This is difficult for most to cope with when losing a limb. Researchers have devised ways to make replaceable limbs, and organs, but no nerves for feeling what they use to feel. New forms of nerve replacements, regeneration, and mechanical sensations have been popping up around the world. The newest innovation in the field of prosthetics is here to reconnect the missing nerves to form more human ingenuity.

INTRODUCTION

An amputation of the leg or an arm is a devastating moment in anybody’s life. There is a significant impact on all areas of life for this individual(s). Especially for people that fought overseas in the U.S. military. They protect America everyday and serve a very important purpose for security. They also serve an important role to their families and friends that support them very much. That’s why the reconnection of nerves to prosthetic limbs is something the nation can give back to its saviors.

What is feeling? Yes, it is commonly known to be emotions. However, feeling is a great way to use the sensation of touch. This allows people to grasp familial things like cups to drink from, a T.V. remote to watch movies, and turn the radio knob when the music gets too loud. Touch is the best way to sense pain if he or she is injured. Hot objects are tough to hold even in a game of hot potato. People would immediately drop it or withdraw their hands from the hot potato. This also includes cold temperatures when the outdoors reaches zero degrees. These everyday examples are so common to people nowadays that knowing its happening isn’t even common.

How does this happen? Well the nervous system coordinated everything without even thinking about it. The example with the hot potato is that just holding it the nerves in the hand will send signals that will have neurons firing rapidly to avoid the heat. The whole nervous system that consists of the brain, spinal cord, peripheral nerves and autonomic nerves, will telegram all the movements, thoughts and sensations to avoid that hot potato. This is also an important survival sense to interact with allsorts of surroundings. This can be either external or internal. The body will coordinate to move the legs voluntarily to get through a marathon or hurdle over trenches in the field. On the inside, the body will involuntarily regulate the lungs for breathing, and make sure the heart is beating with a normal body temperature.

The human body is a massive unit of wiring sort of like a computer. This means the brain is the hard drive that tells everything in the body what to do. Without the spinal cord to send and receive messages the Peripheral nerves in the upper or lower extremities would be unable to communicate with the brain. The nerves have this type of electrochemical that pulsates signals to and from different areas of the nervous system and would discontinue there functions if the
signals were not sent. There are four different types of nerves in the body. First, the cranial nerves connect the sense organs such as the eyes, ears, nose, and mouth to the brain. Second, central nerves connect areas within the brain and spinal cord. Third, peripheral nerves connect the spinal cord with the limbs. Finally, autonomic nerves connect the brain with the spinal cord to send the signals to the organs such as the heart, stomach, intestines, blood vessels, and etc. [Figure 3]

When it comes to nerves reconnecting to the dismembered limbs the simplest type of neural pathway is a monosynaptic, like in the knee-jerk reflex. When the doctor taps a certain spot on the knee with a rubber hammer, the receptors will send a signal through the spinal cord. The sensory neurons will pick up on this transmission and pass the message to a motor neuron that controls the leg movements. Nerve impulses then travel down the motor neuron and stimulate the appropriate leg muscle to contract as an involuntary action. This is not an easy job for nerves to be simply reattached to living mass or bionic materials.

MATERIALS & METHODS

Some people have thought of trying the Osseous Integration technique. This is the direct attachment of osseous tissue to an inert all plastic material without intervening with the connective tissue. This type of procedure is mostly seen in dental implants. Scientists are working to adapt this form of implant on a bigger scale such as an arm or a leg. One such doctor, Dr. Munjed Al Muderis mentioned in his research that, “the structural linkage made at the contact point where human bone and the surface of a synthetic, often titanium based implant meet” (Osseointegration). This refers to his research on placing synthetic limbs on to living flesh using the Osseous Integration technique. This type of technique is to show no effect of rubbing or bruising of any kind on the living tissue but it does offer more mobility to run further. This still doesn’t mean it’s the perfect fit.

In some cases an intra-modularly bar that is inserted into the Femur, Humerus, or Tibia is an improvement implant that links the implant with the prosthetic joint. Most outer couplings that connect any joint on a limb to an implant for the Osseous Integration technique provides a much longer gait when in motion. Implants like these have to be taken care of constantly. Some doctors are smart by predetermined the breaking point in the adapter. Sometimes this will avoid possible damage to the bone and implant, but other times the patient will have to get the synthetic limb readjusted. As a precaution some researchers or facilities will advise that prototypes are just that, “Most new and fancy contraptions can also easily break if the patient were to fall or part-take in a dangerous situation” (Osseointegration).

Scientists have developed sensor technology for a robotic prosthetic arm that detects signals from nerves in the spinal cord [Figure 1]. In this form of research, through the use of mechanical limbs researchers have gotten close to reattaching nerves to living tissues that send messages back to the brain to feel the surroundings of the environment. The patient has to think like they are controlling a phantom arm and imagine some simple maneuvers to show the researchers and doctors that it works. This means patients will have to try to pinch two fingers together or claps hands. Confirmations on these tests are still pending because there is more work to be done.
To control the prosthetic, the sensor technology interprets the electrical signals sent from spinal motor neurons and uses them to understand what to do. Using a motor neuron made from many nerve cells located in the spinal cord helps the patients to try and connect with the neurons. The spinal columns fibers, called axons, work on the outside the spinal cord to directly control muscles in many places among the body.

Robotic arms that are made as prosthetics are controlled by the user twitching the remnant muscles in their shoulder or arm [Figure 2]. In most cases that researchers get or have patients that have been amputated in spots which are often with less damage. The team from the Imperial College of London says, “Detecting signals from spinal motor neurons in parts of the body undamaged by amputation, instead of remnant muscle fiber, means that more signals can be detected by the sensors connected to the prosthetic” (Prosthetic arm technology detects spinal nerve signals). This means that ultimately there is hope that more commands could be programmed into the robotic prosthetic and the cerebellum will be able to receive those commands.

Dr. Dario Farina, who is now based at Imperial College London, said: "When an arm is amputated the nerve fibers and muscles are also severed, which means that it is very difficult to get meaningful signals from them to operate a prosthetic. We've tried a new approach, moving the focus from muscles to the nervous system. This means that our technology can detect and decode signals more clearly, opening up the possibility of robotic prosthetics that could be far more intuitive and useful for patients. It is a very exciting time to be in this field of research” (Prosthetic arm technology detects spinal nerve signals). Dr. Dario Farina is correct in saying that nerve fibers, even after being severed. Those connections still have to get the right signals to the brain, otherwise, the transmission would be scattered. For example, the nerves will seem as what a power line resembles when the cable has been cut.

Lab-based experiments are carried out with plenty of expensive equipment. Luckily, the U.S. Army has been funding many reports in the United States of America. The U.S. Army does this because of the resent fact that came out saying that, “The recent conflicts in Iraq and Afghanistan have resulted in more than 1,600 Americans surviving with extremity amputations (14% of which are upper extremity)” (Targeted Muscle Reinnervation: Control Your Prosthetic Arm With Thought). Some of the material used in making synthetics is comprised of the scaffold that had to be flexible with fluid, but it also needed to be extremely conductive. Otherwise the nerve signals won’t be able to get to where they are needed. An effective neural-prosthetic interface would need to transmit thousands of different signals per second. Unfortunately, it will not be able to mimic the behavior of a real limb. Researchers are working constantly to make that reality.

To create that ideal synthetic nerve hookup for a prosthetic limb, researchers have to mimic the properties of nerve tissue. This is uncharted material because most of the wiring would be made out of metals or silicon which will be porous. So that nerves can extend through it otherwise making electrodes to send the messages would not be sent [Figure 4]. This is a very tricky procedure because certain nerve sites will be very fragile to handle.

When surgeons during an experiment for a type of synthetic nerve hookup said, to check this method, “placed the scaffolds onto the severed leg nerves of rats, it didn’t take long before the rats’ own nerve fibers started to grow through the scaffold and fuse back together” (Ting-
Chen Tseng, Chen-Tung Yen and Shan-Hui Hsu). It’s amazing that the researchers got a response that the synthetic material wasn’t rejected by the rats’ immune systems.

From most of this knowledge, perhaps the most important is the use of peripheral nerves as an interface for prosthetic electrical inputs or regeneration. It’s a possibility, to tap into the central nervous system with simple surgery on the peripheral nerves of the amputated arm to rework an arm or leg. This isn’t easily possible because once a nerve dies it can’t come back. The nerve interface even though there was scarring and the healing process took place at the nerve stump (Included as well is the local trauma). It will be tough on the formation of stumps and nerves. It is still science fiction to have a tissue of a dead arm still be able to have a sense of position and pressure or any other sensation, but it would be interesting if a proven recorded showed positive results.

Peripheral nerve injuries are often caused by trauma and they may result in a partial or total loss of motor function or sensory perception. After nerve injuries, peripheral axons have the ability to regenerate and reconnect the proximal and distal ends of severed nerve axons if the nerve gap is small. For larger nerve gaps, surgical treatments are often required to repair the injured nerves. A lot of how these injuries are viewed is seen with an MRI machine to have a throw diagnosis. An EMG would be better for doctors to see the injuries.

A few researchers say, “With new ideas on the regeneration of nerves in the peripheral nerve after injuries, which include transplantation of autologous of nerve grafts treatment options for the regeneration of peripheral nerve injuries …” (Ciardelli, Gianluca; Chiono, Valeria). The length, and the requirement of a second surgical procedure to remove the graft tissue will take more time. With most injuries to the nerve strand sights the nerve transection will leave an area totally numb. If the amputation to the limb was done correctly then a tingling or a sensation of feeling would provide more results to the bionic research. With very little damage to the nerve sights at the stumps of amputated limbs will researchers be able to regenerate those nerves to attach to a synthetic limb.

Many recent studies suggest that cell transplantation may improve peripheral nerve regeneration through the neurotrophic factor production and Schwann cell differentiation. However, the role of transplanted cells during peripheral nerve repair is largely unknown. Although histological analyses provide some clues, the migration of transplanted cells during the regenerative process in a conduit is unclear. As mentioned, MRI is a potential tool for visualizing the nerve regeneration. To view the full reconstruction on a regenerating nerve is a outstanding project yet to be fully accomplished because this process is still very new.

Recent efforts in scientific research in the field of peripheral nerve regeneration have been directed towards the development of artificial nerve guides. The researchers involved said,” We have studied various materials with the aim of obtaining a biocompatible and biodegradable two layer guide for nerve repair. The candidate materials for use as an external layer for the nerve guides were poly(caprolactone) (PCL), a biosynthetic blend between PCL and chitosan (CS) and a synthesized poly(ester-urethane) (PU). Blending PCL, which is a biocompatible synthetic polymer, with a natural polymer enhanced the system biocompatibility and biomimetics, fastened the degradation rates and reduced the production costs. Various novel
block poly(ester-urethane)s are being synthesised by our group with tailored properties for specific tissue engineering applications. One of these poly(ester-urethane)s, based on a low molecular weight poly(caprolactone) as the macrodiol, cycloesandimethanol as the chain extender and hexamethylene disiocyanate as the chain linker, was investigated for the production of melt extruded nerve as guides” (Ciardelli, Gianluca; Chiono, Valeria). The researchers had to come up with natural polymers such as gelatin (G), poly(L-lysine) (PL) and blends between chitosan and gelatin (CS/G) as internal coatings for nerve guides. This form of work needs to be refined to be continued in a living system. Finding the right materials and electrochemical/nerve guides took a lot of time for these researchers to refine and they’re still refining this.

Discussion

The use of a bionic, and synthetic limbs, and reconstructed nerve recovery are very promising ways to eventually reconnect the nerves to feel again. What I’m suggesting can be applicable in areas that treat cerebral palsy and chronic nerve pain as well. Nerves could be eventually made out of steel or silicon based wiring. The human race is still using science fiction to blossom ideas on how to restore the arm and leg use through neuron-prosthetic feedback and transmission. Some day science will be able to circumvent the tiny wiring to connect some sort of interface to the cervical roots that will go directly to the brain. Which then I know that people will eventually be able to pet the fine furs of a dog or a cat and feel that this animal is soft and warm.

The rehabilitation conditions the uses of nerves have will be perfect for soldiers to reenter society again or return to the army. I’m certain that continued support of research into these areas will unlock even more mysteries to come. More support would be great to make these. Especially, when soldiers that return from combat and are missing a few limbs. When your friend of relative returns from the field and discharged from active duty because you’re not fit to fight isn’t a pleasant thing to hear [Figure 5]. Sure they could have desk jobs, but what about what they lost. The right to write with a pencil or play soccer with there kids, simple stuff in life. It isn’t an easy life when you’re with a disabled limb(s) that handicaps most of the things you could do or would have done.

Conclusion

When it comes to life don’t hold any thing back to make the world a better place by using the power of science. There comes a time that nerves being reconnected to either live flesh or bionic material the patient should be able to feel the world again. This research on regaining the feeling of a limb, even though it is prostatic, is a major benefit for not just the military soldiers but also for anyone that has a lost limb(s). The recent developments in this field of research are still vague but very promising. New forms of nerve replacements, regeneration, and mechanical sensations have been popping up around the world. This is true and eventually all the researchers in the world will make something even better to further along the civilization of man. The use of synthetic nerves may mature in the future, but the robotic view on creating nerves is more advanced to work with. The peripheral nerves are no simple task for most people to comprehend with such detailed research.
Figures

[Figure1] https://images.sciencedaily.com/2017/02/170206111903_1_540x360.jpg Credit to Imperial College London and Science Daily

[Figure2] http://www.ric.org/app/files/public/435/img-stock-Claudia-in-therapy.jpg Credit to the Scientists at the Rehabilitation Institute of Chicago (RIC)
Homunculus of Primary Somatosensory Cortex in Blue

[Figure 3] https://s-media-cache-ak0.pinimg.com/736x/38/20/6c/38206cfbfe4d5d6a38a3dd75d7089c41.jpg

Credit to the Journal of the American Academy of Orthopaedic Surgeons and the scientists involved

[Figure 5] https://www.wired.com/images_blogs/dangerroom/2012/02/prosthetic.jpg Credit to Sgt. Ray Lewis/Bouhammer.com
References


Abstract: Bipolar disorder is a mental disorder that affects millions of Americans and their loved ones. The stigma that surrounds mental illness is hard to break in our society, but research has shown that many people with bipolar disorder are simply affected because of chemical imbalances and differences in their brains. Because it is something people have no control over, it is only fair to treat those who suffer from it the same way we would anyone else. There is no simple solution to bipolar disorder, but many researchers have theories and medications that can help stabilize a person who suffers from it. It is significantly shown to be genetic and can have serious and even deadly effects when not treated or misdiagnosed.

Introduction: Over three million people are diagnosed with bipolar disorder annually in the United States alone. Bipolar disorder is formerly known as manic depression, which in the name itself suggests exactly what patients experience when dealing with the disorder, spells of mania followed by depressive phases that can persist for weeks or even months. While there are always many factors that can lead to any type of mental disorder, the most common arguments that psychologists have are nature versus nurture; meaning is this disorder part of the person's DNA or was their environment a factor? Generally speaking, patients with issues in both realms of nature and nurture are the ones with the most serious issues and are affected in their everyday lives by their disorders. Bipolar disorder is more likely to be caused by genetics, according to Mayo Clinic's website, “Bipolar disorder is more common in people who have a first-degree relative, such as a sibling or parent, with the condition. Researchers are trying to find genes that may be involved in causing bipolar disorder.” People with bipolar disorder also tend to have physical differences in their brains compared to someone without the disorder, specifically the frontal cortex which is responsible for decision making.

Content: There are several types of bipolar disorder that can help classify specific patients and help them get the medicines and therapy that they need to live a stable life again. The first classification is Bipolar I, commonly noted as the most serious case of bipolar that usually affects the patient's everyday life. People with bipolar I are considered disabled and cannot function day to day without assistance from medicine or therapy. In Bipolar I, there are possibilities of psychosis during mania in which the patient breaks from reality, which is why it is the most dangerous form of Bipolar, and when left untreated and can lead to death or suicide. While some may argue the depressive phases would be more dangerous, the detachment from reality while feeling an extreme high is much more common to result in death or injury. Bipolar II is categorized by more depressive stages, and mood swings not as serious as Bipolar I, called hypomania. Bipolar II is also dangerous because it can easily be misdiagnosed as depression, which can cause serious issues with prescribing harmful antidepressants when the patient really needs a mood stabilizer. The least serious subtype of Bipolar is Cyclothymic disorder which is characterized as swings from minor depression to hypomania which are less serious but can still be an issue if left untreated, or mistreated. Comorbid conditions that occur along with bipolar disorder include anxiety and eating disorders, ADHD, alcohol or drug problems, and physical health problems, such as heart disease, thyroid problems, headaches or obesity.
Psychologists and psychiatrists alike can diagnose people with bipolar disorder. It is extremely difficult to diagnose bipolar disorder because it is so closely linked to depression and there is no “test” per se that can tell you whether or not someone has it. Mood charts similar to Figure 2 definitely help with assessing what types of emotions patients are having and help track any suddenly changing moods. Doctors would usually do a physical test first to rule out any physical things the patient could be suffering from such as thyroid disease that could also cause an imbalance in hormones. Next, they look at medical history and address any serious injuries (especially head injuries) that could account for the person's behavior. Then they will do a personality test and ask about family members with psychological disorders because of how genetic it is. The doctor can also ask family members questions to make sure everything checks out. One fifth of those with bipolar disorder that are left untreated eventually commit suicide. People in a manic episode tend to deny that there is anything wrong with them so it is extremely difficult to diagnose, or even get them to see a doctor in the first place.

The mood swings that are involved in bipolar disorder can be explained by the imbalance of certain hormones and key chemicals in the brain such as neurotransmitters, noradrenaline, serotonin, and dopamine. It has also been proven that people who suffer from bipolar disorder and are left untreated have can experience shrinkage in their frontal cortex which is associated with decision making. There is clearly a difference in brain activity during manic periods versus depressed. Researchers are still trying to figure out what genes are involved, but the brain scans alone are extremely helpful to doctors in diagnosing patients. Figure 3 shows the difference between brain activity during depressive and manic states in one person. Research has been done that has proven that people with bipolar respond more negatively to neutral stimuli whereas people in the healthy control group did not. This suggests that psychologically, the mindset of those with bipolar is more pessimistic during their depressed state and can have effects as serious as suicide. The research was done on a set number of people who are already diagnosed with bipolar disorder during their depressive state, to see how each reacts emotionally to external stimuli and compared the reactions to healthy controls. Subjects with bipolar disorder tended to respond more negatively to neutral stimuli whereas healthy subjects did not, suggesting that the depressive stage of bipolar disorder can cause pessimistic feelings and more reactive to emotional cues. They were also proven to have a more emotional reaction to external cues. This research can also be helpful with the diagnosis of bipolar disorder (Figure 1). Although it is qualitative data, rather than quantitative, researchers are able to find out more and more about the emotions and reactions of those with bipolar disorder.

Bipolar disorder can be found in 1-3% of youth (Birmaher B.), and is more commonly diagnosed in adolescents because it is very hard to diagnose children due to their own immaturity, and comorbid disorders that can mask or present themselves as disorders other than bipolar. Bipolar adolescents are at higher risk of suicide, substance abuse, and psychosocial difficulties (Birmaher B.). A study was done to show the impulsivity that goes along with being bipolar can correlate to substance abuse in bipolar patients. They found that many patients who had histories of substance abuse in the past were more easily coerced and compliant, even in a
non-manic state which relates to why so many patients with bipolar commit suicide and are aggressive when abusing substances (Swann AC, Dougherty DM, Pazzaglia PJ, Pham M, Moeller FG.). There may also be a link between not taking their medications correctly and substance abuse because the medicines are mood stabilizing, many patients feel as though they are better off without them because they want to feel mania again. Substances are highly recommended against when on lithium and other drugs for bipolar because they influence mood and heart rate, so it makes sense that many people with bipolar disorder seek the feelings that substances give them.

Because it is so hard to correctly diagnose, researchers have done studies to show that the mania in bipolar disorder is directly related to the disorder and not underlying causes, and were able to state that the manic emotional response is a specific factor of onset bipolar disorder (Park JW, Park KH). This helps the case, not only that mental illness are real, but that our technologies are helping diagnose and create awareness for the public not to be so demeaning toward those with mental illnesses. In our society, many younger people are trying to push for the awareness for mental illness, but some still do not believe it exists and think people just need to “feel better” or get over it. Bipolar disorder is very literally disabling and our view of people with mental disorders definitely does not help them feel better about themselves.

Some research on the subject questions whether or not polyunsaturated fatty acids affect suicidal thoughts, or could potentially help in curing mental illnesses like bipolar disorder and depression. (Pompili, M., Longo, L., Dominici, G., Serafini, G., Lamis, D. A., Sarris, J., & ... Girardi, P.) The article states that “Deficiency of omega-3 polyunsaturated fatty acids (PUFAs) and an alteration between the ratio of omega-3 and omega-6 PUFAs may contribute to the pathogenesis of bipolar disorder and unipolar depression.” They also claimed that less PUFAs were correlated with suicide or attempts at suicide. Compared to a control group with regular levels of polyunsaturated fatty acids, the group with depleted amounts showed a significant correlation with suicidal thoughts or actions. In the end, the researchers used peer-reviewed sources for background information and had their own experiment showing that the levels of PUFAs could in fact be affecting people’s suicidal thoughts or tendencies. Because of research like this, doctors and medical assistants are able to pinpoint exactly what is going on within a bipolar person, and assess exactly what types of medicines and treatment plans would work best.

Effective treatment and management can take anywhere from days to years in some cases to perfect a routine for any patient. According to several case studies and research, most patients need more than just lithium to stabilize their mood and live a normal life. Some patients use Valproate in place of lithium when more mixed-mood episodes occur rather than just mania and depression (Goikolea 20017). Many patients in a manic phase will need more than just one medication in order to bring them to a stable state, and this can be hard for prescribers searching for the correct coinciding medicines for each individual (Goikolea 2007). Bipolar is so commonly diagnosed as depression because patients generally don’t go in to see a doctor when they are feeling manic because they feel great at those times. The danger in that is that the
antidepressants can actually harm the patients and affect the chemical balances in their bodies negatively.

Researchers were testing the \textit{SYNJ1}, which encodes synaptojanin 1, an inositol 5-phosphatase, but now there is linkage analysis showing that chromosome 21q22 could be what contains a candidate gene for the disorder. Because there is significant evidence that the disorder is genetic, the big question now is which gene and could we prevent it from being passed down (Stopkove, Vevera, Paclt, Zukov, Lachman 2004). The human genome project is a big contributor to determining differences in genes between a healthy and disordered person, and studying these genes could one day lead to diminishing the disorder or at least finding what factors into the disorder and how to manage it chemically.

Before any real research was done in the area, common treatments were bloodletting, electroconvulsive (shock) therapy, exorcism, imprisonment, induced insulin coma, and lobotomies. Luckily, our research on bipolar disorder and many other mental illnesses has improved over the years and we are able to help those who suffer from these symptoms and stabilize their moods with the right medications. Treatment for every case of bipolar disorder is different, depending on how severe the case is, body type of the patient, and even gender can influence the medicines used. For mild mood swings a change in diet can be all you need, but for those with bipolar 1, the medicine can feel draining. Lithium is the most common treatment, and one of the first mood stabilizers discovered, although cannot be considered a universal “cure” for everyone with bipolar. Many patients require additional medication along with lithium either due to side effects or just needing to be able to think more clearly. Antidepressants, anti-seizure medication, and antipsychotics can also be prescribed with varying success rates. For more subtle cases, or just occasional mood swings, Healthy Balance suggests eating fish, meditating, going decaf, cutting out sugars, and trying magnesium, inositol, and taurine supplements to help with anxiety and depression and lessen the intensity of mania. Of course, a simple diet change will not “cure” anyone who suffers from genetic bipolar I, but simple changes can help those with low-grade bipolar to feel as though they have control over their lives again.

Having bipolar disorder not only affects the person who has it psychologically, but almost everyone around them as well. It takes a lot of time and effort to take care of someone who doesn’t know they have bipolar disorder, and can sometimes be difficult to make them get the help they need. Julie Fast has a book titles “Loving Someone with Bipolar Disorder”, and in an interview she explains the emotional damage she endured while having to take home an ex who is still psychotic, and how draining it is to see someone you love go through the dramatic changes that bipolar I causes. She is a special case because she dated someone who she knew was diagnosed with bipolar I, and then later one was diagnosed with bipolar herself. She explains how it's hard on her family to have to drop everything to help her, but her book explains a good method to cope with mental illness as a family member and eventually her family did catch on to her methods after two years.
Overall, bipolar disorder is a genetic disorder in which patients are more likely to be affected if they have a closely related relative who also has the disorder such as a mother or sibling. Men and women are equally affected by the disorder in percentages; however the disorder can affect men and women differently. The median age for bipolar disorder is 25, and more than two-thirds of people with bipolar disorder have at least one close relative with the illness or with unipolar major depression. Up to one in five people with bipolar disorder complete suicide, so it is extremely important to be aware of bipolar disorder and help in the research surrounding bipolar, but with adequate treatment these numbers will go down.
Figures

Figure 1

Table 1

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<thead>
<tr>
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<th>Valence</th>
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<td>Depressed group</td>
<td>7.95 ± 0.23</td>
<td>3.82 ± 0.3</td>
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<tr>
<td>Control group</td>
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Note: SD = standard deviation.

Figure 2

Figure 3
References


The Green Flash

James Perlman

PHY112
April 20, 2017
Professor Mike Swingler
A green flash is an atmospheric optical phenomenon where the light of the sun can be briefly seen to be green around a sunset or sunrise. This green light is caused when various atmospheric conditions, including cloud level, and temperature, combine just right to act as a prism, and split the sun’s white light into its full visible spectrum of colors, most of which become obscured by the horizon or other objects with only the green light remaining visible. There are several different types of green flash, some more common than others, each depending on their own unique combinations of the aforementioned atmospheric conditions, sometimes even including the location of the observer, so no two people will see quite the same flash at the same moment, and many may go their entire lives having never seen it at all.

“A green which no artist could ever obtain on his palette, a green of which neither the hints of vegetation nor the shades of the most limped sea could ever produce the like! If there is a green in Paradise, it cannot be but of this shade, which most surely is the true green of Hope” Jules Verne used these words to describe the peculiar green light seen on the horizon in his 1882 novel “The Green Ray”. He, like many before him, was captivated by the elusive, and fleeting sight of a green flash on the sunset, or sunrise and for good reason to. It appears seemingly when it wants to, and for such a brief period that one may not even be sure they’d seen it at all. Naturally such a spectacle has garnered its fair share of legends surrounding it, urban and otherwise to explain the presence, or lack thereof this phenomena. Some say it can't be seen with glasses on, some say it can only appear in the the coldest arctics, and the warmest tropics, some say it can last a dozen or more minutes at a time, but despite the mysteries that may be attributed to it, it is anything but a mystery and in fact is a natural atmospheric event no more unusual than a rainbow, and just as readily explained by modern science.

To understand how a green flash comes to be one needs to first understand how light works, and also what a prism is. At the smallest scale there exists a type elementary particle, that is a particle whose exact makeup, or even if they are made of anything else at all, is currently unknown, called the photon. Photons have zero mass and always travel at the speed of light, about 3x10^8 meters per second, or exactly 299,792,548 meters per second, and as they should because they are light, or more accurately, they are what light is made of. Photons despite being particles, travel in a wave-like pattern that can be measured in terms of wavelength, and frequency, and the categorization of the specific frequency and wavelength combinations that photons may exhibit has become known as the electromagnetic spectrum, and is shown in figure 1.

Waves of this type are mathematically sinusoidal, meaning they have a continuous oscillation between crests, the highest point the wave will reach, and troughs, the lowest point in the wave. In a uniform wave these two points will never change in relation to each other, which makes them a very powerful tool to measure the wave with. These important measurements consist of the distance that one single complete wave occupies starting at the zero point in the middle of the wave, going up to its crest at the top, down through zero again all the way to the trough at the bottom, and finally once more back up to zero. The length between the start and end points of this wave is appropriately called the wavelength, and the measurements of wavelengths on the electromagnetic spectrum can vary from ones stretching thousands of kilometers, to ones whose measurement is just a trillionth of a meter. The other important way to measure a wave is with its frequency. If wavelength could be considered the size of a wave then the frequency
could in turn be considered the speed of a wave. Specifically the frequency of a wave is the
measurement of how many full waves pass by a specific point, in a specific amount of time,
typically one second, it is the cycles per second, which we commonly express with the unit hertz.
Like wavelength, the frequencies on the electromagnetic spectrum can also have incredibly large
variances between them, from just a single wave over the course of one second, quite impressive
considering its photons are still traveling at the speed of light, to waves that can pass fully by a
point more than a quintillion times in a single second, that’s 10 to the 18th power.

Each wavelength has a corresponding frequency, so naturally the larger the wavelength,
the more the photon must deviate from the zero point its wave, the lower the wave’s frequency
is. The electromagnetic spectrum categorizes every wave type from the smallest, most active
waves of the intense radiation of gamma rays, down to the largest, and lowest frequency waves
commonly used today over the radio, but somewhere in the middle of this spectrum, squeezed
between the likes of ultraviolet light, and infrared light, is that light that we can actually see, the
visible spectrum. Everything a person can see with the naked eye is either emitting, or absorbing,
or reflecting some kind of light within the visible spectrum, it is all colors, it is everything
around. Visible light however is only a tiny band on the full electromagnetic spectrum, it
occupies the wavelengths ranging from 700 nanometers, to just 400 nanometers, and as the
waves of light become more, or less extreme the color also changes going from red light at the
beginning of the visible spectrum, the first thing the eye can see past infrared light, to orange,
than yellow, then green, the one we’re here for, blue, indigo, and finally violet right before it
would transition into the invisible ultraviolet band of the spectrum, or our good friend Roy G.
Biv.

Pure white light contains all of these colors simultaneously, and everything that has a
color only does because all of the other visible colors are absorbed by it. If a person were to wear
a red shirt, it would appear red because the material of the shirt only reflects red light, now it is
also possible to split white light up into its component colors without absorbing them into
anything, but to do that you need something called a prism.

Before Sir Isaac Newton came around it was commonly believed that prisms actually
created the colors of light, and that white light was colorless, but by shining a colored light
through a prism, and seeing the color emerge through the other side unchanged he was able to
determine that the colors must be present in light somehow before entering a prism. It’s easy to
see why people would be confused by the interaction between light, and prisms, after all it
doesn't make much sense that white light can also be red, and purple at the same time, and why
does shining it through a prism separate them as it does? When people refer to the speed of light
they specifically mean the speed of light as it travels through a vacuum, which is what space is,
so as light travels from the sun to the earth it travels at the speed of light. However when light
travels through a medium other than a vacuum light slows down, and every material that light
can pass through slows the light by a different amount, this is known as the Index of Refraction
of that medium, and is expressed by the equation.

\[ N = \frac{C}{V} \]
Where “$N$” is the index of refraction, “$C$” is the speed of light in a vacuum, and “$V$” is the speed of light in the new material. Refraction is the key word here to explaining the phenomenon. Refraction is essentially the bending of light, or redirection of light as it passes into a new medium, which in this case is a prism. A prism is simply an object made of a transparent material, whose surfaces are flat, smooth, and at an angle to each other, typically forming a triangular shape. The shape is what is important about a prism, because if one were to consider a wave of light as having some size to it, then shining onto an angled surface in respect to the light source would cause part of that ray of light to hit that surface, and pass into the new material first, this causes the entire ray to quite literally bend inside the prism, and to exit it at a different angle than it entered, rather than passing straight through as one would expect, the relationship between the entry and exit angles is expressed by Snell’s law

$$\frac{\sin \Theta_1}{\sin \Theta_2} = \frac{N_1}{N_2} = \frac{\lambda_1}{\lambda_2}$$

With “$\Theta$”, or theta, being the angle of the light ray in relation to directly perpendicular to the surface of the prism, or the normal of that surface, and “$\lambda$”, or lambda being symbol used to represent the wavelength of the light. As we can see the wavelength of a ray of light has a direct relation to the index of refraction of that material, and the angle that the ray enters and exits, meaning essentially that different wavelengths of light will bend to a different angle while travelling through the same new medium, so violet light with a wavelength of around 400 nanometers will be redirected in a prism more than red light with its wavelength of around 700 nanometers. This effect is known as dispersion, and much like how a glass, or plastic prism can cause a ray of light to disperse into its component colors, the atmosphere can at times cause the light of the sun to disperse as well when proper conditions are met, commonly appearing as a rainbow, and it is also what causes the green light of the green flash to separate from the rest of the colors of light.

The refraction, or distortion of light within the atmosphere is what is known as a mirage, and it is primarily the cause of the green flash. An important thing to note about our atmosphere is that it is not a uniform medium, unlike the small glass prisms one may use to demonstrate refraction with, instead the atmosphere across its various levels, with their own specific atmospheric densities all have their own similar, but still distinct indices of refraction, meaning that as light passes through our atmosphere it is continually bending rather than just being set onto a new path as it enters the atmosphere. This is why distance objects can get that hazy look when it’s hot enough outside, the heat radiating from the ground makes the air immediately around it less dense, changing its index of refraction and causing light to bend to slightly different angles, and this atmospheric refraction effect can even become great enough to produce an inverted imagine, which happens if light able to refract strongly enough is in atmosphere such that rays from the top of the object are able to pass over the light rays emitting from the bottom of the object creating a duplicate and inverted image, which is what that “summer haze” is. This inversion effect as shown in figure 2 is known as an inferior mirage. The Inferior mirage is so named not because it is in some way worse than some other kind of astronomical refraction, but simply because the “mirage” image appears to be below the “real” image, and also upside down, but and despite what common knowledge would tell someone, a mirage is not just an illusion, there is no “real” object, and its “mirage”, because of the way light works all images caused by a mirage effect, whether that is 2, or 3, whether they are rightside up or inverted are all equally real
in that they are all the genuine light from that object hitting your eyes. The inferior mirage is not
the only kind of, but it is the most common, and as such it is also the most common form of
green flash, known appropriately as the inferior mirage flash.

In order for an inferior mirage green flash to occur several conditions must be met. First
the sky must be clear of obstructions, that means no clouds any kind to obstruct the light, and the
presence of haze may also make the flash unlikely to be visible. So you won’t be seeing one
from a smoggy city, or on a rainy day. The horizon must also be equally clear of obstructions,
which generally means nothing but ocean, and most importantly the temperature of the air
directly above the surface must be notably warmer than the layers of atmosphere above it, as this
is specifically what causes the refraction that results in the visible flash, but none of this will
matter at all if the viewer is not in the right position, because in order for the flash to actually
reach the eyes of the viewer they must be looking at it from above the level of this warm air layer
because the light of an inferior mirage is redirected upwards, it would quite literally go over
one’s head should they be at level to it. As the sun sets, and the image of it lowers in the sky it
will eventually begin to pass through this warm layer of air, this is when the inferior mirage of
the sun occurs. The bottom of the solar disk will become inverted in the inferior mirage, and
appear briefly as a second sun rising out of the horizon, this is not simply a reflection of the sun
in the water as it would seem to some. As the two suns continue on their paths towards each
other the second of several strange effects occur, the suns will appear to stretch towards one
another, this is because there is no clear cut line between the two images, instead there exists a
continuous transition between the normal and inverted images, so as light approach what should
be the “fold” between them a vertical magnification occurs, which is now made apparent to the
viewer because it’s gone from stretching the empty sky, to stretching an actual object, when the
images meet they form what Jules Verne referred to as the the “Etruscan Vase”. It is around this
point that one can frequently make out a small red rim around the bottom sections of the sun, in
fact atmosphere’s refractive effect is normally sufficient to reveal the colors of the sun’s light in
the form of red, green, and even blue rims on the bottom or top of the solar disk, but the normal
angle of separation of the images is usually too small for the naked human eye to actually discern
these small colored rims without the aid of a mirage enhancing levels of refraction. As the sun
continues its descent on the horizon eventually the top of the sun will pass into the warm air
layer, now causing the full image to resemble a sort of football shape above the horizon.
Eventually only the very topmost portion of the sun will remain visible, in actuality the entire
sun has now passed beyond the point of the horizon in relation to the viewer, and so should no
longer be visible, but its light is still being bent enough from beyond the horizon by the warm air
layer to reach the viewer, and it is at this point that the aforementioned green rim of the solar
disk, normally indiscernible becomes the only light of the sun remaining visible, and thus an
inferior mirage green flash has occurred. This entire process can also take place in reverse,
starting with the green flash, during a sun rise should the proper conditions be met at that time.
Now as to why green is the final color seen in the flash rather than blue, indigo, or even violet,
the answer to that is because lower wavelengths of light are scattered more easily by molecules
in the atmosphere in a process called rayleigh scattering, this is the reason why the sky is blue,
and so during a green flash the blue, and violet light is scattered out of line of sight leaving green
the last of the sun's light to directly reach the eye, As can be seen in Figure 3, although blue
flashes are technically possible, they are exceedingly uncommon even compared to their
relatively rare green cousins. An image of the Inferior mirage flash can be found in figure 4.
Another type of mirage, and thus its corresponding green flash is the mock mirage, a diagram of which can be found in figure 5. Much like the standard inferior mirage a mock mirage also requires a layer of warm air to occur, but unlike the inferior mirage whose warm air layer is just above the surface, as is the somewhat default state of the atmosphere, the mock mirage requires a layer of warm air to be above a layer of cooler air. This event is called an atmospheric inversion, and most commonly occurs when warm air such as from a warm front, or coastal upwelling passes over top of a cooler air layer. Fog is a typical indication of an atmospheric inversion, and the abrupt ending of the fog layer, where the dense water supporting air meets the less dense warmer air, is the point where the atmospheric inversion occurs, this clear and sudden division is why it has come to be referred to as a blanket of fog. The mock mirage does not require a very strong atmospheric inversion layer to occur, the difference of only a few degrees between the lower cool air, and the upper warm layer is often sufficient to produce a weak mock mirage. Like the Inferior mirage the mock mirage also requires the eye level to be just above the warm layer. Whereas an inferior mirage only produces two images, a normal and an inverted, a mock mirage can produce many images, with more inversion layers increasing the number of images, this produces a sort of banded look to the sun as can be seen in figure 6.

In a mock mirage flash as the sun descends into the inversion layer it will appear as a normal sunset that simply becomes cut off, seemingly disappearing as it lowers as if the horizon were higher than it actually is. As its descent continues the cut off section of the solar disk will appear to reemerge below it, now slightly misshapen by the inversion layer, this is not in fact the sun showing itself once again but the new mock mirage image caused by the inversion layer. Much like how the last vestiges of the top of the setting sun can cause a green flash it is at this moment in the mock mirage sunset that the first light from the bottom of the new image of the falling sun will appear as a red flash. Red flashes are extremely common during sunrise, and sunset, but are rarely noticed as red doesn't stand out as much from the orange and yellow of the rest of the sun during these moments. As the lower image of the sun grows from more of the upper image passing into the atmospheric inversion layer, the 2 images will combine forming a vaguely sun shaped blob with sharp indentations in its sides as if a giant invisible hand were attempting to squeeze the sunset between its thumb and forefinger. These indentations are actually where the top of the atmospheric inversion layer is. Eventually as these sharp indentations travel up the sun, or more accurately as the sun slips past them, as they are not what is moving, a sort of flat plume or hourglass like shape will form at the top of the sun above the atmospheric inversion layer, which will gradually become thinner as the original image of the sun has almost entirely passed by the inversion layer, resulting in a more clear hourglass shape to become apparent. Eventually the neck of this hourglass will break, so to speak, leaving just a small blob of sun remaining above the new refracted mock mirage sun which is well on its way to having completed its descent beyond the horizon, as this small sun finishes fading the green light of the sun will once again be the only of its light still visible resulting in a green flash this time above a setting sun, rather than on its own. It is also possible to witness a second green flash just as the neck of the hourglass reaches its thinnest point and just before the moment of full separation of the two images the neck will be composed of green light. This flash is generally not possible to see with the naked eye as it is most often drowned out by the full light of the sun remaining above, and below it.
To understand how the last of the major green flash types works one first needs to understand the concept of atmospheric ducting. A duct in the atmosphere is caused by the presence of a particularly strong inversion layer. The warmer a thermal inversion layer becomes the more it refracts light entering it, now since the Earth is round there’s really such a thing as a flat, or straight layer of the atmosphere, it will always follow the curvature of the Earth, which means an atmospheric inversion layer will always follow the curvature of the Earth. It is possible should the thermal inversion have a high enough index of refraction that a ray of light entering into the atmospheric inversion layer will be immediately refracted back out of the layer, and along a new straight path where it will intersect with the curved atmospheric inversion layer, and be refracted back out, and along a new straight path where it will intersect with the curved atmospheric inversion layer, and be refracted back out. In this way the ray of light essentially has a curvature matching that of the Earth’s, and can potentially continue on this path around the planet, trapped in an atmospheric duct, forever. This can be seen in diagram in figure 7. The only things that will stop the ducting of the light would be the eventual extinction of the light from scattering and absorption, or if the atmospheric inversion layer stops at some point, which it probably will, because while it is theoretically possible for a single atmospheric inversion layer to circle the planet, it is not very likely that one will. An atmospheric duct does not cause multiple images of something to appear, or inverted images to appear, though it can when interaction with an additional mirage causing phenomenon, it primarily just carries the light along a path over the curvature of the Earth, making distant object, or even object that should be completely obscured well beyond the horizon, visible again, though not completely undistorted. If you’ve ever seen a ship out in the water that appears to be floating well above the waves, it is likely that the ship in question is actually much farther away than it appears, and the image of it is simply being carried to you by way of an atmospheric duct. This is an effect known as Looming.

A ducted green flash is technically a type of mock mirage flash, and so it shares many similarities to the standard mock mirage green flash, as it naturally should. However due to the very large index of refraction of an atmospheric duct a viewer observing the sun from various positions would see radically different images. If a person were to view the sunset from above the thermal inversion layer it would appear much the same as a standard mock mirage flash, with the solar disk appearing to be cut off by the inversion layer, and reappearing below it again, only this time several things have changed, first the inversion layer will essentially redirect the light of the sun from reaching the viewers eyes, and as such that layer of the horizon will appear as a dark strip, and the two images of the solar disk will never meet as they would in a normal mock mirage. The second change is that once again due to the refraction effect of the duct the sun is not actually being cut off but is instead being flattened, until eventually nearly the entire solar disk will appear as a thin line above the inversion layer. Meanwhile below the inversion layer the sun’s image becomes elongated instead, and then experiences a similar hourglass effect as a standard mock mirage, with the breaking of the neck being the source of the green flash. When viewed from within the atmospheric inversion layer it is again very similar to a mock mirage sunset, the sun is cut off then reappears, a red flash occurs, the two images of the solar disk recombine, but then a peculiar thing happens, the sun will seem to fill the duct completely, becoming nearly rectangular as the light is magnified by the duct, and also unable to escape the refractive effects of the inversion layer. From here as the sun continues to descent one again it takes an hourglass form, with the pinching of the neck being the location of the green flash.
most strange occurrence however is seen when viewed from beneath the level of the duct, a sub-
duct green flash. Once again the large refraction causes the flattening of the solar disk, and then
the sun bleeds. A red flash occurs, a large one appearing as if a droplet of the sun is growing
before falling off. This droplet continues to grow, spreading into almost a haze while the upper
solar disk continues to flatten, now gaining a very prominent green rim. Once again the
hourglass forms, though now with a flat top. As the “drop” continues to grow, so too does the
rim until eventually, just before and after “breaking” the entire upper part will be the green flash,
with a very strange green rimmed triangular sunset beneath it, a stage of this effect can be seen in
figure 8.

Green flashes are an elusive and spectacular phenomena, but despite their nearly
supernatural appearances, as we have determined in this paper, they are anything but. An
understanding of physical principles such as the nature of photons, the natural behavior of light
in a vacuum, the principles of refraction, and the bending of light in a prisms, how heat and the
atmosphere interact to create zones of greater refractive indices, and finally the light Sun’s own
complex interaction with our atmosphere during sunrises, and sunsets can lead to a scientific
explanation of the physics behind exactly how such an event can occur.
Figures

Figure 1. The full electromagnetic spectrum, with visible light highlighted


Figure 2. Diagram of an inferior mirage, note light is both refracted by the lower layer of the atmosphere, and reflected off the surface. The crossing of rays is what causes the inverted image.

Model=inferior mirage, Hobs=5 m
Figure 3. Example of the basic principle of a green flash

![Green Flash](https://www.uwgb.edu/dutchs/EarthSC102Notes/102StuffInSky.HTM)


Figure 4. The “Etruscan vase” can be seen forming, as well as the final green flash.

![Green Sunset](http://aty.sdsu.edu/index.html)


Figure 5. Rays of light are shown refracting through an atmospheric inversion layer.

![Mock mirage](http://aty.sdsu.edu/mirages/mirintro.html)

Figure 6. The “Banded” sunset of a mock mirage. A disconnected green flash can be seen above the sunset.


Figure 7. Diagram of a ducted mirage. Note the ray of light “trapped” within the duct

Figure 8. Simulation of the early stage of a sub duct green flash

Sub-duct sunset. Andrew T. Young [Internet] [Updated 2016; Cited April 2017] Available from: http://aty.sdsu.edu/explain/simulations/sub-duct/SDGF.html
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Living Life While Dying
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Professor Julie Olander
Abstract

Everyone has at some point in their lives, wondered when they start to die. No one knows when they’re going to die, but they should get a good understanding of what’s happening to them and what their future holds. The human body is fascinating and everyone should have a clear idea as to what is happening to themselves as their lives go on. It’s important to know the chemical decomposition of when the human body begins to breakdown, what health factors in, and what happens to us after we die. This paper will help those who wish to enrich their minds about what is happening inside themselves.

When the Body Starts to Break Down

The body reaches its physical “peak” at around the age of twenty-five to thirty. This is when the body reaches its maximum size and strength. A person will start to age when a substance called ‘collagen’ begins to replace the cells that can’t reproduce anymore. At this point, everything starts to slow down. One will begin to start slowing down physically, and at times mentally as well. (The aging process- paragraph 4) As humans get older, people tend to think that their minds go dull. They aren’t as “sharp” so to speak. This is actually quite the opposite! The mental abilities of a person can improve during their middle years as well as old age if the ability to learn can remain keen. Dr. Alfred Shwartz, a professor at Drake university, was asked if a seventy year old man in good health can learn as rapidly as a seventeen year old boy. He responded with “yes”! Just because people get older it doesn’t mean that they lose their intelligence. Although it does help if one is in the habit of learning. Meaning they shouldn’t just be sitting around at home waiting for the five o’clock news to come on every night. A person’s ability to learn does not decline with age. Guess kids should stop nagging on their grandparents being too “old” to understand them right?

It’s interesting to see young people make fun of older people. The older people are too “old” and are therefore dumb it down a lot. But what many kids these days don’t know is that parts of their bodies start to break down as early as twenty years old. The human brain starts to age by twenty years old. This happens early because as one ages and get older and older, their nerve cells decrease in number. From birth humans start with around one hundred billion nerve cells and as the aging process happens this number starts to decline. People can lose up to ten-thousand nerves in the brain each day when they get to be about forty years old. But by keeping the brain occupied, these brain cells won’t deteriorate as quickly.

The gut will start to age at around fifty-five years. The gut houses good and “harmful” bacteria. The levels of good bacteria start to drop significantly after this age. Because this starts to happen we suffer from poor digestion and are more prone to get gut disease.

The female body reflects imbalances of estrogen and progesterone levels. By the age of thirty-five the breasts enter the aging stage. This results in loss of fat and tissue, which results in size and fullness.
The loss of bladder control starts to happen around the age of sixty-five. All of a sudden the bladder will start to contract a lot, even when it’s not full. A young person can hold about two cups of urine in their bladder, whereas an older person can only hold about a cup of urine in the bladder.

Lung capacity slowly starts to decrease by twenty. By forty some people will experience breathlessness. Which then will make it much harder to breathe because the lungs won’t be working as hard as can leave some air in the lungs as well. The average male can inhale around two pints of air at thirty years old. By seventy this will decrease to one pint on air intake. (Daily Mail- paragraph 3)

Eyes are one of the few organs that age very early in life. They eye’s muscles start to weaken and makes the ability to focus that much harder. Eye problems typically don’t arise until around fifty years old. It’s not uncommon to wear glasses by forty due to being far sighted.

The heart starts to age at forty years old. As we get older the hearts pumps blood less effectively. The blood vessels in the heart become less elastic, and the arteries can become hardened or become blocked because of fatty deposits forming on the coronary arteries. Blood supply to the heart is also reduced and men and women around the age of forty-five to fifty-five are at a greater risk of heart attack.

One organ in particular seems to defy the aging process. This organ is the liver! It starts to age at seventy years old. The cells in the liver have an extraordinary capacity to regenerate.

The kidneys will start to age at fifty years old. The number of nephrons start to reduce in the middle age. Because this happens the kidneys have an inability to turn off urine production at night, causing people to go to the bathroom much more.

The term ‘bone turnover” means that old bone is broken down by cells called osteoclasts and replaced by bone-building cells called osteoblasts. The bones can start aging by thirty-five. Bone density is still increasing until around the mid twenties. The shrinking in size and density of bones can lead to loss of height. Bones in the back shrivel up or crumble between the vertebrae. We lose two inches in height by the time we're 80. (Daily Mail- paragraph 12)

Muscle is constantly being built up and broken down. But by thirty one will have more downs as the muscles start to age. When adults reach forty they can start to lose between one-half to two percent of muscle each year!

Human skin starts to naturally age by their mid twenties. The collagen in the skin starts to slow and the elastin becomes weaker. This substance has less spring and can break. This is what causes wrinkles and, and thin transparent skin.

Female fertility starts to decline around thirty five. The number and quality of eggs in the ovaries start to decrease. Male fertility also starts to decline at this age. Typically at around forty years old their sperm is poorer and can result in their partners having a miscarriage.

Both men and women begin producing fewer sex hormones. For men, this can cause a flagging libido, muscle loss, erectile problems and prostate enlargement. For women, sex drive often increases as their natural testosterone levels out-compete their dwindling estrogen. Which
can lead to the growth of dark facial hair, or “whiskers”, as well as changes in their menstrual cycles. (Positive Med- paragraph 1)

So as people age their bodies begin to break down slowly. Even though they don’t think they get old until they find their first gray hair. Peoples chemical decomposition of the organs start to diminish as early as twenty. One might think they are young but people start to die earlier than they realize.

The Health Side of Things

It’s true that as one gets older one can become more susceptible to diseases. Decreased immune efficiency, slower repair processes and reduced production of key hormones are a few of the suspected reasons.

As early as forty people can start to develop alzheimer’s. Alzheimer’s will start to occur in some people due to generalized degeneration of the brain. This disease destroys memory and other important mental functions.

People can also develop cancer! That’s true, cancer doesn’t have to necessarily run in the family in order for someone to have it. As a person gets older their cells will become damaged and start to age which causes the genes to mutate which causes cancers.

Dementia can also occur as people get older. This is also caused by brain disease or injury. People develop memory disorders, personality changes, and impaired reasoning. Because people get frustrated with not knowing what’s going on around them they get stressed, which stresses the body, and in turn can cause organ failure early.

Most Gerontologists believe that most people don’t live as long because they refuse to follow a regimen of diet, exercise, and rest. Obviously one can’t turn back the clock and not age, but one can keep in good health by making sure to have regular physical examinations, sufficient exercise, adequate rest, nutritious food, and a positive mental attitude (National Institute on Aging- paragraph 3)

Mark Twain once said: “Whatever a man's age he can reduce it several years by putting a bright-colored flower in his buttonhole.” Anyone can enjoy living at any age if they have a fresh and lively outlook on life. This is the key to living a long and happy life.

People say that exercising is one of the key components to living longer. But is this really true? When a person stops exercising or doesn’t exercise in general they will lose their endurance and strength. This can cause serious weight gain. A person who eats an excess amount of five-hundred calories more than their daily caloric intake can lead up to putting on at least one pound a week, or four pounds a month! When a person starts to gain weight it can lead to high blood pressure, heart disease and type 2 diabetes. Being overweight makes exercise harder because you stress your joints more when you run or jog. (The Scientist Staff, March 2015)

Sitting and lying around all day can a make a person especially weak. The muscle groups in the body won’t strengthen due to lack of exercise. Bones can also lose density with age, and lack of weight-bearing exercise can lead to osteoporosis. (Brittle Bones) The body responds to
the demands that people put on it, and if they do not exercise, the muscles and bones will weaken with time. The body will start weakening and breaking down slowly if not properly taken care of. In short, people can definitely live a much longer life if they exercise, and eat healthy.

When a person starts to age they accumulate a high amount of mutations and impairments in the DNA repair process. Mutations in genes involved in the maintenance of DNA can cause premature aging. An article on “How We Age” stated that “decrease in stem cells’ proliferative abilities, impairments in mitochondrial function, and proneness to protein misfolding can all contribute to aging.” (The Scientist Staff, March 2015) Age is just a number, anyone can develop life threatening conditions at any given age.

Cells can start to die or kill themselves and enter senescence (non-replicating state) once the DNA has become too damaged. Because of the loss of cells in the body it can lead to tissue atrophy and dysfunction. The aging process can actually speed up when senescent cells start secreting inflammatory cytokines thought to contribute to atherosclerosis and other aging-related diseases. DNA damage can cause mutations that contribute to cancer. Jan Vijg, a geneticist at Albert Einstein College of Medicine in New York City said that “There is this exponential increase in cancer risk during aging, so it’s not at all unlikely . . . that accumulation of damage to the genome is really a major factor here”.

Some examples of DNA damage include people who have Hutchinson-Gilford progeria syndrome have mutations in a gene encoding scaffolding proteins called nuclear lamins and can suffer from an aged appearance, vision deterioration, and hair loss. Werner syndrome patients, who develop symptoms of advanced aging as teenagers, have mutations in a gene involved in DNA repair. Some examples of DNA damage include people who have Hutchinson-Gilford progeria syndrome have mutations in a gene encoding scaffolding proteins called nuclear lamins and can suffer from an aged appearance, vision deterioration, and hair loss. Werner syndrome patients, who develop symptoms of advanced aging as teenagers, have mutations in a gene involved in DNA repair.

A particularly influential form of DNA damage occurs at telomeres, which is the repetitive sequences that cap chromosomes and shorten with age. Most cells’ telomeres will shrink with every division which is due to DNA polymerase that cannot fully replicate the ends of chromosomes. Meanwhile germ and stem cells express an enzyme called telomerase that replenishes telomeres. If the telomeres shrink too much or are damaged, cells undergo apoptosis or enter senescence. In humans, mutated telomerase is associated with disorders involving organ dysfunction and elevated cancer risk. An experiment done on mice showed that those that have short telomeres have diminished life spans and reduced stem-cell and organ function, while mice whose telomerase is enhanced in adulthood age more slowly. (National Institute on Aging-paragraph 5)

Telomeres for some reason are targets of stress-induced DNA damage. They are much more sensitive to external stress than the rest of the genome. Telomeres are very difficult to repair once they’ve been damaged. Telomeres protect chromosomes from fusing with one another by recruiting protein complexes called ‘shelterins’. This prevents overzealous DNA repair proteins from mistaking loose ends for double-strand breaks. This may also prevent repair proteins from accessing legitimate DNA damage, however, leading to cell death.
“Telomeres may be especially prone to DNA damage in order to protect the body from cancer” Passos suggests. (The Scientist Staff, March 2015) Telomeres are disproportionately damaged by stressors, and because of this the telomere damage can often lead to senescence. Telomeres may, in fact, be DNA-damage sensors that shut down cell proliferation in times of stress. This is like a double-edged sword, in the sense that senescence lowers cancer risk but also leads to symptoms of aging.

The skin can also start to ‘break down’ or lose elasticity. This starts to happen when a person intakes too much sugar. The chemical balances of the skin become brittle. This is due to Advanced Glycation End (AGE). One can prevent this by intaking plenty of antioxidants. Antioxidants help to delay or prevent bad molecules from damaging healthy cells. A good healthy diet and a good amount of nutrition help keep the brain from aging as much and prevent it from starting at a young age.

**After Death**

Decomposition begins several minutes after death with a process called autolysis, or self-digestion. When the heart stops beating, the cells in the body become deprived of oxygen. The toxic by-products of chemical reactions begin to accumulate inside causing the acidity of cells to increase.

One of the first few organs to break down in the body after death is the liver and brain. In the liver, enzymes start to digest cell membranes and begin to leak out. The brain will also start to leak substances out due to its high water content. Overtime all other organs will begin to breakdown the same way. The skin slowly becomes discoloured when the blood cells begin to spill out of tissues rich in blood vessels.

After death, the immune system stops working and microbes start to move around the body freely. As shown in Figure 1, there are different types of microbes in the body, housed in different regions. This will start at the gut, and bacteria will start to digest intestines as well as the surrounding tissues. Using a ‘chemical cocktail’ that leaks out of damaged cells as a food source, it will invade the capillaries of the digestive system as well as lymph nodes, and begin spreading first to the liver and spleen, then into the heart and brain.

Because everything in the body stops working and is no longer pumping blood and oxygen throughout, the body starts to build up bacteria. As mentioned in an article on decomposition “Anaerobic microorganisms produce methane, hydrogen sulphide, and other gases responsible for the increasing stench that surrounds rotting organic matter”. (Gale, 2005) As these gases being to accumulate inside the body, the body will swell up causing the fluids to move around. This is known as the gaseous period.

After this process the liquefaction period begins. During this time the soft tissues are gradually dissolving which aids in the outer layers of the skin detaching from the inner layers of the skin. Gases are then released and a creamy putrefied substance covers the skeleton. Skeletonization then occurs. When skeletonization occurs bones separate from their ligaments.
Bones become increasingly fragile and lighter over the years, and acidic soils eventually dissolve them.

After death a process known as adipocere begins. This will only happen in children, women, and overweight people. This happens to these certain individuals because of the spontaneous chemical transformation of fatty tissues into a grayish-white waxy matter. Adipocere literally can conserve body parts because of all the fat it contains.

The body temperature will start to drop until it is acclimatised to its surroundings. When this happens then rigor mortis will set in. This process will begin in the eyelids, jaw and neck muscles, before working its way into the trunk and then the limbs. And article on what happens after you die stated that “After death, the cells are depleted of their energy source and the protein filaments become locked in place. This causes the muscles to become rigid and locks the joints”. The locking of the joints is what makes the body become stiff.

Gulnaz Javan, a forensic scientist, suggested that the “microbial clock” may be ticking within the decomposing body. She found that bacteria can reach the liver about 20 hours after death and that it can take at least 58 hours to spread to all the organs after that. Thus, after we die, our bacteria may spread through the body in a systematic way, and the timing with which they infiltrate first one internal organ and then another may provide a new way of estimating the amount of time that has elapsed since death. (Costandi, 2015)

Putrefaction takes place once self-digestion and bacteria overtake the human body. This is known as the molecular death. Molecular death is the breakdown of soft tissues into gases, liquids, and salts. “Putrefaction is associated with a marked shift from aerobic bacterial species, which require oxygen to grow, to anaerobic ones, which do not.” (Costandi, 2015) Because of this, the bacteria feeds on the body’s tissues which ferment the sugars in them producing these gaseous by-products that accumulate within the body, which in turn causes the body to bloat. This is what really causes the body to change color. When the body turns into a greenish-black color this is a sign that it is undergoing active decomposition. Figure two shows that veins will also become much more visible during this process.

When a decomposing body starts to purge it become a ‘hub’ for insects, bacteria, and scavengers. This is called colonisation. Blow flies and flesh flies are the first to arrive at the scene of a dead corpse. They can smell the volatile compounds that change as the body decomposes. Blow flies will lay their eggs in the orifices and wounds of the body. Each fly can deposit around two hundred fifty eggs that hatch with twenty-four hours! Maggots then arise and feed on the rotting flesh and will moult into larger maggots which will eventually pupate and turn into adult flies. This is how coroners, morticians, and forensic scientists know a body is a ‘fresh’ body. Maggots are responsible for the removal of soft tissue. The presence of flies attract beetles, mites, spiders, and bigger predators such as vultures.

Purging is the seeping of broken down materials that will leak into the soil beneath the body. The human body on average consists of fifty to seventy-five percent water and every kilogram of dry body mass eventually releases thirty-two grams of nitrogen, ten grams of phosphorous, four grams of potassium and one gram of magnesium into the soil. This will kill
off some of the underlying vegetation. Decomposition is very beneficial for the surrounding ecosystem.

**Conclusion**

We live so many years and most of us have no clue as to what’s happening to our bodies. Our bodies are how we get through our day to day lives. The chemical decomposition of the human body is something that shouldn’t be unnoticed by anyone. We live with ourselves every day of our lives until death. No one should be afraid to die, because, in a sense we were born to die. The chemical breakdown of our being is essential to the world.
Figures

Figure 1. (Types of bacteria in different parts of the body)
3-4 days after death...

• Discoloration of skin spreads through the whole body.
• Discoloured veins become visible

Figure 2 (Discoloration of skin-veins more visible).
References


The Magic of Visible Light and Rainbows

Angelina Ponce
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Physics 112
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Abstract

Rainbows are an incredible phenomenon created by nature that humans can see. The visible light spectrum of colors plays a major role in the existence of a rainbow. Comprehending, how the human eye and brain translates color is very important. After the rain stops, it is not the only time the human eye can see a rainbow. Every person's interpretation of a rainbow is unique to their eyes, that requires physics equations and angles. Understanding the creation of a rainbow and how the colors come alive is a process everyone should understand. There is not just one type of rainbow, they come in several different “flavors”.

Introduction

The visible light region consists of a spectrum of wavelengths that range from approximately 700 nanometers to approximately 400 nanometers. Also, it has frequencies of about $4 \times 10^{14}$ to $8 \times 10^{14}$ cycles per second, or hertz (Hz). Visible light is a type of electromagnetic radiation. Visible light is the only region of the electromagnetic spectrum that is visible to the human eye. From the shortest to the longest wavelength the visible colors are: violet, blue, green, yellow, orange, and red. All these colors help make up all the colors in the rainbow. The white light is a mixture of the colors of the visible spectrum and black is a total absence of light.

In 1672, Sir Isaac Newton explained the experiment he conducted with sunlight and a prism. It was Newton, who named the component colors. It was said that for religious believes he had included Indigo because he felt like there should be seven instead of six colors. Indigo is a very difficult color to distinguish a separate color in the spectrum. A prism can disassemble and reassemble light, when white light is shined through it can separate the colors in the visible spectrum. The reason is because each color is a different measured visible wavelength. Water vapor in the atmosphere can also break apart wavelengths creating a rainbow.

Objects don't "have" color, they give off light that "appears" to be a color and spectral power distributions exist in the physical world, but color exists only in the mind of the beholder. By the time color reaches the eye, frequencies have been mixed or combined in order to determine the color a person’s eye will see. Light falls on specialized receptor cells (called rods) at the back of the eye (called the retina) and a signal is sent to the brain along a neural pathway (called the optic nerve). This signal is processed by the part of the brain near the back of the skull (called the occipital lobe). In order for the human eye to differentiate colors, depends on the objects properties wavelengths that is reflected or absorbed by the object. Light at the lower end of the visible spectrum, having a longer wavelength, about 740 nm, is seen as red; light in the middle of the spectrum is seen as green; and light at the upper end of the spectrum, with a wavelength of about 380 nm, is seen as violet; and all other colors that we perceive are mixtures of these colors.
The visible light green has a wavelength of 510 nm. For example, grass looks green because all the colors in the visible region of the spectrum are absorbed into the leaves of the grass except green which is why green is reflected and the grass looks green to the human eye. Also, temperature plays a big factor as to how the color is going to radiate. For example, the sun reflects more yellow light than any other color because of the temperature of its surface. If the surface was a few thousand Celsius cooler the color would be more yellow or if the temperature was a few thousand Celsius hotter the surface color would be more blue.

Creation of Rainbows

The fundamentals of a rainbow have been researched for many, many centuries. Rainbows are phenomenal beams of color. When sunlight passes through a prism, some of the light is bent, or refracted, more than other portions. Light leaving the prism spreads out into a continuous band of colors called a spectrum. Colors go from red, which is bent least, through orange, yellow, green, and blue all the way to violet, which is bent the most. Water acts as the prism, the white light goes through the water and the light bends within the water. Once the white light leaves the water prism, it leaves in various colors. A rainbow is arcs of color in the sky often seen after a rainstorm. Whatever color is refracted depends on the critical angle. The critical angle is the angle where total reflection occurs. A rainbow is produced in a mixture of refraction, reflection and dispersion.

The angles of incidence and refraction can have values between 0 and 90 degrees. When the angle of refraction is 90 degrees, the refracted beam travels along the interface. Given that \( i < r \), when \( r = 90 \), \( i = < 90 \). The angle of incidence which results in \( r = 90 \) is referred to as the critical angle and is given the symbol \( i_c \).

For Example:

\[
\frac{\sin i}{\sin r} = n
\]
\[
\frac{\sin i_c}{\sin 90} = 0.752
\]
\[
\frac{\sin i_c}{1} = 0.752
\]
\[
i_c = 48.75 \text{ degrees}
\]

\( n = \) Relative refractive index (water-air interface) = 0.752
\( i_c = \) Critical angle
\( r = \) Angle of refraction Note: \( \sin 90 = 1 \)

A single, or primary, rainbow has red on the outside or top of the bow and blue on the inside. Usually the radius of the arc is equal to about one-fourth of the visible sky, or 42 degrees, to the red. When there are showers nearby, simply look in the part of the sky opposite the sun at a 42-degree angle from your shadow; if there is a rainbow, that is where it will be. Angles are very important almost critical to whether a rainbow is visible or not. The light must
hit the raindrops at a certain angle in order to create a rainbow. A faux rainbow can be created with a garden hose, adjust the hose to a fine mist spray and a rainbow can be observed against the spray when the sunlight goes through the water spray.

Colored light is reflected when the white light enters the spherical raindrop at an angle this process is known as reflection. The Law of Reflection states that the angle of incidence (i) and the angle of reflection (r) are equal.\(^7\) The angle of incidence is the angle between the incoming ray and the normal line.\(^7\) The angle of reflection is the angle between the reflected ray and the normal line.\(^7\)

The Law of Reflection is used not once but twice in the formation of a rainbow. The raindrop has a smooth and curved surface so when the light reflects, it acts like endless number of little, flat mirrors and they each abide by the law of reflection. This law is also followed in the rear of the raindrop when total internal reflection takes place. When the angle of incidence is greater than the critical angle, no refraction occurs.\(^7\) Instead, the incident beam is reflected, obeying the Law of Reflection.\(^7\)

When light travels from air to water it slows down because water is more dense than air is.\(^7\) When light slows down its path bends towards the normal line so that the angle of incidence (i) is greater than the angle of refraction (r), \(i > r.\)\(^7\) As density of the material increases the speed of light decreases. The same process occurs with the formation of a rainbow. The normal line it perpendicular to the tangent at the point where the light strikes the surface of the raindrop.\(^7,e\) When light travels from one medium to another, it generally bends, or refracts.\(^12\) The law of refraction gives us a way of predicting the amount of bend.\(^12\) This law is more complicated than that for reflection, but an understanding of refraction will be necessary for our future discussion of lenses and their applications.\(^12\) The law of refraction is also known as Snell's Law, named for Willibrord Snell, who discovered the law in 1621.\(^12\)

Snell’s Law formula is \(N_1 \sin \theta_1 = N_2 \sin \theta_2\)

\(N_1 = \) index of incidence
\(\sin \theta_1 = \) angle of incidence
\(N_2 = \) index of refraction
\(\sin \theta_2 = \) angle of refraction

The process of refraction occurs as the light exits the raindrop into the air. The white light is composed of the visible light spectrum colors and each of the colors measure at different wavelengths. Each of the wavelengths move at different speeds when they cross into a medium, in this case water that is more or less dense. For the following mediums, the index of refraction for air is measure at 1n and for water is measured at 1.33. The speed of light is measured at a constant \(3 \times 10^8\) meters per second.
**Deviation formula:**

\[ D_f (\alpha) = (\alpha - \beta) + (180 - 2 \beta) + (\alpha - \beta) = 180 + 2 \alpha - 4\beta \] 

Figure 7 shows the graph of deviation, taking the refractive index \( N = 1.33 \) for a particular shade of red. Deviation has a minimum at a value \( \alpha_m \) somewhere in the region of 60 degrees. A rainbow is provided by the minimum angle \( \alpha_m \). As shown in Figure 8, a 2D cross-section of the droplet containing a bunch of rays for refractive index \( N = 1.33 \). The ray entering at the minimum angle \( \alpha_m \) in this cross-section is shown in red and it is called the rainbow ray. The rays that hit the droplet near the rainbow ray (with an angle close to \( \alpha_m \) ) cluster close to it during their passage through the droplet and when they emerge. If the eye happens to catch the rainbow ray from this droplet after it's emerged, it will see many of other rays as well and making the light that comes from the water droplet particularly intense. Since all the clustering rays are of the same color, this particular shade of red which has \( N = 1.33 \), the water droplet lights up red in the sky.

The speed is definitely affected by the dense factor which makes the colors in the white light to separate. This process is known as dispersion. Dispersion is the distribution of the white light into the spectrum of wavelengths. This happens when the direction of light is based on the measurement of the wavelength which can tell what colors will be disperse into the sky as long as the incident angle is 45 degrees. Dispersion, as a general phenomenon, can occur for any type of wave and always involves wavelength-dependent processes.

**Types of Rainbows**

There are 12 different types of rainbows that have identified based on size of water drops or small sprays of water mist and the angle that the sun strikes them. Also, another characteristic is the primary bow and it has the color red at the very top and the color violet at the very bottom. Overlooking the primary bow there is a secondary bow, that is more faint than the primary bow and the colors are reverse. The color violet is at the very top and the color red is at the very bottom. In between the primary bow and secondary bow, there is a dark section called
Alexander’s band. This in between section is not very much of the raindrops light reflects. Approximately 1800 years ago, Alexander of Aphrodisias (the Greeks had a way with names) noticed that when there was a double rainbow, the band between them appeared darker than the rest of the sky. Additional bows, called supernumerary bows, which may occur when the light rays spread and cancel each other out via diffraction and interference in the atmosphere. Based on these characteristics, scientists have discovered the many different rainbows such as one color rainbows or two color rainbows.

The rainbow characteristics were presented by Atmospheric scientist Jean Richard. To capture this rainbow diversity, Ricard and his colleagues gathered hundreds of pictures of rainbows, sorting them into 12 categories based on the visibility of the six colors, the strength of the dark band, and whether any supernumerary bands can be seen. A primary rainbow is a rainbow that goes from the top being red to the bottom being violet and it is also the brightest out of all the types of rainbows. Primary rainbows are the most common and familiar seen by the human eye after the rain. A secondary rainbow is a rainbow that is the inverse of the primary rainbow. The colors of a secondary rainbow go from violet on at the very top and red at the very violet. This rainbow is usually located above the primary rainbow. A double rainbow is made up of a primary rainbow and a secondary rainbow.

Supernumerary Rainbows are faint or pastel colored bows that are located within the primary rainbow. On occasion, supernumerary rainbows would located outside of the secondary rainbow. When formed in rain showers, where there is a broad distribution of drop sizes, these bows are mainly seen near the top of the rainbow arch, but fade toward the vertical portions of the primary bow. They owe their name (beyond the prescribed number) to the fact that an explanation of rainbows based upon a treatment of light as a series of rays is incapable of accounting for them. When the light is treated as a wave, the supernumerary bows become higher-order interference maxima, for which the primary bow is but the first maximum. Also, these can be seen when the raindrops are very small.

Moon bow or white rainbow are other names lunar rainbow goes by. A lunar rainbow is composed of with the light of the moon instead of sun light like most of the other rainbows. Even though the optics of the moon and the sun is the same, the luminance of the lunar rainbow is much lower. As a result of the eye's reduced sensitivity to color at low light levels, the bow may exhibit little color. There are several reasons why the lunar rainbow is seen much less frequently than the solar bow. While the moon and sun spend equal time above the horizon, when they are both present, only a solar bow can be seen. This means that the lunar rainbow could form only half as often. Further, the moon goes through phases, and so even at night may not contribute enough light to produce a discernible bow. Finally, the convective showers in which the rainbow is frequently seen are much less common at night.
Fogbows are sometimes called white rainbows, cloud bows or ghost rainbows and they are made much as rainbows are, from the same configuration of sunlight and moisture. Rainbows happen when the air is filled with raindrops, and you always see a rainbow in the direction opposite the sun. Fogbows are much the same, always opposite the sun, but fogbows are caused by the small droplets inside a fog or cloud rather than larger raindrops. Since the water drops that form fog bows are very small, they tend to have faint colors or be colorless. The size of fog bows are very large, similar to rainbows and a lot more broad. For a person to view fog bows, the sun needs to be less than 30-40 degrees in height. Fog bows can be found with in thin fog and when the sun is shining bright. They can also be found over the ocean.

Red rainbows, reflected rainbows, and spider rainbows are very unusual to appear but they have existed. Red rainbows happen when the sun is on the horizon. They’re created for much the same reason that a sunset or sunrise looks red because when the sun is low, the blue and green of its rays are weakened by scattering during the long journey to the human eye through Earth’s atmosphere. The red light moves more directly in the sky. Reflected rainbows are formed the reflection of the reflected sun light. Two lights make up this reflection, one from the sun and the second is coming from the reflected image of the sun. This kind of rainbow can be seen over a body of water. Spider rainbows are formed when a spider web is covered in very tiny drops of water or mist and the sun’s light strikes through creating a rainbow with in the spider web.

Conclusion

In conclusion, the rainbow is an amazing phenomenon that we are so lucky to see after the rain is done. Visible light is the only part of the spectrum that is visible to the human eye and it’s made up of colors. The shortest wavelength in visible light is the color violet and the longest wavelength is the color red. Sir Isaac Newton was a pioneer in the understanding how we are able to see color in light using a prism as a filter and how it reassembles and dissembles light. I really enjoyed researching how the eye process light and send it to the brain for us to “understand” what color is in front us. We have special light receptors in the eye that signal the brain.

Rainbows are incredible beams of color. The processes of reflection, refraction and dispersion are very mathematical and physics oriented. Never did I think that water was being used a medium for light to go through so the rainbows to be created. Snell’s formula can be used to figure out the angle that light will leave the water drop and the index of incidence or refraction of a material. Discovering that there was 12 types of rainbows not just your typical ROYGBV was very interesting to learn. Overall, this was an amazing topic to acquire more knowledge about.
a Figure 1 - When we pass a beam of white sunlight through a prism, we see a rainbow-colored band of light that we call a continuous spectrum. http://cnx.org/contents/H5KhIDcK@3/Spectroscopy-in-Astronomy

b Figure 2 – How the Eye Sees in Color? The retina contains cells called rods and cones that are sensitive to different colors of light. http://www.livescience.com/32559-why-do-we-see-in-color.html

c Figure 3 – Visible Light Color Wavelength. This shows the wavelength sizes. http://coloring.rogersvillegallery.com/which-color-has-the-highest-frequency-on-visible-light-spectrum/
Figure 4 – Perception of a rainbow from a particular position
http://www.webexhibits.org/causesofcolor/13.html

Figure 5 shows the refraction process
http://www.rebeccapaton.net/rainbows/refrctn.htm

Figure 6 – Shows angle of deviation
https://plus.maths.org/content/rainbows
Figure 7 – shows the graph of deviation.  
https://plus.maths.org/content/rainbows

Figure 8 – shows the rainbow ray in red.  
https://plus.maths.org/content/rainbows
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Nanorobots and Their Potential Applications in the Field of Medicine

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Abstract

Technological advances have greatly impacted the field of medicine by improving health outcomes; along with those advances is the assistance of robots for a variety of procedures in various medical fields. The use of nanobiotechnology and nanorobots in medicine could greatly improve the current methods for surgery, delivery of drugs, and other functions as it provides a more accurate and precise result compared to traditional methods. Production of nanorobots requires more research due to the complexity of constructing technology on such a small size. Nanorobots and their introduction into a variety of fields such as microbiology, hematology, oncology, neurosurgery, and dentistry lead to possible applications such as improved imaging for disease diagnosis and prevention, assistance with chemotherapy, and targeted drug delivery in order to maximize drug treatment. These applications could have a big impact in the medical field and as such, it is important to continue research and development of nanorobots and further explore the field or nanobiotechnology and its future.

History

Advances in technology have greatly impacted the field of medicine by improving health outcomes. In the beginning, medicine was much less sophisticated; there were no technological aids such as robots or other tools, no assistance with imaging, or even medication such as anesthesia. With these advances now available, medicine has advanced and the quality of care has been improved. As progress was made towards less invasive surgery with more advanced medical equipment and prescription medication, the result was more favorable health outcomes. The medical field is always striving for improvement, such as new techniques which could improve the quality of health for patients, and nanobiotechnology seems to be a vital component of such advancements.

Introduction of Medical Robotics

In 1979, the Robot Institute of America provided a definition for a robot as “a reprogrammable, multi-functional manipulator designed to move materials, parts, tools, or other specialized devices through various programmed motions for the performance of a variety of tasks” [1]. The use of medical robots was introduced in the early 2000’s with such robots as the Da Vinci robot system with the promise of more favorable health results that result fewer complications; as such technologies have lived up to their promises, the future relies heavily on new technologies which bring about new fields such as nanomedicine, which is applying nanobiotechnology and nanorobotics to medicine.

Medical robotics currently play a very important role in medicine as they can be used for a variety of functions in various fields and they show great improvement over the traditional methods. There are many different kinds of robots such as those seen in figure 1, which are used in a multitude of areas such as surgery and orthopedics. There is much interest in using robots because more favorable surgical outcomes have been shown as well as a faster recovery and an overall enhanced experience for both the medical staff and the patients [2]. While there are downsides to the use of robots and reasons to be cautious of doing so, they have proven to be a
very useful tool in the medical field as their applications and benefits supersede any possible downsides.

Initially, robots were used as supportive tools for surgical procedures because the use of these tools decreased the risk of bleeding as well as infection while also reducing the amount of time spent in the hospital as a result of fewer complications and quicker recovery [2]. Robots such as the computer operated Da Vinci robot, seen in figure 2 were used by doctors for difficult procedures such as prostatectomy and heart bypass surgery that provided “remote surgical capability and ultrafine dexterity” [2]. The Da Vinci robot was initially approved by the FDA in 1995 and it would be used as a guide where the surgeon would perform the motions on a console and the robot would duplicate the movements with much more control and greater precision [1]. The model contained a 3-D monitor where the surgeon could see what was happening as well as arms to hold certain tools such as an endoscope as well as the EndoWrist which provided simplified movements for suturing and other movements; the main benefit of using robots as opposed to traditional surgery is that the robots have the means to control tremors and can reduce the occurrence of human error while performing surgery or other functions [1]. While the initial purpose of Da Vinci robot was for general laparoscopy, the FDA approved additional procedures robot such as radical prostatectomy, among other procedures [1].

Differences Between Open Surgery and Robot-Assisted Surgery

The differences between open surgery and robotic surgery are that robotic-surgeries consist of small, pen-size hole incisions where a camera and different instruments are inserted into the patient by the arms of the robot as opposed to open surgery which consists of a large incision. The first comparative study was conducted in 2003 of 300 prostatectomy patients, stating that robotic-surgery patients had 14% higher rate of cancer removal, lost five times less blood, had four times less occurrence of complications, had shorter hospital stays, and regained urinary and sexual function about four times faster than open surgery patients [3]. Robots such as the Da Vinci robot and similar models were just the beginning of robotic use in medicine, which has paved the way for new fields such as nanomedicine, which is the use of technology to produce extremely effective nanorobots which can further assist in the medical field.

The field of nanorobotics emerged as a result of more advanced nanotechnology, where tools produced function at a nanoscale, which is $10^{-9}$ meters, and can be used to manipulate things at an atomic level. The topic of nanotechnology and such technologies as nanorobots, can be attributed to Nobel physicist Richard P. Feynman, who discussed this as early as 1959, when he presented a lecture “There's Plenty of Room at the Bottom” [6]. In this lecture, Feynman discussed the possible creation of small machine tools that would therefore produce smaller machine tools that would continue down to the atomic level, and essentially offered nanorobots as a proposed method for curing heart disease [6]. He not only discussed this concept, which is essentially nanotechnology and the production of nanorobots, but he also mentioned key components of what is now the field of nanotechnology, such as increased control and precision as a result of this new technology and even possible applications such as for heart disease.

Introduction to Nanorobotics

Nanorobots are extremely small robots which could perform tasks in much smaller spaces
with great precision and accuracy [2]. Their design would vary depending on what their role in the body would be, but common components would include a power supply, sensors—either external or internal (on-board systems), actuators, detectors, motors created by nanomaterials that would not cause harm to the body [9]. Substructures would include a micro-camera, which would facilitate navigation and operation, a payload section to hold medication when needed, electrodes which would function as a battery with the electrolytes found in the blood, lasers to “burn harmful materials such as arterial plaque, blood clots, or cancer cells,” signal generators for localization, and some component such as a swimming tail or another substructure that would assist with propulsion and mobility in the body [9]. As far as constructing the nanorobot, they could either be constructed via positional assembly or self-assembly. Positional assembly would be based on the natural affinity of the molecules used for construction, meaning they would come together on their own due to their interactions with one another [9]. The other method would be self-assembly, where nanorobots would be programmed to assemble themselves [9]. Both methods require research and extensive studies in order to ensure that the nanorobots would be correctly assembled in order to complete their tasks.

Carbon and like allotropes, such as diamond, would be the ideal principle element [9]. Diamond would be the most desirable element due to its properties such as withstanding high temperatures, high electronic and semiconductor characteristics, its hardness and strength, high thermal conductivity, low frictional coefficient, and chemical inertness all which would potentially make the diamond a successful principle element for nanorobot composition. Along with being an allotrope of the element carbon, which comprises about 18% of the human body, diamonds have smooth surfaces and this is useful because it is not likely to “trigger” the body’s immune system, decreasing the side effects or possible chemical reactions occurring in the body as a result of nanorobot introduction [13]. The possible downside to using diamond would be that they are not easy to manipulate, which can lead to fractures; the ability to create several models of nanorobots with this element stills needs to be assessed [10].

The proposed nanorobots would be used for various roles there, there are certain aspects which would need to be addressed such as their proposed size and shape, sensors, mobility and propulsion, power generation, data storage, telemetry and transmission, as well as control and navigation [7]. It is important to determine these aspects as they may need to be adjusted depending on what role the nanorobot will need to fulfill. For example, the shape and size would vary as they could be spherical or could be shaped as bacteria if they will be serving a similar role in the body; there would be more than one model so the shape and size for each would vary and it would determine their ease and entrance into the body [7]. Sensors would play a critical role so that the nanorobots could sense their surroundings and understand their limits in order to fulfill their roles, some may be surrounded by Newtonian fluids like water whereas others would be surrounded by non-Newtonian fluids such as blood or cerebrospinal fluid (CSF) [7].

Blood and CSF are liquids that are viscous, therefore friction, adhesion, and viscous forces are more important than gravitational force, which is said to be “relatively negligible” [15]. A low Reynolds number (Re) would be obtained by kinetic calculations, where the fluid mechanics in small structures such as nanorobots can be described by the classical continuum equation, where the ratio of inertial to viscous forces is determined by Re, as expressed in calculation 2 [15]. Calculations 3 and 4 describe how the inertial and the viscous ratios can be determined to give the Reynolds number. The Reynolds (Re) number indicates whether the flow
will be laminar (smooth path) or turbulent (irregular flow) around an object of a certain shape and flow velocity [15]. For nanoscale dimensions of particles in fluids such as blood, the Reynolds number would be low and the flow would be laminar, following a smooth path where the particles would not interfere with one another and the velocity of the fluid would be constant [15]. Reynolds number (Re) for nanorobots in blood would be low because of the viscosity of blood and calculations 2-4 describe how to calculate the Re number from inertial and viscous forces and what values of inertial and viscous force a nanorobot would need to exert in order to continue moving in a laminar flow. In order to travel through the body, nanorobots could either roll like balls depending if they are spherical, or they could have a sort of swimming tail incorporated which would enable movement, or could even simply be injected into the body, accompanied by water where the nanorobots would follow the natural path that water travels [7].

In order to power the nanorobot, the proposed energy source would rely on using the entire body and components such as using heat from the body temperature, creating chemical reactions at specific rates from fuel chemicals obtained from blood cells, converting microorganisms into electricity, or fueling the motors by using ATP molecules to create the energy needed to fulfill their necessary functions [8]. ATP is the body’s energy source therefore it makes sense that nanobiotechnology created such as the nanorobots would also attempt to use the same energy source as they will be performing similar functions as the cells of the body; the ATP molecules would function as rechargeable batteries in the body [8]. There are still components that need work and research in order to determine what would be the best approach to take for the creation of the nanorobots, such topics include data storage, telemetry and transmission. As far as control and navigation systems, it is suggested that the nanorobots could be controlled from outside of the body or they would incorporate technology that would allow them to control and direct themselves once inside the body to fulfill their given roles. Some of the components that would make up these robots would be autonomous meaning that the sensors, motors, manipulators, and power supplies could be programmed to function on their own therefore eliminating the need for manipulation and guidance from any other source; they could even assemble themselves once inside the body and communicate and work with other components of the same robot system or with other nanorobots [6].

Swarm intelligence technique for decentralization activity would be incorporated into the nanorobots, modeled after the behavior of animals such as ants and bees which work together towards a single goal [14]. A possible algorithm was proposed by Craig Reynolds, as seen in calculation 1, so that individual nanorobots can swarm to the area of interest and work together on a particular task. This would require determining the velocity and position of all nanorobots in the “robot neighborhood” as seen in figure 7, and this would be calculated as each robot would be equipped with a radio transmitter that would transmit the id and position of each individual robot [14]. Using this algorithm and incorporating into technology of the nanorobot would be extremely beneficial because it is based off of naturally occurring behavior seen in animals such as ants or bees.

**Potential Applications for Nanorobots in the Medical Field**

Nanorobots would potentially be used to perform procedures that would otherwise be very hard or even impossible to perform by surgeons. While surgery is one of the areas in which medical robots have been used and have displayed positive results, they can be used in other
areas as well. The smaller robots currently used enable one to reach tight spaces or difficult areas to work on and can access tumors or other surgical objects. Proposed applications of nanobiotechnology and nanorobots would be include improved imaging for disease diagnosis and prevention, assistance with chemotherapy, targeted drug delivery in order to maximize drug treatment, and insertion and self-replication in order to produce more copies of robots similar enough to duplicate and perform the functions of certain cells in the body such as red blood cells for increased oxygen intake [4]. There are certain medical fields such as microbiology, hematology, oncology, neurosurgery, and dentistry where the nanobiotechnology and nanorobots could have a big impact [4].

Potential applications of nanorobots are seen in the fields microbiology, hematology, oncology, neurosurgery, and dentistry and include a vast array of potential roles. Nanorobots could provide support in the field of microbiology with many benefits such as assisting with strengthening the immune system and delivering drugs to maximize their effect but the downfall with this is that transport of nanorobots could be difficult in the vascular system [4]. As blood is a non-Newtonian fluid, transportation and movement of the nanorobots in the vascular system could be an issue because their viscosity varies with velocity and it is not always constant. It would not be possible to attach any sort of propeller or other component to the nanorobot as a means of getting them to move around through the blood because this could result in damage to blood cells which would be detrimental to ones’ health. Once the details are worked out, nanorobots would have an important role in the field of microbiology because they can help guide drugs to the specific locations in the body where their effects would be maximized. The current method involves the drug traveling through the entire body before reaching its desired location and this would be improved by using nanorobots which are specifically being sent to a certain location at a certain time, ensuring that the drug reaches the destination when it should and possibly decreasing the risk of side-effects. This is not just an idea anymore, as a drug company by the name Elan Pharmaceuticals has begun using this technology since the year 2005 [7].

There could also be the creation of nanorobots whose functions would revolve around serving as artificial antibodies that would be directed to a particular site to fight off any sort of antigen found in the vascular system [7]. Diseases such as diabetes, cardiovascular disease, or cancer could be more easily diagnosed or even prevented with such technology by being injected into the blood [7]. As seen in image 3, nanorobots could remove plaque buildup in the arteries, decreasing the risk of cardiovascular disease such as atherosclerosis. This would potentially help address the burden of disease seen in many industrialized countries whose primary causes of death include nutrition-linked disease such as diabetes and cardiovascular disease.

As far as hematology, there are three proposed types of nanorobots: respirocytes, microbivores, and clottocytes which have very specific roles in the bloodstream [9]. These three types were designed with similar size, shape, and function to cells in our body for example, respirocytes were designed to function as artificial mechanical red blood cells and the nanomolecule used would be diamond, such as most proposed nanorobots.

Respirocytes would consist of three roles in the blood: collect oxygen to distribute through the body, collect carbon dioxide to expel from the tissue to the lungs, and would metabolize glucose in order to serve as its energy source, powering itself to continue serving its
intended purpose [4]. The size would about 1,000 nanometers and within this size it would contain an onboard computer and rotors for oxygen and carbon dioxide such as seen in figure 4; due to these rotors, the respirocyte would be designed to “carry 236 times more oxygen per unit of volume compared to red blood cells” [4].

Microbivores would be artificial phagocytes located in the bloodstream and would work on preventing the onset of disease by “digesting unwanted pathogens including bacteria, viruses, or fungi” such as what is seen on figure 5 [6]. Infection can lead to very severe health complications and for individuals with compromised immune systems can quickly lead to death. The importance of microbivores would be to decrease the occurrence of severe infections, for example septicemia infections. Currently the treatment for septicemia infections last for weeks or even months but injecting microbivores into the bloodstream could resolve the issue in a matter of hours and would not increase the risk of injection because the goal would be to create nanorobots with natural components such as sugars and amino acids which the body can digest [6].

Clottocytes would function as artificial platelets to assist with blood clotting but it would be able to perform at an increased rate, resulting in less amount of blood loss, which is ideal. This nanorobot, seen in figure 6, would contain a fiber mesh that would expand and would be used for improved blood clotting. This material would be bio-degradable so that it would not pose as a possible risk to the body [6]. The introduction of clottocytes into the body could potentially be life-saving after accidents, particularly those that involve mechanical injury, otherwise known as trauma, because clottocytes would be designed to complete hemostasis in less than a second, making them 100-1000 times faster than natural platelets, while only using about 0.01% of bloodstream concentration that natural platelets would [12].

With the many hypothesized applications of nanorobotics in the medical field, it is a very exciting and seemingly promising idea. However, despite the excitement from those who are planning and doing research on the topic, there are some who may skeptical about the idea of having nanorobots either injected or placed into our bodies. But the reality is that they would not be much different from microbes or bacteria that are currently inside of our bodies. This is why nanorobots are being modeled similarly so that they may function like these natural nanorobots. There are about 40 trillion single-celled microbes in the colon and more than a trillion fibroblasts and neutrophils and lymphocytes (white blood cells) [6]. Each of these natural nanorobots perform beneficial functions in our bodies similarly to what the roles of the proposed nanorobots such as clottocytes, respirocytes, and microbivores among other models of potential nanorobots [6].

Oncology is another field where nanorobots could have a variety of beneficial applications. The most important component of successfully treating and beating cancer is typically to achieve an early diagnosis on because there is a higher survival rate when treatment begins in the earlier stages before it can grow further or even spread to other parts of the body. Nanorobots could provide assistance with diagnosing cancers as well as with the removal of tumors and cancerous cells and with improving treatment [4]. By specifically delivering the medication only to the affected areas, it could maximize the efficiency of the medication and reduce the toxic effects of chemotherapy to the non-cancerous cells in the surrounding areas [4]. Chemotherapy and radiation therapy are common treatment methods for cancer which come with
a risk of causing damage to surrounding cells. Reducing the toxic effects would be the focus of nanorobots that would be inserted into the body and would travel to the exact location necessary to provide the most effective delivery of medication. [4] Removing tumors and potentially cancerous cells would also be done with the assistance of nanorobots and this would be beneficial because it would eliminate the need to open surgery which could cause infections or other complications that would be especially dangerous for individuals such as cancer patients who already suffer from a weakened immune system. These applications of nanorobotics in oncology would impact the way cancer is treated as it would improve diagnosis, treatment, and the risk of complications associated with cancers that currently exists.

Surgery is one of the field where robots were initially introduced to assist with certain procedures and the results were so positive that the proposed creation of nanorobots would be able to assist with more difficult surgeries such as those performed by neurosurgeons. Neurons, which are the cells found in the brain and the spinal cord, are unlike most somatic (body) cells as they cannot self-heal and restore their neurological function after a trauma [11]. The use of nanorobots in the field of neurosurgery could help address spinal cord injuries and nerve damage caused by trauma because the proposed application of nanorobotic technology in neurosurgery would be to assist with recovery of spinal cord injuries and nerve damage. By working on a nano scale, the proposed robots could function at the atomic level and manipulate individual cells or individual axons for procedures such as axon surgery [11].

There are two ways by which nanorobots could go about addressing these issues, they could either promote axon regeneration or to go about splicing and repairing the severed axons [11]. Both approaches would ideally achieve the same result, which would be treating injuries in both the CNS (central nervous system) and PNS (peripheral nervous system) [11]. There are injuries or diseases such as cancers that are located in certain areas of the spinal cord or the brain which are very difficult or even impossible for doctors to reach, this is where nanorobots would be ideal as they could be equipped with the necessary tools or medication necessary to treat conditions and diseases of the nervous system that currently are difficult to treat with traditional open surgery as they have a high morbidity rate [11]. With a tool constructed on the nanoscale, it would be possible to perform procedures on the individual cells or axons that are causing the issues.

Sadeeh suggested that virtually all aspects of dental care from cleaning, teeth whitening, hypersensitivity, to orthodontics could benefit from the introduction of nanorobots [4]. One of the proposed application of nanorobots would be to function as anesthesia, eliminating the need for needles to numb an area of the mouth to perform certain procedures. The nanorobots would enter the mouth and travel down to the center, the pulp, where blood vessels and nerves are found. Upon entering the pulp cavity, the nanorobots, following their preprogrammed function or as directed by the dentist, would take command of the nerve impulse traffic, activating analgesic activity by block the nerves in the tooth and could later activate the nerves once again after the procedure has been performed [4]. This would be particularly enticing for those afraid of needles or for children who get nervous at the dentist’s office. Nanorobots could also be employed to function in root canal fillings, in treating infections, dentine hypersensitivity, tooth repositioning, and could even hypothetically be incorporated into mouthwash or toothpaste as to enhance dental
care and reduce the need for dental work. This would improve other aspects as well because dental health can affect other organs of the body such as the heart [4].

Conclusion

In conclusion, since the introduction of robotics in the field of medicine, there have been tremendous strides made towards improving the field of medicine and the health outcomes achieved as a result. The creation of nanobiotechnology and nanorobots and their introduction into a variety of fields such as microbiology, hematology, oncology, neurosurgery, and dentistry lead to possible applications such as improved imaging for disease diagnosis and prevention, assistance with chemotherapy, and targeted drug delivery in order to maximize drug treatment. These applications could have a big impact in the medical field and as such, it is important to continue research and development of nanorobots and further explore the field of nanobiotechnology and its future.

I had read on this topic before and I understood the role that technology played in medicine as it helps improve the quality of care that patients receive. However, researching more and more blew my mind because certain concepts such as creating nanorobots that are injected into the blood and act as artificial antibodies sound like science fiction, but they are not. They are amazing advances that seem to be in our near future and we will hopefully benefit from these advances in our lifetime. To think that we could have nanorobots injected into our blood stream to perform tasks of our own blood cells just does not even sound real but that is what we are working towards. This would completely change the manner in which health care is administered, from diagnosis and imaging to treatment methods and surgery. Medical occurrences such as brain aneurysms could be prevented if nanorobots are injected into the body to monitor and take action when necessary.

Despite the excitement and optimism regarding nanorobots and its integration into the medical field, there will be obstacles to overcome in order to bring this idea to life. Creating this technology will be costly and it may be a difficult task to achieve clearance from the FDA regarding their introduction and application in animals and later into humans. In spite of these issues, it seems inevitable that robots and similar technology are going to play an important role in the future. We are heading into a time where technology is going to be incorporated into everything we do; therefore, it only makes sense that there is such a big emphasis placed into how the application of nanorobots would completely change the medical field. When this technology is put to use, it will impact the quality of care that patients receive. It will help diagnose and prevent disease earlier especially with diseases that are more difficult to diagnose. These applications will make a big impact in how and when we begin treating and can even assist with the delivery of medication or treatment for cancer, diabetes, and cardiovascular disease among others illnesses.
Figures

Figure 1. This image\textsuperscript{1} shows several different kinds of robots that are currently commercially-available for the fields of neurosurgery and orthopedics. They contain arms for holding a variety of instruments as well as a 3-D monitor for the surgeon to be able to see what is happening in the body during the procedure.

Figure 2. This image\textsuperscript{2} show the Da Vinci computer-operated robot system and its components such as the cart, the EndoWrist and controllers, and the FreeHand, endoscope holder. This was one of the first robot systems created and used to assist with surgery and resulted in improved health outcomes for the patient and surgeon.
Figure 3. This image shows a potential model for a nanorobot that could go into the arteries in the vascular system to help remove plaque buildup in order to avoid cardiovascular disease such as atherosclerosis.

Figure 4. This image shows the proposed design for respirocytes. The multiple rotors and sensors for oxygen and carbon dioxide on this nanorobot are the reason for the significant increase in capability to collect oxygen and carbon dioxide as opposed to typical red blood cells.
Figure 5. This image\textsuperscript{5} shows the manner by which microbivores would perform phagocytosis to digest unwanted pathogens and remove them from the bloodstream, decreasing the occurrence of disease and infections such as septicemia much quicker than phagocytes currently can.

Figure 6. This image\textsuperscript{6} depicts the clottocyte and how it would open and expand the fiber mesh which would be used for blood clotting. The fiber mesh would be bio-degradable so there would not be any risk of causing harm to the body by using these nanorobots.

Figure 7. This image\textsuperscript{7} is depicting the robot neighborhood and shows how the nanorobots would detect the presence (location) and velocity of surrounding nanorobots in a particular area in order to enhance their functions together as they would hypothetically swarm and work collaboratively in an area of interest \cite{14}.
Calculations

**Calculation 1**

\[ l = \frac{c}{4f} \]

- \( l \) = length of the antenna
- \( c \) = speed of light, \( 3 \times 10^8 \) m/s
- \( f \) = frequency (must be high because of the small size of the nanorobot)

*This equation is over 4 because it is being assumed that “a simple \( \frac{1}{4} \) wavelength monopole antenna” would be the ideal length of the antenna [14]*

The algorithm calculated by Craig Reynolds discussed how each nanorobot would identify the location and velocity of nearby nanorobots in order to effectively use the swarm intelligence technique. The ideal length of the antenna incorporated into the nanorobots would be calculated by determining the distance that a charge traveling at the speed of light will travel in one period. If the antenna is assumed to be 50 nm, this would mean that the ideal frequency would be about 1.5 Phz (1x10^{15} Hz) which would be practical as the distances nanorobots would swarm in a particular area would be “small and unobstructed” [14].

**Calculation 2**

\[ Re = \frac{\rho V L}{\eta} \]

- \( \eta \) = absolute viscosity of the fluid
- \( \rho \) = fluid density
- \( V \) = velocity
- \( L \) = characteristic dimension

**Calculation 3**

\[ F_{\text{inertial}} \approx \rho V L \]

**Calculation 4**

\[ F_{\text{viscous}} \approx \eta V L \]

The Reynolds number (Re) is the ratio of inertial to viscous force expressed as Re which is determined by calculation 2. Calculation 3 describes how to determine the inertial force and calculation 4 describes how to determine the viscous force in order to obtain the Re value. The Reynolds number (Re) for nanorobots in blood would be low and the flow would be laminar because of the high viscosity of blood. The Re number determines whether flow will be laminar (smooth) or turbulent (irregular) for an object of a certain shape and flow velocity. For a robot about 1 micrometer in size to travel at about 10 micrometers per second, it would need to exert about 1 fN (10^{-15} N) of inertial force and a greater value for viscous (motive) force, of about 10 fN in order to maintain its movement [15].
References


References for Images

How The Eastern Coyote Came to Be and Its Standing as a Species

Cody Radigan
Abstract

Canids are, by nature, species that tend to allow genes to flow from different species rather easily. This easy gene flow creates many hybrids between the four major Canids in North America: Domestic Dogs (*Canis lupus familiaris*), Grey Wolves (*Canis lupus*), Eastern Wolves (*Canis lycaon*), and Western Coyotes (*Canis latrans*). Trying to differentiate between actual distinct species and hybrids can create headaches for taxonomists and conservationists alike. That is why a new widespread hybrid has garnered a great deal of attention in the northeast United States and southern Canada. This hybrid between the western coyote and eastern wolf was proclaimed to be a distinct species by Way et. al (2010). This species came to be by a multitude of factors. A decline in wolf populations, due to human prejudices against the animal, and other human caused environmental factors caused a split coyote migration to the east. There the coyotes interbred with the eastern wolf, bringing about this hybrid. With the other group of coyotes, the hybrids went on to colonize the eastern United States, along with southeastern Canada. This hybrid shares many characteristics with the western coyote, which is where the majority of the DNA is from, while still having a plethora of distinct characteristic. Such distinctions are that of genetics, physiology, and ecology. Some of these distinctions include distinct genetic markers from different ancestral sources.

Introduction

There are a multitude of Canid populations in North America. Most notably: Domestic Dogs (*Canis lupus familiaris*), Grey Wolves (*Canis lupus*), Eastern Wolves (*Canis lycaon*), and Western Coyotes (*Canis latrans*). Recently there have been a number of papers done on a possible new species of Canid. This ‘species’, being predominately east of 80 degrees longitude, is an Eastern Wolf and Western Coyote (*Canis lycaon x latrans*) hybrid (Way et. al 2010). This hybridization, as dubbed by Way et. al as the ‘coywolf’ has been extensively researched and have had a number of studies done on it. By using a sampling of the aforementioned studies, the history, and genetic makeup, along with any significant genetic markers, will be made apparent. Along with this analysis, the hypotheses of the eastern coyote being a distinct species, and that a small population of the hybrid descended west while coyotes came east is what created the widespread eastern coyote population noted in many studies.

Origin

The Eastern Coyote originated as hybridization between Eastern wolves and Western coyotes, with some studies suggesting that domestic dog DNA is a part of the hybridization. Prior to the 20th century, *Canis latrans* populations were primarily found upon the Great Plains and to the west. During the late 19th century, however, the coyotes began to expand westward (Power et al 2015). This followed a decline in *Canis lupus* populations in the eastern regions. The eastern wolf, which Kyle et. al (2005) concluded was a distinct species, prior to the decline of grey wolf population had stuck to forested regions east of the Mississippi river, and expanded their range with in accordance to the expansion of white-tail deer that took place after the grey wolf decline (Kyle et. al 2005). It is with these two expansions that contact is seen between *C. latrans* and *C. lycaon*. Shortly after is when the first *C. latrans x lycaons* start to be noted. The
extent of expansion of the western coyote is fairly significant (shown in figure 1), reaching all the way to Prince Edward Island in Canada (Power et. al 2015).

With the expansion of both species, hybridization began to occur. These hybrids now currently occupy the majority of the northeastern United States and southeastern Canada, being able to live in both wilderness and urban settings (Way et. al 2010). Hybridization was able to occur due to a decrease in Grey wolves not just indirectly through expansion, but also directly. Historically, grey wolves, eastern wolves and coyotes had not been entirely isolated reproductively. While the scale of hybridization had not been like that of now, which gives rise to the question of the eastern coyote, there had been hybridization between the three. However, grey wolves had been limiting the coyote's range, often times aggressively and fatally (Rutledge et. al 2010). This competition had limited the ability of the coyotes to interbreed with wolves too far removed from their (coyote) own range.

A third factor influencing this hybridization event is the anthropogenic changes that took place as a result of European colonization (Bozarth et. al 2011, Kays et. al 2010, Bogan 2014). Prejudice against wolves led to mass hunting and killing, along with mass habitat destruction, is what led to the decline of wolves from 2 million to around 70,000 individuals. The change in habitat from dense forests to urban environments and farms favored the coyote’s expansion east (Bozarth et. al 2011). The grey wolf prefers dense forests like the ones that they had inhabited prior to destruction. Coyotes, on the other hand, are highly adaptable and can thrive in open lands, prairies and urban settings. This allowed the coyotes to expand east, as the landscape changed from the dense forests to farmland and urban cities. The coyotes route east is typically defined by a north and southern route, the southern route going below the Great Lakes into Ohio and the northern route going above the Great Lakes into Ontario and then down into New York, where it converged with the southern route (Kays et. al 2010, Bozarth et. al 2011, Power et. al 2015, Bogan 2014). In New York is where the hybridization event took place, creating (as dubbed by Way et. al 2010) the Coywolf.

Hypotheses

One hypothesis, set forth by Way et. al (2010), is that this eastern coyote population is worthy of being itself a distinct species. Way et. al cites clustering with other genetic “eastern coyotes” as well as genetic and morphological distinction from other canid species in the United States. The study also notes genetic uniformity and widespread similarity of mitochondrial DNA. On the other side, Steven Chambers refutes the findings of Way et. al, noting specifically the genetic diversity of the eastern coyote and instead suggesting that the eastern coyote is merely a subspecies of coyotes that have not yet diverged from the Canis latrans population entirely.

A second hypothesis, as to the origin of the eastern coyote and not its taxonomy, is that a small group of hybrids emerged in far north eastern lands. While the coyote population began expanding in the early 20th century, this small population of hybrids came west creating a hybrid event occurring when the two populations met (Kays et. al 2010). This hypothesis is supported through mitochondrial DNA displacement and frequencies throughout Ohio and southeastern Canada, along with the northeastern United States.
Genetic Differentiations

The eastern coyotes show many characteristics of both western coyotes and eastern wolves. It has been estimated that the eastern coyote is just about 65% western coyote, about a quarter eastern wolf, and about 10% dog (Bogan 2014). In the mitochondrial DNA (mtDNA) of eastern coyotes, it has been found that mtDNA haplotypes of both eastern wolves and western coyotes are in the eastern coyote (Way et. al 2010, Power et. al 2015). With this in mind, it is important to note that Power et. al (2015) noted a change in frequency of certain mtDNA haplotypes the further east the sampling came from. Interestingly, it seemed in their study that a single haplotype (cla 29) had not yet been dispersed to the populations of Nova Scotia and beyond. When examining the different haplotypes, a trend appeared. Of all the eastern coyotes that were examined, nearly a third had the eastern wolf haplotype GL20 (Kays et. al 2010, Way et. al 2010). When looking at the eastern coyotes in Canada, Power et. al (2015) also recorded haplotypes similar to Kays et. al did in the northeast region of the United States, in that the Canids only possessed one of three haplotypes, two originating from the western coyote (cla 28 and cla 29) and one originating from the eastern wolf (GL20). Which makes the fact that only one third of the eastern coyote breed has the GL20 haplotype seem much more understandable. This finding goes hand in hand with the hypothesis put forth by Way et. al in that the eastern coyote is a breed that is of uniform DNA. However, Kays et. al found that as one goes east from the northeastern region, around Ohio and western Pennsylvania, haplotypes become more diverse and less from the eastern wolf.

Physiological and Ecological Distinctions

When it comes to the physical appearance of the eastern coyote, it has many distinct qualities that set it apart from its primarily coyote ancestors. Primarily, the size of the eastern coyote is in between that of the canids that contribute to its existence, western coyotes and eastern wolves. It was shown by Power et. al that size is partially correlated with mtDNA haplotypes. Their data indicates that when defined by haplotypes, male eastern coyotes containing haplotype GL20 are larger than the male eastern coyotes containing either of the two coyote specific haplotypes. However, there was no notable size difference between females defined by haplotypes, and that defining the overall population by haplotype did not produce notable size differences either. Jonathan Way (2007) also notes that going west to east, the Coyote population grows larger in size, with the largest being found in the area that Way et. al (2010) defined for the eastern coyote. Way (2007) also found that, on average, adult female coyotes from the northeast (eastern coyotes) were larger by a mean of 21% than adult male coyotes from outside the northeastern regions. This is peculiar especially when considering that adult male coyotes are typically 11 to 14% larger than their female counterparts, which was true for eastern coyotes.

Size is not the only physiological difference between eastern coyotes and their western counterparts. Kays et. al (2010) also found that eastern coyotes had larger skulls, along with more area of muscle attachment along the jaw. In this, they found another source of haplotypes possibly influencing physiology. Individuals that had haplotype GL20 and cla29 had wider skulls as well as more muscle attachment (Kays et. al 2010). They also found that the height of female eastern coyote skulls was correlated with haplotypes. The formation of these eastern coyote
skulls is similar to wolf skulls in both look and function. The increased muscle attachment along the jaw being a prime example. This muscle attachment is usually found in large prey eaters; they facilitate bite strength as well as reduce the wear and tear of struggling prey upon the jaw (Kays et. al 2010). Wolves have these traits, along with the eastern coyote. However, the western coyote does not have the same broad skull nor muscle attachment as the other two canids. The sexual dimorphism found in the eastern coyote by both Way et. al and Kays et. al (2010) also more closely mirrors wolves than western coyotes. While the eastern coyotes studied by Kays et. al (2010) showed difference between sexes for nearly all traits, much like wolves, the western coyotes did not.

Ecologically, Way et. al (2010) notes that the eastern coyote acts like expected for a wild canid of its size. Despite the coyote’s expansion of the majority of North America (Bozarth 2014), the eastern coyote has a range that is larger than the western coyote but smaller than the typical wolf (Way et. al 2010). The eastern coyote does not form as highly organized of packs as wolves. The pack formed by the eastern coyote is usually comprised of the mating pair and a few offspring of the pair (Bogan 2014, Way et. al 2010). Another distinction from the eastern coyote and western coyote is the diet of both. The diet of the western coyote consists primarily of small to medium sized animals. In contrast, the diet of the eastern coyote contains primarily large game, such as deer and fawn, with some small and medium sized animals (Bogan 2014). Eastern coyotes, like wolves and western coyotes, are opportunistic feeders and will typically feed on what they can. Eastern coyotes are also known to eat plant material on occasion (Bogan 2014). This fact is shown support in how eastern coyotes do no avoid forested regions, unlike their western counterparts (Kays et. al 2010).

**Discussion**

There is a lot of evidence to support the theory of two colonizing groups of coyotes. Firstly is the frequency and displacement of mtDNA haplotypes as well as their diversity. The haplotype diversity decreases when going from west to east, with the highest diversity being found in Western New York and Pennsylvania area (Kays et al. 2010). The theory that the northern group of coyotes had hybridized with eastern wolves prior to linking up with the other group of coyotes is also supported by the mtDNA haplotypes. In southern Canada, which is where the northern group traveled through, only three mtDNA haplotypes were found, all of them being identical to the ones found east of latitude 80 degrees (Power et al. 2015). These three identical haplotypes in this large region suggest that a small group of individuals had hybridized with a singular pack of eastern wolves. The resulting offspring, as well as the original group, went on to colonize southeastern Canada and the northeastern United States. The frequency and diversity of haplotypes in western New York suggests that the northern group came into New York from the northeast, while the group that traveled south of the great lakes came into New York from the west. When considering the fact that west of Pennsylvania no eastern wolf haplotypes were found in examined coyotes, the case for the two group theory becomes strong. It is not just highly likely, it is the best answer, that the a small group of coyotes traveled north of the great lakes while heading east and hybridized with eastern wolves on their journey to the east.
Examining the eastern coyote as a singular species yields variety of results. When looking at the genetics of the eastern coyote, some trends appear. In southern Ontario and eastward in Canada, as well as east of 80 degrees longitude in the United States, there were only three haplotypes reported in coyotes (Way et. al 2010, Kays et. al 2010, Power et. al 2015). This is important for a number of reasons. Firstly, it shows that there were only small numbers of predecessors. This means that a couple of small populations of coyotes interbred with a few small populations of eastern wolves which in turn created the eastern coyote. Then there are the morphological differences between western and eastern coyotes. The skull differences are among the most intriguing. The eastern coyote had larger and wider skulls compared to the western coyote (Kays et. al 2010). These wider skulls are reminiscent of their eastern wolf ancestors. The skulls, morphologically, are more adept at corralling and eating larger prey than those of the western wolf. This shows how the eastern coyotes are adapting to the available prey in their region, namely the white tailed deer. While the western coyote has been known to feed of small and medium sized prey, such as voles and packrats, the eastern coyote takes more after the eastern wolf in that its diet contain much more large game, with just a smattering of small and medium sized prey (Bogan 2014). This change in diet is most likely due to the relocation added to the hybridization of eastern wolves. Had the coyotes not interbred, a need for a dietary shift is non-existent. Small prey is abundant in the east so the shift has more to do with ancestry than anything. This begs the question of the skulls. With this population in question being predominantly of coyote DNA, why did the skull adapt so quickly to the different prey? Selective breeding within packs may have played a part, but this hyper adaptation is very intriguing. At the same time, however, from a morphological and an ecological standpoint, the eastern coyote does resemble the eastern wolf more than the western coyote. The sexual dimorphism displayed by the eastern coyote is much like the eastern wolf’s, whereas the western coyotes do not show nearly as much sexual dimorphism (Kays et. al 2010). It is postulated that these traits helped the eastern coyote to quickly colonize the east (Kays et. al 2010). Even though the eastern coyote is disproportionately of coyote ancestry, it shows many similarities to the activity and physiology of a wolf. This may be because of the fact that these coyotes now inhabit areas that were, for the most part of the history of North America, dominated by wolves. These points all help to support the fact that the eastern coyote is its own distinct species. Its diet is unique from the western coyote and the similarity to the eastern wolf is mainly due to prey availability. The skulls are proportionally wider than the western coyote, although not to the extent of the eastern wolf, and serve a purpose separate from the purpose of the narrow skull of the western coyote. This shows a divergence from western coyotes morphologically not just ecologically. This divergence may possibly be evidence of a break off from the typical *Canis latrans* species into something distinct.

While Way et. al (2010) suggests that these eastern coyotes breed exclusively with other eastern coyotes; the breeding pairs examined were only mentioned as unrelated, and never specified as two eastern coyotes. This mirrors Chambers (2010) in saying that the eastern coyote is not of uniform genetic makeup, because it does not solely breed with other eastern coyotes. While Canids usually are not exclusive to their own species when it comes to breeding, they are still most likely to breed within their respective species. Eastern coyote breeding pairs, on the other hand, have not been demonstrated to be a plurality of eastern coyotes breeding with eastern coyotes. This undermines one of the other points for the distinctiveness of eastern coyotes made by Way et. al (2010) in that the eastern coyote is disjunct from both the western coyote and
eastern wolf with minimal influence from both. Had they provided evidence of eastern coyote and eastern coyote breeding pairs, this claim would have a better foundation. However, there is not empirical evidence that the eastern coyote breeds exclusively with other eastern coyotes. This leaves plenty of room for more introgression from eastern wolves in the area described by Way et. al (2010) or possible admixture from other western coyotes migrating east. These possibilities leave the eastern coyote population to be highly variable from the two parent species. Creating a taxonomy for animals is a very difficult task to achieve, and the eastern coyote does not make it any easier.

Conclusion

Canids as a whole are a very interesting family. They have not, historically, stuck to the strict breeding within its own species that most other species families do. This makes it very hard when examining various canids to distinguish between hybrids and species. When it comes to the eastern coyote population defined by Way et. al (2010), there is many interesting points to examine. I examined the mitochondrial DNA, sizes, morphology, and ecology of the eastern coyote as reported through other experiments. Using this data, I looked to answer the question of how the colonization of western coyotes affected the emergence of the eastern coyote and whether the eastern coyote is deserving of being seen as a distinct species.

I started with examining the theory of a split group colonization. Many of the studies which I had read concurred that the most likely way that coyotes colonized the eastern United States was through two groups. The reasoning is through the evidence of coyote hybrids throughout the proposed colonization route, and a lack thereof in the southern colonization route. This theory is the most likely way, in my informed opinion, that coyotes colonized the eastern United States. This is important because it is the origin of the eastern coyote. This theory is the explanation for the low diversity of haplotypes in southern Canada and the northeastern United States. The split group theory for colonization is the most probable way that the western coyote colonized the east.

The second hypothesis I examined was that the eastern coyote merits being a species in of itself, instead of a subspecies of coyote. This idea, proposed by Way et. al (2010) is a little shakier than the above colonization hypothesis. The eastern coyote does look different from the western coyote, and has many physiological differences from the western coyote. The eastern coyote’s size mirrors more closely the eastern wolf, and is often put into wolf weight brackets. It forms packs in the same ways that wolves do as well as patrol a range that is wider than the coyote’s but smaller than a wolf’s. The genetics of the eastern coyote also present its hybrid origin, with one of three mtDNA haplotypes being of eastern wolf origin. The eastern coyote also has a diet that varies significantly from its western counterparts. Along with this diet change came the morphological adaptation of the eastern coyote skull. All of this put together makes a compelling case for the eastern coyote to be considered a separate species from the western coyote. However, I do not believe that, at this point, the eastern coyote can be considered its own species. The main reason for this is the mating tendencies, or lack thereof, shown by the eastern coyote. Way et. al (2010) said that eastern coyotes tend to only breed with other eastern coyotes, but failed to produce any empirical evidence for such a claim. The only thing that Way et. al showed was that the eastern coyote pack is made up of a breeding pair and eastern coyote
offspring, never identifying the breeding pair. This leaves a large gap in the species verification checklist. While canids do not always satisfactorily fill this check, the eastern coyote would be the most egregious violation of selective breeding within a population there is. The eastern coyote has not been shown to selectively breed with other eastern coyotes, which means that currently the gene pool is highly variable with introgression possible from both western coyotes and eastern wolves or grey wolves. This variability makes it very difficult for me to be able to say that this could be classified as a species as opposed to being a subspecies of coyote. I believe that over time, the eastern coyote population will become the dominate canid of the northeast. When this happens, the eastern coyote gene pool will stabilize and become more distinct from other canid populations. Until that happens, the eastern coyote should remain, for all intents and purposes, a hybrid and subspecies of the western coyote.
Image courtesy of Kays et. al 2010 *Rapid adaptive evolution of northeastern coyotes via hybridization with wolves.* This shows the assumed travel route of the two groups of migrating coyotes in the early 20th century, along with the date that travel started/ date of first sighting in area.

FIGURE 2

Image courtesy of New York State Museum (Brown 2009). This is a comparison of a western coyote (*Canis latrans*) skull (left) and an eastern coyote (*Canis latrans x lycaon*) skull (Right). The key difference between the two skulls is that the eastern coyote skull is wider along with teeth that are bigger.
References


The Physics Involved in Administering an Anesthetic
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Abstract

After the discovery of ether as an anesthetic in the late nineteenth century, not much was created to administer the compound to patients except a mouthpiece attached to a single flask. Since this discovery, not only have new anesthetics been uncovered, but along with these discoveries came more devices that have proved a necessity in administering anesthesia. It’s not only important to understand the various types of anesthesia but it’s crucial to understand how each is issued and how they are impacted by laws of physics. In this report, two distinct types of anesthesia will be discussed. The role of physics will be explained through laws and equations using systems in each practice.

Types of Anesthesia

There are two different practices involved with inducing a patient for a procedure. Each method is given differently and performs a different task, but they are both used to reach the same goal; to decrease and/or eliminate pain during a procedure. The first method is injection for the sole purpose of inducing the patient while maintaining a certain state of consciousness. This is called local anesthesia and an example of this would be going to get a cavity filled at the dentist. Since this is considered a minor procedure, the patient can be awake for its entirety. To maintain the patient’s consciousness, the doctor will inject a local anesthetic directly into the site in order to numb the area. If the site of the operation is too deep to penetrate with a needle, or if the area is too large to numb, a different type of anesthetic will be used. The second type of anesthesia is called general anesthesia. This is the anesthesia that a patient was to get if they were going in for a surgery. During general anesthesia, the patient is induced into a state of unconsciousness, for the patient to be completely unaware of the pain they are in. When a patient goes down for surgery, they inhale the medication through a breathing mask. When the operation ceases, the anesthesiologist shuts off the flow of anesthetics and the patient is taken to their room until they regain consciousness. There is a huge difference in this system of anesthesia than the first system. Anesthesiologists not only have to watch the patient’s state of consciousness during the procedure, but also must keep an eye on the state of the patient’s vital life functions.

Local Anesthesia

When being administered local anesthesia, also known as regional anesthesia, a numbing agent is injected into the area of operation in order to numb the nerves. The anesthetics commonly known as Novocain and Lidocaine numb the nerves, causing the sensation in the nerves to subside. This makes it possible for a procedure to proceed without causing any pain to the receiver. Essentially, the nerves become blocked, prohibiting any signals to go to or from them. This in no way affects the awareness and sensory recognition of other areas of the body except for the procedural site. The process of giving a local anesthetic requires a syringe and a needle and thereof requires the use of physics to be completed.

The use of a syringe to administer local anesthesia incorporates properties of physics in the process. The pressure-volume relationships need to be addressed using the equation \( P = \frac{F}{A} \). To find the pressure of a syringe, the surface area of the plunger as well as the force exerted by the thumb onto the plunger need to be known. When talking about a 2-ml syringe, the surface area of the plunger attached to it should be about \( 5 \times 10^{-5} \) meters squared. If the force exerted by the
thumb onto the plunger is measured around 30 newtons, substitutions for this equation can easily be made. Plugging $5 \times 10^{-5}$ meters squared in for $A$ and 30 newtons in for $F$, yields a pressure of about 600 kiloPascals (kPa). It’s important that the force placed on the plunger by the thumb is very minimal because too much force can cause the glass of the anesthetic cartridge to crack. Above all, the knowledge of physics during the administration of a local anesthetic is not only helpful but it is essential to the well-being of the patient.

The Anatomy of an Anesthesia Machine

The design of an anesthesia machine can be very complex but, this is only because the duties they are designed to perform can be vital to patient lives. The four purposes of this machine include correctly combining anesthetic gases, providing oxygen to the patient, enabling ventilation for the patient and lastly minimizing potential anesthesia linked risks that might surface throughout the procedure. Every anesthesia machine is built to hold pressurized gases that are dispensed by connecting cylinders and tubes. In the years since Boyle gave rise to the first anesthesia machine, only five elements have stuck around and are now a part of the modern machine. The five components of Boyle’s original design that are still present today include a high-pressure supply of gas, oxygen cylinder pressure gauges, flow meters, an ether vaporizer and a breathing system. This mechanism was specifically designed to hold two O2 and two N2O cylinders. The items that hold these cylinders in place include the hanger yoke, which supports each cylinder and provides a tight seal ensuring flow, and the Pin Index Safety System (PISS), which prevents accidental mix up of cylinders. The observation of pressure is crucial when using this machine so as a result, a pressure gauge is placed on top of the hanger yoke in order to read the pressures of the cylinders. Pressure regulators are organized towards the bottom of the hanger yoke to keep each cylinder at a low and constant pressure of about 45 to 60 pounds per square inch gauge (PSIG). These pressure regulators are then connected to the flow meter, located at the back of the machine, through high pressure piping. The job of the bar at the back of the machine is to provide support to the flow meter as well as to the vaporizers. The last arrangement that completes this machine is located at the end of the back bar. This portion is known as the common gas outlet and its job is to connect the breathing circuits to the machine, allowing the anesthetic gases containing O2 to reach the patient. The anesthesia machine overall allows for a licensed professional to deal with gases under immense pressure conveniently and safely.

The Role of Pressure

The gas laws are a series of laws founded through experiments conducted throughout the seventeenth and eighteenth centuries. In the years that followed, they proved crucial in the finding and use of anesthesia. Since everything is organized of atoms and molecules, understanding how these atoms move about and transfer from a solid, to a liquid and eventually to a gas is beneficial. The heat gives way to these phase changes and causes vibrations within the molecules. If enough heat is added to an object, the interlaced structures of the substance can break down due to the force that the molecules exert on each other. This force is known as the Van der Waals force. With more extensive heating, the increase in kinetic energy allows the molecules to subdue the Van der Waals’ forces, eventually causing the liquid to boil and produce a gas. When the molecules are in a full, gaseous phase, they move throughout the space of the container causing continual collisions and something known as pressure.
Pressure serves as one of the basic grounds of anesthesiology. Pressure comes into play when talking about anesthesia because it is essential in moving gases through a space. This machine allows a patient to receive a mixture of oxygen, nitrous oxide and general anesthetics safely while being watched by a licensed professional\(^4\). But these volatile substances would have no way of moving through the machine to reach the patient if it weren't for the laws of physics that were incorporated into its design some time ago. The blueprint of a pneumatic portion of the anesthesia machine can be explained through three main sections; the high-pressure system, the intermediate pressure system, and the low pressure system (Figure 3)\(^10\). But before going into depth about what is involved in each pressure system, it is important to understand the basics of pressure and its relationship with volume and temperature.

Pressure (P) plays an important role in the phase change process and is expressed in the units of Pascals (Pa)\(^5\). When dealing with a gas, Pascal’s Principle explains how the pressure is equal to the force divided by the unit area. (P=F/A). Boyle’s Law demonstrates how the relationship between the pressure and volume of a gas fluctuate when the temperature stays the same\(^5\). This law states that the pressure of a gas increases while the volume decreases when the gas has a constant temperature\(^5\). When the volume of a space is reduced, the molecules have a shorter distance to travel within the walls, which causes an increase in pressure (Figure 4). On the other hand, Charles’ Law demonstrates how the temperature and volume of a gasiffer when the pressure remains steady (V/T=P constant)\(^5\). Due to an increase of kinetic energy that comes with the increase in temperature, the container must expand for the molecules to have consistent collisions (Figure 5). Thus, these two laws lead into the Gay- Lussac’s Law, which declares how pressure and temperature differ when the volume of a gas remains constant (P1/T1=P2/T2)\(^5\). If the volume of a container is kept constant, the rise in temperature will cause the kinetic energy between the molecules to increase (Figure 6). As they hit the walls of the container at more rapid frequencies, a greater pressure within the container is achieved. The Ideal Gas Law equates how pressure, volume and temperature are all related using just one equation (Figure 7). This equation states that PV=nRT, where n is the number of molecules and R is the universal gas constant of 8.3145 Jmol^-1K^-1\(^5\). Now using this knowledge of the four different laws, the three pressure systems of the anesthetic machine can be further investigated.

The High, Intermediate and Low Pressure Systems

The first section of the anesthesia machine is called the high-pressure system. This is the system that deals specifically with the parts of the mechanism that receive gases at cylinder pressures\(^6\). This cylinder pressure is generally measured with an item called Bourdon’s pressure gauge. When this gauge is exposed to a gas, a pliable tube inside the gauge straightens, moving the needle pointer in the gauge (Figure 8)\(^6\). The key component involved in the high-pressure system that physics plays a huge part in are the pressure regulators. These regulators make it possible to keep a constant flow of gases by decreasing the high pressure of the cylinders to a low and constant pressure\(^5\). The regulators work using the basic principle of physics, Pascal’s Principle, that rearranged states that the force equals the pressure multiplied by the area\(^4\). A spring is used to keep the force consistent and as the area of the regulator is increased, the pressure of the gas will automatically decrease (Figure 9). It is important that this does not happen because the output pressure will be greatly modified by the cylindrical pressure changes that occur\(^6\). To avoid this,
the force applied by the springs has to be kept high, causing the changes in cylindrical pressure to have no effect on the decreased output pressure. Luckily, the manufacturing companies automatically fix the output pressure of those regulators, giving them the obvious name of “fixed pressure regulators”\textsuperscript{10}. Because of this factor, the pressures are drastically reduced from their original PSIG readings. The regulators reduce the original pressure of the O2 cylinders from 2000 PSIG to a PSIG of about 45 to 60\textsuperscript{10}. The N2O cylinders start out with a pressure of 750 PSIG and are reduced to 45 to 60 PSIG as well\textsuperscript{10}. It is fundamental that the high-pressure system works to keep the pressure in the line system constant when the pressures in the cylinders vary.

The second portion of the anesthesia machine is called the intermediate pressure system. This system deals with the gases that are received from the pressure regulator at the reduced pressures talked about above\textsuperscript{10}. This is also where the master switch for the pneumatic portion is. This switch controls different aspects of the pneumatic system and when this switch is turned off, all function of the intermediate pressure system will drop to zero\textsuperscript{3}. A major section of this system deals with the oxygen pressure failure devices. These devices are incorporated into the system due to errors that occurred in earlier designs. When the anesthesia machine first came out, the oxygen supply would start to deplete without any awareness from the doctor. This resulted in one hundred percent supply of anesthetic gas to the patient. One of the two devices that can be seen today to prevent this is the pressure sensor shut off valve\textsuperscript{3}. This device uses a “threshold principle” meaning the valve is either open or closed. The pressure from the oxygen moves a pin up and thus opens a valve for the N2O\textsuperscript{3}. This means that if the oxygen levels start to drop, the valve will automatically shut, reducing this problem. The second mechanism that was invented is called the oxygen failure protection device\textsuperscript{3}. Instead of going along with the threshold principle, this device works around a proportioning principle. So, when the oxygen portion of the system starts to fall, the pressure of nitrous oxide will start to fall as well. Although these systems drastically decrease the risk of failure, they cannot totally protect the patient from a hypoxic mixture\textsuperscript{10}. This is due to the fact that the anesthetic gas cannot be stopped from flowing through the machine when the oxygen starts to deplete.

The low-pressure system of an anesthesia machine is of the utmost importance since it deals with the overall adjustment of the total gas that flows from the machine to the patient\textsuperscript{6}. Its main priority is to relate pressure drop to flow by measuring the drop in pressure when a gas passes through\textsuperscript{6}. The main component of this system is the flow meter. In modern machines, the flow meter that is most commonly used is the variable orifice flow meter. This specific flow meter deals with fixed pressure differences. Flow meters involve the use of a tube and bobbin, which indicates the increase or decrease in the flow of a fluid (Figure 10)\textsuperscript{10}. There are two types of tubes that can be used for this meter. A single taper tube, which is used either when there is either a high or low flow, or dual taper tube, which requires two tappers in one tube, one taper dealing with rough flow and the other taper dealing with fine flow (Figure 11)\textsuperscript{10}.

The physics of a flow meter involves 4 different equations that develop into one central equation called The Hagen-Poiseuille equation. The flow through a tube involved in low pressure systems is always laminar, meaning that the fluid’s flow is not disrupted, allowing it to flow in equivalent layers\textsuperscript{4}. For a fluid to move along through a tube, a difference in pressure must exist, \( P = P_1 - P_2 \). Because of this laminar flow characteristic, the flow becomes directly proportional to the pressure, allowing a linear relationship to exist, \( Q = P \), where \( Q \) is the flow and \( P \) is the pressure\textsuperscript{4}. 

\textsuperscript{10}
When the diameter of a tube is reduced in half, the flow is ultimately reduced to one sixteenth of its original size, making the flow proportional to the diameter raised to the fourth power. This produces the second equation of \( Q = d^4 \), where \( d \) is the diameter. On the contrary, when you reduce the length of the tube in half, the flow would consequently double, presenting the equation \( Q = 1/L \). Finally, the resistance to the laminar flow is affected by the viscosity of fluid flowing through the tube. the higher the viscosity, the slower the flow of the fluid will be, yielding the equation \( Q = 1/n \), where \( n \) is the viscosity of the fluid. Using these four equations, the Hagen-Poiseuille equation can be derived by combining all of them together and creating one big equation to find \( Q \). This equation looks like \( Q = \frac{\pi Pr^2}{8nL} \). In relation to physics, the Hagen-Poiseuille equation analogy is comparable to the Ohm’s equation that deals with resistance in an electrical circuit. Analogously both equations depict the relationship between flow rate, motivating force and the resistance. In either equation, the motivational force is directly proportional to the flow rate and the resistance is inversely proportional to the flow rate.

When there is a bend present in the tube, turbulent flow is also present due to an increase in velocity. Other components that have the potential of causing turbulence are fluid viscosity and density, as well as the diameter of a tube. To reduce the turbulent flow that appears due to density, helium is often used, more often in respiratory disorders. Helium is a useful element that can decrease the density of a gas, thus reducing the turbulent flow of the fluid. When the turbulent flow decreases, so does the patient’s refusal to breathe. These aspects of turbulent flow come together to form Reynolds number. Reynolds number equals the linear velocity of fluid multiplied by the density and the diameter of the fluid, all over the viscosity. Reynolds number is vital in determining which type of flow is present during the procedure. An indication of turbulent flow requires Reynolds number to be greater than 3000 and an indication of laminar flow requires the Reynolds number to be less than 2000. Critical velocity, happening between 2000 and 3000, is the marker of when flow switches from laminar to turbulent (Figure 12). Within the critical velocity stage, flow going from laminar to turbulent can alter between being directly proportional to the pressure to being proportional to the square root of pressure.

Conclusion

Anesthesia has been and always will be a crucial component to any medical procedure. The two main ways of administering an anesthetic include injection of local anesthesia and inhalation of general anesthesia. It is provided in operating rooms, physicians’ offices, dentist offices and outpatient facilities. It is a helpful and necessary tool in getting procedures done and ultimately saving patients’ lives. It has allowed medical professionals to exceed in patient care as well as push the boundaries of general procedures to make miraculous medical discoveries. The equations and laws that were established so long ago have led us to the invention of devices and machines that have the capability to administer anesthetics to patients in need.

I believe that anesthesia will continue to help people all over the world. Although I am very optimistic to what medical discoveries anesthesia will allow us to uncover in the future, I do not see any new discoveries regarding new anesthetic drugs. The drugs we have now work very well and have worked well for a hundred years. The developmental cost of finding new anesthetics is very high, and because the need for them is extremely low, I do not foresee new drug development anytime soon. With the help of physics, people have invented new ways to protect against failures...
of anesthesia systems. In the years to come, I have hope that discoveries will be made involving how to eliminate the risk of hypoxic mixtures in the future. I have no doubt in my mind that the devices will be greatly impacted by the properties of physics.
Figures

**Figure 1: Local vs General Anesthesia** - This chart shows the distinct differences between the properties and responsibilities of both local anesthesia and general anesthesia. Available from [http://www.yoursurgery.com/proceduredetails.cfm?br=7&proc=2](http://www.yoursurgery.com/proceduredetails.cfm?br=7&proc=2)

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<td>Area</td>
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<td>Consciousness</td>
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<td>Preemptive use</td>
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<td>Limited non-cooperative patients</td>
<td>Possible</td>
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<td>Poor health patient</td>
<td>Risky</td>
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<td>Care for vital functions</td>
<td>Essential</td>
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**Figure 2: Injection of Local Anesthesia** - An anesthetic, either novocain or lidocaine, being injected directly into the nerve of the procedural site in order to cease sensation. Available from [http://www.slideshare.net/drdhriti/local-anaesthetics-4477248](http://www.slideshare.net/drdhriti/local-anaesthetics-4477248)

**Figure 3: Three Anesthetic Pressure Systems** - The three pressure systems of an anesthesia machine and how they connect to one another. Available from [http://www.ijaweb.org/article.asp?issn=0019-5049;year=2013;volume=57;issue=5;spage=472;epage=480;aulast=subrahmanyam;type=2](http://www.ijaweb.org/article.asp?issn=0019-5049;year=2013;volume=57;issue=5;spage=472;epage=480;aulast=subrahmanyam;type=2)

**Figure 4: Boyle’s Law** - The relationship between pressure and volume while at a constant temperature. As Boyle’s law states, at a constant temperature, volume increases while pressure decreases. Available from [https://en.wikipedia.org/wiki/boyle's_law](https://en.wikipedia.org/wiki/boyle's_law)
**Figure 5: Charles’ Law** - The concept of Charles’ law, showing how a constant pressure yields an increase in temperature as well as an increase in volume. Available from (http://chemistry-reference.com/gases/)

![Charles’ Law diagram](image)

**Figure 6: Gay-Lussac’s Law** - The concept of Gay-Lussac’s law, showing how at a constant volume, the pressure and temperature will increase. Available from (http://chemistry-reference.com/gases/)

![Gay-Lussac’s Law diagram](image)

**Figure 7: Ideal Gas Law** - The relationship between all of three gas laws and how they can combine. This provides an illustration as to how volume, temperature and pressure relate using one equation. Available from (http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/idegas.html)

![Ideal Gas Law diagram](image)

**Figure 8: Bourdon’s Pressure Gauge** - Bourdon pressure gauge, illustrating where the pressure connection is and how the flexible tube connects to the pointer in order for the gauge to read the pressure. Available from (http://firecontrolman.tpub.com/14104/css/Bourdon-Tube-Differential-Pressure-Gauge-233.htm)

![Bourdon’s Pressure Gauge](image)

**Figure 9: Pressure Regulator** - How the pressure regulator operates, showing the spring applying a counter pressure to the high pressure that enters, creating a low pressurized gas that exits. Available from (http://www.parklandscientific.com/anesthesia_accessories.aspx)

![Pressure Regulator](image)
Figure 10: Flow Meter - A bobbin that floating either up or down a tapered tube in a flow meter. Available from (http://healthprofessions.udmercy.edu/programs/crna/agm/04.htm)

Figure 11: Tapered Tubes - On the left, dual taper tube and the nature of flow each taper deals with. On the right, a single tapered tube dealing with either a high or low flow. Available from (https://www.studyblue.com/notes/note/n/anesthesia-machine-and-vaporizers/deck/14080283)

Figure 12: Reynolds Number - Various types of flow by which can be determined using the equation to derive Reynolds number. Establishing Reynolds number will decide which flow is present in the tube. Available from (http://www.anesthesia2000.com/physics/Chemistry_Physics/physics19.htm)
Resources

   http://ortoday.com/anesthesia-in-the-perioperative-setting/
   http://clinicaldepartments.musc.edu/anesthesia/
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5. Gas Laws. [accessed 2016 Nov 08].
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Hypothyroidism: Conventional Versus Functional Medicine Options

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Dr. Browning
Abstract

Hypothyroidism can be a serious condition that affects every aspect of the human body from metabolism to heart disease to cognitive impairment. It is also a disease that is often overlooked by conventional physicians, but is an area of focus for functional medicine physicians because it is so often missed and has so many vague symptoms. Deciding on the best medical care for a specific disease or symptom can be a difficult decision for a patient. This article is to inform patients on the differences between conventional and functional medicine providers specifically on diagnosing and treating hypothyroidism. There are discrepancies amongst these two groups concerning the type of screening processes, diagnostic parameters and typical prescriptions they recommend for hypothyroidism. The main reviewed studies were from conventional governing agencies for hypothyroidism from many different organizations for screening, diagnosis, and treatment of hypothyroidism. These conventional medicine guidelines were compared to the recommendations of Dr. Hyman, the father of functional medicine, who is the director of the Cleveland Clinic Center for Functional Medicine. Functional Medicine evaluates the whole patient, not just their set of symptoms. It is the type of medicine that the goal is helping patients find optimum overall health. It uses a systems-orientated approach to get to the actual root or cause of the disease instead of just treating the symptoms, which are some complaints of conventional medicine.

The thyroid gland is an important hormonal gland and greatly impacts the metabolism, growth, and maturation of the human body. The thyroid affects the heart rate, the metabolic burn rate of calories, skin maintenance, growth, heat production, fertility, and digestion. (Hershman 2017) The thyroid has the shape of a butterfly or bow tie and is located in the front of the neck just below the voice box. (Figure 1 and 2) The thyroid produces two major hormones, Thyroxine (T4) and Triiodothyronine (T3). (NIH 2015) The body’s command center in the brain, the hypothalamus, detects a need for more thyroid- releasing hormone (TRH) which sends a signal to the pituitary gland to make more thyroid stimulating hormone (TSH), which then sends a message to the thyroid to make more T4 along with a small amount of T3. This is the human body’s hypothalamic-pituitary-thyroid axis.

Hypothyroidism is a specific disease of the thyroid, meaning low thyroid function. This disease can occur from two different pathways, “primary” gland failure of the actual thyroid gland or insufficient thyroid gland stimulation from problems originating in the hypothalamus or pituitary gland. This primary gland failure of the thyroid affects one in 300 persons in the United States (Gaitonde et al. 2012). Primary hypothyroidism has many causes such as dietary iodine deficiency, surgeries of the thyroid, certain drugs or radiation, and an autoimmune cause. This autoimmune cause of hypothyroid is called Hashimotos’s thyroiditis and is the most common cause of hypothyroidism in the United States, which usually increases with age and specifically affects women 5-10 times more than men. (Jonklass et al. 2014) Unfortunately hypothyroidism disease is often overlooked clinically and may potentially contribute to hypertension, high cholesterol, infertility, cognitive impairment, and neuromuscular
dysfunction if left untreated. Although, if discovered quickly and treated, is easily managed with no ill effects. (Gaitonde et al. 2012)

Historically, thyroid disease was discovered by the end of the 19th century. By 1891 Murray subcutaneously injected the first sheep thyroid extract into a patient to successfully relieve severe skin symptoms from hypothyroidism, called myxedema. By 1914, Kendall purified the oral use of thyroid extract that was as effective as the subcutaneous injection. This thyroid extract is still recommended and prescribed today by functional medicine doctors. In 1926, the synthetic thyroxine was created and made available in 1930. It is interesting that it took many years before the synthetic thyroxine became the standard of choice over thyroid extract for treatment by conventional physicians. Today, the treatment of choice for conventional physicians is synthetic levothyroxine monotherapy over desiccated thyroid. (Roberts and Ladenson 2004)

The symptoms for both conventional and functional medicine are similar, although functional medicine has a longer list of symptoms and has the patient check basal temperature also. The list of symptoms for both conventional and functional medicine include but are not limited to; slowed metabolism, fatigue, being overweight, constipation, sensitivity to cold, dry skin, hoarse voice, dry hair, decreased libido, and depression. Symptoms alone do not diagnose thyroid disease because 20% of the population has many of these same symptoms even though they have a healthy thyroid. (Chakera et al. 2012)

Dr. Hyman, the father of functional medicine, states hypothyroidism is an under diagnosed disease and is an increasing epidemic in the United States. Individuals can use his thyroid workbook to track their own symptoms so they can be better informed when discussing this with their doctor. He has a list of symptoms to check off and add up how many symptoms a patient has. These symptoms are similar to the conventional medicine list of symptoms, but he also has individuals record if they have had at least two symptoms, and if so, are recommended to then discuss these symptoms with their physician. He also has them track their basal temperature for a few days. Having a basal body temperature consistently lower than 97.6 degrees is a sign for further research into possible hypothyroidism. He also recommends individuals look at the history of environmental exposures such as heavy metals, dental amalgams, and mold exposures, food allergies, hormonal disorders, chronic stress and nutritional status, which he believes impact thyroiditis.

There are significant discrepancies amongst conventional verses functional medicine concerning the diagnostic parameters and typical prescriptions each recommend for hypothyroidism. The first discrepancy is what blood levels or stage of the disease hypothyroidism is treated. In conventional medicine, it is generally agreed patients should be treated for hypothyroidism when serum TSH is above 10 mIU/L, followed by a confirmation of a combined subnormal free thyroxine (T4). If the TSH is between 4.5-10 mIU/L conventional medicine does not believe patients will benefit from treatment, so the decision is left to each individual physician. Once treatment is initiated, it is then the goal to establish a TSH value of 0.4-4.0mIU/L. (Jonklass et al. 2014) If the TSH is
abnormally high, but the T4 is measured at a normal level, then it is categorized as subclinical hypothyroidism which conventional medicine does not recommend treating but again leaves it to each personal physician to decide. When a patient has subclinical hypothyroidism, several conventional clinical endocrinologists recommend testing the patient for autoimmune thyroiditis by testing anti-thyroid antibodies. When these antibodies are present it ultimately predicts a future diagnosis of autoimmune hypothyroidism. (Garber et al. 2012)

The issue of what level of TSH should be treated and once treatment begins what should be the goal value of TSH is controversial even in conventional medicine. There were four main studies on the prevalence of hypothyroidism completed by The National Health and Nutrition Examination Survey (NHANES III), the Colorado Thyroid Disease Prevalence Survey, the Framingham and British Whickham survey. All of these studies used an upper limit of normal TSH of 4.5, 5.0, 10.0 and 10.0 respectively. Conversely, the National Academy of Clinical Biochemists have suggested that the upper limit of TSH reference range should be lowered to 2.5 mIU/L because 95% of individuals with healthy thyroid levels are below the 2.5 mIU/L. This level specifically pertains to patients presenting with autoimmune thyroiditis because above 2.5 mIU/L, individuals are much more likely to develop future overt or subclinical hypothyroidism. (Garber et al. 2012) These varied TSH levels referred to in these studies by conventional medicine organizations reveal the optimal level of TSH is still unknown.

Unlike conventional medicine, Dr Hyman does not recommend only using blood tests to dictate diagnosis and treatment, but to use good clinical judgment and listen to the symptoms of the patient. (Hyman 2015) This is why functional medicine is called patient-centered health care. He recommends patients check many more blood levels than conventional medicine recommendations. He looks at a comprehensive picture of the thyroid related blood tests, such as TSH, free T3, free T4, thyroid peroxidase and antithyroglobulin antibodies. The TSH level Dr Hyman recommends once treatment is started, for optimal thyroid function is between 1-2 mIU/L (milli-international units per liter) and free T4 is 0.9-1.8 ng/dl (nanograms per deciliter). He also recommends testing for free T3 for a target at 240-450 pg/dl (pictograms/deciliter). He also believes T3 is critical for the fat burning of the mitochondria, “lowers your cholesterol, improves your memory, keeps you thin, promotes regrowth of hair loss, relieves muscle aches, relieves constipation and can even cures infertility for some patients.” Then he recommends testing for thyroid antibodies to check for the most common cause of hypothyroidism. His thoughts on the actual cause of autoimmune hypothyroidism is that gluten in the diet can be the culprit of elevated antibodies. (Hyman 2015)

The second discrepancy between conventional verses functional medicine is what drug and/or supplement is commonly prescribed to treat hypothyroidism. Today, synthetic levothyroxine monotherapy is the standard drug of choice in conventional medicine for the treatment of hypothyroidism. Unfortunately, a significant but small amount of patients treated with levothyroxine do not feel well and in fact have reported a poorer quality of life after taking levothyroxine. (Chakera et al. 2012)
In the guidelines for the treatment of hypothyroidism, thyroid extracts are not recommended in conventional treatment because of potential safety issues concerning high blood triiodothyronine levels and long-term safety outcomes. (Jonklaas et al. 2014) Armour has substantially more triiodothyronine to thyroxine than what occurs naturally in the human body and this is an area of concern. (Chakera et al. 2012) Thyroid extracts are made from the thyroid gland of pigs, which is cleaned and dried to make the extract. Desiccated pig thyroid extract, Armour thyroid, contains thyroxine and triiodothyronine in a ratio of 4:1 versus the human body has a ratio of 14:1 of these hormones. Similar to the combination therapy of thyroid extracts, there has been some research on the combination treatment of levothyroxine with triiodothyronine, but conventional medicine does not recommend this either. This combination treatment has shown some positive results but “a met-analysis of eleven randomized controlled trials involving 1,216 patients concluded that triiodothyronine-levothyroxine combination is not more effective than levothyroxine alone.” (Garber et al. 2012) It is interesting to note thyroid extract prescribed by functional medicine doctors is a natural prescription containing a 4:1 ratio of combined thyroxine and triiodothyronine respectively.

Conventional medical care doesn’t recommend thyroid extracts because the dosage of T3 and T4 may not be standardized, but then discusses research where the dosages of T4 are not standardized between different brand-name compared to generics of the synthetic levothyroxine. The American Thyroid Association, the American Association of Clinical Endocrinologists, and the Endocrine Society all disagreed with the FDA’s assurance that the generic and brand-name levothyroxine preparations were bioequivalent and recommend that physician’s be very cautious when switching patients back and forth between the two. They recommended the physician repeat testing of TSH and T4 within six weeks to assure the different forms of the levothyroxine are consistent in treatment. Synthetic levothyroxine also may have absorption issues amongst different brand name verses generic manufactures, so it seems both drugs have standardization problems. (Gaitonde et al. 2012)

The treatment under a functional medicine doctor will include nutritional screening for Vitamin D and selenium deficiencies in the blood and then supplementation if required. A functional medicine doctor may also recommend herbs to help normalize thyroid function, which have been used to heal patients for centuries in other countries. The American Thyroid Association does not recommend the use of dietary supplements or nutraceuticals for treatment of hypothyroidism. A dietary supplement is defined as a product that is intended to supplement the diet and contains “a mineral, vitamin, herb or other botanical, amino acid or any dietary substance used to supplement the diet.” (Jonklaas et al. 2014) Dr. Hyman states that the balance of T4 and T3 can be “disrupted by nutritional deficiencies, toxins, allergens, infections, and stress.” (Hyman 2015) This statement contradicts conventional medicine.

Dr. Hyman recommends starting the ultimate health goal with a self-assessment of numerous screening questions of lifestyle and symptoms related questions for the patient to have an introspective experience and answers to the questions steers the patient to decide for themselves what areas need to be discussed with their conventional provider.
or if the doctor is not responsive to the requests, to find another doctor from a list provided in his book or get some of the blood tests completed that are available now without a doctor’s order. Thyroid related blood tests, such as TSH, free T3, free T4, thyroid peroxidase and antithyroglobulin antibodies can all be ordered now by a patient without a doctor’s order. This ability to order blood tests, puts more control into the hands of the patient about their health.

Critics of conventional medicine admit conventional medicine has it’s place in the medical care system. Conventional based medicine is critical for emergency situations when a patient is in an accident or has an acute life-threatening situation. It is a science based or evidence based medicine that has its foundation and guidelines in research. But there are concerns about conventional medicine. Unfortunately, there is politics involved in everything in the United States and there is no doubt “big pharma” has a huge impact on what research evidence doctors receive about the efficacy of different drugs and influence what drugs doctors recommend. Doctors are swooned by drug representatives with free gifts and free samples of new more expensive drugs. Physicians attend continuing education seminars sponsored and paid for by the drug companies that don’t always tell the whole truth about research related to new drug. (Miller 2007) Other opinions about the conventional health care in the United States is that we have specialized our health care into so many specific branches, making it difficult to actually pinpoint or narrow a diagnosis. Unfortunately, the improvement in the United States health has not improved with increased number of drugs and the millions spent on research. We are living longer but the quote we live to short and die to long is applicable. The question arises if conventional medicine is actually making us healthier. I only see our young becoming more obese and sicker at a younger age.

The typical conventional doctor puts the patient with high blood pressure on a calcium-channel blocker, but down the road causes heartburn, so the patient goes back to the doctor and instead of changing the drug that caused the heartburn, the doctor will prescribe yet another drug, an antacid. So now your stomach has less acid but now can’t absorb vitamin B12 and so the patient gets nerve pain and goes back to the doctor who prescribes nerve medicine. This is what functional medical doctors believe is wrong with our conventional medical system. Unfortunately conventional doctors get most of their continuing education in medicine from the drug representatives. (Miller 2007) Dr. Hyman said after graduating medical school he did what he was taught and focused on finding what drug fits the symptoms of the patient instead of trying to find the cause of the symptom. I know when I first went to the doctor about feeling fatigued and depressed, he immediately wanted to put me on an antidepressants.

Functional Medicine evaluates the whole patient, not just their set of symptoms. It is the type of medicine is that its goal is to help patients find optimum overall health. It uses a systems-orientated approach to get to the actual root or cause of the disease instead of just treating the symptoms. The physicians spend more time with the patients listening and find ways to improve the overall health of the patient by first looking at basic needs of the body such as sleep, nutrition, exercise, stress levels and many other areas. Functional medicine doesn’t believe in just making a diagnosis and finding the
corresponding drug that matches it. If someone develops high blood pressure from being overweight and sedentary lifestyle and goes their doctor, more than likely the doctor will prescribe a drug to lower the high blood pressure with no comment on the patient being overweight or sedentary. If you step on a pin and your toe hurts, it doesn’t matter how much pain-killer you take, the best way to fix the problem is to find the cause and take the pin out of the toe.

Future therapies definitely point to more research regarding standardized combination triiodothyronine with levothyroxine therapy regarding a similar ratio compared to the biochemical level of healthy subjects. Also gene specific research needs to occur for which type of medicine a patient will respond to most efficiently. (Chakera et al. 2012) There have been studies that show an association between certain genes and TSH levels and also that some patients may need an individual reference range for TSH rather than one for the general population reference range. (Chakera et al. 2012)

All the varied reference ranges different entities make of these blood tests are based on normal population averages, but this has to make someone question whether these are optimal levels or just skewed norms that have increased over time from a population increasing in hypothyroid disease. For example, today the average Body Mass Index (BMI) of an American is much higher than the average BMI compared to 50 years ago.

In my experience, after being on Armour thyroid extracts for a few years I was having problems sleeping and some tremors in my hands, which are symptoms of too much T3. My endocrinologist put me on a compounded T3/T4 prescription of a ratio of 1:20 and this has fixed the sleep and tremor issue. So it was interesting to read compounded T3/T4 preparations are not recommended by conventional medicine because there has not been enough studies to confirm a positive outcome for hypothyroidism and also it would be difficult to standardize exact protocol for all compounding pharmacies. (Jonklass et al. 2014) So any research would only represent that exact pharmacy and would not be representative of any other pharmacy.

As an older woman, I want to always function at my optimum status. It’s a shame the medical community overlooks this important disease that impacts a woman’s energy, metabolism, and daily life. It is my opinion that more evidence based research needs to be completed on the alternative treatments of hypothyroidism. But as a woman that wants to always function at my optimum level I believe in functional medicine guidelines and want the screening completed at the earliest time and not wait until I’m actually sick or have heart problems caused by my hypothyroiditis. I think many Americans wait until they have a life threatening crises before they are forced to manage their health; by then it’s too late. I want to prevent disease and live at an optimum level for as long as possible. I hope that functional medicine will start growing all across the country and motivate patients to take more control of their health and prevent disease instead of waiting to become sick before being motivated to change unhealthy habits.
Figures

Figure 1: Thyroid Gland - National Library of Medicine [Internet] [cited 2017 Mar 8]. Available from: https://www.ncbi.nlm.nih.gov/pubmedhealth/PMHT0022083/

Figure 2: How does the thyroid work? - National Library of Medicine [Internet] [cited 2017 Mar 8]. Available from: https://www.ncbi.nlm.nih.gov/pubmedhealth/PMH0072572/?reoirt=printable
References
Oral Contraceptives Reduce Risk of Ovarian Cancer

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April 20, 2017

Dr. Browning
Abstract

It has been found that oral contraceptives can reduce the risk of ovarian cancer. Death rates of ovarian cancer can be reduced drastically with the specific uses of prevention strategies. One of these methods is taking oral contraceptives. As cancer researchers begin to develop new understandings of the molecular level of ovarian cancer, they are stating that they strongly recommend this strategy method of prevention to the public and health care providers. The Society of Gynecologic Oncology determined that this is a scientific breakthrough. With the proper use of oral contraceptives, the likelihood of women being diagnosed can be dramatically decreased as well as mortality rates of this silent disease.

Birth control was brought into the public eye around fifty years ago. Today more than 100 million women are using a form of oral contraceptive. Over the years researchers have found that using a form or oral contraceptive can dramatically reduce the risk of ovarian cancer, although the effects of taking oral contraceptive will highly depend on how long the oral contraceptive is being used to get a significant reduction in the risk of ovarian cancer. It has been found that oral contraceptives can reduce the risk of ovarian cancer. Death rates of ovarian cancer can be reduced drastically with the specific uses of prevention strategies. One of these methods is taking oral contraceptives. As cancer researchers begin to develop new understandings of the molecular level of ovarian cancer, they are stating that they strongly recommend this strategy method of prevention to the public and health care providers. The Society of Gynecologic Oncology determined that this is a scientific breakthrough. With the proper use of oral contraceptives, the likelihood of women being diagnosed can be dramatically decreased as well as mortality rates of this silent disease.

In 1914 the term “birth control” was coined by a woman named Margaret Sanger. In 1916 Sanger opened her first birth control clinic in Brooklyn New York in hopes of revolutionizing women’s lives. Unfortunately ten days later Margaret Sanger was arrested and her clinic was shut down due to violating the Comstock law which outlawed contraception and was said to be overly obscene. For the next forty-four years birth control was still outlawed until 1960, when the Food and Drug Administration approved for sale of this oral contraceptive. By 1968 woman throughout the United States had a variety of birth control pills to choose from that worked best with their body. At this point in time more than thirteen million women were using a form of contraceptive. Margaret Sanger is also known as founder of Planned Parenthood. Through Planned Parenthood it made it easy for woman to obtain oral contraceptives. Alongside Sanger is another woman, Jennifer Erickson a twenty-seven years old pharmacist in Seattle Washington that fought for women to obtain not only contraceptive but for affordable contraceptive. In 200 she was able to convince United States employers to cover contraceptive on insurances plans. These two women impacted millions of lives by helping revolutionize and enhance the use of contraceptive. Over the past 100 years birth control has been dramatically revolutionized, changing women’s lives forever.

Over the last 100 years birth control has revolutionized radically. From oral contraceptives to implants birth control has been an incredible scientific advancement. The first ever documented form of birth control dated back to 1850 B.C. in Egypt. Known as the Egyptian pessary, was a makeshift contraceptive device for women. A bizarre mixture consisting of
crocodile dung, honey and sodium carbonate was used in the form of insertion. Fast forward to 1920 the insertion method was still being used but the contents of the concoction were different and much more dangerous. The most popular contraceptive for women of the 1920’s was Lysol disinfectant, which today is a widely known cleaning staple in most American households. Lysol disinfectant was broadly advertised as a feminine hygiene product including affirmations from countless doctors. The American medical association later did an investigation over this feminine hygiene product and concluded that it did not work as a contraceptive. The investigation revealed that it had harmed several women leaving inflammation, scarring, burns and possible result in death. 1960 chemist Carl Desires discovered synthetic progesterone and norethindrone leading to discoveries of other forms of synthetic progesterone and estrogen, there for creating the first ever FDA approved birth control pill, Enovid. This was a mixture of morthynodre and mestranol. This pill was widely available to the public for use. Following the next two years after the release of this pill more than one million women were taking it. Researchers soon discovered than the man made synthetic estrogen hormone had an alarming increase risk of serious health issues therefore advising users of this drug to take with extreme caution. Next came the first hormone shot, Depo-Provera in 1992. This shot was used to prevent pregnancy for months at a time, this first form of contraceptive that was not used daily or during the time of intercourse. Shortly after the introduction of the hormone shot cam the emergency contraceptive in 1998. It was nicknamed “The morning-after pill” which can be taken up to seventy-two hours after unprotected sex. As of today in 2017 there are almost 300 contraceptives to choose from ranging from implants to daily oral contraceptives.

“Estrogen and progestogens are essential steroid hormones. In women, they are required for normal development of female sex organs and secondary sex characteristics, regulation of the menstrual cycle and reproduction, and many other essential physiological functions in the bones, brain, breasts, adipose tissue, and uterus.” (Harvard University) The two most common forms of birth control today contain various versions of synthetic hormones such as estrogen and progestogen which is called the combined oral contraceptive pill. The other is known as the mini pill which holds only progestogen. These two forms of contraceptives vary in synthetic formulations. Regardless of the form the task of the synthesized hormones are to suppress or prevent ovulation in a woman. During a monthly menstrual cycle the hormones estrogen and progestogen increase significantly. This sends a signal to the pituitary gland to release follicle stimulating hormones (FSH) and luteinizing hormone (LH), which can stimulate the ovary to ovulate which releases a mature egg. Birth control pills catalyze the concentration of the amount of estrogen and progestogen being released during mid cycle, putting a hold on the release of FSH AND LH from the pituitary gland to stop fertilization of a mature egg.

Ovarian Cancer is a very difficult disease to detect and to treat. It is know as “the silent killer” Ovarian cancer has a distinctive biology and behavior at a cellular and molecular level. It presents itself in such a manner that most side effects are not alarming to a menstruating female. Bloating, gastrointestinal irritation, fatigue and loss of appetite are the most common symptoms of ovarian cancer. These are also the effects of a monthly menstrual cycle. It often starts as a cystic mass present in the pelvic region. By the time the cancer is detected it has metastasized to other regions of the body, creating toxic fluid filled tumors that wrap around vital organs advancing the staging of the cancer and making treatment much more difficult. Ovarian cancer is heterogeneous meaning it is both multiple genetic which means the cancer can be
genetic by being passed down from your mother if she carries the expressed gene and epigenetic
which arises from nongenetic influences on a gene expression. Although it is not yet clear how
changes of are selected during the process of tumorigenesis if it is multiple genetic or epigenetic.
One of the most common mutation abnormalities in ovarian cancer is the loss of function of the
TP53 gene. “TP53 gene provides instructions for making a protein called tumor protein. This
protein acts as a tumor suppressor. This regulates cell division by keeping cells from growing
and dividing to fast or in an uncontrolled way” (NLM) this mutation is seen in about 60-80% of
all ovarian cancer cases. “Approximately 10 percent of cases of invasive epithelial ovarian
cancer are hereditary, occurring predominantly in women with germline mutations in the
BRCA1 or the BRCA2 gene The lifetime risk of ovarian cancer is approximately 45 percent
among women with BRCA1 mutations and 25 percent among those with BRCA2 mutations1 -3
Current strategies for reducing the risk of ovarian cancer in women carrying BRCA1 or BRCA2
mutations include prophylactic oophorectomy and ultrasound screening, but the extent of risk
reduction associated with either of these procedures is not known.4 A third potential strategy is
chemoprevention. The risk of ovarian cancer is reduced by 50 percent or more in unselected
women with long-term use of oral contraceptives.5 An oral contraceptive agent is appealing as
a possible preventive treatment, because these agents are well tolerated and their side effects are
known. To evaluate the potential benefit of oral-contraceptive use in women at high risk for
ovarian cancer, we studied 207 patients with BRCA1 or BRCA2 mutations and ovarian cancer
and 161 of their sisters, who served as controls.” (Proquest)

In 2008 The Collaborative Group on Epidemiological Studies of Ovarian Cancer
conducted an experiment involving women from around the world who have had ovarian cancer
and those who have not. The Group of women who had ovarian cancer were given birth control
after treatment to decide that if birth control can reduce the risk of their cancer returning. The
group who has not had ovarian cancer was also given birth control to determine if taking this
could prevent them from getting ovarian cancer or if it could cause it. Here are their findings and
results:

“Methods Individual data for 23,257 women with ovarian cancer (cases) and 87,303
without ovarian cancer (controls) from 45 epidemiological studies in 21 countries were checked
and analysed centrally. The relative risk of ovarian cancer in relation to oral contraceptive use
was estimated, stratifying by study, age, parity, and hysterectomy.
Findings Overall 7,308 (31%) cases and 32,717 (37%) controls had ever used oral
contraceptives, for average durations among users of 4.4 and 5.0 years, respectively. The median
year of cancer diagnosis was 1993, when cases were aged an average of 56 years. The longer that
women had used oral contraceptives, the greater the reduction in ovarian cancer risk (p<0.0001).
This reduction in risk persisted for more than 30 years after oral contraceptive use had ceased but
became somewhat attenuated over time—the proportional risk reductions per 5 years of use were
29% (95% CI 23-34%) for use that had ceased less than 10 years previously, 19% (14-24%) for
use that had ceased 10-19 years previously, and 15% (9-21%) for use that had ceased 20-29
years previously. Use during the 1960s, 1970s, and 1980s was associated with similar
proportional risk reductions, although typical oestrogen doses in the 1960s were more than
double those in the 1980s. The incidence of mucinous tumours (12% of the total) seemed little
affected by oral contraceptives, but otherwise the proportional risk reduction did not vary much
between different histological types. In high-income countries, 10 years use of oral
contraceptives was estimated to reduce ovarian cancer incidence before age 75 from 1.2 to 0.8 per 100 users and mortality from 0.7 to 0.5 per 100; for every 5000 woman-years of use, about two ovarian cancers and one death from the disease before age 75 are prevented. Interpretation Use of oral contraceptives confers long-term protection against ovarian cancer. These findings suggest that oral contraceptives have already prevented some 200,000 ovarian cancers and 100,000 deaths from the disease, and that over the next few decades the number of cancers prevented will rise to at least 30,000 per year.” (ESOC)

While researchers have been studying and regulating ovarian surface epithelial cells, the relationship between hormones and steroids suppressing ovarian carcinogenesis leaves researches uncertain. With the evidence that has been documented the conjecture shows that in particular, synthetic estrogens have more of a tendency to initiate ovarian cancer cells. Progesterone on the other hand offers protections against ovarian carcinogens developing and metastasizing. Synthetic progesterone is much like the progesterone found in women during pregnancies. This hormone suppresses the ovaries causing monthly ovulation to be suppressed as well. When the ovaries are suppressed by this hormone cells are much less likely to develop cancer.

As of 2017 Ovarian cancer still remains the top leading cause of death in women from gynecological malignancies. According to The American Cancer Society ver 23,300 woman will be diagnosed with ovarian cancer and 13,900 of those woman will lose their battle with this cancer just this year alone. Oral contraceptives that are found to be the most effective in reducing the risk of ovarian cancer are those containing pure progesterone. The pure progesterone was found to be the most effective through several medical studies. As researches dig deeper into their studies they hope that over the next few decades oral contraceptives can help prevent up to 30,000 cases. Although it is not a cure, this is a small step towards reducing the risk of contracting ovarian cancer and potentially saving someone's life.
### Figures

<table>
<thead>
<tr>
<th>Year</th>
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<tr>
<td>1960s</td>
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- Enovid-10 is introduced in the US by Searle  
- Anvolar® (Schering) is introduced in West Germany (the 1st oral contraceptive in Europe) and Australia  
- Ovovist® (VEB Jenapharm) is the 1st hormonal contraceptive introduced in East Germany  
- In Europe, the pill is only recommended for regulating menstrual disorders and in married women |
| 1970s |  
- The "mini pill"—i.e., the progestin-only pill—is introduced  
- Initial reports are published correlating COCs and thromboembolic events |
| 1980s |  
- Biphasic pills are introduced, allowing two dose levels of progestin during a woman's menstrual cycle  
- Three triphasic pills are introduced  
- Use of high-dose estrogen pills is reduced to 3.4% of the oral contraceptive market  
- FDA recognizes several possible health benefits of pill use, including a decreased incidence of ovarian and endometrial cancers  
- FDA committee states that the benefit of the pill may outweigh the possible health risks in healthy, non-smoking women over 40 years |
| 1990s |  
- Low-dose oral contraceptives are introduced  
- Low-dose estrogen is added to the placebo week in some COCs |
| 2000s |  
- Extended - (24/4, 84/7) and continuous-regimen COCs allow women to experience fewer or no yearly menstrual cycles  
- New progestins (e.g., Dienogest, Drospirenone, Trimeterysone, Nortestone, Norelgestromin) are introduced and/or under investigation  
- Non-oral combined hormonal contraceptives, e.g., the vaginal ring and transdermal patch, are available |
| 2010s |  
- Use of natural estrogens (17β-estradiol and estradiol valerate) may be used in COC regimens  
- New progestins are investigated  
- Genetic and proteomic targets are under investigation for contraception |
Figure 2 ~ How birth control pills work. (A) Birth control pills maintain high levels of estrogen and progestogen in the bloodstream and inhibit release of hormones FSH and LH by pituitary gland, thus preventing ovulation. (B) Progestogen in the pills thickens the cervical mucus. Consequently, sperm cannot penetrate the uterine wall to reach the egg.
References


Life
Benyamin Rogie
April 20, 2017
General Chemistry II, Section 36396
Professor Julie Olander
Abstract

A long adventurous journey of knowing made possible by the generation of searchers. In the following paragraph, an abstract of what is known about life will be discussed. Although in this short discussion will be impossible to tackle all the questions concerning the creation of everything we know as reality, an attempt will be made to address certain fundamental questions related to life.

Introduction

“According to the Boshongo people of central Africa, in the beginning, there was only darkness, water, and the great god Bumba. One day Bumba, in pain from a stomach ache, vomited up the sun. The sun dried up some of the water, leaving the land. Still, in pain, Bumba vomited up the moon, the stars, and then some animals. The leopard, the crocodile, the turtle, and, finally man. This creation myth, like many others, tries to answer the questions we all ask. Why are we here? Where did we come from?” (Hawking's).

Once human species are standing on two feet, their eyes were no longer fixated on the ground then they were free to look up in wonder. “Where did I come from” was probably the first question man asked. The answer was so important to mankind that they started making up religions and Gods as an explanation. Religions were explaining everything by using nothing, providing nothing, proving nothing. Until heroes stepped in. They dared to challenge the present thought. The adventure starts, the adventure of replacing believing with knowing and facts with myths. While in the age of no freedom of thought, expressing an idea that did not confirm to traditional belief could easily cost their life. Natural born rebels, thinking about the unbounded infinite universe greater than Gods. Huge hunger of knowing made them dare to question everything, test ideas by experiment and observation build on those ideas that pass the test and reject the ones that fail and follow the evidence wherever it leads.

Elements

It is certainly known that universe exists, however, this knowledge alone has not satisfied mankind's quest for further understanding. “Astronomers Edwin Hubble and Milton Humason in the early 20th century discovered that galaxies are moving away from the Milky Way. More to the point: Every galaxy is moving away from every other galaxy on average, which means the whole universe is expanding. In the past, then, the whole cosmos must have been much smaller, hotter and denser.” (Francis). Big Bang broadly refers to the theory of cosmic expansion and the hot early universe. However, sometimes even scientists will use the term to describe a moment in time—when everything was packed into a single point” (Francis). Everything in the universe, all energy, and the matter were born from a point smaller than a single atom.

“space, time, energy and matter all came into being at an infinitely dense, infinitely hot gravitational singularity, and began expanding everywhere at once. Current best estimates are that this occurred some 13.7 billion years ago, although you may sometimes see estimates of anywhere between 11 and 18 billion years.” (“Big Crunch”)

“The story begins at the beginning, as in the Big Bang. That is when, astrophysicists say, all the hydrogen in the universe came into being. Initially, it was just protons, and then, as the young universe expanded and cooled, these became bound to electrons, forming
hydrogen atoms. The very hydrogen atoms in the H2O that makes up over half your body were born then.” (Tyson).

“The Big Bang also churned out helium, the next lightest element. You don't have any helium in you unless you just sucked the gas out of a birthday balloon. But helium is the second most common element after hydrogen. Together they make up more than 98 percent of the matter in the universe. (Luminous matter, that is; dark matter is a whole other story.) A smattering of lithium (element 3) and one or two other of the lightest elements also formed in the Bang, but these were negligible. (Tyson). They get so hot that the nuclei of the atoms fuse together deep within them to form new atoms. Everything else, every other chemical element, including carbon, oxygen, nitrogen, and all the other elements essential for your life, is thought to have been fabricated in stars.” (Tyson).

“Every single atom in your body—the calcium in your bones, the carbon in your genes, the iron in your blood, the gold in your filling—was created in a star billions of years ago. All except atoms of hydrogen and one or two of the next lightest elements. They were formed even earlier, shortly after the Big Bang began 13.7 billion years ago”. (Tyson).

“It's true, according to astrophysicists. You and everything around you, every single natural and man-made thing you can see, every rock, tree, butterfly, and building, comprises atoms that originally arose during the Big Bang or, for all but the lightest two or three elements, from millions of burning and exploding stars far back in the history of the universe. You live because stars died; it's that simple.” (Tyson). Initial atoms got so hot that the nuclei of the atoms fuse together deep within them to form new atoms.

“Over time, molecular clouds of gas and dust out in deep space develop from those strewn elements and begin to contract under their own gravity. Such clouds are almost all hydrogen and helium, but they've got a scatter of heavier elements, too. And the most abundant elements begin to assemble into molecules, simple ones like water and more complex ones like the sugar glyceraldehyde.” (Tyson). The big bang is a story of us. The oxygen we breathe, Calcium in our bones, the iron in our blood all was cooked in hearts of ancient stars. Everyone living thing made of star stuff. We are all made of star stuff.

What does it mean to be alive?

Plants are alive, the fish in a fish bowl moving around is alive. However, rains falling from the clouds is not alive. The computers are not alive, and neither is a couch or table. The parts of a chair that are made of wood were once alive, but they are not any longer. What is it that defines life? How can we tell that one thing is alive and another is not? People have an intuitive understanding of what it means for something to be alive. To make this separation between living and nonliving things, we must come up with a list of properties that are, as a group, uniquely characteristic of living organisms and only living ones.

“In 1944, the physicist Erwin Schrodinger defined living matter as that which "avoids the decay into equilibrium." This definition refers to the Second Law of Thermodynamics, which says that entropy always increases. Entropy is often referred to as chaos or disorder, but really it is the spreading out of energy towards a state of uniformity. This law can be seen in a cold glass of water that slowly grows warmer until it is the same temperature as the surrounding air. Because of this trend toward equilibrium, the Universe eventually will have a complete lack of structure, consisting of evenly spread atoms of equal warmth. But living
things, said Schrödinger, are able to postpone this trend. Consider: while you are alive your 
body maintains its structure, but once you die your body begins to break down through 
bacterial action and chemical processes. Eventually the atoms of your body are evenly spread 
out, recycled by the Earth. To die is to submit your body to the entropy of the Universe. 
Living things resist entropy by taking in nutrients. This biochemical process of taking in 
energy for activities and expelling waste byproducts is known as a "metabolism." If 
metabolism is a sign of life, scientists can look for the waste byproducts of a metabolism 
when searching for life on other worlds." (Mullen)

All living things share life processes such as growth and reproduction. Most scientists 
use seven life processes or characteristics to determine whether something is living or non-
living.

Biologists have identified at least six properties that are shared by all living organisms 
on Earth:

1. Order: Molecules in living things are arranged in specific structures.
2. Reproduction: Living things have the ability to reproduce their own kind. Simple 
life forms, such as bacteria, reproduce by dividing and making almost exact replicas of 
themselves. More complex organisms reproduce sexually, so that their offspring have genetic 
material from two individuals. Offspring with traits from both parents have a greater chance 
of survival because they are better able to adapt.
3. Growth and Development: Living organisms grow and develop in patterns 
determined by heredity, the traits passed to offspring by parents.
4. Energy Utilization: Living things need to capture and use energy, a process 
known as metabolism. An example of such a process is photosynthesis, whereby plants 
convert sunlight into energy.
5. Response to Stimuli: Living organisms respond to changes in their environment.
6. Evolutionary Adaptation: Living things evolve in such a way that future 
generations are adapted to unique situations in their surroundings. For example, the 
hammerhead shark, considered to be perhaps the most highly evolved species of shark, has 
superior vision and sensory perception due to its hammer-shaped head. Organisms that 
cannot adapt to a changing environment decline or become extinct. (Smith)

Water

It is hard to not be aware of how important it is in our lives. Water has important roles 
and functions in chemistry, biochemistry, and biology due to its diverse properties. All living 
things are dependent on water. The abundance of water is a major reason Earth can support 
life. A water molecule at first may seem simple. The polar nature of water and the effects on 
hydrogen bonding explain most of the water's unique properties. These properties include 
cohesion and adhesion, temperature moderation, the lower density of ice compared to liquid 
water, and water's ability to dissolve other substances.

The tendency of molecules of the same kind to stick to one another is called cohesion. 
Cohesion is much stronger for water than for most other liquids. Water molecules are also 
attracted to certain other molecules. The type of attraction that occurs between unlike
molecules is called adhesion. Both cohesion and adhesion are important in the living world. One of the most important effects of these forces is keeping large molecules organized and arranged in a way that enables them to function properly in cells. Trees depend on cohesion and adhesion to help transport water from their roots to their leaves. The evaporation of water from leaves pulls water upward from the roots through narrow tubes in the trunk of the tree. Because of cohesion, water moves against the force of gravity even to the top of a very tall tree.

When a substance is heated, such as a metal pan or water, its temperature rises because its molecules move faster. But in water, some of the thermal energy that is absorbed goes to break hydrogen bonds. That doesn't happen in the metal pan, which has no hydrogen bonds. As a result, the water absorbs the same amount of thermal energy but undergoes less temperature change than the metal. Water also moderates temperature through evaporation, such as when you sweat. Evaporation occurs when molecules at the surface of a liquid escape to the air. As water molecules evaporate, the remaining liquid becomes cooler.

Density is the amount of matter in each volume. A high-density substance is more tightly "packed" than a low-density substance. In most substances, the solid state is denser than the liquid state. Water is just the opposite. Its solid form (ice) is less dense than the cold liquid form. Once again, hydrogen bonds are the reason. Because the molecules in liquid water are moving faster than those in ice, there are fewer and more short-lived hydrogen bonds between molecules. Since substances of lesser density float in substances of greater density, ice floats in liquid water. How is the fact that ice floats important to living things? If ice sank, it would form on the bottom of a body of water as the water was cooling. Ponds and lakes would freeze from the bottom up, trapping the fish and other organisms in a shrinking layer of water without access to the nutrients from the muddy bottom.

The way they are bonded together makes water this wonderful universal solvent, "meaning that almost every substance can dissolve in water. Water is the main solvent inside all cells, in blood, and in plant sap. Water dissolves an enormous variety of solutes necessary for life. In aqueous solutions, a very small percentage of the water molecules themselves break apart into ions. The ions formed are positively charged hydrogen ions (H+) and negatively charged hydroxide ions (OH-). Some chemical compounds contribute additional H+ ions to an aqueous solution while others remove H+ ions from it. Pure water and aqueous solutions that have equal amounts of H+ and OH- ions are said to be neutral. They have a pH of 7 and are neither acidic nor basic. The pH of the solution inside most living cells is close to 7.

Mentioned properties of water can be enough to make the water a medium for elements of life to meet each other.

"The quality of all life on Earth is a dependence on water. Since water plays such a crucial role in all known life forms, many scientists believe that water-use will be a quality universal to all life. But Benton Clark, an astrobiologist with the University of Colorado and Lockheed Martin, says that water is really a side issue. "Water doesn't define life, it is just an aspect of our environment," says Clark. Life on Earth evolved with water, and so today life on Earth is dependent on that resource. But we cannot say that without water, life is impossible. On Earth, life has been able to adapt to the harshest environments, so it is
possible that life may have found a way to survive on worlds that have no liquid water.” (Mullen L)

“Water is the single most abundant chemical found in living things. Virtually all chemical reactions in life processes take place in solution in water. Some organisms can live in a dormant and desiccated state for long periods of time but require water to become active. Water is present both inside and outside cells. In the body of a mammal for example, although it is about 70% water by weight, about 46% (approximately 2/3) is inside cells, and about 23% (approx. 1/3) is present outside cells in blood plasma and other body fluids.” (“Water and Cells”)

**Cells, Building blocks of Life**

Cells are the basic building blocks of all living things. The human body is composed of trillions of cells. They provide structure for the body, take in nutrients from food, convert those nutrients into energy, and carry out specialized functions. Cells also contain the body’s hereditary material and can make copies of themselves.

“Cells are considered the basic units of life in part because they come in discrete and easily recognizable packages. That's because all cells are surrounded by a structure called the cell membrane — which, much like the walls of a house, serves as a clear boundary between the cell's internal and external environments. The cell membrane is sometimes also referred to as the plasma membrane. Cell membranes are based on a framework of fat-based molecules called phospholipids, which physically prevent water-loving, or hydrophilic, substances from entering or escaping the cell.” (Cooper)

“Cells are composed of water, inorganic ions, and carbon-containing (organic) molecules. Water is the most abundant molecule in cells, accounting for 70% or more of total cell mass. Consequently, the interactions between water and the other constituents of cells are of central importance in biological chemistry. The critical property of water in this respect is that it is a polar molecule, in which the hydrogen atoms have a slight positive charge and the oxygen has a slight negative charge (Figure 2.1). Because of their polar nature, water molecules can form hydrogen bonds with each other or with other polar molecules, as well as interact with positively or negatively charged ions. As a result of these interactions, ions and polar molecules are readily soluble in water (hydrophilic). In contrast, nonpolar molecules, which cannot interact with water, are poorly soluble in an aqueous environment (hydrophobic). Consequently, nonpolar molecules tend to minimize their contact with water by associating closely with each other instead. As discussed later in this chapter, such interactions of polar and nonpolar molecules with water and with each other play crucial roles in the formation of biological structures, such as cell membranes.” (Cooper)

“The inorganic ions of the cell, including sodium (Na+), potassium (K+), magnesium (Mg2+), calcium (Ca2+), phosphate (HPO42-), chloride (Cl-), and bicarbonate (HCO3-), constitute 1% or less of the cell mass. These ions are involved in a number of aspects of cell metabolism, and thus play critical roles in cell function. It is, however, the organic molecules that are the unique constituents of cells. Most of these organic compounds belong to one of four classes of molecules: carbohydrates, lipids, proteins, and nucleic acids. Proteins, nucleic acids, and most carbohydrates (the polysaccharides) are macromolecules formed by the joining (polymerization) of hundreds or thousands of low-molecular-weight precursors:
amino acids, nucleotides, and simple sugars, respectively. Such macromolecules constitute 80 to 90% of the dry weight of most cells. Lipids are the other major constituent of cells. The remainder of the cell mass is composed of a variety of small organic molecules, including macromolecular precursors. The basic chemistry of cells can thus be understood in terms of the structures and functions of four major classes of organic molecules.” (Cooper G)

What makes the world such as ours able to host life

We have met only one kind so far, earth life. How many stars? How many world? How many ways of being alive. Scientist looks for life similar to earth life in other planets based on the presence of water, and atmosphere of the planet.

“The "biosphere" is the region of Earth that can support life. More specifically, Earth's biosphere is the area of our planet where living organisms survive and interact with both their environment and with other living organisms. This zone includes most of the hydrosphere (liquid water, frozen water, and water vapor), parts of the lower atmosphere, and the upper lithosphere (Earth's crust and upper mantle).” (Smith)

“Earth's distance from the Sun allows its surface to be within a precise temperature range that makes it possible for liquid water to exist. If Earth's temperature were much warmer, liquid water would evaporate or be lost to space; if it were colder, liquid water would freeze. The region of the Solar System where temperatures allow liquid water to exist on a planetary surface is called the habitable zone.” (Smith)

Conclusion

Just how those atoms and molecules that ended up on our planet went from non-living to living remains one of the great unanswered questions in science. But where the elements came from to start with has now been worked out, in broad strokes anyway, to astrophysicists' widespread satisfaction. It is an amazing story.

“Scientists have discovered what they say could be fossils of some of the earliest living organisms on Earth. They are represented by tiny filaments, knobs and tubes in Canadian rocks dated to be up to 4.28 billion years old. That is a time not long after the planet's formation and hundreds of millions of years before what is currently accepted as evidence for the most ancient life yet found on Earth. The researchers report their investigation Nature. As with all such claims about ancient life, the study is contentious. But the team believes it can answer any doubts.” (Ghosh).

Mankind has, however, come a long way from the mystical beginnings. Scientist came up with answers for many questions. But still, much more are unanswered. we still do not know how life got started. It seems to be inherent in our search for knowledge that questions will always continue to exist. For all, we know Origin of life, is one of the greatest unsolved mysteries of science.
References


Unraveling the Mystery of Black Holes

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AST112
March 22, 2017
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Abstract

This paper will focus on black holes and how they are formed, what they are, and the rules that apply to them. The aim of this paper is to provide information about the core concepts and ideas that revolve around black holes. Data from astrophysicists and scientists will be reviewed and questions that people may have about black holes will be answered.

Black holes may be considered the most complex and illusory objects in our known universe. They are spread throughout the cosmos and can be found in the centers of galaxies, star clusters, seemingly empty space, and just about anywhere else. In the Milky Way galaxy alone there are an estimated 100 million black holes (“How Many Black Holes Are There?” Hubblesite). They are extremely difficult to spot due to the fact that they emit no light by themselves. However, this does not stop scientists from searching for them and studying them. Unraveling the mystery of black holes may reveal concepts in physics thought to be impossible and by studying them the secrets of the universe can be discovered.

Black holes are formed when a massive star burns through all of its fuel and can no longer sustain hydrostatic equilibrium and the star’s core collapses in on itself. This is followed by a supernova explosion that violently erupts and throws out the star’s shell. This explosion alone can be many times more luminous than the entirety of a galaxy. The core of the star then collapses. In this collapsed core protons and electrons are extremely compact, fighting to get closer and closer in what is known as degeneracy. However, if the mass is not enough to
overcome this neutron degeneracy then a neutron star forms. However, if the mass is high enough to overcome the neutron degeneracy it forms a black hole. The formation of a black hole occurs extremely quickly (less than one second). Note that it is also possible for a collapsed core that did not have enough mass initially to form a black hole by gathering material through an accretion disk. Let’s say a white dwarf or neutron star is in a binary system and the other star gets too close. This star must have passed what is known as the Roche limit (see figure 1), which is a distance from a body where if another body crosses this line they will be pulled and attracted towards each other. If one of these stars crosses the Roche limit then the star with more mass will begin pulling material off of the smaller one. This forms a spinning accretion disk of material that is falling towards the star. In fact it is possible to detect and locate black holes that have an accretion disk. As the material is falling towards the event horizon the material closer to the center is rubbing against the material farther out and this rubbing creates friction and heat. This heat can reach millions of degrees and it gives off light which can be observed through a telescope. If the body absorbs enough mass to overcome the Chandrasekhar limit (approximately 1.4 times the solar mass of the sun) then it can potentially have enough mass to form a neutron star or black hole. All of the mass in a black hole is concentrated in a single point in space of infinite mass known as a singularity (Tyson, Strauss and Gott 2016, p. 301).

The Schwarzchild Radius (see figure 2) is the radius of an object with a given mass that is so condensed that its escape velocity is equal to the speed of light. For example, the Scharwzchild radius of Earth for its given mass is 8.88 millimeters. This means that if the Earth were compressed into a ball of 8.88 millimeters then the escape velocity will be equal to the
speed of light. This would form a black hole and no light would be able to escape it. In fact, any object can be turned into a black hole theoretically if it is condensed enough to have this Schwarzschild radius (Tyson, Strauss and Gott, 2016, p. 302).

If a person were to fall into a black hole, many strange things would happen. As they approach the event horizon, they would appear to slow down. This is because the closer to the event horizon they are the harder the light has to fight against the pull of gravity and so it takes longer to reach a viewer’s eyes. Once they cross the event horizon however, they would appear to be motionless. The person would not feel anything different happening to them however. It is only until they reach the singularity where spaghettification would occur. This is when the pull of gravity at their feet is larger than the pull of gravity at their head, and so the person would stretch out. This kills the person almost instantly.

“For a 3-billion-solar-mass Schwarzschild black hole, the graduate student would have 5.5 hours of free-fall time”…”luckily for him, the spaghettification process, from the moment the tidal forces begin to hurt him until he is completely ripped apart and killed, only takes up the last 0.09 seconds of his trip” (Tyson, Strauss and Gott, 2016, p. 306).

When they reach the singularity they would be sucked into it and the mass of the black hole would increase slightly. This slight increase in mass would also expand the Schwarzschild radius ever so slightly.

“A quasar is a glowing disk of hot, dense material that can form around the supermassive black hole at the centre of a large galaxy, often the result of a collision with a second galaxy” (Mortlock, 2014, p. 1). Most quasars were born around 10-12 billion years ago. Scientists have
detected these quasars by searching the sky for some of the highest red shifted objects in the universe. Red shift can occur when a photon’s wavelength is stretched over time due to the expansion of the universe. Scientists are able to calculate how long ago an object emitted the light being observed by looking at how much these wavelengths red shifted. This means that the telescopes observing these quasars are essentially time machines peering back into the early years of the universe.

“The light seen at any given wavelength here and now has, since its emission, been redshifted by an amount that depends on how distant the source is, and hence how far back in time astronomers are seeing it” (Mortlock, 2014, p. 1).

Black holes seem to be the product of science fiction with all of their weird and seemingly rule-breaking physics. However, in the last decade scientists have been able to observe, study, and theorize how black holes function. Nobody knows what it looks like inside the event horizon and it is possible nobody will ever know. There is still a lot of mystery left to uncover about these marvelous forces of nature and the complex physics behind them. However, black holes are no longer complete mysteries and hopefully further advancements in mathematics and technology will hold the key to cracking the mysteries of the universe.
Figures

Figure 1: The Roche Limit in action. Mr Reid, by Reid, 2016, retrieved from http://wordpress.mrreid.org/2013/04/18/the-roche-limit-and-planetary-rings/

Figure 2: The Schwarzschild Radius of a black hole. Physicsforidiots, 2009, retrieved from http://physicsforidiots.com/space/black-holes/.
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Fatal or Fortunate

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General Chemistry II, CHM 152

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ABSTRACT:

Rattlesnakes are known for their deadly effects from the venom where as the Gila Monster is known from their deadly effects from the bite. The rattlesnake venom contains the following enzymes/proteins: adenosine triphosphatase, peptide bradykinin potentiators, polypeptide toxins (Mohave Rattlesnake), proteolytic enzymes, proteases, phospholipases, thrombin like enzymes, nerve growth factor, and biogenic amines. The Gila Monster venom contains the following enzymes: bradykinin-releasing enzymes, serotonin, phospholipases A, protease, Exendin-4 and hyaluronidase, The LD$_{50}$ of the Gila Monster venom is 3 mg/kg and the LD$_{50}$ of the Rattlesnake venom is 2.26mg/kg making the Rattlesnake venom slightly more toxic. The Rattlesnake has hemolytic venom where as the Gila Monster venom contains thrombin-like properties as well as neurotoxic effects. Despite the dangerous enzymes in the Gila Monster venom there is no antivenin that is readily available. Gila Monster venom has medicinal qualities such as promoting insulin production in the human body, where as snake venom has medicinal qualities to help treat the following diseases: Parkinson’s, Alzheimer’s, brain injuries, and injuries sustained from a stroke.

Arizona is one of the hottest states in the continental United States making it home to many ectothermic predators that can be fatal to humans such as Gila Monsters and Rattlesnakes. Out of the 20 different species of venomous snakes that make their home in the United States, 16 of those species are rattlesnakes, of which, 17 species of Rattlesnakes reside in Arizona. Each year there are approximately 7,000-8,000 bites that occur from venomous snakes and from those thousands of bites only about 5-6 people will die (Johnson, S.A., Dr., 2012). A total of 22 people have died within the past 7 years however of those 22 people 15 were bitten by a species of Rattlesnake making the Rattlesnake species accountable for 68% of venomous snake deaths so far this decade. However, Arizona is home to another reptilian predator called the Gila Monster. The Gila Monster is known as a venomous reptile, however, unlike the rattlesnake the majority of the injury is not sustained from the venom its from the bite itself. There are two main reasons these species affect humans in a differing way: how the bite is administered and the venomous proteins/enzymes that are produced by the reptile.

Before comparing the different types of enzymes that are present in both ectothermic predators it is imperative to understand how the venom is injected into a human. Gila Monsters, or Heloderma suspectum, are not known for their toxic venom, however they are most known for their vicious bites. Those vicious bites are caused by the reptile latching on to its pray, for up to fifteen minutes at a time, while at the same time gnawing away at the tissue, creating an open wound, allowing its venom to seep in. While the Gila Monster is gnawing at the exposed tissue, the reptile draws the neurotoxin containing venom from the storage glands, located in the lower jaw, slowly releasing it through grooves in the reptiles teeth. Refer to figure 1.2 for a display of the Gila Monsters sharp teeth. The venom that is secreted contains a mixture of serotonin, bradykinin-releasing substance, protease, hyaluronidase, helodermin, and gilatoxin.
Some common signs and symptoms that can be attributed to a Gila Monster wound are edema, cyanosis, vomiting, diaphoresis, lymphangitis, pain, nausea, and weakness which are all caused by the specific enzymes that are contained within the injected venom and will be further discussed later on.

Now, as previously stated, the majority of the pain that is caused from the Gila Monster wound is from the actual bite itself and not the venom, however that is not the case for the Rattlesnake. The Rattlesnake, or more specifically the Western Diamondback Rattlesnake, quickly bite their prey most often causing pain for a couple seconds. The location of the bite will then immediately swell and will cause the patient pain, however, the pain is most likely from the toxic venom and not from the bite itself like it was with the Gila Monster. The reason being is due to the physics behind how snake venom is injected into its prey, or victim. An article published by Technische Universitaet Muenchen back in 2011 states that, “Most snakes do not inject venom into their victims bodies using hollow fangs, contrary to common misconceptions” (Technische Universitaet Muenchen). Most venomous snakes actually do not have hollow fangs, instead they use grooves in their teeth and canals created by the surrounding tissue to guide the venom into the prey. The reason this form of injection is so successful is because of the high surface tension, which pulls the venom into the grooves of the fangs. However, despite the common misconception, the rattlesnake is part of the one seventh of venomous species that actually do have hollow fangs. Rattlesnake fangs are highly evolved because while not in use the hollow fangs actually lie parallel to the snakes jaw when they aren’t being used (Ivanyi, C., 2017). When the snake seeks out a predator or feels threatened, they could strike which causes the fangs to become erect. As displayed in Figure 1.1, each hollow fang is connected to a venom gland allowing the venom to travel from that gland, through the hollow teeth, and into the prey or predator. Rattlesnake venom has varying proteins and enzymes within the species that range from hemotoxins to neurotoxins, please note that for the following enzymes discussed regarding Rattlesnakes the enzymes could slightly differ depending on subspecies.

Although both the Rattlesnake and Gila Monster are both reptiles their toxins differ. The Rattlesnake carries and injects venom with hemolytic properties where as the Gila Monster venom possess qualities of a neurotoxic venom. Among all venomous snakes there are about twenty different enzymes that vary between the venom but those enzymes that are contained in the rattlesnake are adenosine triphosphatase, peptide bradykinin potentiatizers, polypeptide toxins (Mohave Rattlesnake), proteolytic enzymes, proteases, phosphoipases, thrombin like enzymes, nerve growth factor, and biogenic amines. Enzymes are important in all biological activity because the enzymes lower the activation energy, meaning it helps a reaction happen faster. Please refer to Figure 1.3 for a graph of the activation energy. Adenosine triphosphatase is used in the snake venom to immobilize smaller prey by causing the victim to go in a state of shock by transporting sodium ions out of the cells and potassium ions inside of the cell. This is an important mechanism for the snake because it gives the snake a chance to subdue the prey or a chance to escape the predator if affected. The next enzyme, peptide bradykinin potentiators, are enzymes that are a key ingredient in the snakes toxic venom. This enzyme activates dilation, increases permeability of blood vessels, stimulates pain receptors, and initiates contraction of smooth muscles, by diffusing the venom into the blood and increasing the bleeding (Snake Venom). This enzyme causes great pain due to
the stimulation of the pain receptors and because it does cause the contraction of the smooth muscles throughout the organism that is bit. By diffusing the venom into the blood it can reach the entire body faster aiding in the quick death of the organism. The polypeptide toxins contained in the Mojave Rattlesnake is used to interrupt nerve-impulse transmission causing respiratory and heart failure. Although the reasoning is unclear why these polypeptide toxins are specific to the Mojave Rattlesnake, it is an important characteristic because the brain, in humans, does control the involuntary muscle movements like those of the heart and lungs. If the communication system, or nerves, are inhibited or affected then the body can go in to distress because, for example, it may not be able to recognize if the heart is in rhythm or not due to the loss of communication. Proteolytic enzymes, which are contained in all venomous snakes, are used to catalyze the breakdown of the tissues surrounding the injection site. The enzyme lowers the activation energy required to break down the tissues therefore inducing tissue damage quicker. Proteases also act as a catalyst but in a different manner. They mainly target the nerves and the muscles. The main protease that is found within the pit vipers are called metalloproteases because they use a metal ion to lower the activation energy. They also contribute to the dying tissue around the bite. The next enzymes, called thrombin-like enzymes, are why the snakes have their hemolytic qualities. These enzymes stop the blood from clotting, meaning; the patient could bleed from the inside out if all of the clotting pathways are inhibited. This is one of characteristics that allow doctors to use snake venom in the treatment of certain diseases, such as strokes, which will be discussed later on in this paper. The next enzyme is called the nerve growth factor; this enzyme simulates growth of nerve cells. Biogenic amines also trigger the nerves by interrupting the normal transmission of the nerve impulses and stopping the signaling between nerve cells (Snake Venom).

The next reptile, the Gila Monster, has some similar proteins and some differing ones. The venom contains, as stated above, bradykinin-releasing enzymes, serotonin, phospholipasesA, protease, Exendin-4 and hyaluronidase. The tissue breakdown that is initiated by a bite from a Gila Monster is most likely due to phospholipase A and the protease enzymes and proteins which allows the venom to spread throughout the tissues faster (Strimple, P. D., Tomassoni, A. J., Otten, E. J., & Bahner, D. (1997)). These enzymes most likely aid in the breakdown of the surrounding tissue by lowering the activation energy and catalyzing the tissue destruction. Another symptom, edema, is mostly caused by the hyaluronidase that’s found in the venom along with the hydrolases which result in the spacing of fluid. The edema, or swelling, could be a painful side effect of the patient and could also differ among patients. For example: A patient with a severe allergy to reptiles could experience more edema because, not only are they reacting to the hyaluronidase, but they are reacting because their own body is allergic to the reptile itself. A specific toxin known to gila monsters is called a gilatoxin which has been shown to have thrombin activating activity by cleaving angiotensin I, meaning the gilatoxin induces clotting within its pray. This is an important and dangerous side effect of a Gila Monster bite because if the Gila Monster injects enough of its venom into a human it could cause a large amount of coagulation which puts the patient at risk for a stroke, pulmonary embolism, or a myocardial infarction (commonly known as a heart attack). One of the last proteins found in Gila Monster venom is known as Exendin-4 and is a peptide agonist that actually promotes insulin secretion when in the human body and will
be discussed later in the paper when talking about the medicinal uses of the Gila Monster venom (Ding, X., Saxena, N. K., Lin, S., Gupta, N., & Anania, F. A. (2005)).

In order to treat or counteract these bites it is important to look at the lethal dose, or LD50, of both the differing venoms. The LD50 of the rattlesnake species for a intraperitoneal injection is 2.26mg/kg, meaning that is the dose that can be injected into a human, specifically in the abdomen, to kill half of the people that are bit (LD50).

However, surprisingly, bee venom is more toxic than the actual snake venom itself, it’s the quantity of the snake venom that is injected versus the amount of injected bee venom that makes the snake responsible for more deaths. The LD50 for Gila Monster venom is a little bit lower than that of rattlesnake venom measure in at 3 mg/kg also injected intraperitoneally (Beck, D. D., Martin, B. E., Lowe, C. H., & Wiewandt, T. A. (2009)). This means that the Gila monster takes .04 more mg of venom in order to kill the half of those that are bitten with it. It is important to note with the lethal dose that the higher the milligrams the more it takes to kill half of its victims, therefore the higher the dose the less toxic it is to whatever receives its venom.

Due to the fact that both the Gila Monster venom and the Rattlesnake venom have differing toxic qualities they both would require differing antivenins in order to treat victims when they are exposed. Antivenin for snakes is a high cost medicine and takes a long process in order to create. The purpose of the antivenin is to inhibit the proteins or enzymes that are injected into the patient or victim upon injection. In order to create this venom the snake, in this case Rattlesnake, is milked in order to get its venom from the venom glands. Once enough venom is retrieved from the snake it is diluted down and injected into either a goat or horse. The animal will then produce antibodies to the injected venom (Antivenin). As the animal builds up these antibodies more venom is injected in order to create the maximum amount of antibodies in the blood stream. Once the horse or goat has reached its desired antibody level in the blood stream their blood is drawn and is centrifuged. The blood, or serum, is centrifuged in order to separate venom antibodies from red cells. The serum then goes through a purification process before it is ready for use. When the venom is injected from the snake into the human it acts competitively by binding to the specific active sites located on the cells, similar to a lock-and-key. By binding to these sites it acts by either inhibiting certain functions, like clotting or by inducing certain cellular functions, like clotting (Antivenin). As stated previously the Gila Monster acts as a coagulant and the Rattlesnake venom acts as an anticoagulant. The antivenin, once injected into the body, goes into the body and disconnects venom from the cell allowing the cells active binding site to be open which allows it to resume its normal functions. This is why it is important for a patient to recall the type of snake that they were bitten by because each snake has differing components in their venoms. What one snake has in their venom might not hold true to another, so in order to effectively inhibit all of the proteins or enzymes from that snake venom the correct antivenin needs to be administered. It is also best to administer this antivenin as quickly as possible to minimalize the spreading of the toxic effects such as swelling and necrosis. The spreading of the venom throughout the body relies on certain factors such as the age, height, weight, and medical history of the patient. Snake bites in small children tend to be more severe because the venom is spread more quickly due to the rapid heart beat that small children have.
Now when talking about the Gila Monster venom it is important to consider the fact that there have been no recent reported deaths from this predator. Therefore, there is no anti-venom available. If there were antivenin available it would be safe to assume that the venom would be received the same way. The Gila Monster would be milked first in order to obtain the venom. It would then be slowly injected into an animal such as a horse or a goat until enough antibodies are created in that host animal. Once the number of antibodies is sufficient it will then be withdrawn and centrifuged. That centrifuging will separate those antivenin antibodies from the dark red cells. After that the venom will be purified and ready for injection. Without having this antivenin readily available it could pose a threat to those who are bitten. The patients at higher risk for a possible interaction with a Gila Monster are those with anaphylaxis to reptiles. Those with anaphylaxis or a history of anaphylaxis to reptiles are at greater risk because if they get bit they could potentially go into immediate anaphylactic shock. If the epinephrine and steroids that are given in the emergency room are not enough to inhibit the reactions it would be useful to have a Gila Monster antivenin in order to treat the edema and/or other symptoms that are caused by the bite site to help relieve stress on the patients body.

Along with the main medicinal property of toxic venoms, the antivenin, the venoms can be used in other medicinal ways as well. As described earlier, rattlesnakes can have a hemolytic venom meaning that it causes the prey or victim to bleed. Using this quality of the snake venom it could be used for the circulatory system for either heart attacks or blood disorders (Bushak, L., & Lecia Bushak Lecia Bushak). This is important because usually patients who have a history of a heart attack need to be on blood thinners such as Warfarin or Coumadin. The hemolytic qualities in the snake venom act in a similar way because the snake venom also prevents clotting, therefore thinning out the blood. Along with the hemolytic effects certain snakes also have neurotoxic effects, which can also be utilized for medicinal purposes. These drugs that have been created from these toxins are those that help treat Alzheimer patients, Parkinson’s patients, stroke injuries, and other brain injuries. It could help with the signaling of the nerves in the patients. This neurotoxic effect could potentially help stop unwanted signaling of nerves in the patient or enhance nerve signaling where it has been deficient, however these effects do depend on the type of protein that is used because each protein has a different effect on the human body.

Gila Monster venom also has some medicinal qualities as well. Fortunately, Gila Monster venom has a hormone called Exendin-4 in it, which, is a hormone that helps maintain the glucose levels in humans and also helps with weight loss in patients who have Type 2 Diabetes. Usually the Exendin-4 drug, called Byetta, is coupled with other medicines called Metformin or Sulfonylurea Thiazolidinedione (Drug Derived From Gila Monster Saliva Helps Diabetics Control Glucose, Lose Weight). There is also another form of the Exendin-4 that is derived and it is called Exentide, which is the synthetic form of the naturally occurring enzyme that is found within the reptile. The Exendin-4 is actually 50% identical to the actual human hormone that is found in the digestive tract known has GLP-1, or glucagon-like peptide-1 analog. What this hormone does is increase the amount of insulin when the blood sugar levels are high. What was actually found upon studying as that the Exendin-4 found in the Gila Monster actually stays active or effective for a longer period of time then our own GLP-1 hormone (Drug Derived From Gila Monster Saliva Helps Diabetics Control Glucose, Lose Weight.).
Conclusion:

In the state of Arizona there are two venomous ectothermic predators: the Gila Monster and the Rattlesnake. Both predators are venomous to humans however they both present with differing modes of injection. The Rattlesnake injects its venom into its victims by a quick puncture wound. The venom is then transferred through the hollow teeth and into its victim. The Gila Monster injects its venom by latching on to its prey or victim and slowly secreting the venom through its teeth over a period of up to 15 minutes. Both the Rattlesnake venom and the Gila Monster venom differ in proteins and enzymes. The Rattlesnake venom contains both the hemolytic and neurotoxic effects on its prey potentially causing the prey difficulties with clotting and sending and signaling nerve endings. The Gila Monster venom contains a mainly neurotoxic effect. The two different predators have differing strengths of venoms.

The Rattlesnake venom has a LD$_{50}$ of 2.6mg/kg as compared to the Gila Monsters LD$_{50}$ of 3 mg/kg proving that the Rattlesnake is only slightly more dangerous then the Gila Monster. In order to make antivenin the venomous reptile is milked and then injected into animals in order to create antibodies. Once the antibodies are created they are then separated, purified, and ready for injection upon request. However, it is important to remember that there is no antivenin for the Gila Monster. Both the Rattlesnake and Gila Monster serve other medicinal purposes. The Rattlesnake, due to its hemolytic and neurotoxic properties, can help treat brain injuries, stroke, Parkinson’s and Alzheimer’s. The Gila Monster contains an enzyme called Exendin-4, which, actually creates a better glucose promoter inside the human body. It helps control diabetes as well as weight loss in Type 2 Diabetes patients.

I think it is interesting on how something so deadly could be used in humans for such a good cause. Other than the antivenom that is produced both the Rattlesnake venom and Gila Monster venom can be used to help many people overcome many other injuries and illnesses. It is also interesting to note that despite the quite hi LD$_{50}$ that there is actually no anti-venom required for the Gila Monster. I found that quite interesting because it is easy to run into Gila Monster’s out here in the desert. I also thought it was interesting how some of the enzymes overlapped and I also thought it was interesting how the Rattlesnake venom and the Gila Monster venom act almost as polar opposites. The Rattlesnake venom acts as hemolytic venom, meaning that they cause or initiate bleeding by preventing the body from being able to clot. The Gila Monster venom has a neurotoxic function, meaning that it can inhibit nerve endings from firing or over firing which can cause intense pain. I think the future of preventative and life-saving treatment is contained within the venoms of certain animals. The venoms, not only with Gila Monsters and Rattlesnakes, contain enzymes and proteins that could be vital in saving lives and they could aid in treatment because of these properties and characteristics they possess. Research should continue on the characteristics and properties of these dangerous venoms because one day they could lead to a greater discovery such as a cure for a long term disease like Alzheimers or maybe even cancer.
Figures

Figure 1.1: Snake Anatomy
Picture to the left displays hollow fangs erect as if biting and shows the path from the venom duct, through the hollow tooth, and out the end of the fang. *Snakes Fangs and Venom* [Photograph found in Biology Forums]. (n.d.). Retrieved April 20, 2017.

Figure 1.2: Gila Monster Skull
Picture to the right displays the sharp teeth of the upper and lower jaw of a Gila Monster. *Gila Monster-Heloderma Suspectum* [Photograph found in Carnivora]. (2012, March 14).

Figure 1.3: Enzyme Activity
The figure to the left displays that during a reaction in the presence of an enzyme, or catalyst, the activation energy is lowered allowing the reaction to require less energy for initiation. *Snake Venom*. (n.d.). Retrieved April 20, 2017.
References


All About Lupus

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Abstract: Every year there are roughly 200,000 cases of lupus diagnoses in the United States. It is quite a common disease that is not curable, but current treatment helps. What causes lupus is unknown and there is not a single test that can help doctors diagnose lupus automatically. It could take months or even years. Researchers are still trying to learn more about lupus. This study will discuss what lupus is and what it does to the human body, certain exams and test to detect lupus, and certain antibodies associated with lupus.

In America, there are over 1.5 million people currently living with lupus disease. Every year there are more than 200,000 reported cases in the United States of people diagnosed with lupus. According to Mayo clinic, lupus is defined as “a chronic inflammatory disease that occurs when your body’s immune system attacks your own tissues and organs” (Mayo Clinic Staff, 2014). The history of lupus dates back to 400 B.C. through Hippocrates work (Norman, 2016). He documented the symptoms that were associated with lupus. Lupus comes in four types: Systemic Lupus Erythematosus (SLE), Discoid (Cutaneous), Drug-induced Lupus (DIL), and Neonatal Lupus. Although there is no cure for this disease and the cause is unknown, there are treatments that help people living with this disease lead an active and healthy lifestyle. This study will discuss what lupus is and what it does to the human body, certain exams and test to detect lupus, and certain antibodies associated with lupus.

Lupus disease is very difficult to detect. It can take months or even years for a doctor to diagnose a patient with lupus. This is due to the fact that lupus affects several parts of the body. It affects blood, skin, joints, kidneys, brain, and other organs. Other times it can be because that he symptoms are not usually present at the time. Also, new symptoms can occur at different times and can be different from the initial diagnosis. So therefore, a doctor can easily mistake it for other health related problems, because lupus disease can mimic other diseases, also making it difficult to correctly and accurately diagnose the lupus disease. In order to be diagnose with lupus disease, a patient must have 4 out of 11 symptoms that are associated with the disease. The doctor must have a patient’s entire medical history that includes an analysis of lab tests, severity of symptoms, etc. Some symptoms include joint pain, arthritis, chest pain, fatigue, unexplainable fever, hair loss, mouth sores, skin rash, swollen lymph nodes, and light sensitivity. These symptoms vary from person to person and can come and go. In addition to that, other symptoms depend on which part of the human body is affected.

The causes of lupus disease remain unknown still presently. Many researchers have their own beliefs on how an individual contracts lupus. Some believe that the lupus disease is a hereditary gene. This is due to the fact that, the medical history of some of these patients who get lupus, have family members who also have been diagnosed with lupus. But however, other researchers believe that other factors trigger this disease in people, such as the environment, sunlight, certain medications, stress, etc. It is very difficult to get to the root of what causes a person to get lupus, because it varies from person to person. People of different races other than Caucasians, seem to be at a much higher risk of contracting lupus disease. Some scientists believe that women who obtain lupus are a result of their hormones.

As previously stated, scientists and researchers all have their own beliefs on how lupus is caused. For instance, some believe hormones play a factor in contracting lupus disease.
Hormones are a body’s messenger and they regulate the body’s functions. “Because nine of every 10 occurrences of lupus are in females, researchers have looked at the relationship between estrogen and lupus” (What causes lupus? | national resource center on lupus). Estrogen has a much higher production in females than in males, even though estrogen is present in both genders. When the estrogen levels are high, females are more likely to have lupus like symptoms before their menstrual periods and during pregnancy. Because of those observations, researchers believe that may be one of the indicators on why women are more prone to getting lupus disease than men. But researchers and scientists are looking beyond just hormone levels in male and females.

Other scientists and researchers believe that people get lupus disease based on genetics. “Researchers have now identified more than 50 genes which they associate with lupus” (What causes lupus? | national resource center on lupus). Those identified genes are most commonly seen in those individuals who have lupus disease than those who do not have the disease. However, genetics are not all enough evidence to suggest that they are the primary cause of lupus disease. For instance, twins who have grown up in the same environment and have the same inherited features, but only one of the twins have developed lupus disease. But because twins have same inherited features and are biologically alike, the other twin has an increase chance of developing lupus too. Lupus can develop in people whose family medical history shows no sign of ever getting lupus. But since other ethnic groups are more likely to get lupus, some researchers suggest that the genes most common in them may play a role in getting lupus disease.

Many researchers believe that the environment people live in can play a role in developing lupus disease. Things like certain chemicals or virus in the environment can trigger the disease in individuals. Researchers are not sure which environment factor or setting can trigger lupus disease. However, the most common environment influences can the ultraviolet light, infections, and silica dust in areas of agriculture and industrial settings. But the idea of getting lupus from the environment remains and is maybe likely.

When treating lupus disease, medications are used with more severe or serious conditions. Minor lupus cases are handled without medication use. “Although there’s no cure yet, medications can control symptoms and prevent or slow organ damage” (Treatments and Medications). A physician will usually try and choose a treatment that is beneficial to a patient’s needs and can be discussed to see if it is working. When new symptoms appear, it is best to notify the physician so new treatment options can be discussed and changed if needed. The goal of treating lupus is to prevent flares, control symptoms, and reduce organ damage and other health related damage. With severe symptoms that affect the heart, lungs, brains, kidneys, etc. treatment are those that require a specialist.

Throughout the course of years, the prognosis of people with lupus disease has improved. Many people will have mild symptoms. During the first years after diagnosis and people under the age of 40, the lupus disease is the most active. Women who have lupus can still get pregnant and deliver a healthy baby. Although, lupus antibodies do raise the risk of miscarriages. Presently, there are no known ways to avoid developing lupus disease. “The most likely causes
of death during the first 10 years include infections and kidney failure. During years 11–20 of the disease, the most likely cause of death involves the development of abnormal blood clots” (Carson-DeWitt, Rosalyn, and Laura Jean Cataldo).

When the heart is affected, one of the symptoms that are associated with it is abnormal heart rhythms. Possible complications of that would be the result of fluid around the heart and or inflammation of the heart. Abdominal pain, nausea, and vomiting are symptoms that occur when the digestive tract is affected. When a person is coughing up blood or having difficulty when breathing are symptoms when the lungs are affected. Fluid around the lungs and damage to lung tissue are possible complications. Swelling in the legs or weight gain happens when the kidneys are affected. Abnormal deposits in the kidney cells can result in conditions such as kidney failure, dialysis, and lupus nephritis. Those are possible complications that come with the kidneys being affected. The red blood cells can get destroyed resulting in anemia if the blood gets inflected and blood clots can form in the arteries that lead to the lungs, heart, brain, legs, etc.

Systemic lupus erythematosus (SLE), is the most common type of lupus disease that people can get and is the most serious disease than the other ones. It is more common in women than it is in men at any given age, but tends to be most common in woman between the ages of 15 and 44. Also, it is most common in women near the child bearing stages. Therefore, pregnancy for woman is an important issue. SLE affects people of color more rather than Caucasians. Unpredictable patterns of remission are associated with this meaning that the symptoms disappear or the symptoms are active.

“Approximately two-thirds of people with lupus will observe some type of effect on their skin” (). This type of disease is discoid lupus. There are three forms of lupus skin disease: chronic cutaneous lupus (discoid), subacute cutaneous lupus, and acute cutaneous lupus. Some have or will develop a skin disease called cutaneous lupus erythematosus. This skin disease can cause skin rash or lesions in the skin. They will appear on where the sun is mostly exposed on the body such as the legs, arms, face, neck, and ears. A dermatologist will usually treat it by doing a biopsy and going from there. A biopsy is when a physician takes a tissue sample and examines it under a microscope. “This type of lupus does not affect any of the internal body organs although 1 in 10 people living with discoid lupus will develop systemic lupus” (Types of lupus).

Discoid lupus tends to have a disk-shaped, round lesion. On the scalp or face is where the sores usually appear, but they can appear on other parts of the body too. They are often red, scaly, and thick that do not usually hurt or itch. Scarring and discoloration in the skin can develop over the course of time. The sores that appear on the scalp can cause hair loss which can become permanent if the lesion become scars after they heal. There are some preventable approaches that can be taken such as avoiding the sunlight between a certain time, the use of sunscreen, and wearing sun protective clothing. Subacute cutaneous lupus are areas of red scaly skin with distinct edges or appear as red, ring-shaped lesions. Acute cutaneous lupus is a malar rash flattened areas of red skin on the skin that kind of look like sunburns. It appears across the face on the cheeks and the nose. It takes a shape of a butterfly, so it is known as the butterfly
rash. This type of skin disease does not leave scarring, but changes in color on the skin can happen.

There are treatments that are taken for cutaneous lupus. The medications used all depend on the forms of the cutaneous lupus. Common treatments are ointments, such as steroid cream or gel, or liquid steroid that are injected in the lesions. Topical immunomodulators, is a new drug that treats the serious skin conditions. It shows that it can suppress the activity of the immune system in the skin that includes the three forms of discoid lupus. Thalidomide is another drug treatment that has been highly accepted. It has been shown to really improve cutaneous lupus compared to the other treatments.

Drug induced lupus (DIL), happens when a person takes a certain kind of medication. “Medications that may induce lupus include hydralazine (a drug used to treat high blood pressure) and procainamide (a drug used to treat irregular heart rhythms)” (Carson-DeWitt, Rosalyn, and Laura Jean Cataldo). Like systemic lupus erythematosus, the symptoms are in comparison. They disappear when the medication is stopped, which can usually take 6 months, but the Antinuclear Antibody (ANA) test may be positive for years. Antinuclear Antibody test is used to help diagnose lupus. However, having a positive ANA test does not mean you automatically have the lupus disease. Drug induced lupus is most common in older adults, because they are most likely to require medication due to other health problems that they may have developed in their lifetime, such as heart disease, high blood pressure, etc.

Neonatal lupus (NL) happens when the newborn of a mother who has lupus has neonatal lupus. It is defined as “the presentation of the fetus and the newborn who possess autoantibodies received from the mother” (Johnson, 7). This can cause skin rashes, anemia, or liver problems. It does not cause permanent damage and the symptoms disappear after a few months. Although, newborn babies born with neonatal lupus can be born with a serious heart defect. Treatment for NL, can start as early in the 16th week of pregnancy when the baby is in utero. “Prednisone is a glucocorticoid frequently used to manage SLE flares” (Johnson, 7). A thing that helps with a patient with SLE are steroids. Steroids are considered the primary medication that help manage the pregnancy. As a result of the long-term results, most of the babies go on to lead normal lives. However, the outcomes do vary among patients. Some babies end up being born prematurely, having low birth weight, heart disease, having a heart pacer implemented, etc. Death is a possibility. Care with these types of cases are extremely important. However, neonatal lupus is a rare condition that happens with pregnant women.

Typically, when a person is diagnosed with lupus disease there are multiple exams and tests that need to be done by physicians. So doctors usually order these types of tests if they suspect that their patient may have lupus disease. One of those tests include a blood test. A blood test is important, because human blood is composed of many parts. Those that are affected by lupus are the red blood cells, white blood cells, and platelets. The main issues that arise from this are anemia, which is low hemoglobin or red blood cells, thrombosis, which is excessive blood clotting, blood transfusions, and bone marrow testing. “Hematologists, who are specialists in blood disorders, are often involved in the evaluation and treatment of individuals with lupus” (Rosove Michael Dr.).
“Normally, the white blood cells in the body’s immune system protect a person from harmful substances called antigens” (Carson-DeWitt, Rosalyn, and Laura Jean Cataldo). They are the main body’s defense against infection. A group of white blood cells are called lymphocytes. The main role of lymphocytes is in the human’s immune response. Lymphocytes include B-cells and T-cells, whose roles are recognizing and fighting off infections to keep an individual healthy and prevent them from getting sick. “When a T-cell recognizes a specific antigen, it binds to the substance and produces chemicals called cytokines. Cytokines then cause B-cells to multiply, and some of these B cells turn into plasma cells that secrete antibodies (immunoglobulins)” (How lupus affects the immune system • johns hopkins lupus center). These antibodies circulate throughout the bloodstream.

“Red blood cells play an important role in your health by carrying fresh oxygen throughout the body” (What are Red Blood Cells?). The protein inside the red blood cell that carries the oxygen is called hemoglobin. Red blood cells also remove the carbon dioxide out of your body that are taken to the lungs waiting to get exhaled. When a person has developed lupus, it can affect the red blood cells causing a deficiency in them. When the count of red blood cells is low, that is called anemia. There are several types of anemia. Lupus patients develop hemolytic anemia. Steroids are given to these patients to prevent the damage of the red blood cells.

Platelets are “cells that circulate within our blood and bind together when they recognize damaged blood vessels” (What are platelets and why they are important: Johns hopkins women’s cardiovascular health center). When a lupus disease patient has a low count of platelets, they are prone to easy bruising.

A human body produce antibodies as a response to an infection. “When an invader (antigen) enters the body, white blood cells known as B lymphocytes react by making special types of proteins called antibodies” (Lupus blood tests • johns hopkins lupus center). Antibodies help the human body by remembering antigens. When an antigen enters the body again, the antibodies will easily recognize it and neutralize it by combining with it, so that the body does not get an infection. Because lupus is an autoimmune disease, the body’s immune system can produce these antibodies that will attack the body’s own cells as if the cells were invaders. When that happens, it causes inflammation, damage, and sometimes destruction. These blood tests alone do not determine if a person has lupus, but combined with other tests, it makes it clear whether if a person has lupus or not.

As mentioned, antinuclear antibody test or ANA, are autoantibodies to the nuclei of a person’s cell. “98% of all people with systemic lupus have a positive ANA test, making it the most sensitive diagnostic test for confirming diagnosis of the disease” (Lupus blood tests • johns hopkins lupus center). The way that this test works is a blood sample is taken and sent to the laboratory for analysis. At the laboratory, serum from the blood sample that was drawn is added to a microscopic slide that is already prepared with specific cells. Serum is defined as clear liquid that can be separated from clotted blood” (Medical definition of serum). Next, the serum will bind to the cells that are on the slide if there are antinuclear antibodies present. After that
happens, a second antibody with fluorescent dye is added so it can attach to the antibodies in the serum and the cells that have bounded together. When all that is done, the microscopic slide is observed through a fluorescent microscope. The strongest staining and patterns of the binding are scored at various dilutions (Lupus blood tests • johns hopkins lupus center). In order for the test to be positive, fluorescent cells must be present. “The pattern of the ANA test can give information about the type of autoimmune disease present and the appropriate treatment program” (Lupus blood tests • johns hopkins lupus center). It is extremely rare for a person to have a negative ANA test. People with lupus who have a negative ANA test might have anti-Ro/SSA or antiphospholipid antibodies.

A doctor will usually order more diagnostic tests to help further detect lupus disease in people with the positive ANA test. These other tests will help check for other antibodies to give a confirmation of lupus. Doctors will usually order an ANA panel, that helps check for other antibodies. If any are present, the antibodies and certain blood substances can give information about which ones they are. The ANA panel will check for these antibodies: anti-double-stranded DNA, anti-Smith, anti-U1RNP, anti-Ro/SSA, and anti-La/SSB. There are other antibodies that other laboratories can include in their panels like antinucleoprotein, anticentromere, or antihistone.

Lupus is such a broad terminology for the disease, when specifically, lupus has four different forms. There are Systemic Lupus Erythematosus (SLE), Discoid (Cutaneous), Drug-induced Lupus (DIL), and Neonatal Lupus. The causes of how lupus is contracted remain a mystery, as well as curing lupus. Trying to diagnose a person with lupus is very difficult that can take months or years to properly diagnose. Treatments for this disease are very doable and the goal of treatment is to control symptoms, prevent organ damage, and prevent flares, as well as other health related damage. There are several exams and tests that are used to indicate whether a person has lupus. Lupus disease is a common disease that affects a lot of people and can be developed over the course of time.
Figures

down: Lupus Rash

Butterfly rash

Lupus Disease
Common Lupus Symptoms
Symptoms of SLE may vary widely between individuals.

Brain: Persistent and unusual headaches, memory loss, or confusion

Mouth and Nose: Sores inside the mouth and/or nose

Lungs/Heart: Shortness of breath and/or pain in the chest.

Eyes: Dry or puffy eyes, and increasing sensitivity to light

Skin: A “butterfly” rash on the face usually over the cheeks and bridge of the nose or other rashes that can worsen with sun exposure
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Bridging the Gap Between Vaccinations and Autoimmunity/ASIA: Emphasis on HBV and HPV Vaccines

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Abstract

Recent questions have arisen about the safety of vaccines. Currently, children are recommended to receive 50 vaccinations by the age of 6 according to the Center for Disease Control and Prevention’s (CDC) current vaccine schedule. The high levels of the adjuvant aluminum linked to neurological disorders, autoimmune disease, and Autoimmune/Inflammatory Syndrome Induce by Adjuvants (ASIA) are of great concern, especially considering most vaccines are given to children during critical periods of development. The objectives of this study are to better understand the relationship that vaccines may have on autoimmune disease; however, causation is still not well understood. In this article, strong correlations will be observed among specific vaccine adjuvants, antigens, and specific vaccines themselves to autoimmunity with theories and hypotheses of how it may occur in the body.

Introduction

Autoimmune disease is estimated to affect approximately 50 million Americans, making it one of the top 10 leading causes of death in female women and children, according to the American Autoimmune Related Disease Association (AARDA). The recent rise in prevalence of autoimmune disease has led researchers to question its origins more closely. It is currently known that our genetics, environment, and hormonal and immune defects affect the likelihood of the development of autoimmune disease. Recently, vaccines and vaccine adjuvants have been shown to be a possible environmental toxin linked to the development of autoimmune disease and ASIA.

Currently children receive 50 vaccinations by the age of 6 in the US. This high volume of vaccinations at such a young age is concerning considering the high level of adjuvants in vaccines. As adjuvants are necessary to illicit an immune response, they do come with serious side effects. In some developed countries, children will receive a total of 126 antigenic compounds, usually containing high amounts of adjuvants (such as aluminum) by the age of 4 to 6 years old. This equates to more than 30 vaccines, according to the current vaccine schedule (Table 2).

Like any pharmaceutical drug, vaccines have risks of adverse events. Almost all vaccines are at risk of triggering autoimmune disease in predisposed individuals; however, the risk is greater in some vaccines than others. The connection is not simple involving many different physiological mechanisms to induce such a reaction.

Mechanisms of Autoimmunity

Autoimmunity is a vast and complex subject which may take place through many different mechanisms in the body. The concern is that the same mechanisms used to stimulate the immune system also could trigger autoimmune disease and/or ASIA syndrome. It is widely accepted in the scientific community that infectious pathogens may trigger an autoimmune response in prone individuals through mechanisms including molecular mimicry, bystander activation, epitope spreading, and polyclonal activation.

Molecular mimicry is a theoretical mechanism which refers to an immune response directed towards an antigen which may target host molecules with a similar structure. This is sufficient for resulting in cross-activation of autoreactive T or B cells by pathogens. Bystander
activation describes a phenomenon where T-cells may become activated without a T-cell receptor, bypassing immune checkpoints. This mechanism enhances cytokine production encouraging auto-reactive T-cells to expand. Epitope spreading refers to an immune response to epitopes (the antigenic determinant that the immune system recognizes). This is not to be confused with cross-reactivity. Polyclonal activation ensures that the immune system will recognize antigen epitopes by multiple clones of B cells. These mechanisms are mostly theoretical, but it is the current understanding of how antigen/adjuvant autoimmunity may arise.

An example of how these mechanisms may occur in the body specific to a vaccine reaction is as follows: It is possible that vaccine antigens could share mimetic epitopes with self-antigens. The adjuvant induced increase in cytokines may then trigger polyclonal activation of autoreactive T-cells.

Autoimmune/Inflammatory Syndrome Induced by Adjuvants (ASIA)

ASIA is defined as a chronic state of inflammation after being introduced to adjuvants. These adjuvants include silicone, aluminum, and infectious components. ASIA is not well understood or a fully accepted condition; however, it does seem to be genetic. It is seen often before the development of autoimmune disease, but does not always result in autoimmune disease. In contrast, those with autoimmune disease almost always have symptoms of ASIA. It is seen that when combining adjuvants, ASIA and the development of autoimmune disease are more likely. For example, silicone breast implants are known to cause autoimmune disease in themselves; when combined with vaccine adjuvants the risk is much greater. This phenomenon could help explain why the risk of adverse effects goes up when increasing the number of vaccines given to an individual.

Unfortunately, ASIA may be underreported because of a lack of awareness and failure to connect the syndrome to exposure of adjuvants. If doctors could easily recognize ASIA, it would be possible to greatly minimize the likelihood of the development of autoimmune disease from ASIA if removal of the adjuvant was possible. For a better understanding of criteria for ASIA, see Table 3.

Aluminum Adjuvant

Aluminum is widely accepted as highly neurotoxic and is linked to the formation of neurological disorders, autoimmunity, and ASIA in adults. Despite this information, the toxicity of aluminum vaccine adjuvant is yet to be tested in infants and children. Furthermore, children are exposed to much higher amounts of aluminum with the current vaccine schedule than adults. It is not surprising that infants and children are likely to be much more susceptible to such adjuvants, due to critical periods of neurodevelopment.

The upper limit for aluminum set by the FDA in a vaccine is 850 ug/dose. What is shocking is that this limit is not set based on toxicity, but rather on the minimum amount required to elect an immune response. The FDA has set the tolerable intake of aluminum in diets to 1mg a day; however, the actual intake in some urban areas is around 100mg/day (see Table 1). Moreover, when eaten, only 25% is absorbed; most is eliminated through the kidneys. Aluminum compounds will stay in the body for 8-11 years. Chronic inflammation may be seen in the body due to repeat exposure of adjuvants, which is thought to cause a hyper-activation of the immune system.
Aluminum is necessary in vaccines to successfully stimulate an immune response\(^1\). It drives the immune system to respond to a virus, however, there is a great risk that the adjuvant could make its way to the central nervous system\(^2\). A safe balance of aluminum would be hard to achieve without sacrificing vaccine effectiveness\(^1,2\). As little as 2-3 vaccine adjuvants could overcome the natural genetic resistance to autoimmunity. This was demonstrated by a study conducted on mice who were genetically resistant to autoimmunity. Despite this genetic trait, 10 mice developed severe autoimmune myocarditis when a virus was administered with an adjuvant, compared to no effect on mice who were only administered a virus\(^1,2\).

Aluminum disrupts and damages the blood-brain barrier (BBB). Problems with the BBB are best known for its links to autism and neuroinflammation, but can also cause autoimmunity\(^2\). Aluminum is unique in its ability to pass freely through the BBB resulting in an unsurprising link to neurological side effects by interfering with essential cellular processes\(^4\). When aluminum passes the BBB it can act as a genotoxin (a poisonous substance which damages DNA leading to mutations in DNA\(^15\)), be pro-inflammatory, act as an immunotoxin, or act as an endocrine disruptor\(^9\). An infant’s BBB is underdeveloped in the first stages of life, therefore, making infants more susceptible to neurotoxins. In addition, their immune renal system is also inadequate in eliminating environmental toxins at this age\(^1\).

### Aluminum Adjuvant Effect on the Endocrine System

It is possible that an adjuvant could disrupt the endocrine system leading to endocrine autoimmune disorders such as Hashimoto’s Thyroiditis, Grave’s Disease, and Type 1 Diabetes (T1D)\(^7\). The HPV vaccine is strongly linked to ASIA and seems to have ties to the autoimmune issues associated with the endocrine system. There is much debate around whether viral vaccines could trigger an autoimmune response or not, however, it is widely accepted that viruses are linked to autoimmunity disease. This review states that the viruses in the HPV vaccine have strong immunostimulatory effects and have the ability to induce autoimmunity through many different possible mechanisms in the body. In addition to the possibility of viral induced autoimmunity, it is also likely that adjuvants such as aluminum play a role as well\(^7\).

Primary ovarian failure (POF) has been linked to the HPV vaccine as a secondary symptom. POF is a condition described as a combination of amenorrhea for a minimum of four months, declined sex steroids, and an increase in follicle-stimulating hormone (FHS) resulting in infertility. POF is linked to autoimmune disease and ASIA triggered by the vaccines. The HPV’s development of ASIA and POF is seen in girls who were previously healthy and developing normally before vaccination\(^7\).

There is a great amount of controversy around whether T1D could be associated with vaccine adjuvants or vaccine viruses\(^7\). Most sources suggest that T1D is not associated with vaccination, however, most studies looked at a connection between T1D and antigens in vaccination\(^4\). It is possible that distributions to the endocrine system by vaccine adjuvants such as aluminum could induce T1D. Some studies suggest that vaccination could induce GADA antibodies which are reliable markers for the development of T1D\(^7\).

It is of interest to note the strong body of evidence linking the adjuvant silicone to autoimmune disease. Since many women have silicone breast implants, it is thought that this factor could play a part in increasing the statistics of women having a much greater chance of developing autoimmune disease than men. As it is probable that this does have an effect of
prevalence of autoimmune disease in women, female children also have a greater prevalence of autoimmune disease than males.\(^7\)

Thyroiditis is linked to the adjuvant silicone as vaccines in some instances. There was a report of a man who had a history of autoimmune disease who developed Thyroiditis following the influenza vaccinations. A woman developed Thyroiditis one month after receiving the influenza vaccine. There are many cases of women developing Thyroiditis from silicone in breast implants unrelated to vaccination. The significance of this information is to show that silicone is an adjuvant and should be more seriously considered as a possible trigger.\(^7\)

**HPV Corruption**

A large study was done recently which identified no autoimmune safety concerns related to the HPV vaccine. There are several shocking biases which likely contributed to their conclusion. First, the study was performed on all women who received only one out of three doses of the vaccine. It is known that the more vaccinations and/or adjuvants received in a short period of time, the more likely vaccinations are to trigger autoimmune disease, and even overcome genetic resistance to autoimmunity. Adverse events occur less frequently when fewer vaccine doses are administered. Second, the study failed to recruit a qualified individual with the ability to diagnose autoimmune disorders. Third, the Safety Review Committee failed to account for the fact that many autoimmune manifestations are nonspecific. Full blown autoimmune disorders rarely develop in a short period of time (this could take years); however, autoantibodies are usually seen early on within a few weeks or months. This is when you commonly see symptoms of ASIA and symptoms begin to be expressed but, it doesn’t not always turn into a full blown autoimmune disease. Fourth, Merck, a manufacturer of one of the available HPV vaccines, funded the study entirely. In additions to this information, all authors previously were funded by Merck and/or were consultants for the HPV manufacturer. Lastly, aluminum is used as the placebo. This practice is common in vaccine trials, but can no longer be justified with the known side effect of aluminum, which far outstretch the scope of autoimmunity.\(^14\)

**HBV Vaccine**

An impressive and unique study was done on the HBV vaccine and autoimmunity in predisposed individuals. Compelling evidence has strongly linked the two. The study was conducted on 93 of individuals who were diagnosed by competent individuals with autoimmune disease (neurological, musculoskeletal, gastrointestinal, fatigue and fever symptoms) following the HBV vaccinations. The onset of symptoms occurred on average 43.2 days after vaccination raining from 1 day to 2 years. 71% of individuals were adults, 29% were children, and 70% female. Autoimmune susceptibility, referring to family or personal history was documented in 21% of individuals. 59% of participants received all three HBV injections, 29% received two, 12% received only one. Neuropsychiatric manifestations were seen in 70% of patients (25% went on to be diagnosed with Multiple Sclerosis (MS), Guillain-Barre syndrome (GBS), etc.) ophthalmix manifestations in 32%, mucocutaneous manifestations reported in 30%, musculoskeletal in 59%, gastrointestinal in 50%. 80% were seropositive. In addition, ASIA was applicable to 96% of adults and 68% of children. Of the remaining participants, 11/13 were children, most males. 9 of the 13 were diagnosed with Type 1 Diabetes.\(^6\) The HBV vaccine contains a viral antigen saccharomyces cerevisiae bacterial cells paired with an aluminum
adjuvant. High levels of anti-saccharomyces cerevisiae antibodies have been seen in individuals with T1D, Rheumatoid Arthritis (RA), and Systemic Lupus Erythematosus (SLE)\textsuperscript{8}.

A continuation of this study evaluates 19 patients who went on to receive a diagnosis of Chronic Fatigue syndrome (CFS) or Fibromyalgia (FM). Another study took a closer look at this group of people. CFS and FM are both part of ‘central sensitivity syndromes’ and often share many symptoms. CFS and FM have been linked to vaccines, infectious agents, and adjuvants. The pathogenesis of both diseases is not yet understood; however, it has been hypothesized that they may be linked to autoimmune disease in some way and share many symptoms with ASIA. It is not uncommon for patients with autoimmune disease to also be diagnosed with FM. Higher levels of cytokines are seen in patients with FM suggesting the involvement of immune processes. Both FM and CFS have been linked to autoantibodies. Both diseases are seen in more commonly in women than men, further supporting the hypothesized link to autoimmune disease. Consistent with the previous study, 21\% of patients were deemed autoimmune susceptible due to personal or family history of autoimmune disease\textsuperscript{8}.

FM may be induced by the antigens found in the HBV vaccine due to an already understood association with chronic HBV infection\textsuperscript{8}. Considering FM and CFS have neurological symptoms, it is interesting that the HBV antigen has been found to be neurotoxic\textsuperscript{8}.

It is of interest to gain a better understanding of the genetic profiles of those being evaluated to more accurately determine genetic predisposition, other than solely through personal and family history. Traditionally, an immune response is required between 3-6 weeks after vaccination to be considered as an adverse reaction; however, research has suggested that autoimmune disease may take much longer to develop in the body. This could be a major flaw in much of the current research dispelling any link between vaccination and autoimmune disease. It is a rarity to see research done on predisposed individuals, especially humans. As it may be a downfall that there was no control group in these studies, it provides a benefit through tests done on predisposed humans. However, a bias should be noted that most participants in both HBV trails were undergoing legal action for their injuries. The effect that both an antigen and an adjuvant overwhelming the body at the same time could affect the likelihood of developing autoimmune disease has not been studied\textsuperscript{8}. However, it has been shown that vaccine in combination could amplify the effects leading to autoimmunity\textsuperscript{9}.

In addition to the HPV and HBV vaccine-autoimmune connection, many other vaccines may induce autoimmunity as well. Other vaccines are more controversial and less consistent compared to the strong link between the HPV and HBV vaccines.

**Arthritis**

Rheumatoid Arthritis is one of the most commonly reported vaccine reactions. The tetanus vaccination was reported to trigger the onset of arthritis within 6 weeks in 3.23\% of people according to the Norfolk Arthritis Register database. Rheumatoid factor (RF) titer was recorded in 4.08\% of military recruits between 2-3 weeks after receiving 7 vaccinations at once\textsuperscript{4}. This is a relatively short timeline which could be due to the multiple vaccinations at once. Another article states 5\% of people have been reported to develop reactive arthritis after the rubella vaccine. In addition to this information, it has been shown in a Vaccine Adverse Event Reporting System (VAERS) study that an increase in arthritis is seen in patients following HBV vaccination\textsuperscript{4}.
Arthritis and RF titer may be a symptom of ASIA and can result in the development of full RA. Keep in mind, autoimmune disease takes time to manifest in the body. It would be of interest to follow up with these individuals to see if the development of RA was present over a longer period of time. If so, it might line up with the statistic stated by the CDC that RA effect about 1% of the population\textsuperscript{4,11}.

Cost- Benefit Analysis

The HPV vaccine should be critically analyzed by patients through a cost-benefit analysis. 1 in 40,000 people will be victims of cervical cancer, however, 90% of cervical cancer deaths occur in underdeveloped countries where access to PAP smears is unavailable. In addition, the death rate of girls between the targeted vaccination age of 9-20 is 0%. Women over 55 years old are at the greatest risk of developing cervical cancer at which time they will no longer be protected by the vaccination (generously estimated to last 8-10 years max)\textsuperscript{3,4}.

A Demark study estimated that 1 in 500 girls will be seriously injured by the HPV vaccine resulting in early menopause, being wheelchair bound, seizures, and fainting spells\textsuperscript{10}. Specifically, the most common disorder the HPV vaccination has been linked to include, but are not limited to, Systemic Lupus Erythematosus (SLE), myelitis and Multiple Sclerosis (MS), Guillain-Barre syndrome (GBS, arthritis, vasculitis, antiphospholipid syndrome (APS), myopathy, and death\textsuperscript{4}.

When looking at the cost-benefit analysis of the HBV vaccine, it should be kept in mind that an infants blood-brain barrier is underdeveloped during the first stages of life\textsuperscript{2}. In spite of this information, infants are still recommended to receive the aluminum containing HBV vaccine within the first 12 hours of life according to the CDC\textsuperscript{16}. Detrimental vaccine reactions could be minimized by prolonging the HBV inoculation or by assessing vaccine necessity. For example, mother who have hepatitis B should consider the HBV vaccination. The population at the greatest risk of contracting hepatitis B are sexually active individuals and drug users sharing needles\textsuperscript{18}. In turn, the HBV vaccine is unnecessary on the first day of life, especially considering it will likely no longer be effective by the age of sexual activity\textsuperscript{17}.

Conclusion

It cannot be stated unequivocally that vaccines cause autoimmune disease considering the quality and volume of research done so far. It is important to note that vaccines are not seen as the sole cause for autoimmune disease, but rather a strong environmental toxin with the ability to unmask genetic predispositions. Many factors play into the development of autoimmune disease, including hormonal imbalances. Also, there is a strong gender bias towards women which may be connected to hormonal differences in men and women.

It is true that causation has not yet been determined; however, strong correlations between vaccines and autoimmune disorders have been observed which should be considered further. With the phenomenon affecting 5-8% of the population and rising, it is crucial that we take a closer look at different factors that may be triggering autoimmunity\textsuperscript{8}.

More specific to the broad category of vaccines, aluminum seems to be the triggering agent in autoimmunity/ASIA in predisposed individuals. Aluminum has proven to be an aggressive aggravating factor with unique abilities to freely pass the blood-brain barrier and disrupt the endocrine system leading to neurological autoimmune disease symptoms\textsuperscript{1,2}. 

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Aluminum paired with specific antigenic components may make for the perfect cocktail for autoimmunity in predisposed individuals. However, testing on the effects of the two combined is limited at best. The fact that studies on combined vaccines has not been done is irresponsible considering vaccines are usually given in combination at doctor appointments, especially in light of coincidental evidence leading to the observance that combined vaccines could have an amplified effect.

With the research presented, studies should be conducted urgently to understand the mechanisms of vaccine induced autoimmunity in order to strive for safer vaccines. The aluminum adjuvant in vaccines should be seriously reconsidered. The scientific community should aim to find a new adjuvant with less neurological risk, considering many vaccines are given to children during the important years of brain development. A huge problem with scientific research surrounding aluminum’s link to ASIA is the fact that many studies use aluminum as a placebo. Considering aluminum is suspected to be the linking factor to ASIA, results would be skewed1,2. Going forward, it should be questioned whether adjuvant induced immunity of any kind is safe.

Vaccine safety in regard to autoimmune disease needs to be evaluated urgently. Individuals should undergo genetic testing before receiving a vaccination in the future to better predict the severity of the reaction and have a more accurate cost-benefit analysis. Furthermore, the Hippocratic Oath of doctors should be kept in mind when advocating for preventative measures that are shown to, in many cases, do more harm than good. Scientists and doctors should not default to the all too familiar phrase, ‘vaccines are safe and effective,’ when presented with an adverse reaction, but rather see this as an opportunity to strive for safer vaccines because science is never settled.
Figures

Table 1 – Major sources of aluminum[^2]

<table>
<thead>
<tr>
<th>Major sources of Al exposure in humans</th>
<th>Daily Al intake (mg/day)</th>
<th>Weekly Al intake (mg/day)</th>
<th>PTWI * (1 mg/kg body weight; for an average 70 kg human, PTWI = 70 mg)</th>
<th>Amount delivered daily into systemic circulation (at 0.25 % absorption rate[^*)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural food</td>
<td>1–10</td>
<td>7–70</td>
<td>0.1–1</td>
<td>2.5–25 µg</td>
</tr>
<tr>
<td>Food with Al additives</td>
<td>1–20 (individual intake can exceed 100)</td>
<td>7–140 (700)</td>
<td>0.1–2 [10]</td>
<td>2.5–50 µg (250 µg)</td>
</tr>
<tr>
<td>Water</td>
<td>0.08–0.224</td>
<td>0.56–1.56</td>
<td>0.008–0.02</td>
<td>0.2–0.56 µg</td>
</tr>
<tr>
<td>Pharmaceuticals (antacids, buffered analgesics, anti-ulceratives, anti-diarrheal drugs)</td>
<td>125–5000</td>
<td>882–35,000</td>
<td>12.6–500</td>
<td>315–12,500 µg</td>
</tr>
<tr>
<td>Vaccines (HepB, Hib, Td, DTP)</td>
<td>0.51–4.56</td>
<td>NA</td>
<td>NA</td>
<td>510–4560 µg[^**]</td>
</tr>
<tr>
<td>Cosmetics, skin-care products and antiperspirants[^***]</td>
<td>70</td>
<td>490</td>
<td>NA</td>
<td>8.4 µg (at 0.012 % absorption rate)</td>
</tr>
<tr>
<td>Cooking utensils and food packaging</td>
<td>0–2</td>
<td>0–14</td>
<td>0–0.2</td>
<td>0–5 µg</td>
</tr>
</tbody>
</table>

Table 2 - Antigen exposure in accordance to the vaccine schedule[^1]

<table>
<thead>
<tr>
<th>Vaccine (if antigen)</th>
<th>Birth</th>
<th>2m</th>
<th>4m</th>
<th>6m</th>
<th>12m</th>
<th>18m</th>
<th>24m</th>
<th>4–6y</th>
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<tr>
<td>EngerixB (1)</td>
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<td>Convax (3)</td>
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<td>Prevnar (14)</td>
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<td>Pedvax (2)</td>
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</table>

| Total # antigens     | 1     |    |    |    |     |     |     |      |
| Viral attenuated     |       |    |    |    |     |     |     |      |
| vaccine              |       |    |    |    |     |     |     |      |
| (if attenuated       |       |    |    |    |     |     |     |      |
| viruses)             |       |    |    |    |     |     |     |      |
| Infanrix-IPV (3)     |       |    |    |    |     |     |     |      |
| Rotarix (1)          |       |    |    |    |     |     |     |      |
| MMR-II (3)           |       |    |    |    |     |     |     |      |
| Varivax (1)          |       |    |    |    |     |     |     |      |
| Havrix (1)           |       |    |    |    |     |     |     |      |
| Fluvirax (3)         |       |    |    |    |     |     |     |      |

| Total # attenuated viruses | 0 | 4 | 4 | 3 | 11 | 1 | 3 | 10 | 36 |
### Table 3 – Major and minor criteria for ASIA

**Major Criteria:**

- Exposure to an external stimuli (Infection, vaccine, silicone, adjuvant) prior to clinical manifestations.
- The appearance of 'typical' clinical manifestations:
  - Myalgia, Myositis or muscle weakness
  - Arthralgia and/or arthritis
  - Chronic fatigue, un-refreshing sleep or sleep disturbances
  - Neurological manifestations (especially associated with demyelination)
  - Cognitive impairment, memory loss
  - Pyrexia, dry mouth
- Removal of inciting agent induces improvement
- Typical biopsy of involved organs

**Minor Criteria:**

- The appearance of autoantibodies or antibodies directed at the suspected adjuvant
- Other clinical manifestations (i.e. irritable bowel syn.)
- Specific HLA (i.e. HLA DRB1, HLA DQB1)
- Evolvement of an autoimmune disease (i.e. MS, SSc)
References


10. TV2Danmark. 2015. "De vaccinerede piger" (with English Subs) for international viewing [Internet]. Youtube.com; [cited 2017 March 22]. Available from: https://youtu.be/GO2i-r3h9ok


The Evolution of the Television
Courtney Scott
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Physics 112
Dr. Durandet
Abstract

The first concept of the television was patented in 1884 and the first television reached the consumer market in the United States in 1946. Television sets have improved drastically since the first television set: from the cathode ray tube to digital light processing to liquid crystal display to plasma to light emitting diode and finally organic light emitting diode. With each television advancement televisions have gotten a brighter and more colorful image, a larger display, and more power efficient. Essentially all television sets work similarly, television sets mainly differ in how light is produced and how unwanted light is removed. This paper explores the fundamental physics behind each of these types of televisions, how they function, and the improvements from previous models.

Nielsen’s National Television Household Universe estimates that in 2016 there are 118.4 million homes in the United States with a television, and in 1945 there were fewer than 10,000 homes in the United States with television sets. According the Nielsen’s National Television the average American watches 4 hours of television everyday. Some would argue that the television is one of the greatest innovations in human history, but few would argue on the popularity and growth of the television.

Who invented the television set? There is no clear answer to this question; some believe it was Philo Farnsworth because he created and demonstrated an electric television first, others believe it to be Vladimir Kosmich Zworykin because he patented the idea of an ‘Television system’ first, and then others believe that there was not simply one inventor but multiple inventors who contributed to the idea of a television set.

In 1884, a German University student patented the first concept of an electro-mechanical television. The patented television set was the basis of the television sets created in the 1920’s and 1930’s. The television sets created consisted of a disk with 30 holes in a spiraling patter, this was known as the ‘Nipkow disk.’ In 1926, John Logie Baird conducted the first experiment demonstrating a moving image; he used a spinning Nipkow disk. In 1928, the first drama on television was broadcasted. “The Queen’s Messenger” was a 40-minute drama with only 2 characters. In 1931, a German inventor, Manfred Von Ardenne presented the first ever fully electric television in Berlin. Ardenne’s all-electric television set used electron beam tubes for both the transmitter and receiver to broadcast pictures and film completely electronically. In 1934, at the Franklin Institute of Philadelphia Philo Farnsworth, an American inventor demonstrated his invention of the all-electric television set to the public for 10 days. Farnsworth created and patented his all-electric television in 1927 and showed his television to the press in 1928. Farnsworth and Ardenne’s all-electric television sets were fundamentally different in the way that they worked. In 1934, Vladimir Kosmich Zworykin launched the ‘iconoscope,’ this was the first cathode ray tube used to capture an image used in television cameras. And in 1936, the Berlin Summer Olympics were broadcasted live throughout Germany using Farnsworth and Zworykin’s inventions. Figure #1 shows a camera at the 1936 Olympics. Radio Corporation of America, RCA, was a large contributor to the advancement and standardization of the television. RCA hired many leading inventors, like Vladimir Kosmich Zworykin, and bought television patents from Philo Farnsworth to manufacture and sell television sets in 1939. Also, in 1939 RCA televised the grand opening of the New York World’s Fair where President Franklin Roosevelt gave a the first televised speech of a president. Due to World War II, there were no substantial advancements in television because technology resources were being spent on
defense. By 1947, the full-scale commercial television began in the United States. With the full-scale commercial television no new invention entered American homes faster than black and white television sets; by 1955 half of all U.S. homes had one.

The first television invented was known as the cathode ray tube, CRT, television. This was introduced to the United States market in 1938. Following the release of the CRT television was CRT color television. Color television was first introduced to the public in 1951, but was not popular until 1960 when more television began to broadcast in color. In 1983, the first commercial liquid crystal display, LCD, television was created. LCD televisions were much thinner and lighter than CRT televisions, and at the time produced a brighter image than any other televisions on the market. In 1997, the digital light processing television was introduced. DLP televisions provided a better contrast and better resolution. To this day, DLP projectors/televisions make up most of the cinema market. In 1997, plasma televisions were available to the public for purchase. Plasma televisions were significantly thinner, lighter, and faster than DLP and LCD televisions. They displayed increased contrast, a greater color spectrum, and a wider range-viewing angle. In 1977, light-emitting diode, LED, televisions were invented but were available on the consumer market in 2004. LED televisions are more energy efficient, have a longer life span than LCD televisions, and have a larger viewing angle than LCD televisions.

Johann Wilhelm Hittorf discovered cathode rays in 1869 and Ferdinand Braun discovered the cathode ray tube in 1897, long before the invention of cathode ray tube television sets. A cathode ray is a stream of electrons created when voltage is applied between a cathode and an anode. The first television set to fill the homes of thousands of people throughout the world, were black and white cathode ray tube, CRT, television sets. A CRT television is composed of an electron gun, deflecting and focusing coils, and a phosphor screen. All of these components are contained in a glass vacuum tube. Generally speaking, the electron gun produces a beam of electrons, and then the electrons are guided by the deflecting and focusing coils and collide with the phosphor screen to produce a glowing image. More specifically, the electron gun is composed of a heater, a cathode, an accelerating anode, and a focusing anode. Upon heating the cathode, a cloud of electrons is released. The accelerating anode pulls the electrons toward the screen of the television and the focusing anode transforms the cloud of electrons into a fine beam of electrons. When the electron beam leaves the electron gun, the deflecting and focusing coils guide the beam onto the screen. In CRT televisions, these coils are known as electromagnetic deflection and are in between the electron gun and the phosphor screen. These coils each consist of two magnetic plates used to guide the beam of electrons onto the phosphor screen; the direction of the beam of electrons depends on the polarity and amount of charge on the plates. Two plates will direct the beam of electron’s horizontal location and the other two plates will direct the beam of electron’s vertical location. The way that the plates direct the location of the electrons is by creating an electric field between them. For example, the one horizontal plate is positively charged and the other horizontal plate is negatively charged, the charges create an electric field between the two plates and the magnitude of the electric field determines the horizontal location of the electron beam on the screen. This same principle applies to the two plates controlling the vertical location. This process happens continuously and faster than the human eye can detect to create the illusion of a moving image on the television screen. The screen of a CRT television is composed of a glass screen coated with phosphor. The glass screen is coated with phosphor because phosphorus is a chemical element that will illuminate when in contact with electrons or electrical energy. Figure #2 shows the layout and components of a
CRT television. The electrical power of a television is consumed by the electromagnetic
deflection continuously changing the polarity and charge of the magnetic plates, lost in the form
of light as the image on the screen is projected, and lost in the form of heat as CRT televisions
emit a lot of heat.

While color television revolutionized the way that the world viewed at home media, the
color television did not function vastly different from black and white television. The color CRT
television had all of the same components as a black and white CRT television as discussed
above--an electron gun, electromagnetic deflecting plates, and phosphorus screen. Color
television added two main components internally to the CRT television--three electron guns and
a shadow mask. The three electron guns consist of the same internal components--a heather,
cathode, accelerating anode, and focusing anode--however, one electron gun emits a red beam of
electrons, another emits a blue beam of electrons, and the third emits a green beam of electrons.
The three electron guns are aligned in a triangle formation and any visible color can be created
with some sort of combination of the red, green, and blue electron beams. The three electron
beams are deflected together and strike the face of the CRT. In order to strike the CRT screen,
the three electron beams must pass through the shadow mask. A shadow mask is a thin sheet of
metal that is covered in tiny holes between the electron gun and phosphor screen. The electron
beam is much larger than the holes on the shadow mask; the shadow mask only allows a small
beam of the electron beam through to the phosphor screen to create a clearer image, a visual for
how this works is presented in figure #3. The principles of creating color found in the color
television are heavily utilized even in today’s technology.

While CRT television was a breakthrough for the world it posed many disadvantages; it
was extremely heavy and required a large power supply because of the high voltages used to
accelerate the electron beams. As an alternative to the CRT television, liquid crystal display,
LCD, televisions were created and introduced to the market. LCD televisions are low voltage
devices, and hence use very little power. An LCD television is composed of a liquid crystal
material between two glass screens. The two glass screens are parallel but not aligned so that
light cannot pass through. A backlight shines from behind the television screen through the
liquid crystal panel. Each liquid crystal can be arranged in a variety of ways to allow light to
pass through where desired. When there is no electric current flowing through the system the
crystals are in a relaxed state. While in the relaxed state the crystals are aligned in several
parallel planes, the planes are offset from each other creating a twisted structure and blocking
light from passing through. When an electric current is applied to the system, the crystals will
bend and arrange in such a way to allow light to pass through. The entire screen of an LCD
television is covered in thousands of pixels; each pixel has a red, blue, or green filter. Similar to
color CRT televisions, these three colors can be combined to form any visible color. The LCD is
essentially a light gate, which can be opened to allow light to pass, or closed to shut off light.
Figure #4 shows the layers and components of an LCD television.

Digital light processing, DLP, televisions are based on a technology referred to as Digital
Micromirror Device, DMD. DLP is a trademark name owned by Texas Instrument. DMD is a
device that displays an image through many microscopic, aluminum mirrors called DMD chips.
DMD televisions work very similarly to LCD televisions, except instead of having liquid crystal
between two screens to filter what light reaches the screen DMD televisions have DMD chips to
filter which light reaches the screen. DMD chips are composed of small mirrors measuring less
than one-fifth the width of a human hair and each mirror represents one pixel. The number of
pixels in a DMD television will correlate with the resolution of the television, the more pixels
there are the clearer the image will be. If you look closely at a DMD screen, you can see the separate pixels but if further away the pixels blend together. Each microscopic mirror is on its own hinge on the DMD chip, the mirror can either tilt in the on (toward the light source) or off (away from the light source) direction. Figure #5 shows what a DMD chip looks like. The CMOS DDR SRAM chip is a memory cell that will electrostatically cause the mirror to tilt to the on or off position. Prior to switching to the on or off position, the chip will receive an image code through the semiconductor, if necessary adjust the size, brightness, sharpness, and color quality of the coded picture to fit the screen of the television, and then relays all the information to the mirrors, completing the whole process in just 16 microseconds. The light the mirrors reflect is directed through a lens to the television screen. To get a colored image with a DMD television set, the white light will pass through a spinning color wheel before striking the DMD chip. The color wheel consists of red, green, and blue, again using these three colors any visible color can be created. Each pixel on the screen will either be red, green, or blue however the pixels will flash rapidly to blend these colors and create a different color for the viewer. For example, for a pixel to appear yellow then blue and green will rapidly flash on the screen and the human eye will blend these blue and green flashes to see the intended yellow. Figure #6 shows the components of color DMD television. Some pros of DLP television sets are the smooth images, the backlight source has a limited life but is easy to replace, light weight, and not limited to size.

Plasma flat panel display televisions produce the most natural color of all television sets and are a popular alternative to CRT televisions. Matter comes in several different forms: solid, liquid, gas, and plasma. Plasma is an ionized gas, if heat is applied to gas the molecules and atoms break apart, release electrons, and when the atoms disintegrate they form ions-positively charged particles. The mixture of electrons and ions making up plasma easily conducts electricity. In plasma television, plasma is contained between two glass plates. The plasma is composed of xenon and neon gas in thousands of tiny cells coated with phosphor. On the rear glass plate, there is an address electrode arranged in vertical columns and on the front glass plate is the transparent display electrode arranged in horizontal rows. Figure #7 shows the layers of a plasma television set. Generally speaking, plasma flat panel displays light up pixels to produce an image on the screen. Each pixel is composed of a red, green, and blue fluorescent light. When an electric current is applied to a plasma television set, negatively charged particles rush towards the positive charged areas and the positively charged particles rush towards negatively charged areas. While negative particles are rushing towards positive and positive are rushing toward negative, xenon and neon atoms are excited and release light and ultraviolet photons. The human eye cannot see the ultraviolet photons; the ultraviolet photons interact with the phosphor coated on the inside of the plasma cells, the phosphor releases energy in the form of light photons. The light photons can be red, green, or blue. In general, the phosphors in a plasma display give off colored light when they are excited. When this occurs to all of the plasma cells, an image appears on the screen for the viewer. While plasma television sets were a great step forward from the CRT, LCD, and DLP television sets they had some downsides to them, plasma televisions weren’t as efficient and were still has significant weight even though they were thinner than previous television models.

Light-emitting diode, LED, televisions use LED lights as the backlight for the display. LED televisions are commonly used for large, outdoor displays, such as the advertisement screens in Times Square in New York City. LED televisions are also popular in the consumer market because they use about 20% less energy than an LCD TV. An LED
television is a very similar to an LCD television set, the only difference is that a LCD television uses CCFL backlights and an LED television uses LED backlights. An LED television is essentially an LCD panel with LED lights to illuminate the screen. There are two parallel, polarized glass screens with liquid crystal between the two screens. The oscillation of the light happens in all directions but the two polar glass panels filter the light, the rear glass panel allows vertically polarized light through and the second panel blocks all types of light. The liquid crystal does not produce light, but the liquid crystal changes the polarization of the light to allow the light through the second panel to the display screen. The degree to which the liquid crystal is bent to allow light through is controlled by an electric field, the more voltage applied to the liquid crystals the more they will unbend and the intensity of the light emitted is controlled by changing the voltage. The light comes from the LED backlights. There are two types of LED backlighting- edge lighting and full array lighting. Edge lighting has LED lights arranged on the outer edge of the screen. Full array lighting has LED lights in rows on the screen; full array lighting provides more brightness and dimming because the diodes can be turned off individually. An LED light produces light by a process known as electroluminescence using semiconductors. Electroluminescence is the phenomenon of a material emitting light when electric current or an electric field is passed through it. The electron current or electric field is passed through the material when electrons travel through the material and fill the electron holes. An electron hole is an area that lacks electrons and has a positive charge. Between the semiconductors layers lies the electron hole. The semiconductor is subject to doping, doping is a way to control the amount of electron holes by adding other elements to the semiconductor material to change its properties. Doping can also create two separate layers of semiconductors; the intersection between the two semiconductors is referred to as the p-n junction. A p-n junction allows for the flow of electrons to occur in one direction across the semiconductor, as electrons pass and fill the electron hole light photons are released. Figures #8 and #9 demonstrate the semiconductor, p-n junction, and light emission. LED televisions consume less power than LCD televisions because the LED backlights consume less energy and the diodes turn off when the screen needs to be darkened. The display screen is covered in pixels; each pixel contains a red, blue, and green subpixel. The subpixels allow for a colored image. LED televisions are currently the most popular television sets in the consumer market.

Some physicists would argue that everything in the world relates to physics. A few ways that the television sets explained above relate to physics are: the law of conservation of energy, acceleration of electrons in a CRT television, electricity and power, and the composition of an LED and the semiconductor.

The law of conservation of energy states that while in a closed system energy cannot be created or destroyed, only transferred. Earth as a whole is a closed system and television sets are also closed systems. This means that the electrical energy applied to a television set is not destroyed, it is transferred to several different forms of energy: light, sound, and heat. The law of conservation of energy while a fundamental law of physics is seen in something as high tech as the television. For example, in the CRT television electricity is inputted into the television, that electrical energy is then converted into the electron beam, the electric field used to direct the electron beam, and excess heat that is given off during these processes. All other models of television sets perform similarly, with the input electrical energy being used for the most part to create the image on the screen through a variety of processes and some being lost as heat.

The CRT television is an excellent, obvious example of physics at it’s finest. When the electron gun shoots a beam of electrons (light) to the phosphor screen, the deflecting and
focusing coils direct the beam of electrons to strike the phosphor screen at a specific location. This principle was designed by Albert Einstein and known as the theory of special relativity. The theory of special relativity relates energy and mass using the equation:

\[ E = mc^2 \]

The E represents energy, m represents mass, and c represents the speed of light—which is a constant \(3 \times 10^8\) m/s. Stating that the speed of light is the only constant in the universe. The electrons fired from the electron gun need to be moving very fast and the super-speeds cause the electrons to grow in mass in relation to the rest of the TV set. The deflecting and focusing coils are essentially large magnets that bend the electron beam. Magnetism is related to electricity, when a charged particle is moving through a magnetic field, a magnetic force acts on it. This magnetic force can be expressed using:

\[ F = qvB \sin \theta \]

Where F represents the electric force, q represents the charge of the particle—1.6 \( \times 10^{-19}\) C for an electron, v represents velocity, B represents the magnitude of the magnetic field, and \(\theta\) represents the angle between the velocity and the magnetic field. To find the direction of the velocity vector in a television, one can use the left hand rule. Using one’s left hand the index finger points in the direction of the velocity vector, the other three fingers point towards the direction of the magnetic field vector, and the thumb will point in the direction of the magnetic force. Continuing on with CRT televisions, it is known that a charged particle will experience a force when it is in an area that has an electric field. The force acting on this particle can be calculated using:

\[ F = qE \]

In this equation, F is the force acting on the particle, q is the charge of the particle—1.6 \( \times 10^{-19}\) C for an electron, and E is the electric field. The electron in the CRT will accelerate or experience the force in the opposite direction of the electric field.

While every television to ever be on the consumer market differs internally, fundamentally all types of televisions require electricity to operate. Electricity is the flow of charged particles, such as electrons. Houses receive energy in the form of alternating current, AC, electricity because AC electricity has lower energy loses during transportation. However, television sets run off of direct current, DC, electricity. When a television is plugged into a household outlet it receives 120 volts in the form of AC electricity and converts it to DC electricity using a power inverter. While the TV requires a certain voltage to operate, it also requires a certain amount of amperage to perform the functions necessary to create the image on the screen. Together, voltage and amperage make power, which is expressed in watts and is the unit that power companies monitor to determine the how much electricity a household consumes. In CRT televisions, the power consumption was high and the efficiency was low, and over time the technology in televisions evolved so the power consumed was less than it was in the original CRT sets due to the efficiency of the electrical processes performed being much higher. This improved technology is what allows a modern TV to produce a large, brighter, higher quality image on the screen while consuming a relatively low amount of electrical power.

**Conclusion**

In 90 years, the idea of the television has grown exponentially with increasing technology. As technology continues to develop the ideas and manufacturing of televisions will follow suit. In the future, organic light-emitting diode, OLED, televisions will gain popularity in the consumer market. OLED are currently used in many portable electronic devices such as cell
phones, laptops, tablets, etc. OLED televisions “combine the self-luminescence of plasma displays with the solid-state design of LCDs” (Bungert PJ and Darnay AJ, 2008). OLED televisions were available for purchase in 2009 however the prices are still relatively high, but industry analysts believe that when the last of OLED televisions become more affordable they will one day become the most popular option for the consumer. The high cost of OLED television production has refrained companies from producing OLED televisions at a competitive price. OLED televisions are more eco-friendly than any other television on the market, produce a brighter image than LED televisions, and have a larger viewing angle than any other television. In January of this year, LG Display Co. modeled off the first 18-inch OLED roll-up display television. This television can roll up like a piece of paper or a newspaper. This prototype has been in the making for around 10 years and will hopefully hit the consumer market in the near future. Also earlier this year, Sony released the largest curved television. And Sony released an OLED television that is 4 credit cards thick. The future of the television market is OLED.

While television sets do not appear to be related to physics, the inner workings would not be possible without the research and improvements in electromagnetic physics over the years. Throughout this research I learned all about the different types of televisions and how they relate to physics. The cathode ray tube television set has an electron gun shoot a beam of electrons through deflecting and focusing coils onto a phosphor screen. The deflecting and focusing coils are magnetic plates that create an electric field to redirect the electron beam using the fundamental principles of electromagnetism. Color CRT televisions function using the same technology but with three-electron guns- a red, blue, and green gun to create three different colored electron beams. Liquid crystal display television sets have liquid crystal between two parallel glass screens, when the CFL backlight is turned on the liquid crystals will rearrange to allow light through to the display screen. The fundamental physics involved in LCD television sets is controlling the behavior of the liquid crystal using electrical current. Digital light processing televisions, also known as digital micromirror devices, function using DMD chips, small mirrors, on individual hinges that can rotate to block light or allow light through to the television screen. The development of the DMD chip to redirect light to the screen is the physics required to make DLP televisions work. In plasma flat panel display televisions, plasma consisting of xenon and neon gas is contained between two glass plates in thousands of tiny, phosphor-coated cells, when an electric current is applied to the system the plasma releases ultraviolet photons that will interact with the phosphor to create an image on the screen. Controlling the behavior of the plasma using electricity allowed for the development for this television, which was a large step forward from previous television models. Light emitting diode televisions utilize the components and layout of an LCD television but instead using LED backlights. Understanding the behavior of an LED and liquid crystal were necessary to produce the LED television. While televisions are physics based due to the strong electrical processes that they perform, during my research I discovered that the exact details and finer workings of these television sets is not always publically known. I believe that the exact details of some television sets is knowledge only possessed by those working in the television industries that need to know the finer details. While some of the exact details are not easily accessible, I was able to research and verify the electromagnetic processes performed in televisions, from the original CRT television sets all the way to modern OLED television sets.
Figures


Figure #4: Layers and components of an LCD television

Figure #5: DMD chip components from a DLP television

Figure #6: Color DMD television set components, the light filter through a color filter before striking the television screen
Figure #7: The layers of a plasma television- address electrode arranged in vertical columns, plasma gas, and transparent display electrode arranged in horizontal rows

Figure #8: The layers of a semiconductor, the electron hole, and the p-n junction

Figure #9: How light is emitted from an LED
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Crohn’s Disease

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Abstract: Crohn’s Disease is a permanent condition that affects the small intestine's lining in the digestive tract. A definitive treatment for Crohn’s is still not found but with the right regimen people can suppress its effects. Causes for this disease are also unknown which makes this condition very fascinating yet very troublesome. Fortunately with the right adjustments people can learn how to cope with Crohn’s. There are certain pills and some nutritional adjustments that are crucial in slowing the progression of disease.

Introduction: Crohn’s disease was initially discovered in 1942 by Leon Ginzburg Crohn’s. Back then diagnosing this disease must have been extremely difficult. Since it affects different areas of the digestive tract pinpointing an exact problem is the big challenge. Ulcerative colitis or different stomach illnesses are similar diseases that includes similar symptoms to Crohn’s and distinguished them from another can be a tedious process. “A recent survey done by Crohn’s and Colitis UK acknowledged that patients may even be giving up sport and exercise due to their illness. Due to the wide variance of Crohn’s symptoms, there is no definitive cure or treatment for the disease. Everyone is different and must be treated according to the individual’s needs however, as Crohn’s directly affects the digestive tract, there is a huge effort to treat and manage symptoms through moderating and altering diet. Awareness of Crohn’s disease has increased a great deal in the last 40 years, as patients feel more comfortable to discuss the disorder and share their experiences with others. What was once a very taboo topic is now common knowledge” (Harry D. Fein). Nowadays with the help of social media Crohn’s has gotten more awareness and more research is being done on finding the right medication for certain people and even the use of kinesiology. In addition there are certain website that exist especially for Crohn’s where people can compare symptoms and share what kind of regiment worked best. Awareness for crohn’s has definitely been raised since it was first discovered however since it's a very rare disease there is still more room for improvement for more people to be aware. In addition treatment has also been improved. Research labs continue to develop new ways for people to keep Crohn’s disease symptoms at bay. With the right medicine and treatment someone could
keep Crohn's under control. Another way of managing Crohn's is with right diet. When a patient
first is diagnosed with Crohn's it's crucial that the diet changes. Certain foods can be dangerous
and trigger Crohn's symptoms. There is a variety of foods to avoid because patients diagnosed
with Crohn's have a very sensitive stomach. Describing Crohn’s disease is very extensive
process since it affects certain patients a certain way but there is a common ground that mostly
everybody can learn how to cope with it, receive treatment and adjust their diet which will
improve their quality of life.

**Description:** Crohn’s disease is a inflammatory bowel disease that can affect any part of the
digestive tract. Crohn’s symptoms can affect certain people in different ways. Levels of pain can
vary from mild to severe. Bloating, intestinal obstruction, fatigue, fever, vomiting, cramping,
aesthesia, arthritis, depression, slow growth or diarrhea are all common symptoms. Anal ulcer, and
bleeding in the lower intestine can also happen especially when people first get in contact with
the disease. If there is severe obstruction in the intestine usually patients will require surgery.
Crohn’s patients are in higher risk of getting diagnosed with colon cancer. There are many
theories of this phenomenon but conclusively reasons for this remain unknown. As well as the
cause of Crohn’s disease itself remains unknown. It is however linked with it being genetic or
different ways the immunity system functions, and how the body reacts to certain bacteria.
Crohn's disease can be very stressful and very unpredictable. In certain cases people can even
develop mental disorders. Crohn’s disease is also difficult to diagnose because the area it covers
is so large that could be mistaken for a different disease. Also not many people are diagnosed
yearly with it which makes Crohn’s classified a rare disease. “Prevalence rates in North America
and Europe range from 21 to 246 per 100,000 for Ulcerative Colitis and 8 to 214 per 100,000 for
Crohn’s Disease. Although Crohn’s Disease and Ulcerative Colitis share some clinical and
pathological features, they can be distinguished by localization, endoscopic appearance,
histology and behavior, which suggest differences in the underlying pathophysiology” (David
Ellinghaus, Jörn Bethune).
The comparison above shows the big difference between Crohn's disease and Colitis. With Crohn’s the area affected could be in different places located on the digestive track as with Colitis the inflamed area is located only at the large intestines. Comparing Crohn’s to Ulcerative Colitis results in sharing plenty of the same symptoms. They both are inflammatory conditions however Ulcerative Colitis is only limited in the big intestine whereas Crohn’s affects a bigger area which starts from the mouth to the anus. “Both illnesses do have one strong feature in common. They are marked by an abnormal response by the body’s immune system. The immune system is composed of various cells and proteins. Normally, these protect the body from infection. In people with Crohn’s disease, however, the immune system reacts inappropriately” (Stout, Aaron). Crohn’s is considered an autoimmune disorder. Basically the immune system attacks the GI tract and makes Crohn’s flare up. This is a problem because by having a strong immune system will trigger Crohn’s and make it difficult for patients. Most Crohn's patients don't usually have a strong immune system because of the side effects and flares it cause of Crohn's. By having a strong immune system a whole set of problems comes in place because the body is not strong enough to fight of disease and it takes longer to recuperate. Crohn’s disease has become more popular recently and more people are becoming more aware of the fact of how serious the disease can become. It is recommended that if one or more of the symptoms appear it's to best to run a trial with a doctor that is specialized in Crohn’s. In doing so further progression of disease could be prevented and a special treatment plan can be set up to keep the disease dormant. A cure for Crohn’s has not been found yet and the disease underlies within the
body waiting to start up from time to time. Certain foods or alcohol can trigger Crohn’s and it could very painful for someone. There are however treatments that can keep the Crohn’s from flaring up. Awareness is very important for this disease because the disease could be different for everybody based on the area affected. Thanks to the help of the social media and research lab and communities recently a big movement has been in building up. These websites or labs provide the possibility for people to share their experience with the disease and explain what kind of treatment work best for them. There are so many symptoms associated with Crohn's and being able to share them can be tremendously helpful for somebody else that just started experiencing new symptoms and can look for advice. As long as people learn how to manage Crohn’s symptoms then the disease can be controlled and someone quality of life can be improved. Even many health care doctors are not familiar with the disease and spreading awareness and continuing to work on finding new medicine and treatment could prove to life changing for someone diagnosed with Crohn’s.

**Treatment:** Like any other disease if left untreated can be very dangerous. On the other hand Crohn's Disease can be very tedious. To this day still there is not definitive cure for Crohns. Fortunately more research is being done to improve our knowledge on the disease. Although treatment for Crohn’s does exist which makes the disease less threatening and more manageable. However Crohn’s requires big medical attention because different areas of the body might be affected. As well as certain medications are shown to have side effects when being used during a long period of time. Crohn’s flares can affects a patient's health as well as their mental state. “Different persons cope with physical illness in different ways. Some people can cope with severe illness without an extraordinary emotional reaction. Other individuals experience emotional distress when they develop a serious organic and chronic illness like IBD”(Suzanne Rethenlan). This disease is very interesting because it affects people in different ways and different treatment is needed for each group of patients. For example, when a Crohn’s flare occurs a patient can experience all kinds of symptoms and sometimes it's very difficult for the to know if it's Crohn’s related or if they’re just sick and experiencing something else. This is extremely difficult especially for someone not knowing if they have Crohn’s disease. Often times these symptoms take place for a very long time and it's hard for even doctors to find a cure to treat Crohn’s symptoms. Crohn’s is a rare disease and not many doctors can prescribe medications to lessen Crohn’s symptoms. A crohn’s flare can be mistaken for a stomach flu or a fever and can be challenging to get the right treatment. Fortunately after patients have been
diagnosed with Crohn’s it gets a bit easier to get treatment and cope with the symptoms. “The goal of medical treatment is to reduce the inflammation that triggers your signs and symptoms. It is also to improve long-term prognosis by limiting complications. In the best cases, this may lead not only to symptom relief but also to long-term remission.” (Mayo Clinic)” Usually doctors will prescribe very strong medications to patients at first as that is proven to be long term effectful and lessen up the dosage later when the symptoms are suppressed. Usually the medications are include anti-inflammatory drugs, immune system suppressant, antibiotics, nutrition therapy and sometimes even surgery. First course of action when dealing with Crohn’s are anti-inflammatory drugs as they are crucial to lessen the symptoms of crohns. However most of them have very harmful side effects and are recommended to be taken with other medications. “These drugs also reduce inflammation, but they target your immune system, which produces the substances that cause inflammation. For some people, a combination of these drugs works better than one drug alone.” (Mayo Clinic).” This phenomenon leads to Crohn’s patients taking up to seven to ten pills a day depending on the symptoms presented. In addition some pills that patients take need to be changed in the long run because they develop dangerous side effects later down the road. That is why Crohn’s has to closely supervised by a specialist at all times. If not than medication or changes can affect patients leading into further complications such as Crohn's flares.

Furthermore chronic fatigue is very serious problem when dealing with crohns because it makes it difficult for patients to get through the day and fully function. The main cause of this is those that are diagnosed with Crohn's have problem with fully digesting and absorbing the nutrients out of the food. This leads to lack of essential vitamins and nutrients for the body to maintain itself and thus resulting in fatigue and feeling tired all the time. A common supplement that is essential for people with crohn's is vitamin b-12 because it boost energy and will help with chronic fatigue. Staying active and exercising also is helps people with Crohn's because exercising raises energy levels. Reducing stress and sleeping right also will help people with crohn's because it will reduce fatigue. These medications and treatments are crucial for anybody diagnosed with crohns because it keeps the disease from flaring and progressing into further complications. In some cases surgery is required to remove the damaged intestines affected by Crohn's. “An estimated 75 percent of people with the disease require some type of surgery to relieve their symptoms. Surgery is often considered a last-resort treatment for Crohn’s disease.” (Graham Rogers)” Medications usually are very effective and will help a patient live up to their day to day basis. Surgery interventions are necessary when the Crohn's has affect the organs or its progressing at a faster rate than usual. Symptoms include internal bleeding, bowel
or intestine obstruction, and also those affected with crohn's tend to develop a colon cancer so depending which area is affected surgery intervention is necessary. “In recent years, surgeons have developed methods to perform some of the surgeries with minimally invasive techniques. In the traditional open surgical method, a long incision is made in the abdomen allowing the surgeon direct access to the organs. With minimally invasive surgery—also called laparoscopic surgery—small openings are made in the abdomen through which specialized instruments are inserted. (Surgery for Crohn's Disease & Ulcerative Colitis)” Crohn's is a relatively new disease and there is much more work and research to be done that will help patients and doctors find a solution to more treatments and medications. Surgery for patients with crohn's serves as a last resort measure as it should be avoid at all times because often times problems can occur after surgery and they may not always be successful because they are very complicated to be performed. Usually most symptoms have to do with complications eating and digesting food. Altering the diet and lifestyle changes are necessary for fully recovering from a surgery. Typically if problems consists patients are required to see a doctor and see what is best for them to make their lifestyle steady.

Nutrition: When diagnosed with Crohn’s nutrition is a very important factor. The main problem for people lies with the small intestines. When the small intestines gets damaged the food doesn’t gets digested properly and runs down to the big intestines undigested which can lead to plenty of problems. Although certain foods and diets will work differently for certain people. “When the small intestine is inflamed -- as it often is with Crohn's disease -- the intestine becomes less able to fully digest and absorb the nutrients from food. Such nutrients, as well as unabsorbed bile salts, can escape into the large intestine to varying degrees, depending on how extensively the small intestine has been injured by inflammation. This is one reason why people with Crohn's disease become malnourished, in addition to just not having much appetite (Crohn's and Colitis)”. There is no set rules of what kinds of foods to avoid but is important to know how the body responds to certain foods. Allergies to certain kinds of foods are a common problem because they can cause Crohn’s flare. Some people are allergic to certain kind foods and even medications. “When it comes to Crohn’s flare-ups, your protein selections should be based on fat content. Meats with higher fat content should be avoided, while opting for proteins that are lower in fat is a better choice(Kristeen Cherney ).” There is some general tips on what kind of food will be easier on crohn's. Red meat and dairy foods are usually very high in content and it's hard for
stomach to digest those kinds of food. The small intestines will not break down food properly and when it gets down to the big intestines is malabsorbed and will cause all kinds of problems. “Caffeinated beverages, such as coffee, tea, and soda increase diarrhea. Alcohol can have the same effect. Soda and carbonated water are not good choices either because they can increase gas. (Kristeen Cherney)” Anything that has irritable or inflammatory side effects on the stomach will cause problems for those diagnosed with Crohn's. Dehydrations is also common and certain foods and supplements taken can make the body dehydrated. None of these foods are dangerous to have but as long as they are taken in moderation there won’t be any complications.

**Conclusion:** Crohn's is a very rare disease that can affect the lining of the digestive tract. To this day there is no cure for this disease but there has been lots of improvement on finding treatment and improving the quality of life a patient can have when being diagnosed with Crohn's. With certain diet modifications and medications crohn's flares can be kept under control. This disease affects each one differently but it's very important to be supervised by a specialist at all times. More research is being done and there has been plenty of improvements on finding more treatments for the disease hopefully in due time there will be a definitive cure for this disease.
Figure 1.1 (Medchrome)
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Diversity of Rock Climbing

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Abstract: Rock climbing is a very involved activity. It has a deep history, usually requires a lot of specialized equipment to provide a safety net, training and experience with that equipment, and extensive development of technique. Rock climbing is an involved interaction with the physical world bound by the physical laws of the universe.

Rock climbing is an extreme sport in which climbers defy gravity, risking everything to take on the world's most challenging cliff faces, cracks and mountains. Rock climbing requires a significant amount of strength in a person's arms, legs, back, fingers, and toes. To free climb, a climber must be able to hold their own body weight, sometimes from the tiniest of holds.

"The history of rock climbing in the United States is also about the different cultures, climbing "tribes," and lifestyles that have emerged around these diverse times and places that make up the trajectory of American rock climbing" (Robinson 2013).

Mountaineering is the description of the sport of climbing mountains and began as attempts to reaching the highest point of unclimbed big mountains. Mountaineering has branched into three different areas: rock, snow, and ice.

The history stems from the birth of alpinism in 1786 a style of mountaineering which focuses on climbing in a light and fast manner using limited equipment and as few camps as possible. However, the turn of the twentieth century was when a social change occurred in the United States creating more leisure time and available finances for individuals to spend on mountaineering. Around this time, mountain clubs started to appear in places like San Francisco, New York, Boston, Denver, and Seattle. The United States emphasis was on the importance of wilderness, exploration, and mapping the lands, which led to numerous early ascents made by surveyors. Essentially, climbing for climbing sake made little sense (Robinson 2013)

The development of rock climbing from mountaineering was a process, not a single event, but certain events are important. "Climbing author Chris Jones (1997) describes how, in 1916, 28-year-old professor Albert Ellingwood, from Colorado College, bucked the trend of seeing the areas 50-plus summits (above 14,000 feet) merely as a reason to undertake a "strenuous hike." Thus, in appreciating a hard rock climb merely for its own sake, he and fellow climbers made three successful first ascents in the Sangre de Christo Range, very occasionally using a rope to do so. These were, Jones argues, most likely the first U.S. rock climbs where there was a conscious effort to belay." Another American rock climber and writer Pat Ament believed that Native Americans were the first human climbers on this continent like the Apaches linked to the granite of Prescott, Arizona. He believed the Native Americans were attempting to gain positions of advantage over their enemies or to be able to transmit messages. Although, the debate of “who” was the first person to start rock climbing may never be solved, there is an interesting story of how the sport was established (Robinson 2013).

Rock climbing was viewed as the "poor cousin" of mountaineering before the 1960s because the United States was not suitable for "poor alpinism." Once the 1960s began a culture of rock climbing was recognized that was completely independent of mountaineering. Robinson breathed, "This was when climbing started to be a way of life for some of the most infamous characters associated with the sport, and not just a part-time leisure pursuit." Rock climbing in the United States developed into sport it is today through shifts from aid to free climbing, the establishment of sport climbing, bouldering,
indoor climbing, creation of competition climbing and the development of climbing ethics through the great climbing areas such as the Shawangunks (shon-gums) or “the Gunks” and Yosemite (Robinson 2013).

The Gunks, a dense quartzite area, the mecca of the Eastern U.S. climbing is located 90 miles north of Manhattan, New York including four major climbing areas The Trapps, Near Trapps, Millbrook, and Sky Top. Victoria Robinson, a well-rounded female climber from the mid-1980s, states “Further, it could be argued that no other world class climbing area can equal the moderate grades, 5.5 to 5.7, to be found in abundance at the Gunks.” In the 1930s, Fritz Wiessner, a German mountaineer, the first to climb there had completed the first ascent of “Old Route” at Millbrook, the tallest and most distant cliff at the Gunks. Wiessner and his partner Hans Kraus established many climbs in The Trapps and Near Trapps and in 1941 they climbed the route “High Exposure” considered to be one of the best in the world. In the late 1950s and mid-1960s, the standard of difficult climbing increased rapidly in the area, the establishment of free-climbing ethics, the development of various style, and the heart-felt creation for environmental concerns all led to an appealing site for challenging climbing. It became improper to pull on a piton or sling and inexcusable to rest by artificial means, meaning that the equipment was meant to be used only to catch a falling climbing not for aiding an ascent or for resting on. The 1960s and the 1970s opened up the climbing grades from 5.10 to 5.11 and beyond, thanks to John Stannard, Steve Wunsch, John Bragg, and Henry Barber who progressed climbing standard in the region (Robinson 2013).

With increased climbing standards and new technological advancements, in the 1980s, many difficult new climbs were being established; at this time the Gunk’s were considered a world-class climbing area. The 1980s were also when female climbers including Barbara Devine, Alison Osius, and Rosie Andrews started achieving hard grades here and in other parts of the region. At the Gunk’s in 1984, Lynn Hill, rock-climbing legend gained the first ascent, without any previous knowledge or practice, of “Yellow Crack” a 5.12 R/X which was an extraordinary accomplishment. The Mohonk Preserve banned the use of bolts and pitons, and the chipping or gluing of holds by 1988. The 1990s the Gunks arose as an important bouldering area. In 2009, the climbing magazine U.S. Rock and Ice published Josh Lowell’s account “Bouldering in the Big Apple”, written ten years earlier, about the rapid development of modern bouldering. The area described in the article, New Paltz is now filled with diverse bouldering sites throughout the area in the woods near New Paltz. Indeed, today we have a huge bouldering movement, with individuals like Andy Salo, Andrew Zalewski, Tim Keenan, Paul Jung, Brett Lowell, Ivan Greene, and many more paving the way for dozens of new areas with the forest of New Paltz. The “gold rush” may be in the past, but there are many praises to this Eastern area as the birthplace of 5.10 grade (Robinson 2013).

The East has their treasure and the West has Yosemite Valley quite possibly the best and most famous rock climbing area in the world. The whole of Yosemite is in northern California encompasses areas throughout the Needles, south of Bakersfield; past the Sierra’s highest peak; over to Lake Tahoe; and down to Castle Crags near Mount Shasta. The granite rock cliffs reach up to 3000 feet into the air; everywhere surrounding these cliffs are smaller crags. The Yosemite Valley can be divided by Tuolumne Meadows with forests and monstrous domes on either side, John Muir, played a huge role in the conservation movement of the late 19th and early 20th centuries helping to preserve
California’s treasure. John Muir at age 31, in 1869 is also recorded with making one of the earliest known ascents in the Sierra Nevada without a rope, hardware, or special shoes. In the 1930s, Robert Underhill and a group of mountaineers conquered the ascent of the longest and steepest face of Mount Whitney which was thought to have been the highest peak at the time. The 1930s to the mid-1940s held significant importance for the Tahquitz Rock climbers where they invented the contemporary rating system used today (Robinson 2013).

However, the time of World War II (WWII) with the lack of transportation and funds caused shifts to climbing in closer local area. After WWII, between the combination of using nylon ropes and the breakthrough by John Salathe in fashioning pitons, Salathe and Ax Nelson attained the ascent of Lost Arrow on the southwest face of Half Dome which was a huge historical event in North American climbing. The “climbing bum” was born in the mid-1950s when Warren Harding and Mark Powell dropped out of college to start climbing full-time. The year 1957 was when two philosophies diverged and two prominent leaders arose to outline them. First, a climber known as Robbins and his team Michael Sherrick and Jerry Gallwas summited the northwest face of Half Dome in five days which at the time was the most demanding big-wall climb in the country and the first Grade VI. Later that year Harding, Powell, and Bill “Dolt” Feuerer conquered El Capitan, a sheer 2,900-foot face. Robbins stood for a clean kind of ascent style, used on smaller crags which he believed could be transcribed to the higher climbs. In 27 consecutive days on the wall, Harding and climber Dean Caldwell, with a bolting frenzy, 330 bolts total, climbed their way “The Wall of the Early Morning Light.” Within a year Robbins and climber Lauria, re-climbed the same route, they started chopping bolts, but realizing Harding had used aid skills they left most of the route as it was. One of the last historic events of the 1960s was in 1964 when Robbins, Tom Frost, Chuck Pratt and Yvonne Chouinard climbed the first ascent of El Capitan’s “North American Wall” considered to be the crown jewel of Yosemite’s golden age. In 1973, Sibylle Hechtel and Bev Johnson were the first female team to ascent El Captain on the route “Triple Direct.” The first-ever free ascent of a big climb was done by Ray Jardine and Bill Price in 1979 on El Capitan’s west face; this event in history ensured that Yosemite would go down in history both in the United States and the world. Victoria Robinson remarks that, in Yosemite, “If the 1960s can be seen as synonymous with big wall climbing, then the 1970s are equally associated with free climbing” (Robinson 2013).

The development of Camp 4 in Yosemite was also an important aspect in the climbing history, which came about in the 1960s the same era as the first ascent of “Lost Arrow Chimney.” This unique part of the climbing scene led to “a place where nonconformist and rebellious rock climbers hung out” including Robbins, Harding, Frank Sacherer, Pratt, Chouinard, and Powell. An iconic group named the Stonemasters emerged in the 1970s; this group from southern Californians with goals of soloing hard climbs included members John Bachar, John Long, Ron Kauk, Jardine, Henry Barber, Steve Wunsch and others. The hippie lifestyle developed in Camp 4 gave way to the advanced freestyle climbing mastering thanks to both Bachar and Kauk. Lastly, Camp 4 was just as important a part of history in the development of the remarkable granite bouldering (Robinson 2013).
When in the 1980s, a new wave of competitiveness and progression suddenly appeared as free climb ascents were being picked up by various climbers including events: in 1985, Peter Croft and Bachar climbed both El Capitan and Half Dome in one day; in 1986, Wolfgang Gullich attained the first solo ascent of the difficult “Separate Reality” (5.11d); and in 1987, Croft made the incredible free solo of “Astroman” (5.11c). Lynn Hill made a groundbreaking achievement for women and for climbers overall when she took the first free ascent of “The Nose” in 1993. The next year, she then again worked and earned the redpoint, from the bottom to the top free climbing every single pitch in a row, of “The Nose” in less than 24 hours. It took another four years before “The Nose” saw a second free ascent by Scott Burke in 1998. The other major accomplishment, in 1995, was that of Huber and Zaks, redpointing “The Headwall on the Salathe” on El Capitan (5.13b) (Robinson 2013). Next in 2007, speed was on the board for climbing big-walls, it started with the Huber brothers, Alexander and Thomas, holding the record time of 2:45:45 (2 hours, 45 minutes, 45 seconds) which was beat by climbing team Hans Florine and Yuji Hirayama explains rock climbing expert Stewart Green in the article “Speed Climbing the Nose.” Green also writes that in November 2010, Dean Potter and Sean Leary had taken the record beating the previous record by only 20 seconds. Two years later on June 17th, Alex Honnold and Hans Florine broke the previous record by almost 13 minutes, holding the record at 2:23:46 documented by Green. Overall, climbing in Yosemite has evolved throughout the different styles of rock climbing including bouldering, sport climbing and big wall; this Valley is a place for all climbers both stylistically and eclectically (Green 2016).

Climbing routes are graded based on how long they will take to complete and their level of difficulty. In North America, climbers mainly follow the Yosemite Decimal System (YDS) for a series of classes, grades, and protection ratings. Class 1 in the YDS is like walking on a sidewalk or on a hiking trail which have a very low chance of injury. Class 2 is simple scrambling with the occasional use of hands and little potential for danger. Class 3 is also characterized by scrambling, but with more exposure, however, falling here could easily be fatal. Fourth Class is climbing with expose, ropes and protection may often be used because falls here could cause death. Fifth class is rock climbing without the assistance of any gear; fifth class climbing usually involves the use of ropes, belaying, and protection hardware for safety. If falls occur here without the use of ropes or safety equipment the result will include severe injury or death. Fifth class also has its own scale of rating in which is used to describe progressively more difficult free moves on a scale of 5.0 to 5.15c. It is important to note that a change in difficulty from 5.5 to 5.6 is the same as a change from 5.10a to 5.10b. Finally, sixth class is considered aid climbing, broken down on a scale of A0 to A5, where the gear is used for assistance as well as for safety (Eng & Pelt 2010).

The YDS grade system describes the length and degree of commitment of the route and is marked by Roman numerals. The Grade of a climb is not typically mentioned when talking about short rock climbs, yet is valuable information when mountaineering and big wall climbing. Grade I is a climb that lasts one to two hours. Grade II is a climb lasting less than half of a day. A half-day climb would be considered a Grade III and a full day climb would be considered a Grade IV. If a climb takes two days to accomplish it falls into the Grade V category. If a climb takes multiple days, but less than a week, it is marked as a Grade VI. Grade VII is any climb that takes a week or longer to accomplish.
This grading system can be helpful when looking at climbs to determine how much time the climbing partners are willing to spend on the rock (Eng & Pelt 2010).

The YDS scale, protection ratings, which is represented by letter codes for different climbing routes. The protection rating will specify the spacing and quality of the protection available for a well-equipped and skilled leader. G stands for a climb with good, solid protection or green means go. PG is a climb that is pretty good, where a few sections might have few sections of poor gear or non-existent placements. PG13 is "OK" protection, but the falls will be long and you will probably go home without serious injury. R is a run out route in which some protection placements may be very far apart and if a fall occurs the possibility of serious injury is likely. X-rated climbs are extremely dangerous with no protection in critical places and a fall would result in serious injury or death. Overall, everyday climbs include G and PG routes. R and X climbs are set as a caution to the unwary leader. Application of these protection ratings will vary widely from area to area and from guidebook to guidebook (Eng & Pelt 2010).

Technique is a necessary part of climbing, however strength alone can get you through some difficult climbing routes usually costing you a lot of energy. Gaining proper technique will take time, practice and patience. Technique will help you climb with a reasonable speed without leaving you exhausted. Good technique focuses on the combination of balance, footwork and handwork as well as requires the expertise of placing technical gear for both leader and follower. It is ideal to have a balance of physical strength, power and endurance with proficient technique.

Rock climbing can be both fun and safe. If you are climbing efficiently, you are climbing quickly. The quicker you climb, the less time you spend on the rock which ultimately reduces the chances of potential hazards like weather and rock fall. When out on the rock, climbing, one should observe their surroundings. By looking around you will make observations where handholds, footholds, cracks, and other features might be helping you ascend the wall. The use of footholds and balance are the foundation of rock climbing. Our leg muscles are so much larger and stronger than our arms providing the most effective use of our bodies. It is essential to keep your weight balanced over your feet while slowly moving from foothold to foothold as if climbing up a ladder. Another important part of climbing besides just looking at your environment is to test your environment. When climbing you could encounter loose, cracked, broken, or detached rocks, so as a procedure a climb should check for the obvious and not so obvious loose rocks encountered on your adventure (Eng & Pelt 2010).

When you are moving up a surface of a rock face, in other words face climbing, you are using the various face features available. Face climbing can include a featureless slab that require friction and balance usually using smearing feet and handholds used for strength and guidance. Handholds can be expressed in a variety of ways. The cling hold which can be expressed as wrapping all your fingers close together around the rock feature comfortably, like a pocket that your fingers perfectly fit into. A large cling will fit your entire hand where a small cling hold might only fit your fingertips. A climber might use the pinch grip to help balance themselves to while they reach for a better hold, place gear and reach higher. The need for technique increases as the holds become smaller. Sometimes your thumb might apply pressure into the rock in opposition to your fingers for added strength. The ring grip can be accomplished by making an “O” with your thumb and index finger, but place the thumb over the index finger so it adds pressure.
When this technique is applied when your index finger is pressing down on the rock you will gain strength on the hold. In some places you will find small pockets in the rock which could fit one or two fingers. Climbers can also stack their fingers on top of each other in order to add pressure to the hold. Handholds are usually the best at about head height. The higher you reach the less blood flow which causes a climber’s arm to get worn out quicker (Eng & Pelt 2010).

Smearing and edging are the two main techniques for footwork when face climbing. The technique used is usually left up to the climber’s preference. Edging is the climber places and weights either the inside or outside of the sole of their shoe on the foothold. If the heel of the foot is higher than the toes then more precision will be applied to the hold, however, it will be more tiring. Over time with practice and technique, a climber may prefect this technique progressively using smaller footholds. Smearing is the foot of the climber achieving enough friction between the rock and the sole of the show. Pointing the foot uphill and then smearing the sole of the shoe over the hold works best with a flexible shoes or rock climbing shoe. The way a climber positions themselves is everything. Sometimes an experienced climber might place their knee on a hold in order to avoid making and awkward or high steep. It is important not to make it a habit because the knee are susceptible to injury and unstable. Balance and footwork are the keys to friction or slab climbing because a good smearing technique is so predominantly needed. (Kirkpatrick 2013).

Crack climbing adds an entirely new element of technique when it comes to rock climbing. Crack climbing technique is much more individualized because every individual’s hands and fingers are different sizes. This offers some crack climbing to be easier or harder than other crack climbs based on hand size. Since crack climbs can vary so greatly a climber should experiment what strategies would work best for them. The most basic technique of crack climbing is jamming either a hand or foot or sometimes other body parts inside a crack. The Mountaineers elaborate, “To jam, place a hand or foot into a crack, then turn the foot or flex the hand so that it is snugly in contact with both sides of the crack. This wedging must be secure enough that the hand or foot will not come out when weighted.” (Eng & Pelt 2010).

A hand crack is one of the easiest and can be ascended by either a thumbs up, thumbs down, or thumb across your palm. The thumb up technique will give you a wider range of movement where the thumbs down is a more powerful and secure jam. There are fist sized cracks usually measured with your thumb tucked into your four fingers from the big knuckle of your pinky to the big knuckle of you thumb. Fist jams are made with your palm facing in or out, some crack are in-between the hand and fist jam leaving your with an oblique fist shape. Additionally, there is finger-sized cracks that require several different techniques including a thumbs-down jam, a ring jam, a thumb cam, or a pinkie jam. The smaller a climber’s finger the more the climber will be able to grip. Other styles of crack climbing include chimney climbing; a chimney is a crack so big that a climber entire body fits inside. A squeeze chimney barely fits the climber’s body span, however, some chimneys are bigger in size. Chimney climbing can be maneuvered through wedging your body upwards, pressing the foot and knee on opposite walls, squirming upwards, and repeating. The “off-width” climbing involves cracks which are too big for your hand but too small for your whole body. A climber will jam their arm, shoulders, hips, knees, and a combination of body parts in order to climb these awkward features.
The are many other various techniques that can be utilized applying pressure and friction to the rock around the climber allowing them to make their way up whatever desired climb is above them (Eng & Pelt 2010).

Today, there are many styles of rock climbing including indoor climbing, bouldering, free climbing, which includes traditional climbing and sport climbing, ice climbing, and aid climbing. All of these styles of climbing involve skill sets and knowledge, including strength, courage, raw human power, and important safety gear.

Learning to climb for the first time can be very scary. Indoor rock walls allow beginners to become comfortable and knowledgeable climbers gaining skills and technique for making it up difficult routes. Indoor rock climbing gyms require safety harnesses to keep the unskilled safe while they experiment and learn to climb for the first time. However, indoor climbing gyms can also be an asset for already experienced climbers to help maintain and improve their skills. These gyms, can be especially helpful during cold, wet, or dangerously hot weather, offering these athletes an opportunity to work out (Hamilton 2010).

Bouldering, one style of climbing that challenges climbers to use their raw strength and technique to climb challenging and nearly impossible moves up large boulders and rocks (Hamilton 2010). It once started as a game played by alpinists on days that were too rainy for climbing. The popularity of bouldering has increased and has now developed into a quest of its own (Eng & Pelt 2010). These boulder climbed on usually ranges from three to six meters high. Bouldering uses minimal gear, no ropes, no pieces of protection, only a large crash pad and friends to protect you. The rule of bouldering is to never climb higher than a person would like to fall (Hamilton 2010). John Sherman developed the open-ended V-scale which gives permanent ratings to boulder problems, but does not take into account the consequences of rough landings or uneven terrain (Eng & Pelt 2010).

The goal of free climbing is to climb using your physical strength and ability utilizing hand holds and footholds that you find to move over the rock without weighting protection. Many free climbers will still use ropes and other safety materials to protect themselves and use in case of falls and emergencies, but the intent is to make it up the rock using only their own strength, skills, and knowledge (Hamilton 2010). Free climbing is the purest form of climbing plainly put is the act of climbing relying on your own body and has nothing to do with the protection. A common mistake made by non-climbers is between the meanings of free-climbing and free-soloing; which is climbing without any protection or ropes to catch you if you fall (The Editors of Rock and Ice 2016).

Rock climbing can be taken to its extreme when a climber trusts in their own ability to climb a route without the use of protection or ropes as a safety net. This type of climbing a climber must be in complete control and excellent physical condition because with one false move it could mean their life. Rock climber, Alex Honnold is widely known because of his free solo ascents on big wall climbs including in Yosemite like Half Dome, Mt. Watkins and El Capitan all of which he completed in 18 hours and 50 minutes. In 2007, he was also the second climber to free solo Astroman and Rostrum in one day after Peter Croft in 1987. Free solo climbing is not any joke and should only be attempted at your own risk, as with all climbing in general (Dhuane 2015).

Traditional climbing or "trad" climbing is a style of climbing in which an individual climbs a route by placing whatever devices or pieces of protection necessary to
move up a rock face and protect themselves in case of any falls. The second climber then removes the protection left by the lead climber (Hamilton 2010). Traditional climbing was the original form of climbing up until the mid-1980s when the birth of “sport” climbing. For example, a tradition climb is if you walk up to the base of a climb, making an ascent from the ground up, placing your protection on lead with no rappel, no top rope inspection, or overhead rope protection. Many traditional routes have bolts which were always placed on lead, however, this can create some grey areas between traditional and sport climbing. “Trad” routes will stand out because the bolts were drilled on lead, a daring and physical task, and the bolts are often dozens of feet apart (The Editors of Rock and Ice 2016).

As many people became interested in rock climbing, the idea of making climbing a sport also began to develop. In this style, sport climbing, climbers follow routes that have already been developed with pre-bolted paths to follow. Sport climbs have permanent anchors and bolts that are screwed into the rock wall (Hamilton 2010). Sport routes are generally bolted on rappel and the bolts are set a body length apart. When sport climbing you are clipping quickdraws into the pre-determined bolts which you then clip your end of the rope attached to your harness up through the other end of the draw. The goal being to make it to the top of the route without falling or resting on any bolt. This type of climbing is rather safe permitting you to push your abilities, skills, and flexibility where you can easily practice a route to perfection (The Editors of Rock and Ice 2016).

In Hamilton’s book for the layman he explains, “Ice climbing takes adventurers up frozen waterfalls, into ice caves, and over frozen water flows on rocks and cliffs. Special gear is also required for ice climbing including handheld ice axes and front pointing crampons attached to a climbers' boots” (Hamilton 2010). Since snow and ice climbing have such variable conditions, the rating of this style of climbing is very difficult. The length and steepness of the climb are the only factors that remain for the most part constant throughout the season from year to year. However, there are many factors that affect the conditions of the route like snow depth, ice thickness, and temperature. Certain factors like the nature of the ice and its protection possibilities will determine a route’s difficulty. With all of these factors taken into account there is a designated commitment rating scale regarded with ice climbing (Eng & Pelt 2010).

Aid climbing is the assisted use of gear to ascend a cliff by standing on a nylon ladder that is clipped into a piece of protection. Sometimes you are merely hanging from equipment just to bypass a difficult section of rock that cannot be free climbed. Aid climbing can be a valuable skill in which you learn to place gear quickly and how to get yourself out of a predicament (The Editors of Rock and Ice 2016). Rating an aid climb is different than free climbs which is on a system from A0 to A5. It ratings indicates the severity of a possible fall which is established from the quality of protection available. The Mountaineers explain, “To some extent, an aid rating indicates the difficulty of climbing, but only in that there is a loose correlation between easy-to-place protection and its ability to arrest a fall” (Eng & Pelt 2010).

It would be extremely difficult to credit one individual as being the “best” in the world of rock climbing because it is so diverse in itself. However, we can claim that certain individuals have certain major climbing accomplishments within certain realms of climbing. Early, I noted that Alex Honnold is highly well-known for his free soloing of big walls, another climber Tommy Caldwell can also fit into one of the best when it
comes to big-wall climbing. Both of these individuals are also known for big-wall speed climbing. Individuals like Hayden Kennedy and Sonnie Trotter are both very renowned clean trad climbers; their female counterparts would include Lynn Hill and Ines Papert. The two sport climbing heroes of today and the only climbers to have climbed the grade 5.15c are the epic Chris Sharma age 35 and Adam Ondra age 23. The female sport climbing superstar of today would be Sasha DiGuillian.

The three basic rock types throughout the Earth are igneous, metamorphic and sedimentary. Igneous rock is formed when liquid magma cools either underground or at the Earth’s surface. Sedimentary is formed from the built up and compact pressure of tiny minerals. When rock is squeezed so tightly being baked and molded underground metamorphic rock is created (Rock Types 2014). Rock climbing takes place on many numerous amounts of rock types. Arizona is quite a luck state to be a climber, it is very probable that Arizona has more exposed rock than any other state in the United States. Arizona has Granite Mountain in Prescott and Cochise Stronghold in the Dragoon Mountains near Tombstone both area hold phenomenal multi-pitch granite traditional climbing routes. In Flagstaff, sport climbers spend time at limestone area, The Pit, not far from town; for the “trad” climbing craver a longer drive out west will led to Paradise Forks a columnar basalt treasure. Sedona is renowned for its beauty of colorful cliffs, lovely outdoor scenery, and amazingly adventurous sandstone climbing. Payson, also has its hidden quartzite crag called Isolation Canyon. Some other types of rock include dacite, gneiss, monzonite, welded tuff, and thousands more.

Age is just a number. Climbing is for everyone. Even today old school climbers from the 1960s and 1970s are still getting out on the rock. Climbing Pioneers like Yvonne Chouinard, Stan Mish, and Doug Robinson are still getting out and climbing. In contrast, the youth of climbing will be the generation to push into the uncharted territory. There are two young female climbers that are already well on their way to opening these doors. Ashima Shiraishi, age 15 is known as the strongest young climber of all time. At age 13 she became the second female and the youngest climber to ever free climb a 5.15a sport climb which has only been done by few other athletes. Just this year she became the first female climber to complete a V15 boulder problem. She is certain on the trail to closing the gap between male and female climber and making history of her own (Bosman 2012).

A rock climber’s gear will tell you all about the style of climbing that she is interested in. Almost all rock climbers, excepting aid climbers, will have climbing shoes. Any climber that likes to climb more than seven meters may have a helmet, harness, chalk bag, and a belay device. Additional gear can include but is not limited to rope, cord, anchors, carabiners, offset nuts, hexes, tri-cams, spring loaded camming devices, commonly just called ‘cams’, and other specialized equipment.

One of the most important pieces of gear a rock climber needs to wear is shoes with sticky rubber. Sticky rubber is micro-porous, creating a surface with exceptionally high friction. A climber’s shoe is extra tight, like a second skin around the foot. Different climbing styles call for different types of climbing shoes. There are more aggressive shoes in which it makes it easier to stand on smaller footholds and there are more comfortable all day shoes for climbing all day or multiple day climbs. For optimal performance a foot would fit into the climbing shoe so tightly that the foot cannot flex, roll, or otherwise change shape. Such a fit is extremely uncomfortable and nearly
impossible to walk in. Compromises are met according to one’s technical skill, experience, pain tolerance, near-future goals, and particular climbing objective. A good climbing shoe will protect the wearer from rough, sharp rocks, as well as provide a much better grip than bare feet (The Editors of Rock and Ice 2016).

The type of clothing climbers choose depends on how hot or cold it is where they are going to be adventuring. All climbers try to wear comfortable clothing that allows freedom of movement. Warm weather climbers seek clothing that is breathable, lightweight, and durable. However, cold weather climbers require heavier boots, socks, a layer of long underwear, and layering ‘system’ of clothing that still allows for freedom of movement. Clothing fabric range a variety of fabrics that are suitable for the outdoors, but all of which have their own advantageous and disadvantageous. These fabrics might be cotton for a hot day, wool for insulating qualities, polyester for lightweight wearability, or nylon as a rain barrier. No matter the adventure, the clothes you wear could make a huge impact on your experience and/or survival (Eng & Pelt 2010).

There are many reasons why a helmet is important, but overall it makes climbing safer just like wearing a seatbelt makes a car safer. The helmet is just as necessary as a rope for a majority of climbers. Any climbing certified helmet will suffice will help protect you against hitting your head while falling, being hit by falling rock, ice, or gear, or a leaders fall which causes you to swing into the wall (The Editors of Rock and Ice 2016). It is important to note that helmets will not be able to protect you in every possible situation. Today’s helmets are lightweight, ventilated and available in many designs; the shell of the helmets are made from material like plastic, fiberglass, and/or carbon fiber. The helmets suspension system comes in two main styles. First, the system of strapping which keeps the helmet shell from coming into contact with the head after impact, or secondly the polystyrene core which is designed to shatter upon severe impact allowing the absorption of the impact (Eng &Pelt 2010).

Harnesses should fit snugly allowing the climber legs to move freely. Harnesses come in a variety of styles based on the climber’s needs. The sport harness is going to be lighter, have less padding and fewer gear loops. A harness that is designed for “trad” or big-wall climbing is going to have at least four rigid gear loops, a haul loop, and extra padding for long routes. A majority of harnesses will have an automatically single pull buckles for locking, however, not all do so it is imperative to always double check to see if you and your partner are double-backed. Climbers have died simply because they did not check if they were secured into their harness properly (The Editors of Rock and Ice 2016) The Mountaineers write, “With properly fitted leg loops, a seat harness rides snugly above your hip bones yet transfers the force of the fall over your entire pelvis. It also provides a comfortable seat during rappelling” (Eng & Pelt 2010).

"The route symbolizes climbing and the climber's dependence on another person. The rope protects you when the difficulty of the page or an unexpected occurrence-- a broken hold or collapsing snow bridge-- causes you to fall.” The rope is a critical part in a safety system that includes specialized knots for certain tasks, the harness that attaches the climber to the rope, special equipment used to connect the rope to the rock, and that carabiners that join the various parts of the system (Eng & Pelt 2010).

Ropes for climbing have also gone through an evolution, today, kernmantle ropes are used. These ropes are composed of a core, the ‘kern’, of braided or parallel nylon filaments and a sheath, the ‘mantle’, of smooth, woven nylon. Kernmantle ropes maintain
the advantages of nylon including their lightweight, strength of bearing a load of more than two tons, and their incredible quality of elasticity. For example, nylon rope stretches and dynamically dissipates much of the energy generated by the fall, thereby reducing the forces associated with the fall. Due to the construction of kernmantle ropes, the problems associated with early nylon ropes like stiffness, friction and excessive elasticity are greatly reduced (Eng & Pelt 2010).

Dynamic ropes come in different diameters acceptable for technical climbing. The average beginner diameter rope would be around a 10 mm which is very comparable for most rock climbing need. There is a size range in dynamic rope diameters from 8 mm to 11 mm. The smaller diameter rope system, typically used in pairs, rely on the flexible properties of both ropes to protect the climber. A rope length also varies depending on the need of the climber, but the useful lengths range from 30 meters to 70 meters. The new climber usually invests in a rope of about 60 meters (200 feet) in length. However, a climber might choose a rope length, either shorter or longer, based on a multiplicity of reasons including rope weight, length of a climb, the type of climb, or the ability to rappel safely (Eng & Pelt 2010).

It is important to note that because of the ropes design there is both a static elongation which is measured when just the weight of the object sits on the rope and a dynamic elongation which is measured at the peak of the falls arrest. Interestingly, the requirements for the test results of static elongation are required to be noted on the any manufacture’s label. It is thought that the requirements were finalized before tests could accurately measure dynamic elongation (Raleigh, p. 67).

The UIAA (Union of International Alpine Associations) conducts severe drop tests on ropes. These tests are much harsher than most real-life falls, so they provide a conservative measure of a rope’s suitability for climbing. Before the impact test they condition each rope at a given temperature and humidity. During the test they drop an 80-kilogram mass 1.8 meters onto a 2.8 meter long piece of rope (the test mass starts above the anchor point). They drop the test mass repeatedly every five minutes until the rope breaks.

A single rope must hold at least five falls, and the first drop must not exceed 12 kN (2700 pounds) of impact force on the “climber.” If the rope does not stretch enough, the impact force will be too high for the rope to pass the test. More importantly, if the rope doesn’t stretch enough in a real fall, the impact force may damage the climber’s internal organs and break climbing protection. Each subsequent drop causes a higher impact force because the rope loses some of its elasticity. This is why it’s smart to let your rope “rest” a few minutes after taking a high-impact fall. (Luebben 2007).

Rock climbing is weaved by the laws of physics: if the foot will stay on the hold, how a climber makes his move, and why the gear holds a fall. Physics also determines how much force is generated in a lead climb falls on route. The main goal of rock climbing is not to fall.
By discussing Newton’s Laws of Motion in application to rock climbing it can be explained how physics plays its role. The first law states that an object that remains at rest unless acted upon by another force and when an object will keep moving with constant velocity unless the object changes its direction. A climber also creates a balanced force in which the action and reaction apply the same amount of force in opposite directions. The first Law can be explained by when the rock wall pushes up on the climber when he pushes on it, making him change direction (Luebben 2007).

The second law states that the rate of acceleration of an object is proportional to the forces applied to the object. An unbalanced force is what causes the rock climber to move. For instance, if the force of one object is greater than the object with less force will move in the same direction as the greater force. Gravity is the constant pull towards the earth’s center, equal to our body weight. Luebben remarks, “In a free fall, gravity accelerates a falling climber’s body at 9.8 meters per second per second, or per seconds squared: A body falls 4.9 meters the first second, three time further the second, and five times further the third second. The body accelerates until it reaches terminal velocity—the speed where wind drag balances gravitational pull—after about five seconds.” The acceleration of a climber is 9.8 meters per second per second until the falls arrest. Rock climbers use dynamic climbing ropes which stretch to help control the climber’s rate of deceleration, decreasing the impact force on the climber and gear (Luebben 2007).

Newton’s third law states that every action has an equal and opposite reaction. When a climber stands on the rock the rock exerts a force that is equal and opposite their body weight. The hand holds and foot holds support the force equal to their weight. The impact force is created from the force needed to catch a climber in a fall. Essentially when a climber falls, the impact force on the rope pulls on the belayer who opposes. The top anchor holds the force of both the fallen climber and the belayer and that force is opposed by the surrounding rock. The force created in the lead fall is dissipated through the transfer from the rope to the belayer, anchors, and the rock (Luebben 2007). This law can be plainly observed when a rock climber steps up on the rock causing you to go up. In terms of Newton’s law you pushing onto the rock is the action and the rock pushing on you is the reaction.

As a climber performs work to move themselves upward against gravity a certain amount of energy is being stored. The gravitational potential energy is stored energy based on the pull of gravity and your position to the earth. Once, a leader falls all the potential energy is quickly adapted into kinetic energy as gravity accelerates your body downwards. Kinetic energy is simply the energy of motion. As the length of the fall increases, the faster a climber goes as their potential energy is transformed into kinetic energy (see Figure 1 and Figure 2). In order to decrease the length of a fall, a climber can set more pieces of protection meaning more safety. However, more gear placing can mean more time spent messing with gear, taking energy from you both mentally and physically. On a clean lead fall on a vertical or overhanging face causing the rope to primarily absorb the energy by stretching. A high impact force might cause the rope to slip through the belay device and the belayer’s hand. Hopefully, the fall will be clean, but if it is not that energy will go into breaking bones and bodies (Luebben 2007).

Luebben exclaims that, “In a lead fall, the climber’s body exerts an impact force on the rope that must be countered by the belayer. Friction at the high carabiner, and from the rope running over the rock and through other protection allows the belayer to feel less
impact force than the leader. The force on the top protection equals the force on the climber and the belayer combined. The magnitude of the impact force created is largely determined by: belay method, fall factor, body weight, and rope elongation” (Luebben 2007).

The belay method being described it that of a dynamic belay, some slip occurs through the belay device as the fall is stopped. This method of belay can drastically decrease the impact force in a fall with a high fall factor. A belayer’s hand can only hold so much force causes some rope to automatically slip after a hard fall. Two examples of a static belay include: a belayer’s use of an autolocking device which the rope locks tight in a fall or if the belayer is tightly anchored causing the belay to be almost completely static. These two scenarios will create the highest impact force possible for that fall. It is very important to realize that the impact of a fall can be huge if the leader falls close to the belay station (Luebben 2007).

A fall factor is measured by the vertical distance fallen over the length of the rope out. The higher the fall will cause a great impact force in a fall. The closer the fall is to the belay creates the greatest impact force because a limited amount of rope is between the belayer and the climber to absorb the energy of the fall. As a climber place protection moving higher up the route, the more rope that will come into the system to stretch and absorb energy which will decrease the force created. Basically, the fall factor takes into account the total of energy released in the fall and the length of rope available to absorb it. The longer a fall is the increased dangerous possibilities of hitting a rock or ledge. The severity of a longer fall is due to the fact that the force impacts the climber and the anchors for a longer time (see Figure 3, Figure 4 and Figure 5)(Luebben 2007).

A true factor 2 fall creates the greatest force possible on the climber, belayer, and anchor, when the leader is directly above the belay on a vertical wall with no protection making the fall twice the length. The use of a belay device with minimal slippage will cause great force than a belayer with slip through the device. However, in this case using the more dynamic system would decrease the force significantly, but may still cause injuries. A situation were fall does come directly on to the anchors, it becomes difficult catch and a huge amount of stress on the anchors. Becoming a smart climber, you learn to place adequate gear in order to protect yourself. After starting a climb after a belay station the first pieces of protection are critical because they are backing up the belay station. A 10 foot fall at the anchor system is much more force than a 10 foot fall 100 feet above the belayer (Luebben 2007).

Body weight, more accurately the weight of you and your gear can change but is rather constant. The bigger the climber the higher the impact force will be. It is the climber’s job to making sure there systems are efficient and strong enough.

When a climbing rope catches a fall most of the kinetic energy is put towards stretching the rope. The higher you climb, the longer the rope length, means the more likely for the energy absorbed into the rope to stretch. A much lower impact force but a longer fall. The more stretchy the rope is “softer” the catch. A rope like this would bring a lower impact force, but might stretch the climber to the ledge. Luebben proclaims, “As a dynamic climbing rope catches a fall the force on the climber, belayer, and anchors builds as the rope stretches. At the instant when the rope reaches its maximum stretch the load reaches its maximum impact force. Then the force diminishes until the top anchor holds only the climber’s weight and some of the belayer’s weight” (Luebben 2007).
The momentum is an object equal to its mass times its velocity. The faster an object or the bigger the object, the more momentum an object will have. Calculating the impulse by multiplying the climber’s mass by his change in velocity. The moment the rope starts arresting a fall is when a climber slows down from maximum velocity, down to zero velocity at the instant of the peak force. The change in velocity equals the maximum velocity since final velocity is zero. The length of a fall directly correlates to the maximum velocity. An impulse created by a halting stop equals the mass of the climber times the maximum falling velocity. A static rope barely stretches which stops a climber quickly with less time slowing and stopping. The fall onto a bungee code has a huge elongation spreads the deceleration over a much greater time. The deceleration keeps the impact force low, and the impulse is the same as a static rope. The dynamic rope is the compromise because it stretches just enough and dissipate the force of the fall without hurting the climber and has the ability to contain the same impulse that a static rope or a bungee would have to stop a falling rock climber. The dynamic has much less force than a static and far less stretch (Luebben 2007).

“Trad” climbers and big-wall climber typically have a large selection of gear for the ultimate range of protection. The gear will either be passive in there protection with no moving part or will the active with moving parts. Passive gear is beneficial to a climber because they place in a widening crack will be much more securely, they save weight and money, and they minimize the cost of leaving gear behind. Spring loaded camming devices are beneficial because they have a broader working range, they fit into pockets and parallel cracks more readily, and they actually increase in strength when a fall exerts a dynamic force on them (Kirkpatrick 2013).

Passive protection has many names such as chocks, stoppers, and tapers all of which are referring to a tapered metal wedge attached to a wire cable with a loop on the end. Imagine taking the metal wedge locking it into a crack and the other end gets fastened to the anchor. Engineered to jam into place when a load is placed on the nut’s wire. Nuts range in size from 1 to 13, with each sizes diameter increasing with size, they also vary in size based manufacturer and the shape. Climbers can also find micro-nuts, size 1-6, or offset nuts, featured with a top-to-bottom taper and a front-to-back taper, for protecting on very thin cracks, pin scares, flares, and seams. “Hexes” or Hexentrics, an asymmetrical six-sided tube, can be used for tapering, parallel-sided cracks, and widening cracks. Hexes and nuts are placed similarly, by putting it in a crack, pulling downward until it rotates into place tightly. The tri-cam is a useful piece of gear, it is attached to by a sling to a metal rounded on one side and a point of the other and it has no moving parts. The unique part about the tri-cam is that you can place it like a nut in a passive manner or you can place it like a cam by the force applied to the sling rocking the curved edge and pushing the point into the rock (Kirkpatrick 2013).

Out of all the active protection, the cam is by far the most popular. When looking at a cam it is important to look at the number of cam lobes, stem design, number of axles and the expansion range. Three to four aluminum curved cam lobes are typical with cams. Pulling on the spring-loaded trigger wire, moves squeeze these load tighter together making the device narrower. Now, ready to place inside of a crack, releasing the trigger causes the lobes to expand to fit the rock. Cams when place correctly are very powerful in places like parallel cracks where passive gear would just fall out. Spring-loaded wedges are small circular sliding piece that enlarges the size of the wedge once it
is placed in a crack. The sliding circle presses against the rock and larger metal piece of the wedge to fasten it in place. The tube-chock also known as Big-Bros are meant for parallel cracks, pockets, and for wide crack climbing such as “off-width.” Tube chocks come in sizes that fit cracks from 3 inches to 12 inches wide. It works like a curtain rod, a powerful spring loaded mechanism expands and lodges the ends into place against the rock. The locking collar then tightens into place at the desired width. These devices are so convenient because they resist pull in any direction vertical, horizontal, and angled cracks (Kirkpatrick 2013).

Reinhold Miessner, an old-time climber, proclaimed, "Mountains are not fair or unfair, they are just dangerous." Rock climbing is a very extreme and very dangerous sport. Although, accidents do happen, people make mistakes, and equipment fails, there are many climbers that live through many scary situations. The people who use their brains and muscles will get the chance to live to climb again, however, deaths do occur. The number of deaths is countless, but from 1951 to 2012 there were 1,680 deaths. In 2013, there was a total number of 21 deaths in the United States from rock climbing accidents (The American Alpine Club 2014).

Since 1938 the books *Accidents in North American Mountaineering* have published annually documenting climbing accidents that are significant and teachable. Each incident is analyzed thoroughly to show what went wrong, in order to help climbers avoid similar problems in the future. On August 10th, 2001 a 22 year old climber Kyle was teaching some kids at his church how to rappel when the accident occurred at Papago Buttes in Tucson, Arizona. It was said that he was anchored when he began the descent. It is unknown what actually happened, but is thought that his knot supporting climber may have failed or he lost his footing when descending (The American Alpine Club 2001).

In recent years I have begun to call myself an outdoor enthusiast. I have begun to experience the outdoors with such love and passion. I have encountered my own experiences with rappelling that could have ended badly. It was mid-March 2010 when my mother agreed to let me leave on what she and I believe to be a camping trip with some of my new rock climbing friends. After camping at the base of a trailhead to West Clear Creek, six of my male friends and myself journeyed off in the opposite direction into a mile and a half long slot canyon, Sundance Canyon, a Grade III technical canyon. She was beautiful and terrifying with sandstone walls towering up over one hundred feet high surprisingly with large piles of snow on each side of the canyon. We had to rappel into several keeper pools of water each time becoming more frozen when finally a two hundred foot rappel into the bottom of West Clear Creek. I know today that I most likely was on the verge of hypothermia with an aching body, clouded mind, and uncertain spirit. Down the 200 foot free-hanging rappel, I monitored my hands, not being able to feel them, left me terrified and scared, yet euphoric and enlightened.

Sundance Canyon had shown me a very intense, but utterly addicting feeling. Learning to rock climb has been a humbling experience and I am still learning. I enjoy the sport because it forced me to face the problem in front of me: the fear, the anxiety, and the physically demanding movements. I witnessed progress within myself physically. After only a short few weeks the effects were present both mentally and psychologically. I climb because I believe it helps me cope with the emotions I no longer have to bottle up. I can express myself when leading a route, I relax, and I face my frustrations and push
past each of the problems "one at a time." Climbing is a form of release for me, the healthiest escape I have from life’s stresses.

Exercise increases my heart rate and respiratory rate which sends blood flowing through the body to the brain which releases oxygen and other chemicals making an individual naturally happier and calmer. Ratey passionately announces, “I tell people that going for a run is like taking a little bit of Prozac and a little bit of Ritalin because, like the drugs, exercise elevates these neurotransmitters. It’s a handy metaphor to get the point across, but the deeper the explanation is that exercise balances neurotransmitters – along with the rest of the neurochemicals in the brain. And you’ll see, keeping your brain in balance can change your life.” Rock climbing is my exercising drug that helps me find clarity, increases relaxation, and has opened my mind. Rock climbing can help a body and mind grow more resilient, ready to take on future challenges, and adapt easier in stressful situation. Simply put, as the individuals fitness level improves, so will the individuals state of calmness and safety (Ratey 2008).

The adventure sport of rock climbing was developed from a rich history filled with events, people and places. This demanding sport can be further categorized into different types of climbing including: free-climbing, soloing, indoor, bouldering, sport, traditional, multi-pitch big-wall, and aid. The precision and technique needed to climb these rock walls is no doubt a task needing a lot for power, strength and balance. Testing the limits of physics by moving oneself up a rock face using precise hand and foot techniques.
The rock climber is 45 meters above the belayed and there last piece of protection is 10 meters below them when they fall. The fall factor being the change in vertical distance fallen divided by the length of the rope creating a fall factor of 0.44 = 20 meters/45 meters (Luebenn 2010).
T = tension => T\Delta x = mg(2d), 2d = falling distance; distance is 2d + \Delta x_{max}

Hooke’s Law: force delivered to rope = \( F_{el} \)

\[
T = -M \frac{\Delta x}{L}
\]

\( L \) is length, \( M \) is elasticity

\( M = EA; E \) is Young’s modulus, and \( A \) is the rope cross section

Rope Elastic energy: \( E_{el} = \frac{1}{2} M \Delta x_{max}^2 \)

Energy conservation requires that

\[
mg(2d + \Delta x_{max}) = \frac{1}{2} M \Delta x_{max}^2
\]

gives \( \Delta x_{max} = \frac{L}{k} [1 + \sqrt{1 + 2kf}] \) where \( k = \frac{M}{mg} \) and \( f = \frac{2d}{L} \)

\[
F_{el, max} = -M \frac{\Delta x_{max}}{L} = -mg[1 + \sqrt{1 + 2kf}]
\]

The total force acted upon the climber is

\[
F = mg - \frac{M}{L} \Delta x
\]

Fall Factor

The fall factor determines the hardness of a fall: the higher it is, the harder the fall. Its value, lying between 0 and 2 in climbing conditions, is calculated by dividing the height of the fall by the length of rope deployed. The hardness of a fall is not a function of its length but of this ratio, because the longer the rope, the more it can stretch to cushion the fall. This theoretical fall factor assumes that there is no friction between the belayer and the highest runner to allow all the rope in play to absorb energy equally.

THE FALL FACTOR (f)

\[
f = \frac{\text{Height of fall}}{\text{Length of rope}}
\]
Figure 4

The graph below represents the distance in meters fallen over a certain amount of time in seconds.

Figure 5

The graph to the right is a velocity vs. time graph of a freely falling object that eventually reaches "terminal velocity." (Kraus 2016)
References


The History and Evolution of Lighting: Campfires to LED Lighting

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Abstract: The evolution of our ancestors and their interaction with fire has paved a way to the discovery of electricity. There is no single moment in time where the discovery of fire or electricity can be pinpointed, rather, it was a convoluted process that took time. The ancestor’s first major role with fire came with the development of the *Homo* genus and the physiological changes towards becoming bipedal. It took millions of years before *Homo sapiens sapiens* came into play, and still longer, before electricity made its mark. It was only in the 18th century that major efforts were put towards exploring electricity, leading eventually to the development of light bulbs and LEDs. Electricity is interwoven with the laws of physics, yet, electricity was one of the slowest branch of physics to be developed.

“Give me food and I will live; give me water and I will die. What am I?” Fire is a destructive element that millions of years ago would consume all in its path with no creature daring to stop it, but some creatures benefiting from its aftermath. How is it that our ancestors came to approach this uncontrollable monster in the first place? The growth of human evolution was sparked by the discovery and increased use of fire from our ancient ancestors through “three distinct… forms of fire use: first, fire foraging for resources across landscapes; second, social/domestic hearth fire, for protection and cooking; and third fires used as tools in technological processes, e.g. for firing pottery,” states J. A. J. Gowlett, renowned anthropologist and journal author (Gowlett, 2016).

Fire is a part of the natural cycle that help clear the forest floors and feed the soil with necessary nutrients. All animals have a healthy and natural reaction to fire, causing them to flee their homes due to the disturbance that fire has on many landscapes. Even our early ancestors were aware of the beauty and danger that fire held. The discovery of fire use cannot be pinpointed to one single moment in time; however, it was more of a set of processes happening over millions of years that eventually led to the evolution of the intellectual human. This process of the domestication of fire first can be noted at its earliest stage when the ape and human lines diverged, between five and ten million years ago. The next stage took place three to four million years ago when the ancestors’ important physiological changes adapted towards bipedalism and some dietary habits; closely followed by the rapid ancestral change around 2.6 to 2 million years ago when *Homo genus* became present. The final stage which is much more recent, emerged only 200 thousand years ago with our modern species the *Homo sapiens sapiens* (Burton, 2009).

Between 6 and 4 million years ago (denoted as 4 mya, etc.), during crossing from the Miocene to the Pilocene (see Figure 1), the first evolutionary line of our ancestors gained the ability to walk on their two rear legs, creating free hands. These bipedal ancestors walked vertically with their legs straight and forward; they only stood a meter tall with still relatively small brains comparable to that of the chimpanzee today. The first bipedal ancestors were mainly herbivores eating tough fruits and leaves. Frances D. Burton, the author of *Fire: The Spark That Ignited Human Evolution* explains, “The molar teeth of the early hominid and had thick or enamel, the jawbone was more robust, the molars were low where, and the incisors wider. Pitting on the incisors as well as striations on the molars indicated that abrasive vegetation was used.” It is believed that they did communicate through various grunts and gestures, however, they did not have a complex language due to their higher larynx. As the evolutionary line became bipedal,
this allowed the ancestors begin walking towards the intellectual changes to come (Burton, 2009).

Pausas and Keeley, authors of *Burning Story: The Role of Fire in the History of Life*, elaborate that, “early hominids (genus *Homo*) appeared in Eastern Africa about 2.5 mya (during the Pilocene, refer to Figure 1), and fire has been closely integrated into many stages of their evolution. It is believed that the rise of *Homo erectus* from its more primitive ancestors was fueled by the ability to cook -- that is, to use fire.” The ancestor *Homo argaster* that lived about 1.9 mya were taller and had even bigger brains, demonstrating intelligence now that they moved to different environments across the old world. These were our ancestors that showed the first attempts at using fire. Fire is vital for cooking meats and vegetables which allowed the ancestors physiology to gain the opportunity for more energy and brain growth. Even still there were no major technological improvements at this time. The first possible signs of tinkering and improvements towards technology that may have been transmitted by social learning happened around 1.8 mya by the *Homo argaster*, which paved the way into the Pleistocene (See Figure 1). It is important to note that there is evidence around 1.5 mya of controlled fire use by *Homo erectus* in Africa, but arguably the earliest non-controversial evidence out of Africa can be dated around 0.79 mya (Pausas & Keeley, 2009).

Since fire destroys, feeds, and paves the way for new growth and life, it influences the reactions of fear from animals due to these dangerous situations, and in turn, creates a pattern for response. The phrase, “fight or flight” for so many of these vulnerable creatures cannot hold sway; insects, small amphibians, reptiles, and small mammals can’t outrun the devastation of the fire. Large mammals, on the other hand, have the ability to flee from treacherous fires by seeking refuge in underground dens, caves, and rock crevices; however, these places can become depleted of oxygen depending on the severity of the fire (Burton, 2009). If so many creatures flee from fire, then what made our ancestors approach such a dangerous element?

The key behavior for our ancestors to become comfortable approaching fire was the willingness to recognize and associate fire as a valuable food source which, in turn, also requires the presence of three shared behaviors that have already been documented in monkeys and apes. One of the first important behaviors is the ability to remember the location where they had once found food, which is common among a number of various mammals. Second, the ancestors would need to use digestive aids such as the consumption of earth soil and charcoal which is thought to have allowed the eating of foods that contain substances normally toxic or that interfere with digestion. The consumption of soil and charcoal with plant matter allowed for the various toxins within these plants to be either neutralized or absorbed into the substances that would usually make them sick. Lastly, the desire and need to eat insects due to the changing conditions became unpredictable, adding to the pressure to become omnivores and explore diverse diets. Burton illuminated, “Although food may have been the primary reason for the ancestor to approach fire, there are other attributes of fire to consider as well. Heat and light are the two most obvious features…. Fire with its heat and light endowed the ancestor or with power and the ability to ward off danger” (Burton, 2009).
Nonetheless, the next big step for the ancestors was the construction of hearths, which
was the first major sign of the ancestors cooking foods. The general consensus for the earliest
ancestral hearths dated to the middle of the Paleolithic, about 250 kya, yet in 2012, “the
discovery of charred bone and primitive stone tools in a cave in south Africa tentatively pushed
the time back to roughly one million years ago... But the number of sites dating from that early
period is small, and the evidence of fire might not have been preserved,” clarified Adler, a
former Newsweek editor and author of the article “Why Fire Makes Us Human” (Adler, 2013).
Continuing the journey through time and the ancestor’s relationship with fire, the Homo sapiens,
can be securely dated between 200,000 and 195,000 in the Pleistocene (195 kya, see Figure 1
and 2) when our closest ancestors used stones to construct hearths in order to roast meats and
even make steam for ceremonial uses (Burton, 2009). Pausas and Keely remarked that around
100 kya archeological site evidence proposed that the ancestors had the ability to set fire at will,
even in diverse environmental settings (Pausas & Keely 2009).

There is no doubt that fire supported a variety of human activities including: cooking,
heating, clearing areas, ridding of unwanted pests and predators, hunting, and primarily lighting.
These activities would take place around three different types of fires, comprised of tree-stump
fires, grass and bushfires, and campfires. Tree-stump fires are thought to have been used for the
large heated coals in order to make spears by hardening their wooden tips in the fire, first
recognizably dated back to 400 kya. Grass and bushfires were used in various ways; for instance,
to clear areas, to minimize insects and other pests, to produce fresh grass, or to steer herds into
traps for killing. Campfires are mainly used to give light and are highly effective in keeping
predators and insects at bay. Campfires can be made directly on the ground, in a pit or
surrounded by rocks with a variety of wood to burn, typically the most readily available (Burton,
2009).

Still, as our ancestors evolved into the genus Homo, the dispersal of modern humans
began marking different regions at various points in time— the ancestors arrived in Australia 50 –
60 kya, in Europe 40 kya, and in the Americas 10 –20 kya. The new colonizers sometimes cut
across the immense climate changes in the Holocene during the transition from the last glacial
period. In China, nearly 20,000 years ago, originated some of the first evidence of pottery related
to the major new interactions with fire. Around 10 kya hunting and gathering transitioned and
became replace by agricultural and pasteurization; this new culture had widespread effects. Up
until this point populations were relatively low, creating very low impacts from the ancestor’s
use of fire; it is not until very recently, less than 0.5% of the Pleistocene, that the human impacts
of fire use became a significant issue. Within the last 5000 years, the development of
metalworking formed, starting with copper and bronze, then quickly followed by iron. The art of
metalworking requires raising the temperatures to a heat far above that of the open fire;
metalworking being a true development in pyrotechnology (Gowlett, 2016).

The discovery of fire was such an important phenomenon throughout the evolution of
humans, and was the critical point that allowed us to continue evolving towards the discovery of
electricity and the use of LED lights today. Electricity is so interwoven into the culture of today,
it would be difficult for members of our society to imagine a world without it. In the grand
scheme of things, it has only been a blink of an eye since scientists began to study the electrical phenomenon and the nature of electricity; electricity has only been an important part of our technological society for approximately 150 years (Vlahakis, 2011).

One of the first times that the electrical phenomenon was observed was around 600 BCE, by one natural philosopher in ancient Greece, named Thales of Miletus. Interestingly enough, this remained one of the only references for thousands of years. Still, the cause of this strange phenomenon remained unexplained. It wasn’t until the end of the 16th century that another philosopher introduce the word “electric,” becoming the godfather of electricity: the Englishman William Gilbert (Vlahakis, 2011).

The turn of the 18th century gave way for a more systematic investigation of the electrical phenomenon. The first two individuals that worked seriously on electricity were Stephen Gray in England and Charles Francois de Cisternay DuFay in France. Only a short decade later, in 1745, the Leyden jar was invented, the first kind of electrical condenser, by Peter van Musschenbroek, a Dutch physicist. The years following were still very productive with the increasingly popular use of electrostatic machines which were demonstrated in European courts to noblemen. The most notable two figures investigating electricity around 1750 were Abbe Nollet in France and Benjamin Franklin on the other side of the Atlantic (Vlahakis, 2011).

A serious debate started in the scientific community due to two different theories suggested about electricity. Benjamin Franklin is most commonly known for his experiments using kites, in order to establish that lightning is a form of static electricity. From a scientific standpoint, his work relative to the nature of electric matter is much more fundamental. He proposed that electricity was a single common element, passing through all matter, and it had no weight. It was in the last quarter of the 18th century that Franklin’s theory gradually triumphed (Vlaharkis, 2011).

Throughout the 19th century during the study of electrical phenomenon there was dramatic progress, mainly due to the first battery, which opened new horizons to electrical applications. Professor Alessandro Volta at the University of Pavia in Italy created the so-called voltaic pile. This was the first time in history that individuals and scientists had the access over an extended period of time to study with reliable access to an electrical current. Hans Christian Oested, a Danish physicist, found that electrical current would deflect magnetic needles which established the discipline of electromagnetism; the equations for electromagnetism were developed in 1820s by Andre-Marie Ampere (Vlahakis, 2011).

In 1826 George Simon Ohm (1787-1854) proposed the law defining the resistance of metallic conductors. During the same decade Michael Faraday (1791-1867) implied electromagnetism even further by building the first electric motor, transforming electric energy to kinetic energy. In addition, Faraday’s theoretical proposal about dynamic lines provide a foundation for the Scotsman James clerk Maxwell (1831-1879), who in 1856 wrote the essay “On Faraday’s Line of Force,” establishing in peer mathematical language
The significant development of Maxwell’s laws of electrodynamics paved the way for many useful applications through the 20th century, like electric power stations, radio, television, and even the computer. In 1840, Samuel Morris invented the electric telegraph, which caused a real revolution in communications. Shortly after, Thomas Edison became famous for his electric lamp and a multitude of other inventions like the phonograph. The invention of the incandescent lamp can be accredited to William Sawyer and Albon Man in 1878 whilst again in 1879 by Thomas Edison in the United States. Similarly, the Englishman Joseph Swan patented one of the first version of incandescent light bulbs. The invention and patent of the incandescent lamp gave way to the decline in use of carbon arc lamps; carbon arc lamps were used around the world extensively until the late 1970s (Vlaharkis, 2011).

The first electric light was demonstrated in 1835, which would leave scientists around the world with a spark for tinkering with the filament and the bulbs atmosphere in order to produce the incandescent light bulbs. The first task upheld by Edison and his researchers was the focus on improving the filament. They correspondingly tested carbon, then platinum, but eventually returned to carbon. Edison’s team continued to experiment with a variety of filaments until confidently settling on a filament of bamboo, which gave the lamp life up to 1200 hours. This became the standard for the next 10 years. Edison’s thirst for technological advances led him to other improvements to the light bulb by creating a better vacuum to fully remove the air from the bulb and the development of the standard socket fitting known as the Edison screw (U.S. Department of Energy, 2013).

Thomas Edison played a huge role towards the contribution to electric lighting primarily because he was continuously improving the bulb. Edison’s lighting technology was based off the existing gas lighting system. Edison was able to concentrate on improving a variety of features including, but is not limited to, improving the generation of electricity, developing the first commercial power utility, and how to track consumer’s electrical usage. Despite Edison’s eclectic interests in the lighting system, the next big change in the incandescent bulb came to be in place with the invention of the tungsten in 1904. The tungsten filament lasted longer and had a brighter life compared to carbon filament bulbs. In 1913, the bulb doubled its efficiency when Irving Lanmuir figured out how to place a gas like nitrogen inside the bulb. Over the next 40 years little improvements were made towards the incandescent bulb (U.S. Department of Energy, 2013).

In the 19th century, Heinrich Geissler, a glassblower and physician, and Julius Plucker learned that light could pass through an electrical current by removing almost all of the air from the long glass tube, which became known as the Grissler tube. It was not until the 20th century that these discharge lamps became the foundation for different types of lighting technologies like neon lights, low pressure sodium lamps, and florescent lighting. Florescent lamps had their breakthrough in the early 1900s, shortly after Thomas Edison and Nikola Tesla experimented with florescent lamps, when Peter Cooper Hewitt’s generated a blue-green light that could pass
an electrical current through mercury vapor and started regulating the flow of the current through the two with a ballast (U.S. Department of Energy, 2013).

Experiments were done, in the late 1920s and early 1930s, with neon tubes coated with ultraviolet (UV) absorbent phosphors which could transform in visible light into useful white light. After this the United States increased their research in florescent lamps by the end of the 1930s. These new lights were demonstrated for the U.S. Navy; these lights were three times more effective and lasted much longer. At the time of the American war, the need for energy efficient lighting led to the rapid adoption of florescent lights, and by the 1950s, the majority of lights in the United States were produced by linear fluorescent lamps. It was not until 1974, when researchers began investigating how to miniaturize the ballast and leave it into the lamp. The first compact fluorescent light (CFL), which was a bulb bent into a spiral shape, was created in 1976 by Edward Hammer at General Electric. It was in the mid-1980s that CFL’s were sold in store at a retail price of $25-$35 (U.S. Department of Energy, 2013).

The United States Department of Energy clearly outlines, “One of the fastest developing lighting technologies today is the light emitting diode (or LED). A type of solid-state lighting, LEDs use a semi-conductor to convert electricity into light, are often small in area and emit light in a specific direction, reducing the need for reflectors and diffusers that can trap light.” A gentleman, Nick Holonyak, Jr., while employed by General Electric, developed the first visible spectrum LED in the form of red diodes, closely followed by pale yellow and green diodes. The improvement of red diodes began appearing as indicator lights and calculator displays in the 1970s. In the 1900s, the invention of the blue diode led to the rapid discovery of white LEDs through simply coating the blue diodes with a phosphor to make it appear white. It wasn’t before long that researchers were able to demonstrate white light using red, green and blue LEDs which were the breakthroughs that led LEDs to be used in a variety of ways, for example, traffic lights, flashlights and TVs. In order for LEDs to be introduced to consumer lighting, researchers needed to focus on improving the efficiency of LEDs, which at first were no more efficient than incandescent bulbs. (U.S. Department of Energy, 2013).

As lighting companies continued to advance in both the quality of light and energy efficiency of LEDs, the cost of LED bulbs had fallen more than 85 percent. Astonishingly, the LED bulbs of today are 6 to 7 times more energy-efficient, lasting 25 times longer than the conventional incandescent lights and cut energy use by over 80 percent. Interestingly, many of the existing light features and incandescent that are used all around us date back to Edison’s time. The switch from incandescent bulbs to LEDs is only the beginning for the savings to come both in cost and energy. It only makes sense that pairing an LED bulb with an LED lighting system would produce a greater energy saving potential compared to forcing LED bulbs into 19th century fixtures (U.S. Department of Energy, 2013).

Since ancient times, examples of electricity like lightning, electric eels, and magnetic stones had been known to our ancestors. Understanding the behavior and properties of light is necessary to become knowledgeable about electricity. Furthermore the development of electricity took a much slower turn through time than any other branch of classical physics (Light, Electricity, and Magnetism, 2012).
It was in the 17th and 18th centuries that the subject of electricity really began to receive attention. It started with experiments that showed various materials could be electrified by rubbing them with silk or fur, which indicated two types of electricity or what might be called charges today. The saying opposites attract really comes into play when we talk about these charges. These experiments showed the repulsion of others that were the same and the attraction of their opposites which could not have happened if there were only one kind of electricity (See Figure 2). The observed electrical charges are either positively or negatively charged (Light, Electricity, and Magnetism, 2012).

For the most part, objects are equal in their positive and negative charges, however, when those objects have a net negative or positive charge then electrical forces between the two will arise. The basic positive charge is known as a proton which are located in the nuclei of atoms. The nucleus is surrounded by a cloud of negatively charged electrons. Electrons are negative charges that also has the same magnitude charge as a proton (See Figure 3). It is important to note that electric charge is always conserved. A charges not created in an object; an object becomes charged when two neutral objects are rubbed together. This happens because the negative charges transfer from one object to the other (Serway & Vuille, 2015).

It was Charles Coulomb, in 1785, who established the fundamental laws of electrical forces between two stationary charged particles. These electrical forces contain three major properties, which are outlined by Serway in the textbook “College Physics”:

1. “It is directed along a line joining the two particles and is inversely proportional to the square of the separation distance are between them.
2. It is proportional to the product of the magnitudes of the charges \(|q_1|\) and \(|q_2|\), of the two particles.
3. It is attractive if the charges are opposite sign and repulsive if the charges have the same sign.”

This led to Coulomb proposal of the mathematical formula (see Figure 4) we use the electrical forces between two charged objects, stating that the magnitude of the electrical force between charges \(q_1\) and \(q_2\) with a separation distance from the center radius of one particle to the center radius of a second particle all being amplified by Coulomb constant (Serway & Vuille, 2015).

It was in the 1800s that Volta’s discovery of the electric battery that electrical current came into play; his invention of the electrical battery showed a study production flow of direct electrical current and opened up doors for research to continue in electricity. This new source of electricity helped to discover a variety of different avenues, for instance, electric current could be used to break up dissolved substances. This led to the discovery that an electrical current can generate magnetism and vice versa (Light, Electricity, and Magnetism, 2012).

A battery is also known as an electrochemical power source that derives electricity from energy being release in a chemical reaction. Batteries of today are easily portable source of electric power, however, they can also be used for storing electricity from an external source. The batteries are either primary or secondary, so they are either rechargeable or not rechargeable.
Throughout the decades batteries have gone smaller and smaller and can now fit in small household items such as smoke alarms remote controls flashlights and much more. Volta, read about an experiment his friend Luigi Galvani conducted, which led to the discovery that two different metals interconnected by a moist, salty intermediary produced an electric current. Thus the first modern battery was created as Volta piled copper and zinc discs interspersed in cardboard moistened with salt solution (Batteries and Fuel Cells Industry, 2012).

The battery is associated with voltage which can connect to capacitors and resistors creating electrical current through an interrelated system. In an electric circuit the capacitor devices used for a variety of reasons, for example, to tune the frequency of radio receivers, or initiates sparking in auto mobile ignition systems. A capacitor is separated by a distance between two parallel metal plates and then connected to either the positive and negative terminals of the battery. A resistor in an electric circuit is a conductor that provides ace pacified resistance. Resistance and a circuit can arise when electrons collide carrying the current with fixed atoms inside the conductor which inhibits the movement of charges in the same way a force of friction does.

Capacitors can be set up in two simple configurations either parallel or series. When capacitors are set up in parallel the voltage across them has the same potential difference (See Figure 5). This means that if one capacitor is cut out of the system the other capacitor/s will still receive the same amount of voltage. However, when it is set up in a series the magnitude of charge will be equal to the voltage of the battery when the voltage across one conductor is added to the voltage across the second conductor (See Figure 6) (Serway & Vuille, 2015).

Resistors can also be set up in either a parallel or series circuit. The voltage across a resistor is equal to the magnitude of the current in a particular direction magnified by the resistance on a particular resistor. If we take a look at the voltage disbursement across resistors when they are set up in parallel the flow of voltage across each resistor will equal that of the voltage in the battery (See Figure 7). Similarly, if one resistor is cut out of the system, the other resistor will still receive the same amount of voltage as the battery. When taking a look at resistors set up in series the total voltage is equal to the sum of the voltage across each resistor (See Figure 8) (Serway & Vuille, 2015).

It was James Clerk Maxwell, in 1873, who published a highly significant theory of electromagnetism which discussed concepts like the phenomenon of electricity, magnetism and light and their interrelatedness. Maxwell hypothesized that electromagnetism was composed waves of electric and magnetic fields that moved across space at the speed of light, which led him to believe that light is also an electromagnetic wave. Heinrich Hertz, a German physicists, not only detected, but deliberately produced electromagnetic waves in the 1880s. The wavelength that he produced were far longer than those of visible light, which are now known as radio waves. This discovery assisted in the development of that radio by the Italian physicist Guglielmo Marconi (Light, Electricity, and Magnetism, 2012).

An electric field is stated to be the region of space that exists around a charged object; this electric field exerts an electric force on any other charged object within the field. The
production of an electric field is given by a charge at a given location of the small “test” charge, which is then described as the electric force exerted by a charge on the test charge divided by the test charge. Serway and Vuille wrote, “The direction of the magnetic field at a point in space is defined to be the direction of the electric field that would be exerted on a small positive charge placed at that point.” The magnitude of the electric field due to a point charge at a distance from their central separation from the point charge can be given by its magnitude equation (See Figure 9).

The article Light, Electricity, and Magnetism states, “Infrared and ultraviolet radiation were found to fit the electromagnetic wave model as well. So did x-rays, which were discovered by German physicists Wilhelm Roentgen in 1895. The various forms of electromagnetic radiation known today include (from longest to shortest wavelengths) radio and television waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays, and gamma rays. Together they make up the electromagnetic spectrum” (Light, Electricity, and Magnetism, 2012).

Electromagnetic waves are composed of the electric and magnetic fields; it is also in the form of visible light allowing humans to view the world around us, infrared waves warm our environment, radio – frequency waves carry television and radio programs and x-rays allowing us to look at the structure within our own bodies. It was in 1865 that James clerk Maxwell provided the mathematical theory outlining the relationship between electric and magnetic phenomenon (Serway & Vuille, 2015). His theory, rewritten in College Physics by Serway and Vuille, stated four main concepts:

1. “Electric field lines originate at positive charges and terminate on negative charges
2. Magnetic field lines always form closed loops; they don’t begin or end anywhere.
3. A varying magnetic field includes an EMF and hence an electric field this fact is stated of Faraday’s law.
4. Magnetic fields are generated by moving charges (or currents), as summarized in Ampere’s law.”

It was the discovery of radio waves by physicist Hertz that essentially confirmed Maxwell’s theory of electromagnetic waves existed and had all the properties of light waves. The resonance frequency formula was what helped Hertz investigate the electromagnetic waves (See Figure 10). Scientists have now recognized that light is an electromagnetic wave because electromagnetic waves travel at the same speed as light in a vacuum. All electromagnetic waves travel in a vacuum with the speed of light. After Hertz’s discovery of the radiofrequency electromagnetic waves a scale or spectrum was created to a scale which we now know as the electromagnetic spectrum (See Figure 11). There is a relationship between frequency and wavelength because all electromagnetic waves travel through free space with the speed of light. We can also calculate the electromagnetic waves based on this relationship (See Figure 12).

Our bipedal ancestors started walking the earth between six and four million years ago, this was a pivotal moment for the evolutionary line of Homo sapiens sapiens. The presence of increased intelligence in our ancestors lives became increasingly more apparent around 1.9
million years ago when *Homo argaster* began showing signs of tinkering and improvements towards technologies. The earliest noncontroversial evidence of controlled fire use in Africa can be dated around 790,000 years ago. The construction of hearths, nearly 250,000 years ago, demonstrated the first major signs of our ancestor’s reliance on cooking foods with fire and our ancestor’s ability to create fire at will. Then the ancestors began to spread out across the world leading to the first evidence of fire produced pottery approximately 20,000 years ago. It was only within the last 5000 years that metalworking formed which is mainly associated with the beginning of the Bronze Age.

The evolution of electricity up to the use of LED lights is nowhere nearly as long as the evolution of fire with our ancestors. However, it is one of the last branches of physics to be developed. It was in the 16th century that philosopher William Gilbert first introduced the word “electric.” The first major invention, in the 18th century, related to electricity was the Leyden jar, the first kind of electrical condenser. Benjamin Franklin was a crucial asset to the development of the incandescent light bulb, mainly because he was so intrigued and constantly tinkered in order to improve its structure. It was also in the 19th century that the first battery invented by Prof. Alessandro Volta, around the first time in history that electrical current was readily accessible. It was in 1904 that the tungsten bulb was invented, a filament that lasted longer and had a brighter life than that of its predecessor the carbon filament bulb. It was in the 1930s that the first florescent lamps (CFLs) were established; it was 1976 when the first compact fluorescent light was developed by bending the bulb into a spiral shape. Finally, the light emitting diode (LED), one of the fastest developing technologies, was introduce, first looking at red diodes, then pale yellow diodes, green diodes, and followed by blue diodes which create white LEDs.

I believe our future is filled with lights and electricity, in ways, only imaginable to those individuals and innovators that don’t just think it’s possible but believe it’s possible. The future of lighting is headed towards the implementation of LEDs throughout cultures. Although LEDs are still expensive to produce they’re getting much cheaper due to technological advances. Still to this day the Edison socket bulb is widely used across the world, and it’s most likely replacement will be the flat-panel LEDs. I believe that flat-panel LEDs could be implemented in a variety of ways, one of my favorite examples, the production of solar roadways. Solar roadways are the future of lighting our streets, creating a world of light with every step. Solar roadways are specifically engineered solar panels in the shapes of hexagons that can be fit together like a puzzle piece and can take the place of the concrete world we have today.
This table outlines the dates corresponding to the various evolution time periods for the early ancestors during their evolution of fire use.


This diagram helps to demonstrate the reactions that charged particles have on one another. This diagram also outlines Charles Coulomb’s law the two point charges that are separated by a distance r, which exerts a force on the other. The picture show how the force on one particle is equal in magnitude and opposite in direction to the force on the second particle.
Table 15.1 Charge and Mass of the Electron, Proton, and Neutron

<table>
<thead>
<tr>
<th>Particle</th>
<th>Charge (C)</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron</td>
<td>$-1.60 \times 10^{-19}$</td>
<td>$9.11 \times 10^{-31}$</td>
</tr>
<tr>
<td>Proton</td>
<td>$+1.60 \times 10^{-19}$</td>
<td>$1.67 \times 10^{-27}$</td>
</tr>
<tr>
<td>Neutron</td>
<td>0</td>
<td>$1.67 \times 10^{-27}$</td>
</tr>
</tbody>
</table>

This table outlines the charge and mass of the electron, proton, and neutron. Despite the discovery of electrons and protons in the 1700s, neutrons were not discovered until later on.

Figure 3

The mathematical equation for Coulomb’s law is given by:

$$F = k_e \frac{|q_1||q_2|}{r^2}$$

The constant $k_e$ depends on the choice of units. The SI units of charge is the coulomb (C) which equals:

$$k_e = 8.9875 \times 10^9 \, \text{N} \cdot \text{m}^2/\text{C}^2$$

Figure 4

Capacitors in parallel

The Voltage Equation for this circuit can be denoted as:

$$\Delta V = V_1 = V_2 = V_3$$

The voltage can also be calculated if you are given the capacitance $C$ and the magnitude of the charge on the conductor, $Q$. This equation can be written as:

$$\Delta V = \frac{Q}{C}$$

Figure 6
Capacitors in series

The Voltage Equation for this circuit can be denoted as:

\[ \Delta V = V_1 + V_2 + \ldots \]


Figure 7
Resistors in parallel

The Voltage Equation for this circuit can be denoted as:

\[ \Delta V = V_1 = V_2 = V_3 \]

The voltage can also be calculated if you are given the values for current \( I \) and resistance, \( R \). The equation can be written:

\[ \Delta V = IR \]

Figure 8
Resistors in series

The Voltage Equation for this circuit can be denoted as:

$$\Delta V = V_1 + V_2 + V_3 + \cdots$$


Figure 9
Electric Fields

The force $\vec{F}$ exemplified on a charged particle $q$ magnified by the electric field $\vec{E}$ can be calculated using the following formula:

$$\vec{F} = q\vec{E}$$

According to Coulomb’s law, the magnitude of the electric force of a charged particle can be written:

$$F = k_e \frac{|q||q_0|}{r^2}$$


This equation can be rewritten since the magnitude of the electric field at the position of the test charge is defined as $E = F/q_0$. 
Since, $E = F/q_0$, we have

$$E = k_e \frac{|q|}{r^2}$$

Figure 10

*Resonance frequency* is the frequency of oscillation and LC circuit.

The formula is given by:

$$f_0 = \frac{1}{2 \pi \sqrt{LC}}$$

Figure 11

Electromagnetic Spectrum


Figure 12

Equations for Electromagnetic Waves

Since electromagnetic waves have a relationship because electromagnetic waves also travel through space at the speed of light we can form a relationship to also calculate the electromagnetic waves.

$$c = f\lambda \quad \lambda = \frac{c}{f}$$
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What Would Happen if the Earth Lost its Magnetic Field?
Abstract

While it may go unnoticed by most people, the Earth’s magnetic field is vital to all forms of life. This magnetic field, also known as the magnetosphere, essentially acts like a giant shield blocking out harmful cosmic rays and solar winds. Radiation from cosmic rays is very damaging to cells and would lead to illnesses and even death. Without the magnetosphere solar winds would have enough power to pull gases out Earth’s atmosphere making the planet unsuitable for life. Many species navigate by use of internal compasses that interact with the magnetic field, this is the reason for migrations. Even humans navigate using the magnetic field with the help of compasses. Even though it may not seem like it, the magnetosphere plays an extremely important role in the condition of the Earth.

Introduction

Many individuals are aware that the Earth has a magnetic field but are not sure what causes it or how it affects our lives. Far below the surface of Earth there is a thick layer of molten metals such as nickel and iron known as the outer core. The movement of the charged particles creates electric currents which then produce magnetic currents (physics.org). This is what gives the Earth its magnetic field. All planets in the solar system have magnetic fields, some stronger than others (Union University 2004). The shape of the magnetosphere is determined by solar winds. This means that the shape of the magnetosphere is constantly changing based off the patterns of the solar winds (SWPC NOAA). Powerful winds from the sun compress the magnetic field on the closer side and then it travels outward in a tail like fashion (Figure 1).

If the magnetosphere was gone solar winds would do great amounts of damage. Over time they would strip the gases out of our atmosphere. The lack of oxygen would make the planet uninhabitable. Solar winds would also have a negative effect of technology, eventually wiping out power completely. Satellites often suffer damage due to solar winds. In 1989 all power in Quebec, Canada was knocked out for twelve hours due to a large solar flare crashing into the magnetosphere (Futurism 2015). The surrounding areas were also negatively affected (Futurism 2015). In addition to protecting the Earth from solar winds, the magnetic field also protects it from dangerous cosmic rays. Particles coming from the Sun can travel at extremely high speeds of up to 800km/s (Windows to the Universe 2010). If these particles have enough power they can heat up the atmosphere and cause a disruption in its formation (Figure 2). Cosmic rays give off radiation that can chemically alter the genetic makeup of cells and cause damage. Exposure to radiation has been shown to increase the risk of developing cancer (EPA 2016). Without the protection from the magnetic field the levels of radiation would be high enough to cause death within days or even hours. The magnetosphere protects the Earth by deflecting the high energy particles causing them to move around the magnetic field instead of reaching the surface. Some particles are able to enter through openings
over the poles. The particles always enter through the pole on the side of the magnetic field that is farthest from the sun. These particles are highly charged, possessing a current of twenty-million amps at 50,000 volts (Windows to the Universe 2010). When these particles collide with gas particles in the atmosphere the change in energy causes the bright colorful lights known as the aurora Borealis (northern lights) and the aurora Australis (southern lights). The different colored lights are caused by different gases in the atmosphere. Oxygen gives off a green color while Nitrogen causes blue or red colors (Imester 2017). Many of the particles get stuck in rotation around the Earth. The areas in which the particles travel are called the outer and inner radiation belts. The discovery of the belts was in 1958 by James Van Allen, giving them the nickname of Van Allen belts (Gardiner 2003).

Many animals rely on the Earth’s magnetic field to properly navigate. This process is known as magnetotaxis. Animals such as birds, salmon, honeybees and sea turtles migrate and navigate through use of the magnetic field. The ability to use their internal compass is a key element in survival for these creatures. Even though it is widely accepted that animals use magnetism to migrate the specific details about how they do it can be difficult to obtain. Rays and sharks may use electroreception to interact with the magnetic field. These animals have hundreds of tubular ducts behind their pores. The walls of these ducts are very resistive and the ducts are filled with a gel like material which is highly conductive, causing them to act like electrical cables. In the cavity at the end of the duct there are a group of cells that are highly reactive to small changes in voltage. This sensitivity means that this method of magnetoreception is theoretically possible, however it is unlikely due to the fact that this sensitivity only occurs in elasmobranchs. A majority of the animals with electroreceptors have too large of an electric threshold for this to occur (Johnson, Lohman 2009). The only cases of confirmed magnetoreception have occurred in some bacteria and phytoplankton. This is because they contain strands of ferromagnetic minerals such as magnetite. Ferromagnetic means that the material still experiences a net moment due to the fact that the moment is greater than those of anti-parallel spins that are close by. The torque that the Earth causes on the strands can be strong enough to cause the whole organism to align with the Earth’s magnetic field (Johnson, Lohman 2009). One of the most commonly studied magnetoreceptive animals is the homing pigeon. Birds are known for being excellent navigators, some of them even travel thousands of miles for migration. Researchers at Baylor College of medicine have found evidence that neurons within the brainstem communicated with parts of the inner ear. This means that there might be cells within the pigeon’s ear that are capable of detecting the magnetic field (Gorman 2012). A scientist from the California Institute of Technology believes that humans may also be capable of detecting magnetic fields. His research showed that there was definitive changes in alpha brain waves when the surrounding magnetic field was changed. The results were not large enough to provide conclusive results.
Conclusion

The magnetic field of the Earth affects daily life more than we realize. This world would be a drastically different place without the defense of the magnetic field from the dangers of the solar system. Without the magnetosphere the natural phenomena of migration wouldn’t occur, and it is likely that many species that use magnetism for navigation would cease to exist. Even though we take it for granted, the magnetic field is extremely important.
Figure 1.

Figure 2.
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Impact Forces and Concussions in Football

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Physics 112

Dr. Durandet
Abstract
Football is America’s sport. Unfortunately, there is a dark side to America’s sport; one that has only recently been brought to light. To say that football is physical is stating the obvious; however, understanding how dangerous football is, and how far the consequences of a life spent on the gridiron reach are only in the infant stage. Studies have been conducted to document concussions in football; head trauma is the biggest medical issue the Nation Football League and football as a whole is facing. Experts are finding that linear and angular acceleration; core concepts of physics, and inherent components of a football hit are the primary culprits in causing a concussion. Researchers can now pinpoint the approximate angular and linear accelerations which are most likely to yield a concussion.

Americans loves sports, especially baseball, basketball, and football; in addition to these three there are many additional less mainstream sports such as NASCAR, soccer, boxing, tennis, etc. Even of the big three, football is the most popular (Revsine, 2014). Baseball may still officially be America’s pastime; however, baseball may have given up this title several years ago. Basketball has greater global exposure than football with such worldwide stars as Michael Jordan, LeBron James, Kevin Durant etc. Despite no true global stars, less worldwide appeal, and a shorter existence, in America, football is king. No other sport can rival football in terms of popularity, fan passion, and revenue, but it has not always been this way.

The origins of football can be traced back to the 1880’s, although in a more primitive form than the multibillion dollar sport seen today. Football can be considered the distant cousin of two other well-known sports, rugby and soccer. Football is essentially a combination of rugby and soccer, primarily rugby. Most historians agree that football began in the elite Northeastern schools; Rutgers, Yale, Harvard, Princeton, Columbia, etc. In its infancy, football was played by student athletes much like today’s college players and was around for 10 or more years before any legitimate professional play began (Peterson, 1997).

Many historians argue that the first players to be considered professional by strict definition, (i.e., being financially compensated for play) probably took place during the 1880’s as college players. There exists compelling evidence that Princeton University paid their student athletes for playing football through various forms of compensation. The National Football League acknowledges in their hall of fame that William Heffelfinger was the first player to be financially compensated for playing football. Heffelfinger was reportedly paid $500 for one game, pennies by today’s standards, but the amount actually equaled the yearly salary for a schoolteacher at that time (Peterson, 1997).

The National Football League has been around since 1920, the first year of play. The game was much different then; the field was 110 yards from end zone marker to end zone marker, (10 yards longer than the current field), and the field was 53 yards wide, (one foot narrower.) The goal posts were much shorter, reaching only 10 feet high. There was no mandatory protective equipment. In fact, the only required piece of equipment was a ball. Forward passing was not allowed, and there were no substitutions except for injuries. Players were much smaller then by today’s standards, with the average running back weighing approximately 150 pounds and the average linemen weighing approximately 170 pounds (Crepeau, 2014).

Attendance at the early football games was around 1,000 people, with a high attendance reaching a few thousand. In stark contrast to today’s football there was no Super Bowl. The championship was decided via vote due to a lack of balance among season schedules (Crepeau,
This may come as shocking when compared to the current ultra-popular annual Super Bowl; a multimillion dollar fan attraction, that routinely draws tens of thousands of spectators, a massive television audience, and charges millions of dollars for advertisement.

Football is a notoriously violent sport; one only need watch a few minutes of a game at any level to recognize that the human body is not designed to endure the trauma that football players experience every game. No medical degree is necessary to understand that there are substantial risks involved with playing football, or that the ramifications of play can lead to dire consequences. A comparison is often made between playing football and being involved in a car accident. Broken bones, torn ligaments and muscles, damaged backs, separated joints, arthritis, and concussions have long been associated with playing the game, and are only a very brief generalization of the depth of injuries associated with being a football player. Many retired football players complain of lifelong ailments and diminished quality of life due to their football careers. Players also complain of memory loss, lack of mobility in their knees and backs, arthritis, and constant pain (Cottler, Abdallah, Cummings, Barr, Banks, & Forchheimer).

Although the physical toll of playing football was established long ago, we are only beginning to understand the far reaching dangers and impact of playing football. The extent of head trauma in particular has only recently come to light in approximately the last 10 years; this may be due to the possibility that only recently has there been any genuine interest in investigating and researching these risks. In fact, the National Football League spent decades denying any relationship between playing football and concussions; this only changed in the last few years when evidence came to light that the league had hidden evidence that proved the link between football and head trauma. Once discredited, the league quickly agreed to pay a nearly one billion dollar settlement to retired players. To be fair, football is not the only area where there seems to have been a lack of responsibility regarding the effects of head trauma. The military for example, did not seem to truly understand or appreciate the impact until the mid-2000’s when thousands of soldiers began suffering from what is now termed traumatic brain injury during the Iraq and Afghanistan wars (Findings on Head Trauma, 2015).

Only after the National Football League was caught lying and had to endure public castigation did they demonstrate any willingness to admit and understand the link between football and head trauma, and to implement treatment plans and prevention regulations. When personnel did finally begin researching the issue of head trauma the results were staggering at best and horrifying at worst. A study conducted from 1996-2001 found that there were 887 instances where a concussion took place, and this is before the newer methods of research, testing and treatment were implemented (Pellman, Viano, Casson, Tucker, Waeckerle, Powell, Feuer, 2004). In the 2015 season for example, there were 271 documented concussions from preseason to the end of the regular season (Breslow, 2016). Through advancement of research and knowledge many of the old beliefs regarding concussions were debunked; the archaic belief that one had be knocked unconscious to suffer a concussion has been dispelled, the formerly prevailing belief that a concussion was not a serious injury has been replaced with a required medical suspension and immediate tests to determine the extent of the injury. Also, new evidence has shed light on practice safety; evidence has emerged that suggests that practice is a significant source of concussions (Harmon, 2016). Possibly most frightening of all for players is the knowledge that concussions may not be the biggest fear, but that the repeated sub concussion hits football players sustain may also lead to long-term health problems.

In light of the new evidence verifying the impact of concussions, radical and immediate changes have taken place within the game of football. New techniques for tackling have been
implemented at every level of play, specific types of hits (e.g. helmet-to-helmet collisions) have
been proscribed, and an exponential increase in fines for illegal hits has been put in place. There
exists new protocol and regulation for treatment and testing of head trauma; continuing to play
after enduring any questionable hit to the head is no longer optional. When a player is involved
in a hit and shows any signs of head trauma they are immediately taken out of the game, their
helmet is taken away, and they undergo a battery of tests to determine if a concussion has been
suffered. Also, players are immediately medically suspended from play while undergoing
concussion protocol. If it is determined that a concussion has occurred, the suspension is
extended as decided by medical staff.

Due to more advanced understanding of head trauma and other physical repercussions of
playing football another trend is emerging, players are retiring early, or, pursuing other sporting
careers. In recent years more football players in their 20’s, after only a few years in the NFL are
retiring, citing their desire for a higher physical quality of life as their reason for retiring.
Among well-known players to retire early in recent years are Calvin Johnson, Jason Worilds,
Jake Locker, and Marshawn Lynch; these are not players who were old, unwanted, or could not
play anymore (Noah, 2016). None of these players were older than 30, and all could have
continued to play for millions of dollars. It would appear that for many, the risks associated
with football no longer outweigh the reward of fame and wealth. During case studies, Boston
University found that of those tested, 90 of 94 deceased former NFL players were found to have
chronic traumatic encephalopathy (bu.edu [date unknown]). In all likelihood, the newer trend of
early retirements is only beginning; the medical field is only in the beginning stages of
understanding head trauma. The more head trauma is understood the more likely football as a
sport is to watch young player retire early. While this trend cannot be considered good news for
the NFL it also does not unequivocally spell the end for professional football, or collegiate
football for that matter. As long as there are millions of dollars to be made for playing football
there is also likely to exist athletes willing to risk long-term health and quality of life to play the
game.

While there are many facets of physics involved in football depending on what aspect of
the game one is focusing on, this paper will focus on those facets involving force and impact. A
few immediately come to mind: acceleration, mass, velocity, and torque. Two other slightly
more in depth components of physics are implicit in their effect on head trauma in football, and
will be discussed in more depth in later sections. In order to understand how these concepts are
involved in football one must first understand what they are as defined by physics. Below are
the definitions and formulas for finding these values.

Acceleration: is a vector meaning it has magnitude (size) and direction, and is defined as the rate
of change of velocity per unit of time (Serway & Vuille, 2012). Acceleration is measured in
meters per second squared:

\[
acceleration = \frac{\text{velocity (in meters/second)}}{\text{time (in seconds)}}
\]

\[
15m/s \over 3s = 5m/s^2
\]

Velocity is also a vector, meaning it has both magnitude (size) and direction, and can be defined
as the change in position over a given time (Serway & Vuille, 2012). Velocity is measured in
meters per second:
Using the formula for velocity, a football player who runs 36.576 meters (equivalent to the 40 yard dash) has a velocity of 7.95 meters per second. This means the player is running over 8.6 yards per second.

Mass is a property of the physical body; the measure of an object’s ability to resist acceleration (Serway & Vuille, 2012). Mass is measured in Neuton meters per second squared:

\[
\text{mass} = \frac{\text{force (in Neutons)}}{\text{acceleration (in meters per second\(^2\))}}
\]

\[
\frac{9.8N}{4.4m/s^2} = 2.23N \cdot m/s^2
\]

Torque is a measure of how much force acting on an object causes that object to rotate (Serway & Vuille, 2012). Torque is found by multiplying the force, \(f\) by \(r\), the distance from the point of rotation to where the force is applied, by the sin of theta, the angle between the force and the rotation:

\[
\text{torque} = \text{Force (in neutons)} \cdot r\text{(in meters)} \cdot \sin(\theta)[\text{in degrees}]
\]

\[
5N \cdot 3m \cdot \sin(45) = 1.06N \cdot m
\]

Angular acceleration is the change in angular velocity in a prescribed time (Serway & Vuille, 2012). Angular acceleration is measured in radians per second squared:

\[
\text{Angular acceleration} = \frac{\text{Change in angular velocity (in radians per second)}}{\text{change in time (in seconds)}}
\]

\[
\frac{200 - 0}{6 - 0} = 33.33 \text{ r/s}^2
\]

In general terms it is easy to recognize these factors utilized in football. Players speed up, slow down, collide with each other, rotate, and change position on the field constantly. Running backs and wide receivers in particular apply these forces every play. When a receiver slows down while running his route this is negative acceleration because his velocity is decreasing. When a running back speeds up this is considered positive acceleration because his velocity is increasing while also maintaining a direction.

Sir Isaac Newton’s three laws of motion are also profoundly involved in football. Newton’s first law of motion says that an object will remain at rest or in uniform motion in a straight line unless acted upon by an external force. Ultimately this means that an object wants to keep doing whatever it is doing unless an outside force compels it to do something else.

Newton’s second law of motion says that the acceleration of an object depends directly upon the net force acting upon the object, and inversely upon the mass of the object. Chiefly, this means that an object’s ability to accelerate is dependent upon the object’s mass and the force acting on the mass; usually gravity. Finally, Newton’s third law of motion dictates that for every external force that acts on an object there is a force of equal magnitude but opposite direction which acts back on the object which exerted that external force. Fundamentally, Newton is saying that for
every force at work there is an equal and opposite force working in resistance to that force (Serway & Vuille, 2012).

Players and coaches may not even understand that what they are doing is heavily reliant on physics, but one can be sure that they know how to implement the power of physics. Paying special attention to tacklers, it is easy to observe the players utilizing physics. Linebackers leverage their bodies to place the perfect hit on receivers and running backs with every collision. Linemen are taught to keep their bodies low, so as to lower their center of gravity making it harder to knock them off balance. Undersized players, for example, safeties and cornerback use leverage velocity, acceleration, and timing to tackle larger players such as tight ends and running backs. Even kickers use elements of physics during kicking plays; projectile motion and aerodynamics immediately come to mind when a kicker must decide on distance and flight time of the ball.

Another factor that has come to mind over the last several years as head trauma has become an increasingly greater concern is that collisions in football have become more violent due to the increase in mass of players at nearly every position. As previously stated, when football was in its infancy, the average weight of a lineman was 170 pounds. By today’s standards that would be small for even a high school lineman. Today, linebackers, tight ends, and running backs are over 200 pounds, and linemen are commonly weighing over 300 pounds. Further, adding to increase in collision physicality is that while the mass of players has vastly increased, the acceleration and velocity of players has also increased. The fundamental physics aspects of football have effectively changed the way the game is played. Player’s time in the 40 yard dash has improved while these same players carry nearly twice the weight of the first football players. To put it brusquely, today players are bigger, stronger, and faster than they were 100 years ago.

Possessing an understanding of physics and their involvement in football will allow the reader to better understand the impact of physics on concussions. A concussion is defined as “a complex pathophysiological process affecting the brain induced by traumatic biomechanical forces” (Tong, Winter, Jin, Bennett, & Waddell, 2015). What causes a concussion is a sudden linear and/or acceleration or negative acceleration of the brain inside the skull (Marshall, 2012). Armed with the knowledge of what linear and angular acceleration are it is easy to observe these components of physics in football. Both defensive and offensive players accelerate linearly and rotationally constantly throughout a football game. However, they are more commonly referred to as a player’s direction or movement.

It was once believed that the brain must collide with the inside of the skull to sustain a concussion; modern research has disproven this. A concussion can occur when a strong enough force causes the brain to jolt or shake violently inside the skull; although common, no actual collision with the skull is necessary. If a force is strong enough to disrupt portions of the brain, a concussion may occur. Using the formulas provided, and through clinical studies, experts are able to determine the force necessary to sustain a concussion, and an approximation for how often they may occur. According to Sport Sciences Resident Cameron Marshall while examining high school and collegiate football players, “it was found that the range of linear acceleration causing concussion ranged from 74.0g to 146.0g (g=force of gravity), and the angular accelerations ranged from 5,582.6 rad/[s.sup.2] to 9,515.6 rad/s (2.3). Using data from over 57,000 impacts, it was determined that an angular acceleration of >5,582 rad/[s.sup.2] and a linear acceleration of >96.1g yielded the highest predictive value of concussion” (Marshall, para 2, 2012). Essentially, when a 220 pound running back collides with a 220 pound linebacker,
both of whom are running at or near full speed their bodies may stop moving; however, their heads and the brain inside continue their moment. When the head stops violently due to the opposing force the brain jolts or shakes causing the concussion, or sub concussion damage. Figure 1 demonstrates the effect of linear and angular acceleration on the brain.

Keen comprehensions of the concepts of linear and angular rotation are vital to truly understand head trauma, namely concussion; their roles in causing concussions cannot be overstated. To bolster understanding of the significance of linear and angular acceleration, one should consider a study which used these concepts as tools for determining the probability of sustaining a concussion during a collision based on the measure of linear and angular acceleration sustained by the head. Two datasets were used for collecting evidence, a Head Impact Telemetry System (HITS), and NFL data involving over 63,000 hits. The goal of the study was to better predict concussion risk from a collision to aid in developing improved safety equipment (Rowson & Duma, 2013). From this study, figures have been used to provide insight into the relationship between levels of linear and angular acceleration and risk for concussion, reference figures 2, 3, and 4 for detailed findings.

The concussion illustrates Newton’s first law; that when a player is moving in a given direction, and abruptly stops, (usually due to an opposing force from another player) the head continues on its direction until the neck prevents any further movement. Once the neck reaches its maximum mobility, the head snaps, causing a violent jarring. This is where the sub-concussion damage or outright concussion takes place, in the few seconds involved in a violent hit. Given the size, speed, and strength already discussed of football players visualizing how this type of force, acceleration, and velocity is created and then inflicted on the brain does not require a great deal of creativity.

Throughout the course of researching this paper I found a cornucopia of information verifying what most football fans already know, that playing football is extremely taxing on the body and is very dangerous. The data goes beyond the obvious and provides indisputable evidence that links football to head trauma. More importantly for this paper however, the data explains the physical forces at work during a football collision. Newton’s laws of motion are at constant work; mass, acceleration, and velocity impact the outcome of every play. It is enjoyable to witness these forces at work during a breakaway run, or when your team scores a touchdown.

Unfortunately, these same forces can also cause catastrophic results; the same forces that lead to much excitement can also lead to paralysis, concussion, and a host of other injuries for the players. Research has identified linear acceleration and rotational acceleration as the two primary influences on the likelihood of whether a hit causes a concussion. When an angular acceleration of >5,582 rad/[s.sup.2] and a linear acceleration of >96.1g are reached a concussion is likely (Marshall, para 2, 2012). Research also indicates that football is the leading cause of sport related concussions for student athletes. Concussions continue to be problematic for football and also players; due to the physicality of football I do not believe this is likely to change. The science behind football makes it clear that under the conditions of which football is currently played, head trauma will continue; the physics essentially mandate it.

In light of the research becoming available administrators at every level are evaluating safety and equipment, searching for safer regulations and protective equipment. I believe that fans will continue to see regular changes to the game for years to come. The more the medical community understands the severity and prevalence of head trauma in football the greater the responsibility of addressing the issue. Better helmets, technology that indicates the likelihood of a sustained concussion, etc. are great tools for decreasing the amount of head trauma involved in
football. However, if we are being honest, and I do not believe many of us are, the only way to substantially reduce head trauma is to radically change the format under which football is played. However, given the meteoric rise in popularity of mixed martial arts, a relatively new sport which only came into existence in the last 25 years, and which is arguably more violent than football, it does not appear we are interested in less violence.
Anatomy of a concussion

Researchers have learned a lot about the physics of sports concussions, using helmet impact sensors, game footage, lab animals, cadaver heads, crash test dummies and computer simulations. The key concussion forces are acceleration and shearing. Impacts shift momentum to the struck player’s head. That momentum rapidly accelerates the brain, distorting its shape and causing damage when parts slide over and shear away from each other. Most sports concussions result from a combination of two types of acceleration.

1. Linear acceleration
   This is a sudden change in velocity occurring in a straight line, like a car accelerating from a stop light. Linear acceleration results from a direct hit aimed at the head’s center of gravity. The focus of impact and the brain damage it causes are narrowly focused. Research shows concussion is likely when the impact is at least 21 mph, accelerating the head at 98 Gs, or 98 times the pull of Earth’s gravity.

2. Angular acceleration
   This change in velocity results from an off-center blow, such as to the chin or cheek. It rotates the head around its center of gravity like a roundhouse punch. Research suggests this may be the more damaging type of acceleration, causing shear stress throughout the brain as the head twists. If the head could spin freely like a top, a concussion-causing blow would accelerate it by 916 revolutions per second, every second.

SOURCES: "Long-Term Consequences of Repetitive Brain Trauma: CTE" published by the American Academy of Physical Medicine and Rehabilitation; interviews with Dr. Robert Stern, Dr. Robert Cantu, Dr. Randall Benson.
Figure 2

Combined probability of concussion contours relating overall concussion risk to linear and rotational head acceleration. Rowson S, Duma SM. (Figure 2. Annals of Biomedical Engineering; 2013. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3624001/)

Figure 3

ROC curves for the HITS (left) and NFL (right) datasets for linear acceleration, rotational acceleration, and the combined probability of concussion. Rowson S, Duma SM. (Figure 3. Annals of Biomedical Engineering; 2013. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3624001/)
Figure 4

ROC curves for the top 50% of HITS data (left) and top 25% of HITS data (right) for linear acceleration, rotational acceleration, and the combined probability of concussion. (Rowson S, Duma SM. Figure 3. Annals of Biomedical Engineering. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3624001/)
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Alcoholism and Its Destructive Effects

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3/9/17

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ABSTRACT

Alcohol is widely consumed around the world for various reasons. It is used for its emotionally altering and sedative effects as well to relax and socialize. Many humans are prone to developing alcohol addiction; this contributing to alcohol abuse that is common and widespread in the United States. Alcohol is processed by the liver, the main metabolizer of alcohol, and does this with several enzymes including dehydrogenase and aldehyde dehydrogenase. The breakdown of alcohol leads to feelings many are attracted to and can become sought after, thus, abused. In many cases, alcohol abuse is often overlooked or denied in western culture which tends to escalate the abuse to the point of dependency. A clear majority of research has shown that susceptibility to alcohol dependence is linked primarily to genetics. The same studies show connections between alcohol dependency and an environment normalizing substance abuse. This paper covers the biology behind alcohol, its effects both physical and mental, studies showing how genes have a key role in alcohol abuse and addiction, and an observational in-the-field study on Alcoholics Anonymous.

INTRO

Alcohol has been made and consumed by humans for thousands of years. There are many different categories of alcohol; the primary group alcohol used for consumption is referred to as ethanol. Ethanol (C₂H₅O) is a chemical formed through the fermentation of glucose and other sugars consumed by yeast (Abuse NID 2016). Ethanol alcohol can react differently between people depending on their body weight, gender, genetics, family history with alcohol use and metabolism (Hurley and Edenberg 2012). (Figure 1) shows the chemical equation for alcoholic metabolism as well as an in-depth description of the specific breakdown and processing of alcohol. Links between genetics have been proven by studies conducted by (Edenberg and Foroud 2013), (Kareken et al. 2010), and (Hurley and Edenberg 2012). Their research has shown that there are certain genes that help to block feelings associated with addiction when consuming alcohol. These “blocking” genes are not commonly found in populations of European descent, however, (Edenberg and Foroud 2013) cover genes that are common among European people and their ability to promote or discourage addictive tendencies. There are more negative consequences/qualities to alcohol consumption than there are positives. Negative long term effects include liver and/or cardiovascular disease, nervous system damage, cancer of many parts of the digestion tract, and even death (Alcohol (Ethanol) Effects 2012).

ETHANOL METABOLISM WITHIN BODY

Alcohol is metabolized by the liver through two pathways involving the enzymes dehydrogenase (ADH) and aldehyde dehydrogenase (ALDH) (Alcohol Metabolism 2007). The alcohol molecules are broken down by into the toxic substance acetaldehyde. The acetaldehyde is then converted to acetate before being completely metabolized as water and carbon dioxide. These are the primary enzymes that metabolize alcohol when low to moderate amounts are consumed. There is another enzyme known as CYP2E1 that aides in acetaldehyde breakdown when excessive amounts of alcohol are consumed. CYP2E1 works along with catalase to speed up the metabolism process. Along with excessive amounts of alcohol consumption comes the production of fatty acid ethyl esters. Fatty acid ethyl esters are can cause further damage to the
liver that the acetaldehyde has not already caused. Recent studies show that acetaldehyde can produce some of the feelings associated with alcohol consumption including incoordination, memory impairment, and sleepiness (Alcohol Metabolism 2007). (Figure 1) may be referred to as a visual representation of alcohol metabolism.

The levels of impairment from the same amount of alcohol consumption varies by the individual (Alcohol Metabolism 2007). Through the process called “The Alcohol Clamp Method” researchers have could test the differences between alcohol absorption between different people. “The alcohol clamp is a method of administering alcohol intravenously to subjects, allowing researchers to circumvent variations in alcohol absorption. This technique enables researchers to administer precise doses of alcohol to achieve an exact breath alcohol concentration (a measure of how much alcohol is in the body). The actual dose of alcohol is calculated per the individual based on his or her specific alcohol elimination rate, controlling for factors like gender and body mass. This allows researchers to compare the alcohol elimination or metabolism rates without complicating factors”. It was found that men overall eliminated alcohol much faster than women (Alcohol Metabolism 2007). This means that women should feel the effects of alcohol sooner and with less alcohol consumed. The metabolism of alcohol still follows the same steps in women as it does in men just at a lesser rate. In a related study, it was found that the way alcohol is metabolized is constantly changing based on nutrient availability, hormones and the overall health of individual. These factors attribute to metabolism variation because of the varying number of nutrients needed for the body to use. The body needs more nutrients when it is under high physical loads than when the body is at rest; therefore, the metabolism changes so that there are no excess nutrients produced leading to metabolic disease (Zakhari 2013). This is reason for varied affects and feelings while consuming alcohol on separate occasions.

**ADDITION**

Though the damaging effects of alcohol on the liver are commonly known, a large majority of adults still decide to consume it. This is due mainly to the intoxicating effects that alcohol causes. This attractive quality of alcohol can lead to an addiction centered around it. Addictions in general come about through enjoyment or habit or a mix between the two as well as the environment they are developed in (Levy 2014). Certain substances, however, have brain altering characteristics to them that intensifies the addictive qualities they carry (Williamson, Buckland, Cunningham 2013). These qualities increase the density of excitatory amino acid neurotransmitter receptors in the brain. The main excitatory neurotransmitter in the brain is glutamate which controls the intensity/ density of receptions. As glutamate makes these receptors stronger (denser) and weaker, the neurotransmitters develop individual neural networks. These networks are responsible for memory which is a key component in developing an addiction as well as promotes cravings (Williamson, Buckland, Cunningham 2013). Over time, if one is susceptible to alcohol addiction, the transmitters develop memories that associate alcohol with “pleasure” and other good feelings. When glutamate makes excessive connections to metabotropic receptors near the prefrontal cortex, these pathways become stronger than they are meant to be. The strengthened pathways only intensify addiction and cravings. Addiction and (especially) cravings are intensified when the addiction is developed in certain environments.
This addiction phenomena are termed “addiction memory” (Williamson, Buckland, Cunningham 2013).

When alcohol is used at certain times be it after work every day to relax, the brain’s neurotransmitters create memories that associate alcohol with relaxation in the evening in a home environment. If one would continue to make a habit of this, it could become very difficult to relax without consumption of alcohol thus causing intense cravings for it. This is how addiction begins. It can be extremely difficult to stay sober in similar environments that one’s addiction was formed in for one attempting to become sober after becoming addicted. This relates back to addiction memory and environments. The environment itself is a part of the memory and can cause extreme cravings and in some cases feelings of withdrawal; all without the presence or availability of the addictive substance (Williamson, Buckland, Cunningham 2013). Along with these addiction memories other brain functions can/ are altered through excessive alcohol consumption. Brain chemistry can change over time to the point where alcohol dependency occurs. Alcohol dependency is caused by the body becoming so accustomed to alcohol in its metabolic system that it begins to depend on alcohol to keep bodily systems functioning (Gilpin et al. 2011). The risk for dependency has been linked to genetics and family members whom had issues with addiction (Edenberg and Foroud 2013).

GENETICS

Alcohol dependence affects nearly 12.5% of Americans as well as another 17.8% are considered alcohol abusers (Edenberg and Foroud 2013). Alcohol dependence has been medically termed as alcoholism, a complex genetic disorder. The observation of alcoholism running in families has been understood for years and recent studies have shown genetics play a major role in developing alcoholism, 65% of susceptibility is from genetics. This figure includes those susceptible to alcohol sensitivity and preference. Alcohol dependence is the result of hundreds of gene variations due to outside variables. These variables physical environment, social environment, and upbringing (Edenberg and Foroud 2013). For example, the use of alcohol around one as a child by parents or other family members can subliminally convey the normality of alcohol use.

Though there is no “alcoholism gene” there are several genes that clearly contribute to alcohol dependence (Edenberg and Foroud 2013). These genes include ADH1B and ALDH2, both of which are the basis for alcohol metabolism. As previously stated, ADH and ALDH break down ethanol in the body to produce the toxic substance acetaldehyde (Hurley and Edenberg 2012). An ALDH2 gene causes a high level of acetaldehyde to be stored in the body when alcohol is consumed; therefore, making those with the gene to have a very low tolerance to alcohol. Developing alcohol dependence is unlikely in individuals with an ALDH2 gene because they cannot handle high levels of alcohol in their system. However, this gene does not guarantee protection from developing alcohol dependence. ALDH2 can be overcome by social or environmental pressure to consume alcohol. ADH1B has similar characteristics to ALDH2, though they do not cause as severe reactions to alcohol as ALDH2 nor the buildup of acetaldehyde. ADH1B is very comparable to ALDH2 in its ability to protect from alcohol dependency. The issues with ADH1B and ALDH2 are they are mainly found in Asian
populations and rare for individuals of European descent to carry them (Edenberg and Foroud 2013).

Those that are at the most risk to develop alcohol dependence are individuals whom parents are alcoholics, do not poses genes that make the individual sensitive to alcohol and drink regularly (Kareken et al. 2010). Individuals with alcoholic parents were found to have smaller responses in their amygdala when stimulated through behavioral inhibition, fearful images and when recognizing others’ emotional cues/ states. (Edenberg and Foroud 2013) state that chromosome 4p was linked to alcohol dependence. This link was the most common and strongest among people of European descent. Event related oscillations or EROs contribute to alcohol dependence in both already alcohol dependent people and their children. It was found that ERO is extremely common to be inherited from alcoholic parents. In individuals with the KCNJ6 gene, ERO can trigger the gene to encode potassium rectifier channels. The reaction that takes place afterward influences neuronal networks (including addiction memory networks) that center around excitability (Edenberg and Foroud 2013).

**SHORT TERM EFFECTS**

There are more negative consequences/ effects of alcohol consumption than there are positives. Many of these effects are only short term, however. Alcohol consumption can bring about feelings of euphoria, relaxation, and increased confidence (Alcohol (Ethanol) Effects 2012). Though these qualities sound attractive, they are accompanied by intoxication, impairment, lack of coordination, and reduced reaction time (Short and Long Term Effects 2017). These effects can lead alcohol consumers to make decisions or relay personal information that they otherwise would not have made nor shared with others. Alcohol acts as a depressant along as a sedative which can make an alcohol consumer, primarily women, vulnerable to outside forces. The depressant effect not only clouds the mind, but physically slows the consumer’s breathing. This depressant effect becomes extremely dangerous when a high blood alcohol content or BAC is achieved (more than 0.40 grams/mL). The individual can asphyxiate from lack of oxygen often leading to coma or death. (Short and Long Term Effects 2017)

**LONG-TERM EFFECTS**

The long-term effects of alcohol tend to be more severe and life altering. Long term effects include liver and/ or cardiovascular disease, nervous system damage, cancer of many parts of the digestion tract, and even death (Short and Long Term Effects 2017). When an individual drinks excessive amounts of alcohol, more than one drink per day for women and three per day for men, one can form an alcohol tolerance (Edenberg and Foroud 2013). This tolerance is when the body becomes used to a certain intake of alcohol at one time and more is needed to be consumed to achieve effects that were previously obtainable with lesser amounts of alcohol. With tolerance comes increased amounts of alcohol consumed which further increases an individual’s tolerance and so on (Edenberg and Foroud 2013). This habit of drinking can lead to alcohol dependence; dependency being the one of the more severe long term effects (Short and Long Term Effects 2017). Once dependent on alcohol an individual will experience debilitating symptoms of “severe
anxiety, tremors, hallucinations, and convulsions” (Short and Long Term Effects 2017). These symptoms are termed “withdrawal symptoms” and can be fatal. Another long-term effect is liver disease. Alcohol is filtered through the liver and over time the liver becomes damaged and starts to produce excessive amounts of enzymes which cause abnormal liver function. This can lead to cirrhosis, a buildup of scar tissue that replaces healthy cells after long periods of being consistently damaged, and hepatitis of the liver. Problems with the liver are the most common long-term effects of heavy alcohol consumption and will eventually lead to death (Short and Long Term Effects 2017).

**RECOVERY**

Alcohol dependency is a treatable disease, and in many cases, it is possible to completely reverse damage caused by excessive alcohol consumption. The success rate for sobriety is considerably low, only 18.2% of individuals can maintain long-term sobriety (Cui et al. 2015). The weight of recovery is primarily placed on the alcohol-dependent individual and their mental state of mind. During recovery, the user will normally experience compulsive alcohol seeking behavior because of withdrawal symptoms. They will experience panic attacks and insomnia with these symptoms being intensified when addiction memories are triggered. These experiences will induce great amounts of depression and stress, thus making the percentage of recovering addicts relapse shortly after abstaining from alcohol. In most cases, the dependent individual will not be able to cut alcohol out of their diet at once. They may have to wean off alcohol to avoid fatal symptoms. Nearly all recovering alcohol-dependent individuals are recommended to attend meetings and schedule counseling sessions for the rest of their lives. The success rate for sobriety is significantly higher for individuals whom receive lifetime counseling (Cui et al. 2015).

**CONCLUSION**

Alcohol is a product of yeast fermentation and is consumed for its intoxicating and sedative effects. In the western world, alcohol, also referred to as ethanol, is used during social events and relaxation. In many cases, alcohol is abused by individuals to escape from reality, for pleasure, and because of physical dependence to the substance. Ethanol (C₂H₆O) is a chemical formed through the fermentation of glucose and other sugars consumed by yeast (Abuse NID 2016). Ethanol alcohol can react differently between people depending on their body weight, gender, genetics, family history with alcohol use and metabolism (Hurley and Edenberg 2012). Links between genetics have been proven by studies conducted by (Edenberg and Foroud 2013), (Kareken et al. 2010), and (Hurley and Edenberg 2012). Their research has shown that there are certain genes that help to block feelings associated with addiction when consuming alcohol. These “blocking” genes are not commonly found in populations of European descent, however, (Edenberg and Foroud 2013) cover genes that are common among European people and their ability to promote or discourage addictive tendencies. There are more negative consequences/qualities to alcohol consumption than there are positives. Negative long-term effects include liver and/or cardiovascular disease, nervous system damage, cancer of many parts of the digestion tract, and even death (Alcohol (Ethanol) Effects 2012).
I have first-hand seen and felt the effects of alcohol abuse. Alcoholism has been an extremely large problem on both sides of my family for generations and it has led to many issues between family members and the mental state of everyone involved. My great grandfather on my father’s side of the family was an alcoholic and his alcoholism caused him to be heavily abusive to his wife and children, both verbally and physically. This had a long-term effect on my grandfather who became mentally instable along with developing his own alcohol addiction when he was still in his teens. These addictive traits carried on to my father and so on. My uncle became alcohol dependent and I can remember watching him having to drink heavily throughout the day to stay functional. The impact that this behavior caused not only on the alcoholic, but everyone involved in their life is enormous. Both my grandfather and father are recovering alcoholics; I was able to grow up watching their recovery as well. The research that was conducted and the writing of the paper itself allowed me to connect my personal experience with data and analysis from years of study around the disease alcoholism.

As an additional step in understanding alcoholism, it was decided that hands on research would be conducted. Several substance abuse treatment options were considered for further analysis including Alcoholics Anonymous, rehab facilities, and halfway homes. Ultimately, Alcoholics Anonymous (AA) was chosen based on the majority of their members being alcoholics. AA is a nonprofit fellowship where members mutually assist each other in their alcohol addictions. For this research, the way AA meetings were conducted was studied as well as treatment pathways that they offered. No interviews took place, however, verbal permission to listen to conversations between members was received. During this study, I learned that AA has devised a “12-step program” that acts as a guide to sobriety. Along with the 12-step program, the importance of faith and spirituality was apparent. This so in that prayer was held at the end of the meeting as well as a central agreement between members that they could only maintain sobriety with the help of God. Though there is a religious component to AA, they are tolerant of other’s views. The group observed consisted of only males, who has a general discussion about their current and past struggles, how well they are doing staying sober, and offering helpful words of advice in response. There is a mutual feeling of empathy between the members, this, I infer contributes immensely to the mental support needed to abstain from alcohol. The observational study allowed me to see first-hand the damage that alcohol can cause (outside of personal life) as well as a brief introduction to the recovery process.
The chemical name for alcohol is ethanol (CH\textsubscript{3}CH\textsubscript{2}OH). The body processes and eliminates ethanol in separate steps. Chemicals called enzymes help to break apart the ethanol molecule into other compounds (or metabolites), which can be processed more easily by the body. Some of these intermediate metabolites can have harmful effects on the body.

Most of the ethanol in the body is broken down in the liver by an enzyme called alcohol dehydrogenase (ADH), which transforms ethanol into a toxic compound called acetaldehyde (CH\textsubscript{3}CHO), a known carcinogen. However, acetaldehyde is generally short-lived; it is quickly broken down to a less toxic compound called acetate (CH\textsubscript{3}COO\textsuperscript{-}) by another enzyme called aldehyde dehydrogenase (ALDH). Acetate then is broken down to carbon dioxide and water, mainly in tissues other than the liver.

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Exposed to Common Industrial Chemicals and Metals: The Effects
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ABSTRACT

Industry has had, in some way, made an impact on every person to live since the Second Industrial Revolution in the late 1860’s. Industrial workers have faced various dangerous situations and handled hazardous substances since the late 1800’s. Hazardous substances are an issue dealt with even in modern industrial settings. The hazardous substances covered in this report are sulfuric acid, carbon disulfide, and aluminum dust. Each of these substances are very common in nearly every branch of industry. Each substance has its own unique set of hazards that lead to different effects on workers exposed to these substances. The link between aluminum exposure and the development of early onset Alzheimer’s Disease and the necessity for further research is emphasized as an important area for discussion. The advancing safety standards in industrial environments and how they apply to the specified substances is also described. This paper will cover these points in thorough detail as well as the chemistry behind it all.

INTRODUCTION

In today’s civilized regions, industry is the backbone to economic structure because it is responsible for everything manufactured or produced; from the products sold at the grocery store to jet fuel used in passenger airplanes. Industry is “a department or branch of a craft, art, business, or manufacture; especially: one that employs a large personnel and capital especially in manufacturing” (Industry 2017). Per the U.S. Bureau of Labor Statistics, there are over 12 million employees in US goods manufacturing (nonagricultural) making up nearly 8 percent of the entire workforce (USBLS 2015). Toxic and hazardous substances are used throughout most of processes involved with industry (Brody 2002). Most of this work force handles these substances daily and pose a hazardous threat to most workers (OSHA). These substances include sulfuric acid, carbon disulfide, and aluminum dust. These substances are dangerous both through short and long term exposure. When exposed to high amounts of sulfuric acid, respiratory damage can occur as well as deterioration of internal bodily system when ingested orally (CDCP 2015a). Carbon disulfide leaves chemical burns and blisters when bare skin comes into direct contact with it (CDCP 2015c). A hazardous substance that does not appear to a threat at first glance is aluminum, specifically aluminum dust (CDCP 2015b). Aluminum dust has been linked to multiple neurological diseases and impairments (CDCP 2015b). However, high federal regulations and standards for safety and handling of industrial materials have advanced significantly since the Second Industrial Revolution of the late 1800’s; therefore, they keep industrial workers safe, but no amount of safety precautions can alleviate accidental exposure to hazardous substances.

HISTORY

The industrial marketplace has been around for nearly 150 years. Large scale industry began to be more and more present once the Second Industrial Revolution began in the late 1800’s (Engelman 2015). During this period, technology advanced exponentially and manufacturing practices began to increase while becoming more stream lined. Technologies including railroads and steam engines allowed products to be manufactured and distributed
further distances in less time. These advancements are what lead the United States to become a wealthy and powerful country; thus, attracting large amounts of attention from immigrants looking for jobs. This influx of fresh laborers caused the rate of industrialization to grow at an even faster pace. Working conditions were, however, terrible and the rate of death and disease was high. Despite these conditions, over fourteen million immigrants had immigrated between 1860 and 1900 to work in the various industrial fields at the time (Engelman 2015). Those with industrial jobs were working long hours and with materials that hazardous to their health.

Factories and manufacturing plants were normally surrounded by urban cities where the workers lived. The overwhelming number of workers living nestled together near the plants along with open sewers in the streets and tainted water supplies allowed for disease to flourish (Http://Www.Loc.Gov/Teachers/Classroommaterials/Primarysourcesets/Industrial-Revolution/Pdf/Teacher_Guide.Pdf). The factories themselves were no better in terms of their conditions. Many of the workplaces had little to no safety rules/physical features; serious accidents and deaths were a daily occurrence. Workers were exposed to various chemicals regularly and many of the machines that burned coal for fuel produced unventilated smoke that would be breathed in by workers during their shift. Exposure to these harsh conditions lead to an early death for most exposed (Http://Www.Loc.Gov/Teachers/Classroommaterials/Primarysourcesets/Industrial-Revolution/Pdf/Teacher_Guide.Pdf). The general practices involved with industrial work have not changed all that much since the 1800’s, but there have been major advancements in technology and safety standards since then.

DANGERS OF INDUSTRY

Though industrial work has become relatively safe since its beginning, there are still inherent risks involved due to a multitude of factors. In nearly every form of industrial production, large amounts of substances are handled and combined due to the scale of most manufacturing production orders. Common substances that can be found in the average household such as cleaning solutions, degreaser, and even dust become exceedingly hazardous when handled in the high quantities seen in industrial environments. Long term exposure to many substances can lead to lung and skin cancer, Alzheimer's Disease, Parkinson's Disease, and other conditions that can shorten life expectancy (OHS 2015). The human workers involved with industry are not the only beings at risk to industrial hazards.

Damage to the environment has been an ongoing issue with large scale manufacturing and other forms of industry. Under normal operating conditions of an industrial plant, waste materials, apart from air pollutants, are treated so that they can be safely introduced into the environment (SVIVA). Air pollutants are difficult to capture/filter; therefore, they are normally released into the atmosphere. Greenhouse gasses such as sulfur dioxide (SO₂) and nitrogen oxides (NOₓ) are common byproducts in an industrial setting. Greenhouse gasses are harmful if inhaled in excess and contribute to global climate change. Regulations are in place to keep chemicals and other toxic substances from entering the environment, but nothing can elevate the possibility of environmental contamination completely. Untreated wastewater from a factory can seep into the ground and surface water around in a variety of ways including broken pipes, containment tanks that exceed capacity, or operator error. Wastewater can introduce heavy metals and salts into lakes and streams rendering them unsafe to use for human consumption.
More common as well as dangerous pollution is leakage from the fuel and energy industries. Leakage of petroleum into the environment can have devastating consequences that lead to long lasting damage to the environment (SVIVA). For example, the BP oil spill of 2010 in the Gulf of Mexico released over 200 million gallons of oil into the ocean that affected 16,000 miles of United States’ coastline and killed 8,000 animals (11 Facts About the BP Oil Spill).

CHEMICALS

Sulfuric acid, a chemical used widely throughout the industrial field and found in household environments, can cause severe health problems with limited exposure time (Moore et al. 2017). In an industrial environment, sulfuric acid (H₂SO₄) is used to produce phosphoric acid which is then used to manufacture fertilizers and to prepare rolled steel for distribution; it can be found in store-bought liquid drain cleaners as well (CDCP 2015a). Sulfuric acid is formed when sulfur trioxide gas (SO₃) combines with water molecules to form the liquid sulfuric acid; refer to (Figure 1) for a visual representation of the chemical formation of sulfuric acid. Sulfuric acid is dangerous and affects the body negatively. Due to its clear colorless appearance, it can be easily mistaken with other liquids like water, for example. When water and sulfuric acid come into contact, a violent reaction occurs that produces toxic sulfur trioxide gas and creates high amounts of heat. In an industrial environment where hundreds of gallons of chemical are used, the risk factor is multiplied exponentially because a small amount of water introduced to a large amount of sulfuric acid could cause an explosive reaction. This violent reaction with water is a noteworthy characteristic of sulfuric acid (CDCP 2015a).

The human body is over 70 percent water and so it does not fare well when exposed to sulfuric acid. When inhaled, sulfuric acid combines with the water droplets in the respiratory system, producing heat, toxic gasses, and irritation (CDCP 2015a). The corrosive nature of sulfuric acid allows it to cause chemical burns. These burns can be severe enough to completely deteriorate flesh. This is most often seen when sulfuric acid is ingested; here, the acid burns the mouth, esophagus, and can erode a hole in the stomach. When ingested like this, death is a likely possibility. The long-term effects of sulfuric acid exposure can be more life threatening than the short-term irritation sulfuric acid causes in minute amounts. It has been found that in individuals subjected to long-term exposure of sulfuric acid, like those found in industrial environments, have been found to have a higher chance of developing cancer of the larynx. This connection between sulfuric acid and cancer of the larynx has not been enough for the EPA to classify sulfuric acid as a carcinogen, however. Along with cancer, sulfuric acid inhalation can cause deterioration of the teeth over extended periods of time (CDCP 2015a).

Another commonly used chemical found in industrial settings is carbon disulfide (CS₂). In its pure form, carbon disulfide “is a colorless liquid with a pleasant odor that smells sweet” (CDCP 2015c). The pure form of carbon disulfide is used less often than its impure form, which is a yellowish liquid with a putrid odor. From this point, onward only the impure form of carbon disulfide will be discussed. At room temperature, carbon disulfide evaporates and its mass is more than double that of air (29 g/mol). A combustible molecule, carbon disulfide is very flammable and explosive under the correct conditions. Its main use is in in the tire manufacturing industry. Raw carbon disulfide is used to dissolve organic rubber that is then used in the production of rubber tires and similar products. Those who are most likely to be exposed to high levels of carbon disulfide work within these industries. However, because carbon disulfide has
such a high mass compared to air, it tends to fall to the ground where it sinks into the soil; eventually making it into ground water reservoirs. Carbon disulfide does not easily dissolve in water nor bond to soil well so it will evaporate off the surface of the ground water; thus, going back into the soil and falling back to the water and the cycle repeats. If the carbon disulfide makes it back through the soil, it is possible for an average person to be exposed to it. It is still unclear how carbon disulfide decomposes in the natural environment and its effects on the environment (CDCP 2015c).

Carbon disulfide is mainly introduced to the body through breathing in air that contains it. In higher concentrations, it may be absorbed through the skin and mouth (CDCP 2015c). Once ingested, carbon disulfide enters the blood stream and 90 percent of it will leave the body through urine over a short length of time. When exposed directly to the skin, carbon disulfide will cause chemical burns and blisters. Carbon disulfide becomes life threatening when exposed to high levels (10,000 ppm). At this level, the nervous system is burdened by the carbon disulfide as well as heart issues and permanent damage in sue. The brain, liver, lungs and heart are permanently affected after breathing 225 ppm carbon disulfide for more than 24 hours. An increased number of birth defects and still births were noticed in animals exposed to 225 ppm carbon disulfide for more than 24 hours. Studies conducted on railroad workers who were exposed to intense amounts of carbon disulfide from a spill showed chest pains and difficulty breathing as side effects from the carbon disulfide inhalation. The OSHA standard for carbon disulfide exposure is 20 ppm over the course of a five-day work week. This is interesting because studies on workers exposed to anything more than 20 ppm carbon disulfide experienced headaches and difficulty sleeping for six months after initial exposure. Though carbon disulfide is not listed as a carcinogen, it is possible to be diagnosed with carbon disulfide related cancer if exposed to more than 0.1 mg of carbon disulfide per kilogram of body weight per day (CDCP 2015c).

METALS

When discussing hazardous materials, one is quick to think of harmful chemicals and gasses, yet metals are most likely to get overlooked. The most abundant metal in the earth’s crust, aluminum, is used in nearly every product manufactured today including beverage cans, automobiles, electronics, furniture, fireworks, and automotive materials (CDCP 2015b). Aluminum makes an appearance in most consumer products such as antacids, aspirin, food additives, antiperspirants, cosmetics, vaccines, and in packaging. Due to the varied applications for aluminum, it can be found in nearly every part of any industry. Those who are especially vulnerable to aluminum’s effects are workers within industries that process aluminum dust, be it cutting raw aluminum, manufacturing of aluminum based powders, or where aluminum is welded. Aluminum ingested orally has not been found to be harmful in about 99 percent of cases because it does not easily dissolve in the human body. Those that the aluminum does effect from oral ingestion had pre-existing condition(s) that caused the aluminum to be absorbed and stored in the body. Hazardous effects become apparent when fine aluminum dust is inhaled into the lungs in high dosages (CDCP 2015b).

Workers that breathe large amounts of aluminum dust tend to develop lung problems (CDCP 2015b). These problems start as a light cough that transforms into a heavy cough. When enough aluminum is inhaled into the lungs, lung function decreases as well as lung changes and
spots are visible in chest X-rays. In a moderate number of workers who breathe in aluminum dust, tests that calculate nervous system function have shown a decrease in nervous system function in these individuals. These decreased nervous system functions typically include lack of grip strength and decreased joint movement. Typically, low to moderate amounts of aluminum ingested orally is harmless because it does not have time to dissolve in the body. However, as an exception to this normality, those with kidney disease have the opposite effect; their bodies store the aluminum in the kidneys. This is a result of the disease disallowing the aluminum to be released through urine; because the aluminum does not dissolve quickly, it slowly builds up over time. Once enough aluminum has accumulated, the concentration of the small amount that is dissolved is high enough to have adverse effects on the patient’s nervous system, brain and bone structure. Many of the effected developed brain and/or bone disease while being treated for kidney disease. Aluminum is possibly dangerous for pregnant women and their fetus as well. Though it is not known for certain if aluminum causes birth defects, through animal testing, it was found mothers exposed to aluminum dust while pregnant gave birth to offspring that were alarmingly uncoordinated and unusually inactive. As the offspring grew older, they tested lower on memory tests compared to a healthy animal of the same age (CDCP 2015b).

It has been speculated since the late 1990’s that aluminum could be a key factor in those diagnosed with early onset Alzheimer’s Disease. There have been studies that confirmed Alzheimer’s to be linked with aluminum and others that allegedly disproved these studies stating that there was no link between Alzheimer’s and aluminum exposure (CDCP 2015b). Recently, studies have been uncovering solid experimental data proving aluminum’s link to Alzheimer’s along with a few other diseases “such as breast cancer and neurological disorders” (Study 2014). Studies show aluminum stops the body from excreting toxins by blocking glutathione production in the liver. Glutathione is an intracellular detoxifier; an antioxidant that acts as a defense against free radicals (highly reactive single molecules) and foreign heavy metals. It neutralizes the free radicals by donating H⁺ ions to the reactive molecule. Without glutathione as a defense, the body can become overwhelmed with aluminum; this is termed aluminum toxicity. As previously stated, aluminum affects the nervous system. When comparing the symptoms of aluminum toxicity to nervous system diseases such as Alzheimer’s and Parkinson’s, the symptoms are strikingly similar (Study 2014). Further research is needed to be certain aluminum can cause early onset neurological diseases, but the data seems promising so far.

SAFETY

Safe industrial practices have become a top priority for workers and is constantly improving. A combination of federal regulations and standards have kept safety advancing as industry progresses (OSHA). The federal association in charge of developing and regulating safe work, chemical handling, and manufacturing processes is the Occupational Safety and Health Association or OSHA. OSHA has standards for safely dealing with the hazardous materials discussed thus far. The limit for concentration of sulfuric acid to air is 1mg/m³ (CDCP 2015a). Per OSHA’s standards for carbon disulfide exposure, “OSHA requires that workroom air contain no more than an average of 20 ppm of carbon disulfide over an 8-hour working shift for 5 consecutive days in a work week” (CDCP 2015c). “OSHA set a legal limit of 15 mg/m³ (total dust) and 5 mg/m³ (respirable fraction) aluminum in dusts averaged over an 8 hour work day” (CDCP 2015b).
CONCLUSION

The Second Industrial Revolution in the late 1800’s boosted the world into the technological age with the exponential rate of industrial advancement that continued to build on itself until present day. Those in the industrial field in the 21st century face similar dangers and hazards that were first endured by the industrial workers in the seventeenth century. Other than an improved working environment (adequate lighting, clean air, reasonable working hours), industrial workers are still handling hazardous substances in large quantities with simply improved safety techniques. The effects of exposure to the substances covered in this paper are just as deadly as they were 150 years ago, yet workers are harmed far less often than they previously had. However, accidental exposure to harsh chemicals and other hazardous substances still does happen. It was surprising after researching the topic to realize how little we know about certain substances and their effects on humans and the environment alike. For example, there is a lack of understanding how carbon disulfide, a common industrial chemical, interacts with the environment. We know that its density is more than double that of air and it does not break down easily once introduced to liquid water. Based on the research conducted, there is nearly no other data on how carbon disulfide reacts with its environment or how it affects humans. The perceived effects of carbon disulfide where not conclusive and the symptoms at certain levels of exposure were theorized to be caused by the carbon disulfide, not proven. It is interesting that without conclusive evidence of carbon disulfide’s effects at a certain ppm that OSHA and the EPA would suggest “safe” daily exposure limits.

The basis for the topic, effects of industrial substances on workers/ humans in general, was chosen out of personal curiosity. This curiosity about these effects stems from a personal tie to industrial labor and exposure to similar environments. Being exposed to various industrial hazards such as lacquer thinner, automotive paint, welding fumes, and various powdered metals nearly since birth made me think about the potential permanent effects that these chemicals, gasses, and inhalants could cause. My trade of welding/ fabrication increases the exposure to welding fumes and aluminum dust. The specific attention given to the effects of aluminum and its link to neurological diseases was intentional due to more personal ties to the metal. Medical testing has made myself aware of an excessive amount of aluminum in my blood stream; these levels well above normal. Those with aluminum toxicity experience symptoms related to lack of memory, attention disorders, and depression; all these symptoms have personally been ongoing struggles for me throughout my life. Knowing very little about this link and wanting to understand the link better was the driving force behind choosing the topic researched and discussed in this paper. In the future, further research and analysis of aluminum and its links to neurological diseases is needed specifically to achieve a complete understanding of the topic, but the research conducted thus far is adequate for the broader topic “the effects of common industrial substance exposure”.

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The Physics Application in Medical Prosthetics
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Abstract:
Prosthetics are artificial limbs that can replace biological limbs that may have been lost in a trauma, or birth defect. With prosthetic, people can achieve a normal life with their recovered functionality of their limbs. Each prosthetic must be custom built because every patient is different from each other, and with prosthetic that gets developed, there are many physics applications that must be considered. The physics application are Newton’s three laws, and the different forces that it encompasses: the force of gravity, normal force, the force of friction, force of tension, and the applied force, also the different potential energies of gravitational, or elastic. Then there is the relationship between the potential and kinetic energies, and how there is a need of a seamless transfer of energy, but the materials are important, and play a critical role in that transfer of energy and overcoming of forces. In current research and clinical trials, the future of prosthetics is very bright with the use and research of bionic limbs, and it will change patient’s lives for the better.

Body:
If somebody loses a limb due to trauma or disease, then they lose all the functionality of that limb, and are left without one. Over the course of the past years a developing field has been prosthetics. Recent wars have propelled the need and use of prosthetics thereby introducing research and money to help this field of medicine. Prosthesis is defined by the dictionary as “a device, either external or implanted, that substitutes for or supplements a missing or defective part of the body.”

Prosthetics gives the chance to achieve a healthy, normal life for many people. Prosthetics has changed drastically since the beginning as now the developers are able to customize the artificial limb using different materials depending on where the location of the limb will be thereby increasing compatibility and efficacy of the prosthetic. The components of prosthetics are the pylon, socket, and the suspension system. Depending on the component of the socket, the material used for it will change for optimal results. Prosthetics contain many field that range from developing a proper artificial limb, to making a cosmetic limb what will match a person’s body. However, the developer must take into account the many forces that are associated with prosthetics. Some of the main forces associated with human and animal leg prosthetics are: the force of gravity, normal force, the force of friction, force of tension, and the applied force. While producing and developing the prosthetics, the prosthetic developers must take into account the physics aspect and how it affects the body and prosthetics. There are many physics applications that goes into the design of prosthetics that includes the materials used, the shapes of the prosthetics, the different forces applied, the new technological prosthetics are based on physical principles that can drastically revolutionize prosthetics and greatly improve the lives of many disabled people.

The main components of prosthetics are the pylon, socket, and the suspension system. The pylon is the frame of the prosthetic. It provides the structure and it produces the artificial limb to provide support and be in place of the limb. The socket is where the residual limb of the person connects with the prosthetic. The socket is very important because the prosthetic must for properly so the person could effectively use it, but also the prosthetic must not irritate the person, and there must be sufficient support that the prosthetic won’t cause furthermore damage to skin or nerves. The suspension system is the component that attaches the prosthetic to the body.
Depending on the limb, and the stump that is left behind, a prosthetic can be joined directly to limb, or a harness system may be required that a strap, or belt, or sleeve will need to be used in order to attach the prosthetic. Depending on the amputation, the prosthetic must be custom designed in order to achieve a successful artificial limb that will be successful and helpful for the person.

There are many forces that are associated with the prosthetics of the legs. Some of the main forces associated with human and animal leg prosthetics are: the force of gravity, normal force, the force of friction, force of tension, and the applied force. The Force of gravity and the normal forces are both used in the development in the prosthetic legs. The force of gravity can be defined by Newton’s law of gravitation, force of gravity equals \( (Gm_1m_2/r^2) \). \( G \) is defined as the universal gravitation constant which is equal to \( 6.67 \times 10^{-11} \) Nm\(^2\)/kg\(^2\). The two mass in this equation, when it is pertaining to the forces of the prosthetics, is the mass of the prosthetic and, and the second mass would be the mass of the person. However, the force of gravity is used differently when developing the prosthetics for humans and animals. Using this equation, the designers of the prosthetics and see the force the prosthetic needs to handle in order for the product to be sturdy and not break while it is being used. That it is why each prosthetic must be custom made because every person is of a different weight, so the gravitation forces exerted by each person is different. Depending on the exerted force of gravity, there is a needed upkeep and maintenance that the person must visit a doctor in order to adjust the socket and maybe even reevaluate the prosthetic due to weight changes. For animals, it is different because they have four legs instead of two, so they have a more even distribution of weight, and the forces are even split, which reduces the force magnitude per leg. Also since animals are shorter, they have a lower center of gravity, so they are a more stable animal, which reduces the stress and pressure on each leg. The physics theory of the force of gravity is one of the forces that is very closely looked at when prosthetics are being developed and chosen for the patients, as it is critical for the success of it.

Another force that is associated with prosthetics is the normal force. The normal force can be denoted by \( N \) or \( F_N \), and it is equal to the opposite forces in a system. The normal force can be defined by Newton’s Second Law which states the principle that there is a mass pushing down due to the gravitational force, and in a reactive force, there is an upward force that is equal to the gravitational force pushing down, in the case of prosthetics for the legs. This is directly related with the gravitational force, as it is the opposing force, which allows people and objects to be standing firm on ground. The normal force can be calculated using the equation \( F_N=mg \), where \( m \) is the mass of both the prosthetic and person combined, and \( g \) is the gravity constant of \( 9.81 \) m/s\(^2\). For the prosthetics, the normal force is applied from the ground to the prosthetic. This force allows for maintaining all the movement within the legs for humans and animals. This opposing force is necessary to understand the balancing of forces, but also shows the vertical forces that the prosthetic undergoes, and necessary rigidity of it, but also the flexibility and proper sockets are critical for it to be successful.

The force of friction is another force that is associated with prosthetics. The force of friction can be denoted by \( F_F \) and it can be calculated using the equation \( F_F = \mu N \), where the \( \mu \) is the coefficient of either static and sliding friction, and \( N \) is the Newton’s that a person is. Again, this shows that the development of prosthetics is different for each person, as there are different
parameters that need to be taken into account. When a person is walking or running, then the
with the ground and the prosthetic, there is a frictional force that is generated between the two.
To calculate the frictional force between the two, the N would be the value of the number if
newton of the combined prosthetic and person, and the µ would be the frictional coefficient that
would be given or known. However, the frictional force would be different for a prosthetic and
human skin or another object because the prosthetic has a smoother surface.\textsuperscript{8}

The force of tension is also a force that is also critical to the development of prosthetics.
Prosthetics need to be flexible and be able to move with a wide range of motion. The Force of
Tension can be denoted by T or FT, and it can be calculated by using the equation T = mg + ma,
where T is the tension, m is the mass of the combined person and prosthetic, g is the gravitational
constant of 9.81, and a is the acceleration of the pace at which the person is walking or running at.
The force of tension is something that needs to be taken into account of because a prosthetic
need to be able to handle the changing weights that the person will incur with lifting or
dropping weight, so there needs to be a withstanding ability so it will not break under pressure.
To take into account of this force, the prosthetic can be controlled or administered by a cable that
is connected to another limb or harness. For example, if there is a right arm prosthetic, then there
could be a harness that is attached to the left arm so the prosthetic and its movements can be
controlled.

The last force that is important to prosthetics is the applied force. The applied force is the
force that is exerted upon another object. The force that causes another object to
cause a change in velocity, direction, or could be a push, or pull is the applied force. In order to
do another, the applied force is the force that causes all the actions. The prosthetic must be able
to withstand and do enough actions where it could provide enough applied force for a person to
do the action. With all the force of gravity, normal, friction, and tension, one must overcome all
those barriers in order to do an action, and the applied force is the one that drive the actions. In
order to find the applied force, Newton’s Third Law is used, of $F_{net}=ma$.

Sample Calculations of Each Force:
An example for calculating the force of gravity would be, if a person weighs 66 kg, and
they have a prosthetic that is 3 kg, and the radius of the prosthetic is 0.5 meters then to calculate
the value of the force of gravity, use the equation $F_G=Gm_1m_2/r^2$, then plug in the values to the
equation to be $F_G= ((6.67 \times 10^{-11} \text{ Nm}^2/\text{kg}^2) (3) (66))/ (0.5^2))$, then that would equal $5.28 \times 10^{-8}$
N.

An example of calculating then normal force would be, if the combined mass of the
person and prosthetic is 70 kg, and the gravitational constant is 9.81 on Earth, then using the
normal force equation $F_N=mg$, then plugging in those values, $F_N=(70 \text{ kg}) (9.81 \text{ m/s}^2)$ and that
would equal 686.7 N.

An example of calculating the frictional force would be, if the combined force vector of
the prosthetic and person is 66 N, and the frictional coefficient is 0.2, then using the equation $F_F = \mu N$, then plugging in those numbers, it would be $F_F = (0.2) (66 \text{ N})$, and the frictional force would
equal 13.2 N.
An example of calculating the tension force would be, if the mass of a prosthetic is 3 kg and a person is rotating their arm at an acceleration of 3 m/s² then to calculate the Tension, using the equation $T = mg + ma$ and plugging in the values, $T = (3 \text{ kg}) (9.81 \text{ m/s}^2) + (3 \text{ kg}) (3 \text{ m/s}^2)$, $T$ would equal 38.43 N.

An example of finding the applied force would be, if the mass of the prosthetic is 5 kg, and they are running at an acceleration of 5 m/s², then to find the value the equation $F_{net} = ma$ would be used. Then plugging in the values in the equation $F_{net} = (5 \text{ kg}) (5 \text{ m/s}^2)$, then the applied force would be 25 N.

Prosthetics incorporates the principles from all three of Newton’s Laws: First, Second and Third Laws. Newton’s First Law states that an object will stay at rest unless an external force is acted upon it. The external force would be an unbalanced force that would come and disrupt the action or rest that the second object is in. Inertia is a property of matter that will continue to stay in a state unless acted upon it, and that is why Newton’s First Law is referred to as the Law of Inertia. This is related to prosthetic as one cannot move or be mobile unless there is a component that would allow for walking. A leg will stay at rest unless a force (applied force) is applied to move around.

Newton’s Second Law states that an object will gain an acceleration when a force acts upon a mass. However, depending on the mass of the object, the larger it is, the greater amount of force it would require to move, and gain an acceleration. Both the normal force, and applied force are dependent on this law. For the normal force, it is mass times acceleration, and when the prosthetic is at rest pointing downward, the acceleration that can be used is the gravitational constant, because there is gravity acting upon it. This law explains the forces, and shows the principles of the need to overcome a barrier for an action to occur, so this can quantify the force and explain the needed strength of the prosthetic.

The last law is Newton’s Third Law, and is most well-known for its quote “For every action, there is an equal and opposite reaction.” Each action has a response or consequence, because there is always a force that is equal reactive force that occurs. In the case of prosthetics, for every step takes, there is an applied force, but in response for each step, there is frictional force acting back. This explains both of the force, and how both of those force are needed to counterbalance one another in order to maintain a balance. This dynamic balance will change with different prosthetics because each one has different surfaces, and that is important to take into account of when developing prosthetics.

In prosthetics, there are three types of energies that are associated with it: Potential Energy, Potential Gravitation, and Kinetic Mechanisms (Kinetic Energy). Potential energy is the stored energy of a specific position of an object. In a prosthetic, there are both springs and different positions that it stays in. Due to that, there is elastic energy, and that all will be converted into kinetic energy. However, to allow for this energy transfer, a prosthetic can help balance the person, and it will allow for a seamless energy transfer. In dogs or four-legged animal, if they lose their paw or foot, they can receive an artificial paw. This prosthetic will serve as a large “bootie,” and the bootie will help provide a balance for the animal and allows for a seamless transition between different energies.
Potential Gravitational is the potential energy that is gained and stored up because an object is at a height. The potential energy gained is due to the force of gravity pushing downward, and the prosthesis would be above the ground which is resisting from falling. To calculate the potential energy from gravity it would be using the equation $PE_{\text{gravity}} = m \times g \times h$. To calculate the potential energy of the prosthetics, is depends on where the prosthesis is if it on the arm, or the leg. If the PE is calculated for the arm, then the M is the mass of the prosthesis, and g is the gravitation constant of 9.81 m/s$^2$ and the h is how high the arm is from the ground. If it is a prosthetic leg, then the M is the combine mass of the person and the prosthesis, and the following variables would be the same. Depending on the mass of the prosthetic and person, the potential gravity would increase or decrease.

Prosthetic would also have elastic potential energy in the system. Elastic potential energy is the energy stored in a system due to the stretching of a spring. In prosthesis to gain more control of movements of the prosthetics, a harness composed of elastic bands will be used, and that will help administer the movements. In that system, potential energy gets built up the stretching, and that will be used for kinetic energy when there is movement. The potential energy from the spring can be calculated by solving for the work done by that spring. The equation to find the potential energy is $W = (0.5)(k)(x^2)$. K is the spring constant, and x is the distance that the spring travels. However, to calculate the amount of force that it took to elongate the spring, that can be solved for by using Hooke’s Law. The equation to find the force is $F = -kx$. The force is directly related to the amount of distance stretched.

Kinetic energy can be defined as the energy that an object exhibits when it is in motion. Regardless of its direction, if it is moving, it has kinetic energy. Prosthetics, will have different types of kinetic energy which includes: rotational, and translational. Rotational kinetic energy is the kinetic energy which is used when it is rotating. For a leg prosthesis, it would be rotating when they are doing multiple activities or exercising, and for an arm prosthetic, that would include most actions. Translational kinetic energy is the energy which is used when moving or changing locations from one place to another. Kinetic Energy (KE) can be calculated using the equation $KE = (0.5)(m)(v^2)$. M is the mass of the prosthetic which may include the persons mass depending on the location of it, and the v stands for the velocity at which the prosthetic is moving at.

Sample Calculations:
An example of calculating the potential energy due to the gravitational force would be, if the mass of the prosthetic is 3 kg, and the person is holding their prosthetic arm 3 meters off the ground, then using the potential energy equation $PE_{\text{gravity}} = m \times g \times h$, then plugging in those values, $PE_{\text{gravity}} = 3 \times 9.81 \times 3$, would equal 88.29 J.

An example of calculating the elastic potential energy would be, if the harness is stretched out 1.5 meters and the constant of that harness is 0.2, then using the elastic potential energy equation $W = (0.5)(k)(x^2)$, then plugging in those values, $W = (0.5)(0.2)(1.5^2)$ and that would equal 0.225 J.

An example of calculating the kinetic energy would be, if a person is running at 5 m/s and the combined mass of the person and prosthetic is 80kg, then using the kinetic energy
equation KE=\(0.5\) \(m\)(\(v^2\)), then plugging in those values, KE=\((0.5)(80 \text{ kg})((5\text{ m/s})^2)\) and that would equal 1000 J.

When the developers are customizing the prosthetics for their patients, they must take into account the material of the prosthesis. Initially, prosthetics used to be made up of old wood, but now with testing and material development, prosthetics are made of advanced plastics, fiberglass, aluminum, and carbon-fiber composites. The advanced fiberglass has revolutionized prosthetics. It is able to improve patient care as it reduces the stress and all the following forces. It is able to withstand a longer use of time, but it cannot handle too much weight. Aluminum is a common choice for many patients because it is very sturdy and can support more weight than other prosthetic materials. It can withstand all weather conditions, and it is very light weight, and is preferred by many. Wood used to be the main material for prosthetics but it is not as used anymore. People used to have wood prosthetics because it was cheap, but it can break easily, and has to be replaced often. Our current technology has allowed us to move towards modern materials where they weigh less, and are more comfortable, and now prosthetics is moving towards robotic prosthetics.1

Scientists and Physicists have made major progress towards making bionic limbs. Bionic limbs are technological limbs that can be controlled by a number of things that includes sensors, and even with the brain. At the Applied Physics Laboratory at Johns Hopkins University, there has been developing research and clinical trials about these bionic limbs, and it is a part of the Revolutionizing Prosthetics program. The goal of this lab is to develop a bionic limb that can mimic and become a biological limb. On the prosthetic arm there are sensors which can be used for touch, sense the change in temperature, the vibrations of the area, and the ability to understand the position of the arm, and where it is on the body. Also, there is clinical trials going on where upper arm amputee can receive this bionic limb, and it can communicate with the surrounding nerves, and the brain can then manipulate and control the prosthetic. To achieve this brain control, in one clinical trail the technology used is electrode arrays. This relates to the cathode ray where the flow of an electron is due to the different partial charges on different ends, so the transfer of signals from the brain to the limb follow the same principles.

In this paper I researched the physics principles surrounding the mechanics of prosthetics. In my research I found that the ideas of different forces, potential and kinetic energies, material development, and Newton’s Laws are all very critical components to the development of prosthetics. For the different forces, I found that the forces of gravity, normal force, the force of friction, force of tension, and the applied force are all very critical and balancing for prosthetics. The forces are all needed to balance, and maintain a function prosthesis. However, with changing conditions of the prosthesis the effects of each one will change as well. The potential and kinetic energies are also very critical to the functionality of the prostheses because those also help overcome the forces acting upon them. Each prosthetic is produced must be custom made to each patient, and that is why the material used for it is important. Depending on the different lifestyles that the people enjoy, the prosthetic will vary with each person. Newton’s Laws are able to explain each force and how they are all related to one another, and how one force must overcome another for an action to occur.
From this research, it is evident that the consideration of physics principles are critical when developing a prosthetic. If one force is not taken into account for, then it may not be strong enough to withstand the pressure, and the prosthetic could break. The prosthetic would not be doing its job if it cannot properly support a person in its activates. Newton’s Laws were the principles that are most important to take into account of, as it explains the different barriers, and the different forces associated with each one. Prosthetics is a very interesting field, and is going in a very bright direction where the patients can really benefit from, where their abilities would lack very little in comparison too other.

There is a bright future for the field of prosthetics. Comparing prostheses from 20 year ago to now, they are very different. Before it would only be wooden prosthetics, but now there are many different types of materials that can be used depending on the person. In many labs, and especially in the clinics like at Johns Hopkins University and at the Veterans Affairs clinics, the new bionic limbs technology is out where the limbs can be controlled by the brain using the electrode rays. If this is where we are now, then in the future we can start of expect actual nerve attaching bionic limbs, so now there will be the same feelings and sensation that a attached limb could do. The technology will be more savvy, and the limbs will be made out of materials that will be even more safer, and lighter, so there will be no pain that the patient would feel. Patient lives are going to drastically improve with the future bionic limbs.
Figures:

This is a picture of one of the bionic limbs in the lab at Johns Hopkins. It is one of the limbs with use the electrode array.

Source: http://www.jhuapl.edu/prosthetics/medical/default.asp

These two images depict the major progress that has been made from a wooden leg to an aluminum leg.
Source 1: http://science.howstuffworks.com/prosthetic-limb3.htm
Source 2: https://sites.google.com/a/cpsdigital.org/peraplegic/human-prosthetics

This image depicts the changing angles of the leg, and with each angle and movement the pressure upon the leg changes, and the forces changes at each different movement.

Source: http://www.oandplibrary.org/popup.asp?frmItemld=AF49DC28-7031-4956-BBFF-CAA486A6005&signType=image&f
Chemistry and Respiration

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General Chemistry II, CHM152

Professor Olander
ABSTRACT:
There are two types of exercise a human can do; anaerobic exercise and aerobic exercise. In more understandable terms, it is weight-lifting and cardio, respectively. Most know from both of these exercises, after comes some kind of annoying soreness. This soreness is because of the lactic acid that is produced by the human body. In essence during aerobic exercise, the glucose in the body and the oxygen inhaled turns into carbon dioxide and water. Refer to figure one to visualize this process. The carbon dioxide and water are just waste products. During anaerobic exercise, oxygen is taken out of the equation. The glucose in the body is converted to lactic acid. Refer to figure one here to see this as well. Aerobic exercise should be used after anaerobic exercise as it can lead to a decrease in muscle soreness.

This real world application of this subject deals with exercise. The fitness industry is becoming, if not is, a popular fad in today’s society. When the human body is put under extreme amount of stress, different kinds of chemical reactions can occur. There are various different factors that have an effect on what chemical reactions happen during the body. This paper will only elaborate on the chemical reactions that occur during physical conditioning and physical activity of humans. The first type of exercise will be explained, which is anaerobic exercise. After, the chemical processes of aerobic exercise will be explained. Finally, applying critical thinking will show how pairing these two processes can create efficiency in strength training programs.

By definition, anaerobic exercise is high-intensity activity in which the body’s need for oxygen surpasses the body’s ability to supply it (Mueller, Nichols). In common terms, anaerobic activity is considered as weight-lighting or an activity that puts extreme stress on the muscles of the body. Cardio is generally considered an aerobic exercise; but higher intensity cardio such as sprints and box jumps is considered to be anaerobic activity. That small anaerobic sprint can turn into an aerobic jog, or vice versa. This is called the anaerobic threshold, also known as the lactate threshold (Piedmont). It is called the lactate threshold because the body produces lactic acid during anaerobic exercise. This lactic acid contains a chemical called lactate within it. This lactate flows through the blood of the body. When the body is not under stress the amount of lactate produced and removed is at equilibrium (Kravitz, Dalleck). It is when the body is put under stress from physical activity is when the lactate production spikes. There are many factors that play an effect on what this lactate or anaerobic threshold is. Some of the factors are age, weight, training goals, and time periods of training (Kravitz, Dalleck). Knowing an individual’s lactate threshold would allow them to train for strength in a more efficient way. It would allow them to maximize muscle recovery and train for strength in an efficient way.

On the other hand, there is aerobic exercise. Aerobic exercise is considered as moderate physical activity for an extended amount of time (Blackburn). This is considered is cardio or endurance in common terms. This doesn’t just include running, it can include major muscle groups. This could vary from running a half-a-marathon at a slow space or lifting weights for a higher amount of repetitions. The chemical reaction that occurs during aerobic respiration is shown here (Figure 1). Glucose and oxygen combine to create carbon dioxide, water, and a significant amount of energy. The carbon dioxide and water are considered as waste products.
The carbon dioxide is released through our exhale and the water is excreted as urine. It should be noted that a certain amount of energy is created with this reaction. This would confuse most people because people considered energy should be on the other side of the equation. They would think that the energy needs to be put in (which is the exercise) to create aerobic respiration. This could be true, it depends what is considered as part of the system. The system in this case is considered the muscle itself. When the glucose and oxygen combine to create the reaction carbon dioxide and water are created. The energy gained at the end is the energy that is provided to move the muscle. This process not only happens during aerobic exercise, but practically throughout an entire lifetime. Aerobic respiration occurs every second as it is the process of breathing. So how does one increase the efficiency of aerobic respiration? Through aerobic exercise! Aerobic exercise with increasing amount of difficulty with respect to time will increase ones lactate threshold, which in common terms means the athlete can breathe in more air at a faster pace (Exercise).

Who even cares if an athlete can breathe in more air? Does this mean they can lift more or throw a discus further? Indirectly, yes. There is a large benefit for an athlete if they are able to breathe in a larger amount of air with a faster pace. There is two ways to break this down. The first way is anaerobic exercise first then followed by aerobic exercise. An example of this would be lifting weights followed by a mild jog. This is a common training method for the majority of people. Most people follow this rule just due to folk lore; they don’t know there is science behind it. As earlier mentioned, weight lifting has been categorized as an anaerobic exercise. The body’s need for oxygen is exceeded and in turn lactic acid is created. So at this point during the athletes training the athlete has a build-up of lactic acid. This lactic acid is blocking the path for more oxygen to enter the muscles. For most reactions in chemistry, there is a reverse reaction for each reaction that occurs. This happens to be one of those reactions. As anaerobic respiration occurs, gluconeogenesis also occurs. Gluconeogenesis occurs under anaerobic activity which is basically when an excess of lactic acid is present. Right before gluconeogenesis occurs, the body transfers the lactate in the muscle to the liver. When the lactate is inside the liver, this is when the actually process of gluconeogenesis occurs. The lactate loses a couple hydrogen items to turn into pyruvate (Biochemist01). Pyruvate is considered an intermediate in many chemical reactions, including the transfer of lactate to glucose. Refer to figure two for a visual. After gluconeogenesis is complete, the glucose in the liver returns back to the muscle. The glucose in the muscle then starts this process all over again. In time, it will turn into lactic acid once again after anaerobic activity. Gluconeogenesis occurs naturally after anaerobic activity. So what is the point of aerobic activity after anaerobic activity? Aerobic activity increases the amount of oxygen intake as stated before. This means that more oxygen will be supplied to the blood, including the lactic acid. The reverse reaction shows that if more oxygen is supplied to lactic acid, then glucose will be produced (Ivyrose). This is basically speeding up the process of gluconeogenesis. This will remove the lactic acid from the athlete’s body faster, which in turn allows them to train more frequently and become stronger even faster.

More professional athletes than not train with anaerobic exercise first followed by aerobic exercise. This is because the science behind it proves it is a more efficient way of training. Some methods of training work better for others because each body reacts different. The other way to combo the types of exercise is aerobic exercise first followed by anaerobic. This process was briefly mentioned as aerobic activity can increase the lactate threshold. The athlete must ensure not to exceed this lactate threshold in order to increase it. If the lactate threshold is exceeded this
means aerobic exercise turns into anaerobic exercise which will produce lactic acid. This is not
the goal. The goal is to not produce lactic acid and increase the lactate threshold. This means the
athlete should not push their limits. This sounds counter-intuitive, as the general mindset is to
work-out as hard as possible. The best way to increase the lactate threshold is to work right under
it. There is a complicated way to find the lactate threshold by correlating it with a heart rate. It is
difficult to track as each person is different and the numbers will vary as they strengthen. The
numbers used here should not be applied, only used a demonstration. The selected man has a
given lactate threshold at 155 heart beats per minute. Once the man is above 155 beats per
minute, it is considered anaerobic. Fewer than 155 beats is considered aerobic. As mentioned, the
best way to increase the lactate threshold is to push the limit of it but not exceed it. Training at
90% to 95% of the beats per minute would be a good example of this. This man should be
training between 140 and 147 beats per minute to increase his lactate threshold effectively. What
is the point of increasing the lactate threshold after all of this? The first benefit of increasing the
lactate threshold is to increase the heart rate at which lactic acid is processed correctly. If lactic
acid is processed correctly at higher heart rates, this means the athlete is able to train harder and
for longer as it takes more to exceed this lactate threshold. The second benefit relates to the first
point of doing aerobic activity before anaerobic. With the increased lactate threshold from
aerobic activity, this will decrease the amount of lactic acid produced from anaerobic activity.
This is because the increased oxygen intake and the higher lactate threshold acquired from
aerobic activity will aid in faster processing of lactic acid produced from the anaerobic activity
of the athlete. In common words, doing mild cardio as a warm up and in general before strength
training will increase the muscles endurance overtime.

Exercise is considered a large part of today’s community. At a young age, many students
are encouraged to stay in some kind of sport to become stronger. This message has spread across
the world and as a population many people take physical activity and take care of their body.
Most people attend the gym just to stay in shape; many people could see advance in their
strength with these small advancements to their workout. First step would be to understand
aerobic exercise. In essence, aerobic exercise is exercise with the oxygen. It is classified as
cardiovascular activity, but scientifically it is when glucose and oxygen combine to produce
carbon dioxide and water to move the muscle. The next step would be to understand how
anaerobic exercise works. This is exercise without oxygen and is usually classified as lifting or
fast sprints with short intervals. This process converts glucose alone into lactic acid. This is the
most important thing to understand is how to train under the lactate threshold. Training under the
lactate threshold basically allows the person to train their muscles without the production of
lactic acid which allows the maximum amount of blood flow. People can manipulate these two
processes to maximize their strength.
Figure 1: This shows the processes of aerobic and anaerobic respiration. The equations are familiar since they both have glucose on the reactants side.
Ivyrose Holistic. Lactic Acid Formation. Formation of lactic acid in muscles (Simple Explanation). [accessed 2017 Apr 19].

<table>
<thead>
<tr>
<th>Aerobic Respiration</th>
<th>Anaerobic Respiration</th>
</tr>
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<tbody>
<tr>
<td>Equation in words:</td>
<td>Equation in words:</td>
</tr>
<tr>
<td>Glucose + Oxygen → Carbon Dioxide + Water + Energy</td>
<td>Glucose → Lactic Acid + (smaller amount of) Energy</td>
</tr>
<tr>
<td>Equation written in chemical symbols:</td>
<td>Equation written in chemical symbols:</td>
</tr>
<tr>
<td>C₆H₁₂O₆ + 6 O₂ → 6 CO₂ + 6 H₂O + Energy</td>
<td>C₆H₁₂O₆ → 2 C₃H₆O₃ + (smaller amount of) Energy</td>
</tr>
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Note: CO₂ and H₂O are waste products. They are excreted from the body, the water in urine and sweat and the CO₂ by breathing out (CO₂ carried in blood from the muscle tissue to capillaries in the lungs where it is released into alveoli then expelled from the body - see internal respiration).

Figure 2: This shows the complete circle of how glucose turns into lactate and vice versa. Glycolysis is referred to as anaerobic respiration in this paper.
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Pharmaceutical Companies and Competitive Sports

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BIO181

Dr. Browning
ABSTRACT

At the present day, doping and the widespread use of the performance enhancing drugs are the issues of global concern, which go hand in hand with international competitive sports all over the world. In the course of the last 50 years, the global sports federations, which are directed by the International Olympic Committee, have tried to stop the spread of this issue along with the extensive impact that pharmaceutical corporations have on professional athletes. It was projected by the experts that, with the help of the instructive programs, medical assessments, and helpful medical treatment, the problem of performance enhancing drugs would reduce. Nonetheless, the debate over the beneficial and adverse effects of the substance abuse and the methods of dealing with doping among the professional athletes continues to be of primary concern. It is often argued that in spite of the negative image of the pharmaceutical companies in the domain of professional competitive sport, a certain amount of performance enhancing drugs can have some positive effects from the biological point of view.

CONTENT

From the beginning of the history of competitive sports, people have been making various attempts to get any potential advantage against their opponents. All in all, the wish for any benefit that will lead to winning is an absolutely reasonable component of nature of human beings. Remarkably enough, there appears to be confirmation of the usage of performance enhancing drugs that was dated more than 3000 years old. In spite of this extensive and documented account of performance enhancing drugs in competitive sport, using these drugs is perhaps the most provocative and most debated subject in contemporary sports. This issue can be traced in all kinds of competitive sports, with no regard to its technology, acceptance, or practices. It has a substantial impact on those sports that are conventionally regarded as being connected to muscle development, for example, football and bodybuilding. On the other hand, the dispute regarding the performance enhancing drugs has been noted in other competitive sports, in which the muscles seem to be not so essential, for example, gymnastics and Olympic sledding.

The improvement of the athletic performance could be achieved with the help of numerous methods, for example, nutrition, exercise habits, and hard work. On the other hand, the improved performance of an athlete can and has been attained from the times of ancient competitive sports by utilizing a broad range of physical, mechanical and medicinal doping practices. At the same time as the winning prizes and endorsement rewards enlarged, the knowledge about and misuse of performance-enhancing methods developed as well. At the present day, as athletes always thrive to excel and be the best among all - no competitive sport is safe from the sportsmen being dishonest by the means of the banned performance improvement techniques.

Encouraged by the millions of dollars that are presently usually offered for getting a first place in a sports event, corrupt pharmacologists, general practitioners, coaches and sports institutions have functioned in secret, and, from time to time, lacking
the approval of their sportsmen, in order to advance complex doping practices with the help of which the competitive abilities of the athletes will be improved, regularly having negative impacts on their well-being\(^3\). At the modern day, various similar doping strategies are shifting from the market of the professional sporting events to the younger generation that tends to lack the general knowledge and also other unprotected populaces as well at disturbing rates.

More than several hundred types of already established and possibly bigger amount of unidentified doping drugs and methods are recognized at the present moment, which are misused by professional sportsmen across the globe\(^1\). In order to clearly evaluate the issue of the performance enhancing drugs, their effects and their place in the industry, the history of the drugs needs to be assessed. In spite of the decades of vigorous anti-doping examinations that were performed by global sports federations for various athletes in cycling, athletics and soccer competitions, numerous scandals regarding the excessive use of steroids relating to the famous sportsmen continue to be on the front pages of newspapers all over the world.

The use of performance enhancing drugs among the professional athletes might include doping in an attempt to receive a competitive advantage against other opponents. On the other hand, it might comprise the usage of various elements, for example, alcohol or marijuana that is clearly lacking the intention to improve the performance of an athlete\(^2\). This can be explained by the fact that professional athletes might be subject to the illnesses, which are connected to substance abuse similar to any non-athlete individual. From the biological point of view, professional athletes might resort to various legal and illegal substances, including performance-enhancing drugs, in order to deal with many stressing aspects. These stressors can include but not limited to pressure to accomplish higher results, numerous sports injuries, physical discomforts, and leaving the career of sport, which usually occurs long before the retirement from the vast majority of other occupations\(^4\).

In addition, professional sports competitors might be considerably less expected to get proper management of the basic mental disorders, for example, depression\(^1\). In the majority of cases, athletes obtain all-inclusive medical care and further therapy for physical injuries. Nonetheless, the issue of mental illnesses is not the matter of primary concern for the pharmaceutical companies\(^1\) for the reason that disorders of the mind could be sometimes regarded as an indication of weakness\(^2\). Those mental issues that are not handled are frequently connected to substance abuse\(^4\), maybe in an attempt of the athletes to treat themselves without any increased attention to the problem. Then again, substances of abuse might lead to various mental illnesses as well.

The contemporary industry of pharmaceutical companies can be traced back to two primary origins. Big corporations, for example, Merck, Eli Lilly and Roche, which had formerly provided natural produces such as morphine\(^1\), quinine and strychnine, shifted their area of business to the far-reaching manufacture of drugs almost 150 years ago\(^4\). At the same time, recently created dyestuff and chemical corporations, for example, Bayer, ICI, Pfizer & Sandoz, generated their own laboratories for medical research and
gained an innovative medical use for their products. On the other hand, the development of these companies was comparatively simple and unassuming for the reason that up the middle of the 20th century, the majority of medications did not require any prescription to buy them. The pharmaceutical companies had a far-reaching impact on the performance of the athletes at that time as around 50% of all performance enhancing drugs and the pharmacologists produced other medications locally; moreover, usually, the general practitioners of that time distributed various medications straight to their patients.

These days the relationships between doping, sports and Big Pharma has changed, following the world globalization trends of the recent decades. As the resources of pharmaceutical companies continue to increase along with their capitalization, the competition between the companies also grows, as the giants of the industry have to fight for the limited pool of customers. This leads to the situation where the role of marketing continues to increase, taking a greater and greater piece of funding. Pharmaceutical research is extremely expensive and has a very low chance of producing a product, which is going to be successful on the market. In this way, to make sure the expenses on research will eventually pay off, the companies need the massive involvement of marketing in order to sell the product to as many customers as possible. This leads to cases where pharmaceutical companies get accusations of pushing their products through the use of marketing strategies, which are not fully justifiable from the moral point of view. Basically, in order to cover their expenses and eventually start getting profits to fund new research, pharmaceutical companies are often cornered to push the product to audiences that are beyond the original pool of users. The new users are persuaded to use the product in an off-label way.

There are also allegations about the cases of certain employees of pharmaceutical companies, who try to meet the unrealistic demands on producing the inadequately high sales rates, end up selling the portions of the products to black market purchasers. Sometimes, it is even possible that certain managers or workers engage in negotiations with the criminals, which can result in thieves breaking into the warehouses to steal the product and then sell it illegally. Managers, who allow such actions are left with good money in their hands and the product, which technically been realized. There is no real evidence that the higher levels of pharmaceutical companies’ management are involved in such schemes, but the described plan may end up being more profitable as the company may get greater revenue from technically selling the drugs to thieves under the cover of a “robbery” than from selling product to the licensed retailers, where the product undergoes all the steps of taxation and examinations.

However, the involvement of the pharmaceutical companies in the professional sports does not necessarily imply the purely negative connotation. Within the framework of the Second International Pharmaceutical Conference named “New Developments for Clean Sports and Society”, which was held in Tokyo, Japan in January of 2015. At this conference, the representatives of leading anti-doping organizations had an opportunity to meet with professionals from pharmaceutical spheres in order to cooperate for mutual benefit. The goal of the conference was to enhance the security and standards of pharmaceutical productions for the sake of decreasing the amounts of drugs sold illegally
at the black markets. Also, during the conference pharmaceutical professionals were invited to share the information about the new products that have a potential to be used as doping or as a new component for making one. Such kind of early alerts to the anti-doping organizations will help them to develop a more effective response to new doping drugs in a way of developing new tests in a timelier regime. Anti-doping organizations, in their turn, share the amassed knowledge about doping drugs and the ways of testing for them with the pharmaceutical companies, which would benefit the research process.

Sharing the knowledge between the anti-doping organizations and pharmaceutical companies is a matter of great importance as not only it helps to timely develop the adequate test to screen for new doping, but it also makes it easier for the fair athletes, who have to take certain medications, because of actual health issues. Sometimes, drug tests produce confusion when athletes are tested and found to be taking a certain substance from the list of prohibited ones. However, those people did not have intention to cheat, because they were taking the substance in the connection with the legitimate medical condition, but they may still be forbidden to compete. Solving such issues is a matter of great importance as such unfair conclusions harm the competition and are capable of ruining the athletes’ entire careers. That is why the recent cooperation of pharmacy and anti-doping organizations is seen as such a positive change for the future.

Pharmaceutical companies, though restricted to FDA guidelines and regulations, have notoriously found legal, however, unethical methods to propel their research, significantly impacting professional athletes. Professional athletes have been the subjects of exploitation by these companies, often being unwitting research subjects. The motivational necessity of professional sports in today's culture provides the foundation of new interventions that have spawned controversy and question their authenticity. Currently, athletes can choose from a lengthy list of metabolic enhancements to improve their field time, and examples include, enhancing recovery by utilization of platelet rich plasma, preemptive surgery, particularly tendon replacement surgery, and those experimenting with gene transfer methods. Athletes can be made vulnerable to new techniques as their professional careers expand.

Research has shown that there is a direct relationship with ungoverned clinical research and performance enhancing methods and drugs broadly conceived among competitive athletes. A high conflict of interest arises and is problematic with athletes, their long term health, and their short term enhancement gain; as gaining a competitive edge is weighed heavier than the long term well being of the subjected athlete. It is due to this analysis; the current modes of research participation have fallen under ethical questioning. Various analyses and comparisons offer different conclusions on the ethics of clinical research pertaining to professional athletes, though the analysis Camporesi and McNamee constructed through an objective and unique perspective offers a notable read.

Comparing two separate, but equally involved, research subjects; those who profit from participating in Phase 1 clinical trials, and those professional athletes who essentially engage in clinical research that is considered unregulated. The main points to
this particular analysis can be divided into three main core aspects, the multiplicity, consistency, and visibility of the research subjects and their results\textsuperscript{6}.

Analyzing the aspect of professional athletes and their seemingly unregulated and unethical experiments in clinical trials can be divided to three core lens; visibility, consistency, and multiplicity. Visibility lens can be defined as the level of information that is available to individuals regarding the types of pharmaceuticals and drugs they are being administered\textsuperscript{6}, including any other surgeries or regimes they undergo alongside the trial. Analyzing through a visibility perspective also implies an apparent transparency level and therefore a responsible accountability to those in context\textsuperscript{6}. Based on these definitions, professional athletes lack the necessary and related information on the effectiveness and safety of the drugs they are being administered.

This is also true to the technologies involving performance enhancing, such as training schedules or post trauma surgeries, which they are subjected to during the trial. These risks cannot be substantially or accurately determined prior to trials and therefore makes the implication that many athletes consider great risk on their wellbeing without gaining any benefit. Although unethical in the laws of health care, it is legal under the WADA CODE, "does not require that a substance have a demonstrably performance-enhancing effect."\textsuperscript{2} This translates to a lack of accountability on transparency\textsuperscript{7}, further undermining a subject's comprehensive understanding of their procedure or drug.

Multiplicity, the next lenses utilized to analyze the inconsistencies of pharmaceuticals are imposing and influencing on professional athletes, can be defined by a number of ways. Namely and simply, it is in reference to the infinite possibilities and causations of reality\textsuperscript{6}. In the world of professional sports and pharmacy research, this definition can be applied to the subject's perspective. Definitively, these research subjects are being administered multiple drugs at once, with their respective combinations often having an n-number of possible drug to drug interactions\textsuperscript{7}, being extremely difficult, if not nearly impossible, to predict. This is the multiplicity effect of professional sportsmanship and pharmaceutical research. Camporesi and McNamee offers the example of German athlete, Birgitt Dressel who came in ninth place in the Olympic Games of 1984 and fourth place the European Championships of 1986\textsuperscript{2}. Despite being a heptathlete, Dressel died in 1987 at the age of only 27, due to multiple organ failure linked directly to a cause of the combination of drugs she had been ingesting\textsuperscript{2} in order to enhance her overall performance. Her autopsy revealed 101 different ingested drugs\textsuperscript{7}. The multiplicity factor in this regard was infinitely relatable.

Elite cyclists are also subjected to intense body regimens and schedules, often requiring extensive practice and training to prepare their physical health for rigorous races throughout the year. It is for this reason, among others, that cyclists may feel influenced to attempt some form of blood doping or pharmaceuticals to enhance their performance, primarily their endurance. One such example would be Lance Armstrong, as several of his cycling entourage reported the use of multiple supplements, including erythropoietin, human growth hormone, and testosterone\textsuperscript{8}. American track athlete, Florence Joyner, ubiquitously known as Flo Jo, the fastest woman of all time, was an
athlete where rumors of various drug abuse surrounded her career until her premature death in 1998 at age 38. Although the cause of her death was inconclusive, the conducted autopsy revealed the presence of a variety of drug cocktails in her body. Inferably, these long term effects of drug interactions cannot be determined while taking such a high number, exponentially increasing the risks of organ failure and untimely death.

Doping practices are common; more so in particular sports than others, such as cycling. Professional cycling is one competitively athletic sport that indirectly promotes doping, as one of the most important factors to being successful is high endurance. Doping practices are quite widespread in the world of cycling, as athletes expect to gain some form of enhancement benefit by associating in various forms of doping practices. Figure 1 shows the cocktail of drugs a professional cyclist stated to be ingesting at a control visit. It is also important to note that the cyclist only listed drugs they declared to be taking, and may not account for the full combination of pharmaceuticals. This extensive list, along with the fact that athletes participate in intense training routines, makes for a lethal combination of effects that cannot be individually maintained, predicted, or treated.

Consistency is the final perspective lens utilized to address the dangers and risks of pharmaceuticals associated with professional athletes. Consistency is, by this definition, relating to fairness and similarity or equality across the boards of sport. Doping is a perversion of sports and athletic talent, thus contaminating the contest's integrity. Understanding sports as athletic experiments, they should not be poisoned by extraneous variables and circumstances, such as corruption, excessive luck, incompetent judging or officiating, and undoubtedly, doping. Legislators of sports make substantial efforts and strides to maintain the game's integrity by keeping an equitably balanced playing field, with fair opportunity for outcomes of uncertainty. Doping is one way to bring about inconsistency and contamination to this stride.

The data on the so-called potential of performance enhancement effects of specific agents and catalysts are being currently being abused in clinical trials for therapeutic purposes. Though it is important to note that the group of individuals being subjected have little in common with the targeted group, the population that will ultimately be ingesting the drug. It is paramount to recognize that professional athletes are often the subjects of research in an unethically unregulated system of enhancement research. This recognition will prompt a reflection on further problematic aspects of clinical research, particularly the mode of participation that involves healthy individuals who make living volunteering in Phase 1 studies of clinical research.

CONCLUSION

Professional athletes have throughout the history of sports been the subjects of much controversy in regards to their seemingly superhuman feats. Although not all positive critique, the negativity of their potential to utilize pharmaceuticals and regimes in hopes of gaining the competitive edge necessary to enhance their overall performance and win, has in turn, been immensely influenced by pharmaceutical companies and their
unregulated clinical research trials. Many circumstances surround these influences, however it has become apparent that it is an unethical though legal dilemma.

In this research, I concluded that pharmaceutical companies, by bypassing loose and outdated FDA regulations, have been successful in stipulating the doping of professional athletes in elite sports. Through three lens: multiplicity, visibility, and consistency, I analyzed the circumstances and ethics of doping and possible inaccuracies pharmaceutical companies engage in with professional athletes in clinical research trials. It has become evident that doping and other forms of possibly lethal drug enhancements are common among various forms of elite sports, partly due to the increased misconceptions of the safety of these drugs and methods. With future regulation focusing more on the long term effects of drug to drug interactions, rather than simply predicting the short term effects of individualized drugs on specific and inconsistent population subject groups, doping and other forms of detrimental pharmaceutical enhancements can be conducted through safer, more informative, and comprehensive trials.
Figure 1. Extensive list of pharmaceuticals being combined by a professional cyclist on their own declaration at a drug control. Courtesy of UCI.
How Blood Doping Works

Elevated levels of red blood cells found in an athlete's bloodstream can be a sign of blood doping.

NORMAL BLOOD
The blood of a typical adult male is made up of 40 to 50 percent red blood cells, which carry oxygen to tissues. Typical levels for women are 35 to 45 percent.

DOPED BLOOD
Red blood cells (from a donor or previously removed from the athlete) or the hormone erythropoietin (EPO) are injected. The increase in red cells allows muscles to work longer and harder without cramping.

Sources: Harrison's Principles of Internal Medicine; Quest Diagnostic Laboratories

Figure 2. Illustrated explanation on the biological and molecular aspects of blood doping. Sources: Harrison's Principles of Internal Medicine; Quest Diagnostic Laboratories.

Drug Suspensions by Type

Figure 3. Line graph exemplifying correlation of professional athletes and suspensions due to drug related violations. Sources: USA Today, Baseball America, Nathan Aderhold, MLBDD
References

Exercise and Nutrition Used to Treat and Prevent Degenerative Bone Diseases

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Degenerative bone diseases such as osteoporosis, osteopenia, and osteoarthritis can be treated successfully with proper nutrition and exercise intervention. It is easier to prevent these conditions than to treat them with the above methods, but will be beneficial in both cases. When weight bearing exercise and resistance training are paired together and used for prevention of bone disease, the probability of ever struggling with degenerative bone disease is very low. Longitudinal studies show great results on both a chemical and physical level when use of exercise and proper nutrition is utilized over time, and is considered as a viable treatment and prevention option.

Degenerative bone diseases and disorders are an issue that is becoming more common as time goes on. As the age of death is later in life than it ever used to be, the body has more time to break down over time potentially causing serious crippling disorders, some are manageable or reversible, others leave a patient frustrated and in pain. These diseases and conditions not only hinder day to day activities, but take away the peace of mind of the individuals at risk. By implementing a healthy lifestyle, with proper nutrition and exercise, one can prevent and overcome degenerative bone diseases and improve quality of life. Studies show that when bones are under pressure or stimulated it promotes a greater bone density when in comparison to those who do not put strain on their bones outside of the normal day to day activities. Greater bone density means less risk of degenerative bone diseases occurring later down the road.

Bones are a form of connective tissue that can become susceptible to breaking down over the years of an individual’s life. There are many different reasons and conditions on why this may occur, but most of the time, there is usually a very large lack of osteoblast production within the bone tissue and a high level of osteoclast production. Osteoblasts are cells that create bone tissue and osteoclasts are cells that destroy bone tissue. The reason these cells exists are to counter balance each other out in order to achieve an ideal and healthy bone density, not too thick and not too thin. When there is an abundance of bone density the endocrine system sends a signal to release parathyroid hormone (PTH) which simultaneously releases osteoclasts from the bone marrow. The osteoclasts attach onto the bone and release proteins with acidic properties that dissolve the bone away. Once the osteoclast cell has released all of its protein, the cell dies. The body will continue to do this until ideal bone achieved. Unfortunately as we age for multiple reasons, such as vitamin deficiencies and other disorders, the body will begin to release more and more PTH to compensate for irregularities, this in turn will cause more osteoclasts to be released resulting in cases of osteoporosis and osteoarthritis. On the other side of the spectrum when a bone is weak or damaged, a healthy individual will release osteoblasts to attach to the area of concern and from there regulate intake of calcium. It will continue to do this until it has served its purpose and then it will remain attached to the bone as a living piece of the bone.

The bone diseases and conditions that are most prevalent in the present are those such as: osteoporosis, osteoarthritis, and osteopenia. The following bone diseases can be treated through proper nutrition and exercise under professional supervision. If bones are already in a weak or damaged state it is important to have a health care professional design and guide an individual through certain exercises in order to prevent bone fractures. Osteopenia is defined by Mosby’s Dictionary of Medicine, Nursing, and Health Professions as ‘reduced bone mass due to a
decrease in the rate of osteoid synthesis to a level insufficient to compensate for normal bone
lysis” or “any decrease in bone mass below the normal.” Essentially this is the condition that
occurs before osteoporosis, in a sense it is almost the warning stage that something far worse
could be around the corner. Osteoporosis is defined by Mosby’s Dictionary of Medicine,
Nursing, and Health Professions as “a disorder characterized by abnormal loss of bone density
and deterioration of bone tissue, with an increased fracture risk.” This is where some real
intervention needs to take place and a change needs to be made to improve overall quality of
health. Osteoporosis is the most common bone disease effecting humans in the present.
Osteoarthritis is defined by Mosby’s Dictionary of Medicine, Nursing, and Health Professions as
“a form of arthritis in which one or many joints undergo degenerative changes, including sub-
chondral bony sclerosis, loss of articular cartilage, and proliferation of bone spurs and cartilage
in the joint.” The most common form of arthritis is osteoarthritis and usually goes hand in hand
with many of the above disorders. To put a picture with a name refer to figures 1, 2, and 3.

The diseases and conditions mentioned above can be prevented and can affect anyone.
The conditions are linked to less than ideal bone density due to a sedentary lifestyle, low intake
of vitamins or deficiency, and poor diet. It is proven that exercise helps stimulate osteoblast
production (cells that build bone tissue) which will help prevent osteoporosis and other bone
diseases from occurring. Proper intake of vitamins and food can aid in prevention and treatment
of various bone diseases. Prevention is the best course of treatment when it comes to these
conditions, although it is possible to treat the diseases, it is always better to prevent them. If from
a young age an individual continuously stays active and performs weight bearing activities, bone
density will be increased which will decrease the probability of complications in the future.

Weight and obesity can be linked to certain bone disorders. In many cases it is not
uncommon for a doctor to tell their patients to lose weight to help with their condition. Losing
weight is a great way to remove stress from bones, but if done wrong it can actually wind up
damaging the bones further. A recent study titled “Multilevel Approach of a 1-Year Program of
Dietary and Exercise Interventions on Bone Mineral Content and Density in Metabolic
Syndrome” showed that when weight loss programs are combined with some form of exercise
such as resistance training, patients both lost weight and increased their bone mineral content and
densities. The study concluded that “Exercise is therefore beneficial to bone in the context of a
weight loss program.”

Most medical professionals will agree that exercise and proper nutrition will help the
healing process when it comes to osteoporosis. These claims aren’t wrong. For example another
study titled “The Effects of Combined Treatment with Naringin and Treadmill Exercise on
Osteoporosis in Ovariectomized Rats” used an assortment of rats diagnosed with osteoporosis
and subjected them to treadmill training of a long period of time. Testing the rats often for their
bone mineral density, it was found that exercise actually increased their BMD, and eventually
reversed their symptoms of osteoporosis. Refer to figure 4 to see the rats on treadmills.

In 2002 an NAU student named Christina Henrichs performed a study comparing 12
students from the NAU volleyball team and 12 regular students. Over a long period of time the
24 students were examined for their BMD’s and were examined at common fracture areas for
osteoarthritis such as the spine, hip, and forearm. The study concluded that the volleyball players
had higher BMD content than the regular students and also concluded that the volleyball players
had greater BMD at common fracture areas. This was related to the amount of physical activity
that the athletes performed in comparison to the students who were not athletes. This correlates a positive result in bone health while the body is under certain forms of healthy stress. This study relates a positive influence on bone health and bone density with physical activity. If more individuals lived a more active life, there would be a drop in the amount of bone related issues.

From a nutritional standpoint, osteoporosis is usually treated with vitamin D and calcium supplementation. A change in diet is also strongly recommended. Avoiding foods with high sugar and salt content is crucial while avoiding carbonated beverages is a must. Carbonated beverages such as soda are linked to reducing bone mineral density and making an individual more susceptible to degenerative bone disease. In a study titled “Physical activity and lifestyle effects on bone mineral density among young adults: sociodemographic and biochemical analysis” 350 young adults with different lifestyles were studied. The research found that bone mineral density correlated positively with physical activity and calcium intake. The research also found that bone mineral density correlated negatively with intake of caffeine, carbonated beverages and low intake of calcium. The researcher concluded that “body mass index, physical activity, low calcium consumption, and abnormal lifestyle have a role in bone mineral density and prognosis of osteoporosis in young adults.” This study showed a correlation between nutrition and level of activity. Essentially the results are as expected. Poor diet and lack of activity attribute negatively to bone healthy, while eating healthier and removing certain things from consumption and being active attribute positive results.

Some medical professionals may advise against exercise if diagnosed with osteoarthritis because of their fear of worsening the condition. Studies have shown that if an individual diagnosed with osteoarthritis performs circuit training under close supervision of a healthcare professional that their condition has a chance of improving. A study titled “Effects of proprioceptive circuit exercise on knee joint pain and muscle function in patients with knee osteoarthritis” tested 14 individuals diagnosed with osteoarthritis. 7 were used as a control group and the other 7 were introduced to circuit training. The control group did not improve while the circuit training group showed significant improvements in joint function and strength. Obviously when this kind of intervention is used for treatment it is advised that patients are under supervision so that conditions are not worsened, but this study shows how exercise can be used as treatment in otherwise debilitating conditions.

Proper supplementation can be quite effective in treatment and prevention of degenerative bone diseases. Consumption of calcium, phosphorus, and glucosamine and chondroitin has been proven to have success in combating these disorders. On the other hand avoiding certain things have also lead to success as well. Avoiding excessive sugar intake, carbonated drinks, and excessive dairy will provide positive results. Studies have shown that when milk is drank in excess it is detrimental to bone health. Milk is acidic and actually causes bones to break down over time when compared to just taking calcium on its own.

Many studies have shown the significance of proper nutrition, supplementation, and exercise as a means for treatment and prevention of degenerative bone disorders such as osteopenia, osteoporosis, and osteoarthritis. Prevention of these disorders is obviously the ideal strategy, but treatment of these diseases using the above methods prove to be just as successful at curing, improving, and lessening the severity of these cases. Overall it has been proven that exercise and nutrition are viable treatment options for these diseases and will continue to be used over the years.
Figures

Figure 1

Figure 2
Figure 3

![Evolution of Osteoarthritis]

1. Bone
2. Cartilage
3. Thinning of cartilage
4. Cartilage remnants
5. Destruction of cartilage

Figure 4

![Image of rats in a cage]
References


Genetically Modified Organisms in the Twenty First Century
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Abstract

Genetically modified organisms (GMOs) have seen an astounding amount of popularity and controversy in the twenty-first century. Many different types of genetic engineering technology and techniques have been developed due to the high demand that GMOs have currently, and genetic modification has also seen a wide variety of applications in society within agriculture and medicine. Although these new technologies are faster and more precise than previously used methods, the history of GMOs in the United States and the rest of the world is still an important concept to understand. Furthermore, genetically engineered organisms have both advantages and disadvantages in the eyes of consumers and companies, and a large amount of controversy has arisen due to society’s differing legal and ethical perspectives of GMOs. However one of the most interesting topics that society is speculating upon is how GMOs will be utilized in the future. Scientists and engineers have already been able to alter the genetic makeup of plants and animals, but the question still remains as to whether or not GMOs will be used in humans. Genetically modified organisms are one the most prevalent and debatable topics among the scientific community currently, and since they have become so popular, new applications and technologies are being created at an increasing rate. Although GMOs are popular currently, society still questions how they will change in the future, along with the applications of genetic engineering in the twenty-first century and beyond.

Introduction

Over ninety percent of the soy, cotton, canola, corn, and sugar sold in the United States between the years of 2014 and 2015 was genetically engineered. A genetically modified organism, or GMO, is defined as being an organism that has had its DNA altered or modified in some way through genetic engineering to create desirable traits within an organism. The recent arrival of genetic engineering has completely changed the way organisms interact with the environment, and many people are skeptical of the chemical, legal, and ethical characteristics of genetically modified organisms. Before genetic engineering was discovered, however, genetically modified organisms still existed, just not using the same processes that they do today. For thousands of years humans have bred organisms with desired traits together to create new types of crops or animals, but this process was not able to be completed in a laboratory on a computer. In addition to the discovery of genetic engineering, other forms of GMO technology have also been invented recently, giving scientists a large array of tools for editing the genetic makeup of a species. The reason why society is so skeptical of genetically modified organisms is because one trait from an organism can be inserted into another related organism very quickly, without having to wait for genetic breeding to occur. Furthermore, genetically modified (GM) species are able to have longer lifespans, resistance to chemicals and diseases, and higher levels of nutrients; but all of these characteristics are seen as either advantages or disadvantages to both industrial food companies and local farmers. Both plants and animals alike have already been affected by the increased use of GMOs in society, and genetic engineering has the potential to be used on human beings in the near future to cure disease or to remove undesirable traits from one’s genetic makeup. The many applications that GMOs have currently prove how popular they have become among the scientific community, and even though a great amount of backlash has been received by Non-GMO organizations, the increased use of GM products in society cannot be overlooked. However, the future of GMOs in the twenty-first century and beyond is still unknown and society has yet to see genetically modified organisms being utilized to their fullest potential.
Differences between Selective Breeding and GMOs

To begin with, the most fundamental concept to understand about GMOs is the different techniques that are used to create them. A common misconception about genetically modified organisms is that they are a brand new concept being utilized in the twenty-first century. Selective breeding has been used for many generations by both farmers and scientists alike, and although the breeding processes used previously are unlike the methods used today, the animals and agriculture that exist in the present are genetically and biologically different than the organisms that existed in the past. Three main forms of GMOs have been used throughout history, and these forms consist of selective breeding, advanced breeding, and genetic engineering. As depicted in figure 1, selective breeding has been the most utilized GMO process throughout history. Although selective breeding is not always recognized for being a genetic modification process, the act of breeding together well-performing species has the potential to change both the biological and chemical structure of an organism.

The second technique for creating genetically modified organisms is known as advanced breeding. This method is performed by identifying a desirable trait from a certain species and cross-breeding two genes together to create an organism that is better adapted to the environment that it lives in. However, the most recently discovered procedure for constructing GMOs is genetic engineering. Genetic engineering is the most controversial way to create modified organisms, and has been very popular among both scientists and engineers since its arrival. Creating GMOs through this process gives scientists the ability to alter the genetic code of a species with unmatched precision and speed, but this method also has the potential to drastically change the biological and chemical makeup of the organism.

But what are the advantages and disadvantages of using one method over another? First of all when utilizing selective breeding and advanced breeding, large pieces of genetic code can be transferred between species, which can lead to undesirable traits being inserted into an organism along with the desirable trait that was already isolated. Furthermore, genetic modification techniques can take place over a very short period of time, but some of the more traditional breeding methods take effect over multiple generations. Selective breeding, advanced breeding, and genetic engineering have all proven to be viable methods for creating GMOs throughout history, but each technique has advantages and disadvantages when compared to the other procedures.

The Gene Splicing Process

In addition to identifying the difference between GMOs and organic foods, one of the most important topics to mention when discussing genetically modified organisms is the gene splicing process, as shown in figure 2. Multiple methods exist for creating GMOs, and the discovery of new forms of genetic engineering has allowed scientists to create GMOs almost entirely through technological means. Before GMOs were made with technology, however, they were created in laboratories through the gene splicing process. This process essentially allows genetic engineers to take one desirable trait of an organism and insert that gene into another living species to change the chemical makeup of that species for a specific purpose. The first step of the gene splicing process consists of identifying the desirable trait that is going to be transferred to another species. Desirable traits could range from resistance to chemicals and climates to increased yield and nutrients for crops, depending on the environment of the crop that will be genetically modified. After identifying the desirable trait, the next step in the GMO process is to isolate the gene that carries the trait by “copying” the gene from the genetic
structure of the organism. For example, scientists have taken genes from winter flounder and inserted them into tomatoes to create genetically modified tomatoes that are more resistant to cold climates and freezing. This example represents a small fraction of what scientists have been able to do with genetic engineering technology, but it also shows how an everyday consumable item can carry traits from a completely unrelated organism that is not consumed very often. The third step for creating a genetically modified organism is to insert the desired gene into the species that is going to be genetically modified by “pasting” the gene into the species’ genetic code. After the desired trait is inserted, the gene splicing process is complete and the GMO will be grown and reproduced under constant supervision of scientists.

CRISPR-Cas9

Although the gene splicing process has been used constantly since the arrival of genetically modified organisms in the twenty first century, the recently discovered CRISPR-Cas9 (CRISPR) method utilizes new technology and techniques for creating genetically modified organisms. CRISPR stands for Clustered Regularly Interspaced Short Palindromic Repeats, and is essentially a genome editing tool that gives scientists the ability to edit sections of an organism’s deoxyribonucleic acid (DNA) strand with a level of precision that has never been seen before in genetic engineering. The DNA editing tool is being recognized for its simple and precise methods, and CRISPR is becoming more and more popular among both scientists and engineers alike. Since CRISPR is being adopted quickly by many researchers, the tool has become one of the most powerful ways to create GMOs in the twenty-first century. Unlike the four different steps in the gene splicing process, CRISPR only utilizes two steps, making it more efficient and effective than any other DNA editing method. As shown in figure 3, CRISPR alters the DNA of an organism by introducing two different molecules to the species. The first molecule that is introduced to the organism is an enzyme known as Cas9, which cuts the DNA strand in a way so that different genes can be edited or removed. At the same time, a piece of RNA (ribonucleic acid) guides the Cas9 enzyme to the specific point where the DNA needs to be cut. The guide RNA (gRNA) for every organism is different, however, because the RNA is specifically created to match with the portion of DNA that is going to be edited. As shown in figure 4, the main difference between DNA and RNA is the sugar that is found in the acid. Although the sugars found in RNA and DNA are ribose and deoxyribose respectively, the bases of each acid are quite similar and they share guanine, adenine, and cytosine as like nucleobases. Although CRISPR-Cas9 was only invented two years ago, the tool is already changing the way scientists edit genetic code, and some say that the system is the “least biologically disruptive form of plant breeding that humans have ever devised.” This powerful statement shows just how much of an impact CRISPR has had on the scientific community, and also foreshadows how the tool could be utilized differently in the future.

Applications of GMOs

Although knowing how GMOs are created is an important concept to understand, perhaps the most interesting characteristic of genetically modified organisms is how they are applied to agriculture and medicine throughout society. As depicted in figures 5 and 6, the use of various genetically modified crops in the United States has risen dramatically between the years of 1996 and 2007. Soy, cotton, and corn have been the biggest contributors to the increased use of genetically modified crops recently, and almost one-hundred percent of all farm acreage in America is GMO. Although GMOs have been mainly used in agriculture throughout the course
of history, the appearance of them in medicine has increased the amount of applications that they have. For example, genetically modified insulin has been created from a type of bacteria that lives inside the intestines of pigs; and the insulin can then be used to lower an individual’s blood sugar. Furthermore, the artificial sweetener Aspartame and the hepatitis B vaccine are also byproducts of genetic engineering.

However, genetic modification is most widely used in agriculture and is known for altering the DNA of a species to increase performance in a certain environment. GMO crops in particular can be engineered to increase resistance to insects, pesticides, or temperature, and can even yield higher numbers of nutrients and vitamins. In fact, a genetically modified strain of rice, known as Golden Rice, has been altered to increase the levels of Vitamin A that are present in the species. This method of increasing how nutritious certain foods are could potentially be applied and adapted to different societies and could possibly make the people that live in those societies more healthy. In addition to making organisms have higher levels of nutrients, scientists utilize many other techniques to make crops more resistant to insects and pesticides.

Genetically modified BT (Bacillus thuringiensis) crops are used to repel various pests and therefore increase the lifespan of the species that has been modified. BT is a type of bacteria that has been used as an insect repellent for almost one hundred years, and since the arrival of genetic engineering, the bacteria is now actually inserted into the DNA of an organism, which creates what is now known as a BT crop.

In addition to GMOs being used in agriculture and medicine, they are also being utilized in a process known as bioremediation. Bioremediation is defined as the use of bacteria and other microscopic organisms to purify water and contaminated soil, and since the organisms that are used for this process do not have a long lifespan, genetic modification could be used to create superior traits in the microbes. Just like plants and animals, bacteria are also subject to their own set of complications that they have to deal with in order to survive in their environment. The organisms used in this process can be affected by levels of oxygen, climate, pH, and nutrients available in the soil, and genetic engineering could therefore be utilized to generate a resistance to some or all of these conditions. However, the question still remains as to when or why bioremediation may be used. The point of this process is to remove any hazardous substances that may be present in a piece of land or a body of water, and this removal allows new food sources to be planted, and also makes any nearby soil safe to use. Since bioremediation and GM plants are both linked in different ways, GMOs could be used for both the cleansing of soil and the planting of food, giving genetic engineering even more ways to be applied to society.

Along with genetic modification being used on plants and bacteria, certain species of animals are also being genetically modified to make them perform in different ways. Many different GM animals have already been created, some more controversial than others, but all of them are characterized by the transfer of traits from one species to another. Goats that can produce silk and pigs that glow in the dark are just a few examples of some of the shocking advancements that genetic modification has made among animals, but larger salmon and featherless chicken are some of the more practical applications that GMOs have had on living organisms. GM animals give scientists the ability to produce more reliable food sources for society, and also allows them to synthetically produce materials that would otherwise be less common or nonexistent in the twenty-first century. The scope of the applications that GMOs have currently is very wide and broad, and although their main uses right now are within the fields of medicine and agriculture, this scope may change within the near future.
Advantages of GMOs

In addition to seeing the wide range of applications that genetically modified organisms provide, GMOs are also subject to a great deal of controversy in modern society, and local farmers and large companies both have opinions about whether or not genetically modified organisms should be implemented in the ways that they are today in the twenty-first century. Since GMOs have become popular in a variety of different ways, many people see key advantages and disadvantages of naturally grown organisms versus genetically modified ones, initiating intense debates about the legal, ethical, and scientific aspects of GMOs. In the eyes of an industrial company, GMOs offer the potential to have food that is more resistant to chemicals, disease, and pests, and also allow certain species to produce more nutrients. Due to the resistance of chemicals that GMOs can possess, stronger pesticides could possibly be used such as DDT, or dichlorodiphenyltrichloroethane. Furthermore, the amount of time needed to create a genetically modified organism is far less than the amount of time needed to plant natural foods, and once a GMO is created, they can be grown and reproduced rapidly under close supervision of genetic engineers. Also, if a specific type of organism has to be altered to adapt to an environment, the traits of that organism can be manipulated to support the nutritional needs of the society that lives around it. If a group of people are known to be deficient in certain minerals or vitamins, a food source can be created that makes that group healthier and also more aware of what their personal nutritional requirements are. This method could also be applied to third world countries, which would stabilize the health conditions that people may have due to the lack of resources that those locations are characterized by.

Looking at GMOs from the point of view of large companies and scientists, genetically modified organisms appear to have a series of both chemical and biological advantages over naturally grown food sources. However, because of the ever increasing popularity that GMOs have seen recently, many people also believe that the disadvantages of GMOs outweigh the advantages, and that consuming non-natural organisms can be a danger to one’s health.

Disadvantages of GMOs

Although GMOs are becoming ever more popular among the scientific community, the other side of the spectrum believes that genetically modified organisms have many disadvantages in society. One of the most notable disadvantages that GMOs are characterized by is the process of containing genetically modified crops and not allowing them to transfer into organically grown crop fields. Deciding where specific genetically modified organisms are going to grow can be a challenge to large companies, due to the fact that a storm or a gust of wind could push modified seeds into other farmer’s fields. Furthermore, from the eyes of local farmers and grocery stores, GMOs and the companies that create them can be tough to compete with, and could possibly put smaller enterprises out of business. Another topic of debate about GMOs is whether or not they are ethically and legally acceptable in the twenty-first century. Numerous propositions and bills have been written pertaining to GMOs, and the large amount of backlash that modified organisms have received is definitely a disadvantage to the scientists and engineers that create them. For example, Proposition 37 in California and the Right to Know movement across America ask that all genetically modified products be labeled so that consumers know what they are putting into their body.

Another disadvantage of GMOs is that they can sometimes be difficult to identify and control. Although a simple solution appears to exist to this problem, GMO detection has become increasingly more problematic for companies, and almost all crops have to pass a quality
assurance test to make sure that no impurities in the food is sold to consumers \(^{10}\). Genetically modified corn specifically is being subjected to this dilemma, and many research studies have been conducted on how to sample contaminated kernel lots for impurities. Utilizing various sampling techniques, researchers are able to determine the Total Sampling Error (TSE) and the Total Analytical Error (TAE) of a group of genetically modified organisms, therefore discovering whether or not the GMOs are contaminated \(^{13}\). In addition to controlling and identifying genetically modified organisms, the scientific community as a whole is also having trouble communicating to society about how GMOs are produced and distributed. People want to know what they are putting into their bodies, and since most GMOs are not labeled, consumers are skeptical as to what it is actually inside the food that they eat. Since most genetically modified crops are resistant to pesticides, some chemical residue could be left over inside the genetic makeup of an organism after the crop is sprayed, and those chemicals could be harmful to ones who consume that organism \(^{5}\).

One of the most fundamental problems about genetically modified organisms is that society simply does not know how they are made or what they are made of. In order to resolve this problem, the National Research Council of the National Academy of Sciences organized a GMO workshop in 2015. The goal of this workshop was to find out what a common citizen knows about GMOs, and also to see what various types of social sciences know about communicating and engaging with the public \(^{12}\). In conclusion, the focus of genetic engineers currently is to inform and show society the science behind GMOs, along with how they are created, without being biased towards one philosophy or another. However, many people are still skeptical of genetic engineering because they have not seen the potential side effects of consuming GMOs.

Although mankind has been modifying plants and animals for generations, the GMOs that are made today through gene splicing and CRISPR are quite different than any genetic modification the world has seen in the past. Because of this fact, nobody has had the opportunity to experience any side effects of consuming or using GMOs, and only time will be able to tell whether or not genetically modified organisms are safe to eat \(^{15}\). Genetic engineering is definitely one of the most talked about topics in science and technology currently, and genetic engineers will have to prove that GMOs are safe to eat before people begin to think differently about them. GM products have both distinct advantages and disadvantages depending on one’s views, but there is no denying the amount of popularity that GMOs have seen recently, along with the intense debates that have been taking place in America and across the world.

**The Future of Genetically Modified Organisms**

Although society has already seen how GMOs are being used currently, the future applications of genetically modified organisms is an often speculated upon topic. Will GMO be used on humans? How will genetic engineering technology advance? Will scientists be able to prove that GMOs are not dangerous? All of these questions will eventually be answered sooner or later, and the applications of GMOs will most definitely increase in the near future. One of the main problems that will have to be resolved is the lack of communication that genetic engineers have. If scientists want society to trust GMOs, they will have to be able to announce and show any new genetic technology or applications of GMOs, and if this criterion is not met, then the future of genetic engineering will not be a bright one.

In addition to scientific communication, the growing desire among society for healthy and organic food sources could prove to be a problem for GMOs. Many food companies are
attempting to switch the products they use from genetically modified ones to organic ones, and this movement could make GMOs less powerful in the agricultural industry. Furthermore, other types of technology have recently been discovered, and these techniques could change the way GMOs are created in the future. For example, the CRISPR-Cas9 genome editing tool does not technically meet the guidelines used for genetic engineering, and since the tool barely disrupts the biological and chemical makeup of an organism, CRISPR may be more welcome in society than traditional breeding methods \(^\text{15}\). Systems that use RNA-guided endonucleases (RGENs), are becoming more popular among both scientists and engineers alike, and these methods may replace the traditional genetic engineering technologies that have already been established in the twenty-first century \(^\text{9}\). RGEN systems also give engineers the ability to edit the DNA of a species with unmatched precision and speed, and due to this fact, regular GMOs may become less apparent in agriculture, and more apparent in the field of medicine. Since the medical field has already seen the arrival of genetically modified organisms, much of society is speculating about the use of GMOs on humans to either cure disease or remove undesirable traits. Although GM medical products such as insulin and the hepatitis B vaccine have already been created, the question still remains as to whether or not engineers will be able to actually edit the DNA of mankind.

Although many complications of this topic still stand in the way of the use of GMOs on humans, researchers have already been able to develop next-generation RGEN technology. Utilizing the techniques of lipofection and electroporation, the Cas9 and RNA molecules used in CRISPR can be injected into human cells to change one’s genetic makeup \(^\text{9}\). Lipofection is the use of liposomes to inject genetic material into cells, and electroporation is defined as the introduction of an electrical field to a cell to make the membrane of the cell more penetrable \(^\text{9}\). The adoption of both of these methods, combined with RGENs, have the potential to completely change the way genetic modification is used in society, and also have the ability to make people more healthy through the process of altering one’s DNA. The side effects of this process have yet to be seen however, and use of GMOs on humans will likely ignite new debates about the ethical and legal characteristics of genetic modification.

In addition to speculating the future of GMOs used in medicine, genetic modification has also seen new methods discovered recently in the field of agriculture and in food sources. Since traditional genetically modified crops have been produced and distributed in such large quantities, the taste and grade of the food that people eat has severely diminished. Scientists have discovered new ways to resolve this problem however, and the solution does not involve genetic engineering. Through the use of marker-assisted breeding, scientists are now able to combine the speed of DNA editing with the reliability of traditional plant breeding, all without the use of the genetically modified organisms. This form of breeding essentially allows genetic engineers to analyze the genes of a well-performing species, and gives them the ability to cross-breed two organisms together that have desirable traits \(^\text{8}\). Although this process sounds very similar to what society has been doing for thousands of years, the execution of the technique is quite different, making marker-assisted breeding one of the only forms of DNA editing that does not involve genetic engineering. Although GMOs are already being applied to both animal and plant species currently, the applications that lay in the future of genetic modification have yet to be seen to their fullest potential, and the first genetically modified human may come sooner than one may think. Traditional GMO processes will likely become less important in agriculture in the future, due to the various new technologies that have been invented, but the popularity that
GMOs have seen in the twenty-first century will still be apparent in other scientific fields such as medicine or biology.

Concluding Thoughts
The impact that GMOs have had in the twenty-first century is astounding. Due to the advanced types of genetic engineering technology that have been developed, new applications of GMOs seem to be occurring much more frequently in society. I have been amazed learning about cutting-edge technologies such as CRISPR-Cas9, and since these genetic editing tools are more precise and simple to use, the future most definitely looks bright for the applications and acceptance of these techniques. Although CRISPR is extremely popular currently, the question still remains about what types of technologies will replace the gene editing tool in the future. New methods of genetic engineering will make traditional GMO procedures become less used and therefore less important, but I also found myself wondering when or how society will be able to trust scientists about genetic modification. I am curious to see how the scientific community, along with the industrial companies that support them, will communicate with society in the future. I am also interested to see if the world will be able to accept GMOs more readily with the new technologies that are being developed. The science behind the development of GMOs is becoming more powerful and accurate at an increasing rate across the world, and I wonder if in the future the altering of DNA will be able to occur without the utilization of genetic engineering.

In addition to all of the new experimental forms of GMO creation that are being developed, genetic modification is also being used on plants, animals, and most recently, humans. First of all, the idea of altering the DNA of plants is definitely interesting to me. I tend to believe that genetic modification of the objects that we consume is justified depending on what kinds of traits are being transferred from one species to another. For example, select genetically modified tomatoes have been altered by the genes of winter flounder to create a resistance to cold climates and freezing. This example intrigues me because although I have never consumed winter flounder, I eat tomatoes on almost a daily basis. Although the genetic modification of plants in the twenty-first century has proven itself to be quite interesting, I find myself even more interested by the genetic modification of animals. Some of the genetic engineering that has been performed on animals, such as creating larger salmon, is a reasonable modification to an animal to increase the amount of food it yields. However, the construction of goats that can produce silk and pigs that can glow in the dark are a bit too farfetched and unnatural in my opinion. Furthermore, the genetic modification of humans has also begun to develop in order to remove undesirable traits from one’s DNA or to cure disease. I believe that if a person has the consciousness and self-awareness to decide whether or not they want to be genetically modified, then they should be able to do so since they are making the decision themselves. On the other hand, I believe that the genetic modification of human embryos should not be allowed since the embryo is not self-aware enough to make a decision.

The genetic modification of plants, animals, and humans will become even more apparent in the near future. Even though I do believe in some applications more than others, I am most of all just interested in seeing how GMOs will develop and whether or not they will be accepted and trusted by the rest of society. Overall, the amount of technology that has been developed for the creation of GMOs is truly amazing, and I am both excited and curious to experience the new technologies and applications that GMOs will have in the twenty-first century and beyond.
Figure 1:

A chart comparing and contrasting the different techniques for creating genetically modified organisms.

Figure 2:

A visual representation of the four steps used in the creation of genetically modified organisms.
Figure 3:


Figure 4:

A chart comparing and contrasting the structures of both ribonucleic acid and deoxyribonucleic acid.
Figure 5: Adoption of genetically engineered crops grows steadily in the U.S.

A graph showing the increased use of genetically modified crops in the United States between the years of 1996 and 2007.

Figure 6: Global area of genetically modified crops

A pie chart comparing the global area percentages of genetically modified organisms in various countries across the world.
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Shedding Some Light Onto the Subject: LASIK Surgery

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Dr. Casey Durandet
Abstract-
LASIK surgery is becoming a well known operation. To understand how LASIK works and why it is done, many things need to be understood. The anatomy of the eye is important because it contains key structures to help focus images. Deformities occur in the eye such as irregular cornea shapes. There are many different lenses in the science world and each kind works differently to bring things to a focus and the human eye has a particularly unique one. To develop clear images light rays are refracted onto the retina. LASIK uses a special type of laser to help reshape the cornea and the complete procedure is quick.

The human body is a very complex system that is made up of different structures to help the human species live. When breaking down each structure, some can be very complex while other are explained through physics. An example of a human body structure that can be broken down into conceptual physics is the human eye. The whole thought about how people see can be very complex but by taking the structures of the eye apart and looking at their individual purposes the eye is easier to understand. Just like everything human, there are faults that occur. Sadly, the human species is not perfect but thankfully with technology, scientists and doctors are able to find solutions to help the human body correct some issues that develop over time. As humans age the eye ages as well and can become distorted in shape causing visual issues. For the eye, there are many different issues that can arise but one that is fixable is having focusing issues. LASIK surgery has become very popular. This surgery uses lasers to help shape the eye correctly so no additional lenses are need to see things in focus.

To understand how LASIK surgery fixes some eye issues, the anatomy of the eye must be explained first and to follow along refer to image 1. As light rays travel toward the eye they will hit the cornea first. This is the outer lining of the eye and the light enters a fluid called aqueous humor. This fluid “presses the cornea into a bulge so it can bend incoming light and direct it through the pupil onto the lens” (The Incredible Machine…1994). The light ray then travels through the pupil. The size of the pupil is controlled by the iris which is the colored ring. This is sensitive to the amount of light that is being transmitted to the eye. If it is very bright outside the iris will contract and makes the diameter of the pupil smaller. This will allow less light rays into the eye. If the environment is dark the iris will relax and this will increase the diameter of the pupil. By doing this the eye can receive more light. After the light rays have traveled past the pupil they will enter the lens. The lens of an eye is a muscle that can contract to create a thicker lens. This lens is called a crystalline lens. A thick lens is beneficial in order to magnify things that are in close proximity to the eye. To see objects that are farther away the lens loosens up and becomes thinner in order to make a focused image on the back of the eye. By changing thickness the lens is able to adapt, creating clear images of objects of many different distances. Of course, you cannot see something that is 10 meters away and something 10 centimeters away both in focus at the same time. The human body is not that skilled. After passing through the lens the image will be focused on the back of the eye which is called the retina. Here the image is decoded by rods and cones. Both rods and cones are very small structures in the retina. Rods detect the brightness of light rays entering the eye. The cones are what detect the different wavelengths of color. For people with color blindness they have issues with cones. In old televisions people could get really close and see three colors, red, green, and blue. Cones have censors for these three colors. The combination of the three will pick up the wavelengths for the whole visible light spectrum. They then transform that information and send it to the optic nerve.
that takes the information to the back of the brain to be interpreted. Something that is fascinating is that everyone has a blind spot and that is cause by the little area where the optic nerve is. This area does not have any rods or cones so images cannot be detected at that specific point.

As the eye ages the level at which it performs can become weakened. To have focused and clear vision the eye should be as close to a perfect sphere as it can be just like a ping pong ball. As the eye grows it might become elongated and shaped more like a football or become shorter. Also, the lens can lose its ability to contract causing focusing issues. These are just a few of the issues that can arise. There are three very common focusing issues that are known as nearsightedness (myopia), farsightedness (hyperopia), and astigmatism. These “occur when the light from the object you are looking at is not focused on the retina” (Farndon 2010) correctly causing the image to be blurry. With having nearsightedness vision, the lens focuses the image at a point that is before the retina like in image 2. Now for long sightedness an image is projected to be focused past the retina causing the image to be blurry as well. This is shown in image 3. Lastly astigmatism occurs when there is a deformation in the cornea causing multiple focal points onto the retina which can be seen in image 4.

Now that the anatomy of the eye and the path that light travels through the eye is understood it’s time to look at the different kinds of lenses and how they work. There is a wide assortment of different kinds of lenses and the different arrangements of lenses but mainly they “may be concave, convex, or flat(infinite radius)” (Simanek). A concave lens is one that curves inward as shown in image 5. This lens will cause light rays to become more divergent. As for convex lenses, light rays will enter farther apart and come together at a focal point which is called converging which is also shown in image 5. For a flat lens the light rays continue to travel straight and do not converge or diverge as seen in image 6. A converging lens is a lens that is thicker at the middle of the lens and thin around the edges. And the opposite is a diverging lens which is thin in the middle and has thicker edges which is called diverging (Simanek). Thankfully the word converging lens basically tells the reader that the light rays are going to converge. The light is bent and meets at a focal point. As for diverging lens the light rays separate and get farther apart just like the word diverge implies.

As it is said earlier the lens of the eye is a muscle that can become thicker which creates a very strong converging lens. In image 8 the picture shows how the shape of the cornea changes for objects being at different distances away from the eye. The lens of the eye “essentially acts as a convergent lens with a focal length where the retina is” (Department of Physics and Astronomy). The thickening of the lens becomes “A lens with two convex surfaces, fatter at the center than at the edges, can be used as a simple magnifier.” (Simanek). So, when looking at something that is fairly close to the eye the lens becomes very thick to be able to magnify the image. Objects that are close are going to refract light rays that become farther apart over distance. Now this explains why older people have a hard time reading things up close and require reading glasses. As the eye ages its ability to become thick is lost or at least weakened and needs help magnifying the image which can be done by wearing glasses. As the eye focuses on something that is farther away the lens relaxes and becomes thinner which is known as a converging lens. It becomes thinner because there is less refraction that is needed to be done in order to bring the image into focus (Accommodation of the Eye to Different Focus Distance…). As for objects that are at a farther distance, light rays are going to be more parallel because the distance between the object and the eye is farther away than something that is close to the eye. Since the light rays are more parallel this explains why the image can be refracted less.
In order to focus light rays that are being transmitted from objects to the eye they must be converged. This is done by a process called refraction. Refraction is when a light wave has a slight change in speed that occurs from entering different materials which then changes the direction. Snell’s law can be used to explain the change in direction of light when traveling through different substances. Snell’s law states \( n_1 \sin(\theta_1) = n_2 \sin(\theta_2) \). Where \( n \) is the index of refraction for a specific material and \( \theta \) is the angle of incidence. The index of refraction for a certain material is found by taking the speed of light in a vacuum and dividing it by the speed of light in a certain substance. This equation helps find the refraction angle in the new material. As light enters the eye it travels through multiple different index of refractions which helps the lens with focusing. Image 9 shows the different indexes of refraction throughout the eye as it goes through the different materials. To show how Snell’s law is applied take a light ray going to the eye at a 20 degree angle through air that is in a vacuum. The index of refraction for air is 1. For the cornea it is 1.336 according to image 9. Now to find the refraction angle we know three of the four variables and now can solve for theta 2. Once plugging in the values to Snell’s law the equation should look like this; \( 1 \sin(20) = 1.336 \sin(\theta_2) \). Solve for \( \theta_2 \) which ends up being 14.83 degrees. This degree means that once the light ray has passed through the cornea it will no longer travel at 20 degrees from the horizon but will now travel at 14.83 degrees. Next it will pass through the lens. The lens has two index of refraction but for this example the light will travel through the middle of the lens which has an index of refraction to be 1.406. To find out the angle of refraction take the second half of the equation above and set it equal to the index of refraction for the lens and theta 2. The equation would look like this. \( n_1 \) is the index of refraction for the cornea with the angle of refraction and \( n_2 \) is the index of refraction for the lens. \( 1.336 \sin(14.83) = 1.406(\sin(\theta_2)) \). Solving for \( \theta_2 \) which equals 14.07. There is a very little refraction difference which shows that the cornea does most of the refracting, and the cornea is where most of the errors can be corrected.

Since scientist know that the eye is going to develop issues over time they have found a surgery known as LASIK. The word LASIK is an acronym for “laser-assisted in situ keratomileusis” (Mayo Clinic 2014). As mentioned before nearsightedness, farsightedness, and astigmatism are three common focusing issues. LASIK is able to help all three. Nearsightedness is when someone has no problem seeing an object up close but things that are farther away are blurry. Farsightedness is when someone is able to see things far away but cannot focus on things up close. As for astigmatism, objects far away and close up are not able to be focused because the shape of the cornea is deformed. LASIK surgery is able to help these three disorders because this surgery focuses on the cornea. This surgery is done by using lasers. Very few people know that the word laser is an acronym. It stands for light amplification by the stimulated emission of radiation. Since the eye is a very sensitive organ it is important to use a technique that will cause the least amount of damage. Lasers are a very accurate instrument for cutting and it “seals blood vessels as it cuts. It is used for delicate operations such as eye surgery” (Farndon 2010). There are many different kinds of lasers but “LASIK is performed with an ultraviolet (UV) excimer laser” (Do You See What Eye See…). This laser contains a noble gas and a halogen. An electrical discharge is supplied to the atoms causing them to have a higher energy state. When the atoms disassociate they release photons which are then concentrated to release a high energy beam. The proteins of the cornea absorb the laser beam which breaks the bonds. This allows the laser to cut parts of the cornea off (Manche et al. 1998). The excimer laser is able to break the bonds in the cornea because it has a higher energy than the actual bonds themselves. This laser has a certain wavelength that enables it to remove corneal tissue as accurately as possible. The
“specific wavelength (typically 193 nanometers)” of the excimer laser helps reinforce the accuracy (Wachler). A concern that occurs with lasers is heating or burning. One of the great things about an excimer laser is that it actually doesn't burn. “The laser literally vaporizes microscopic bits of tissue without burning the adjacent tissue” stated by Cornea Associates of Texas. This feature is very convenient in the fact that it can be very precise along with not damaging surrounding tissues. The laser is also pulsed into “short bursts about 10 nanoseconds long” (Do You See What Eye See…). The pulsing feature also helps with not heating the actual tissues. There are many different kinds of lasers, also there are different kinds of excimer lasers. Scientist and doctors are improving them constantly in order to perform to their highest potential. Their pulse rates range, along with their wavelengths, energy levels, and their ability to track the eye.

With both LASIK surgery and regular prescriptions for contacts or glasses a doctor needs to find out some information about the patient's eyes. The focal length is usually looked at by doctors. If the patient has myopia and images are being focused before hitting the retina the focal length is shorter than it needs to be. The ideal focal length is the distance from the cornea and lens to the retina at the back of the eye. As for someone with hyperopia the focal point would be past the retina causing the distance to be farther than it needs to be. To fix myopia doctors want to lengthen the focal distance so they prescribe diverging lenses. The lens will be placed before the cornea and crystalline lens causing light rays to diverge before hitting these two structures. Once the light rays reach the cornea and crystalline lens they will be farther apart and the light will converge and be refracted correctly so that they focus on the retina. As for hyperopia light rays have a focus point that is too far so the magnification of an object needs to be amplified. As stated earlier converging lenses are great magnifiers and converging lenses will be prescribed. These lenses will converge the light rays even more than the eye so that the focal point will be correct and focus on the retina. Image 7 shows the correcting lenses in front of a myopia and hyperopia eye. Optometrist find focal points in diopters. “ A diopter is defined as a unit of lens power equal to 1/focal length of the lens in meters”(Wilkinson). To find a patient’s prescription in diopters the following equation is used with the focal length in meters:

\[ \text{Diopter} = \frac{1}{\text{focal length}} \]

Focal length is the difference between the object distance and image distance. With the image distance being the length from the lens to the retina. An example to find the diopter of an eye would be to take the inverse of the distance from an image to the cornea and the inverse for the distance from the cornea to the retina. Say an object is 1 meter away from the eye and that the image distance is 0.2 meters the equation would look like this 111-10.2=D. For this example D= -0.25. For someone with myopia their prescription will be negative because a concave lens will be used and for someone with hyperopia their prescription will be positive because a convex lens is being used. Since the example above is negative this prescription will be used for someone with myopia.

With having the knowledge behind corrective lenses, it is easier to understand what will happen during LASIK surgery. Before the operation day, the doctor will request that the patient stops wearing contacts, stop wearing makeup, and arrange a ride home according to Mayo Clinic. The doctors main goal is to make the eye be as natural as it can be before surgery. Contacts and makeup can irritate the eye or even cause infections which is what the doctor wants to avoid. Once the doctor has determined the thickness of the cornea, the focal length is projected. The eye surgeon then figures out what the correct focal length should be so that the focal point perfectly occurs on the retina rather than before, after, or in multiple places. Once the numbers are figured out the surgeon knows how he/she is going to cut the cornea to fix the
focusing issue. For the three different main focusing issues the laser “corrects nearsightedness by flattening the cornea; it corrects farsightedness by making the cornea steeper. And astigmatism can be corrected by smoothing an irregular cornea into a more symmetrical shape” (Wachler). As explained earlier nearsightedness is when light rays are converging a focal point before the retina and by making the lens flatter the light rays will experience less refraction. Less refraction will cause the light rays to perfectly focus on the retina. As for farsightedness objects that are close car out of focus and are being focused beyond the retina. By making the cornea steeper it will cause the cornea to make the light rays converge more and make the focal length shorter. Lastly for astigmatism the cornea is irregularly shaped and by using the laser the cornea can be shaped correctly so that focusing happens at one point on the retina.

LASIK surgery is not for everyone. Patients have to meet certain requirements to receive this surgery. According to Brian Wachler there are multiple requirements that need to be met. These include, having good eye health, so the patient does not have any other eye issues like dry eyes, the cornea needs to be thick enough so that some can be removed, a patient’s prescription must be stable for at least one year, and lastly the patient must have good health in order to receive this surgery. Due to the cost of the procedure many people eliminate this procedure to correct their vision. “In 2015, the average price for LASIK and other types of laser vision correction surgery was $2,077 per eye” states Liz Segre in an article from 2016. If you take this average and times it by two it would cost a patient $4,154 to correct both of their eyes. Most patients have focusing issues in both of their eyes so they can not avoid getting them both done.

Once all of the dimensions of the eye are taken into account the actual surgery can proceed. LASIK starts out by numbing the eye tissue. Patients are kept awake and the eyelid are taped back so they are out of the way. The patient is then told to focus on a light so that the eye is in focus and is not moving during the procedure. Once the eye has been numbed “a hinged flap is created and folded back, and the exposed stroma is photoablated using an excimer laser” (Marcos 2001). Once the flap is pulled to the side the surgeon can now access the part of the cornea that they would like to reshape. Depending on the patient’s conditions the cornea is shaped in different ways as stated earlier. The flap that is cut is very thin. Once the desired shape is achieved the flap is gently placed back of the cornea. These few steps are shown in image 10. The doctor does some calculations on the depth of the cornea essentially to make sure that there are no eye bubbles. If both eyes need correcting they can be done in the same day and the surgery is “usually completed in 30 minutes or less” (Mayo Clinic 2014). Once the operation is complete patients will not have perfect vision right away. It can take a few months. There will be a follow up appointment. For a few weeks makeup cannot be worn (Mayo Clinic 2014). Since the eye was cut open doctors want to ensure that no bacteria get into the incision so precautions are taken into place to prevent any infections.

The human body is capable of many things and when picking one structure to focus on loads of information and science come spilling out. The eye might be a small part of the body but it is one of our most valuable senses. I have myopia and found it very interesting to learn what LASIK would do to my eye so that I did not have to wear contacts or glasses. In physics, I played around with lenses and was able to create a focused image by changing the focal length. Thankfully from my anatomy classes I was already knowledgeable about the structures of the eye which made the description much easier and the LASIK process easier to follow. When it comes to the rods and cones in the retina I never looked at it in a complete physics point of view and realized that wavelengths are what are being captured. I love to paint and color is very important in my hobby so now when looking at shades of colors and combining colors I will
specifically think about the wavelengths being received by my cones. When it comes to lasers I had no idea that it was an acronym but once I saw what it stood for, it made sense. I always thought a laser was just a beam of light and never knew it was amplified by radiation. I found the fact that when getting LASIK surgery, the patient does not feel any burning sensation very interesting. The technology and understanding of physics is very intriguing. Personally, I have considered LASIK surgery and I still feel the same about it. I found that it is not always a positive fix and that some focusing issues can occur like a halo look around lights. I have seen commercials for discounted LASIK surgery but I would not be interesting in that deal. My eyes are very precious and if I were to receive this surgery I would not mind spending a little bit more for my procedure. Currently without glasses lights already have a halo look and part of me just wants to keep my cornea the way it is. Since I have myopia it was pretty interesting being able to go farther in depth about what is actually causing my focusing issues. When it comes to my prescription I never went searching for why my prescription is negative. Once learning more about lenses and concave lenses specifically it was explained. Since a concave lens diverges light rays the focal length is negative since we are making them become more distance from being focused. As for glasses for people with hyperopia the plus sign in front of the number also is a little clearer and I have a better understanding for it. Since the cornea cannot condense as much as it is supposed to it needs help converging light rays. Convex lenses are best for this and these have a positive focal length which explains the plus sign in front of the prescription.

Thanks to physics many health problems are fixable and not permanent. I knew LASIK surgery had some physics but never as much as I have found. Some of the physics is easy to understand like converging lenses and diverging lenses but when it comes to the physics behind lasers the physics is still a little blurry for me. LASIK surgery still blows my mind at how quick this operation can occur but it freaks me out at the same time. I would be worried that I would need to sneeze but have no warning and the laser would do irreversible damage.

Now for the future of LASIK surgery I only see it improving. As scientist research the risk factors that occur from the surgery they will be able to develop a more delicate procedure that has even more minimal risks as the one before it. Potentially LASIK surgery could be done robotically and human error will be eliminated. Of course, doctors will still need to be around because every case is special and a computer system cannot accommodate for these changes. There are already multiple different kinds of LASIK surgery like LASEK and some other. LASEK surgery The improvement for laser can occur in the pulse rate. By increasing the pulse rate the procedure could be done even quicker. Also the wavelength can be altered. A major difference between different LASIK procedure is the laser that is used. They operate at different wavelengths, pulses, and temperatures. Knowing that they already have different ways to perform this surgery tells me that it will only improve. The future for eye surgery is just getting started in my eyes. As physics is investigated the technology for eye surgery will just broaden in the most positive ways kind of like a diverging lens. One idea enters the playing field and then they develop in their own direction.
Figures-

Image 1- This picture shows an overall map of the main eye structure.
http://www.brightfocus.org/macular-glaucoma/infographic/anatomy-eye

Image 2- The eye on the left shows light being refracted to a focal point that is on the back of the retina and the eye on the right shows the light rays making a focal point before reaching the back of the retina.
SEO Recommendations. myopia eye Gallery. [accessed 2017 Apr 18].
http://keywordsuggest.org/gallery/693677.html
Image 3- Hyperopia is when light rays focus after the retina as shown in the image.
SEO Recommendations. hyperopia Gallery. [accessed 2017 Apr 18].
http://keywordsuggest.org/gallery/94917.html

Image 4- Astigmatism is shown below where light rays are focused in many spot on the retina causing blurry vision.
SEO Recommendations. eye astigmatism Gallery. [accessed 2017 Apr 18].
http://keywordsuggest.org/gallery/419024.html
Image 5- The left shows a convex lens which will cause light rays to met after passing through the lens and on the right a concave lens is shown and light rays spread apart after passing through the lens.


Image 6- As shown below light rays travel through a flat lens and go unaffected and continue traveling in the same direction as they entered.


Image 7- At the top of the image the disorder hyperopia is shown. To the right there is a convex lens placed in front of the eye and the light rays are shown hitting the retina in the correct place. As for the eye on the bottom myopia is shown. By placing a concave lens in front of the eye as seen on the right light rays are focused onto the retina.

Image 8- The eye on top shows how light rays from an object far away are farther apart and the cornea is elongated to focus the image correctly. As for the eye on the bottom it shows that light rays from an object close are spreading apart so the eye needs to drastically converge the lens and the cornea becomes very thick to make this change happen. SEO Recommendations. pupil accommodation Gallery. [accessed 2017 Apr 18]. http://keywordsuggest.org/gallery/616316.html

Image 9- They eye below show different index of refraction numbers (n) for the different material of the eye which can be used in the Snell’s equation to find the angle of refraction that occurs. The Cornea. Scale Model of Human Eye. [accessed 2017 Apr 18]. http://hyperphysics.phy-astr.gsu.edu/hbase/vision/eyescal.html
Image 10-This image shows LASIK surgery in 4 steps including the thin layer of the cornea that is cut, along with the laser corrections, and lastly the replacement of the thin layer that was cut.

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1. Accommodation. Accommodation of the Eye to Different Focus Distance. [accessed 2017 Apr 17]. http://hyperphysics.phy-astr.gsu.edu/hbase/vision/accom.html
The Evolution and Limits of the Hard Disk Drive

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Abstract
The storage of data is pivotal to technology age, and without some way of storing data personal computers and portable phones wouldn't exist. The hard drive has gone through many iterations and improvements, but it is reaching its technical limit, and without a replacement the advancement of technology will stagnate. Below I will discuss the concept that drives hard disks, and the evolution they went through to reach this point. I will also discuss how it is necessary to replace this form of technology, as advanced and useful as it is, with something better. The limits of traditional data storage devices is becoming apparent, and the need for quantum data storage is on the rise. I hope to convey how pivotal the research done into magnetic data storage was, and how pivotal the research and development of a new form of data storage is necessary.

In order to understand the limits of a hard drive, one must first understand what a hard drive is, and the principle of magnetic information storage. As well as understand the extent to which hard drives have evolved. A Hard disk, also known as a disk drive, is the part of a computer whose only function is to write, store, and retrieve data. Without the hard disk the digital age would not exist to anywhere near the extent that it is today. The invention of the hard drive was a crucial step for the technological age, and without it personal computers and portable computers couldn't exist. The first hard drive was invented in 1953 by IBM engineers. (Harley 2016) In only 3 years the first hard drive was sold. It held only 5MB's, weighed a ton, and sold at $10,000 per Megabyte. Over the next 20 years advancements continued to improve the hard disk. More compact designs, standardized disk drives, and other various improvements. These improvements continued on through 1980's when home computers began to emerge, and past the 1990's when computers became portable. (Harley 2016) Although the shape, and especially size, of the hard disk has varied throughout the years, the main components and concepts have stayed the same. The components of the hard disk seem simple at first sight, but even though there are few components, they are complex micro machines that have laid the foundation of digital information storage. The structure of the hard disk has 3 main components: The spindle, the disk platter, and the disk arm. (A figure of a hard disk is shown in figure #1) The spindle, connected to a motor, spins the disk platter at anywhere from 7,200 rotations per minute (RPM) to 15,000 rotations per minute. (Remzi Arpaci-Dusseau and Andrea Arpaci-Dusseau 2015) The spinning allows the disk head to read the different parts of the track by moving the track in a counter clockwise direction. This spinning is done at a constant rate, and allows the read head to quickly get through the tens of millions of data points on the platters. The disk platter itself is where data is stored. A single hard disk can have multiple platters which are stacked on top of each other. The data is stored on circular paths called tracks. These tracks can be further organized into many other sections. Which allows the data stored to be stored in a more organized manner. Hard disks today hold trillions of bits of data, and it's reaching the point where they cannot get more compact with the given principles of magnetic information storage. The ability for the disk drive to quickly search for specific information is crucial in improving current data storage technology. The disk arms function is to move the disk head, which is connected to the end of the disk arm, from one track to another. This is how the read head physically gets to location on the platter where the data is stored. A single disk drive also has multiple disk arms. One for each disk platter located in the hard disk. although it is the disk head that both reads and writes the data on the tracks of the disk platter. Each disk head reads and writes on its specific platter independently. (Remzi Arpaci-Dusseau and Andrea Arpaci-Dusseau 2015) The disk head is
made up of the write head and the read head. Whose functions are to "write" data onto the tracks, and "read" the data previously written on the tracks by the write head. The write head is an electromagnet that magnetizes each bit on the track as it passes over it to be magnetized in one direction or another. (Mueller 2002) It changes each bit to be magnetized as either north facing up or down. It accomplishes this by reversing the direction of the current, thus reversing the direction of the electromagnetic field as it passes over each bit. This in turn magnetizes that bit to be semi-permanently magnetized in that direction. (Mueller 2002) A direction of magnetization that can be distinguished from either up or down by the read head. It is this concept, along with many other concepts, that allows for data to be stored magnetically. The concept of magnetic information storage is simple, and is made possible by the process of a magnet magnetizing another material. That material then keeps (remembers) that distinguishable direction of magnetization. This material can be something like iron oxide. Iron oxide is what is known as a ferromagnetic particle. Meaning it can be magnetized by a magnetic field. (Mueller 2002) This substance, such as iron oxide, it what is called the recording medium. The recording medium is a thin layer of a magnetically retentive substance. It is here where the magnetic information is physically stored. Two popular examples of these substances that are used at the magnetic media are: an oxide medium, or a thin-film medium. (Mueller 2002) Although the oxide medium is made up of various compounds, the active ingredient in the medium is iron oxide. This is coated over the aluminum platter by placing a thick liquid containing iron-oxide particles, and then spinning the platter at high speed. (Mueller 2002) Which creates an even layer of the material. The surface is then polished and cured. This oxide coating is typically 30 millionths of an inch thick, and is brownish or amber in color. (Mueller 2002) With the advancement of hard drive technology, and as the density of drivers increase, the magnetic medium is required to get thinner and more perfectly applied to the disk platter. This problem requires a different substance than the oxide medium. The oxide medium is very soft and prone to damage, and it is because of this that there are very few oxide media drives today. (Mueller 2002) Thin-film medium is thinner, harder, and more easily and perfectly formed around the hard disk. Thin film plated disks differ in their creation from oxide-coated hard disks in many ways. First the aluminum/magnesium, or glass platter is bathed in a chemical bath. Thus coating the platter with layers of metallic film. (Mueller 2002) The expensive process of sputtering to creates thin-film sputtered disks, is the process of first coating the aluminum platters with a layer of nickel phosphorus, then applying a cobalt-alloy material in a "continuous vacuum-deposition". (Mueller 2002) This process results in an even thinner, harder, and more perfectly coated medium. It is these platters, with their metallic coating that looks like a mirror, that are most recognizable and common in media today. The last main component of the drive disk is the read and write heads. What is called a write head on a hard disk uses an electromagnet to change unmagnetized bits on the disk to be magnetized either north facing or south facing. (Elliott  2004) North facing is read as a 1, and south facing as a 0 by what is known as the read head on a hard disk. These ones and zeros are what is known as binary. Where the position of the ones and zeros can be translated into meaningful information.

The specific way in which data is stored is very complex, and uses many different concepts of the physics of magnetic fields. A closer look at writing heads and how they work shows how complex this small tool is, and shows how the physics fits into the hard drive. (Shown in figure #3) As shown in the figure, The writing head is a two pronged magnet with coils. The writing head floats on a thin layer of air, an advancement made in the year 1961, and
allows for the reading/writing heads to be kept closer to the disk platters. (Harley 2016) Which in turn increases storage density. The writing heads, as stated previously, uses a small magnetic field to magnetize the bits on the disk track to be either north facing up or north facing down. This is accomplished by semi-permanently magnetizing bits on a track. (Shan 1999) The modern inductive writing element uses perpendicular recording, as opposed to longitudinal recording. Longitudinal recording is where the write head places the north and south poles of the magnetized bits in a left to right fashion. As opposed to the up and down fashion of perpendicular recording (Figure {2} shows longitudinal writing heads, whereas figure {3} shows perpendicular recording heads). The write process is based on the process known as "saturation recording". Where the medium is "saturated" by the magnetization of the write head. When the write head changes direction of the current, and therefore the electric field, the direction of the magnetization is also changed. The section of the medium changed, known as the write bubble, is now magnetized to that direction. The write bubble is defined by the "$H_x = -H_c$ contour". (Shan 1999) Just as important as the storing and writing of data is the fetching and reading of that data. This is accomplished by the read head. The first hard disks used what is called "magnetoresistance" to read and store data. Magnetoresistance is defined as follows:

"Magnetoresistance is the change in a material’s electrical resistance in response to an applied magnetic field." (Mazhar et al. 2014) Magnetoresistance is a weak effect found in typically non-magnetic compounds, and magnetic materials normally have negative magnetoresistance. As defined by "\[\rho(H) - \rho(0)\]/\rho(0), and \(\rho(H)\) is the resistivity in an applied magnetic field \(H\)." (Mazhar et al. 2014) This form of magnetoresistance was used until the discovery of giant magnetoresistance in the year 1988. Typical magnetoresistance requires a lot of space to make up for how small the resistance induced is, and giant magnetoresistance allows for much smaller forms of data storage. One of the great advancements made to hard drives was the discovery of giant magnetoresistance (GMR). Which was a breakthrough in the branch of physics known as spin electronics (a.k.a. magnetoelectronics). Spin electronics is the concept that makes use of the spin state of electrons to store data and perform calculations, and not just the electric charge state. (The Columbia Encyclopedia 2016) This is taking advantage of the quantum-mechanical property of electrons. This property is called "spin", and every electron can either have a spin up or a spin down. (The Columbia Encyclopedia 2016) This spin affects both the electrons themselves and the material that they make up. The spin of an electron can be detected as a magnetic force, and can therefore be used to encode information in electronic circuits. Giant magnetoresistance was discovered independently by Albert Fert, from France, and Peter Grünberg, from Germany, in the year 1988. (The Columbia Encyclopedia 2016) Fert and Grünberg found a large and measurable change can be created in electric resistance. This change is found in a material with alternating layers of both magnetic and non-magnetic atoms. (The Columbia Encyclopedia 2016) Using chemical techniques, they were able to make layers of different materials only a few atoms thick. It is this that is known as Giant magnetoresistance, and it is this that created data storage devices that were much smaller and more dense than previous data storage devices. (The Columbia Encyclopedia 2016) It is this concept that allows for storage devices found in smartphones and Ipods, and without it mobile computers wouldn't be possible. But it is with that that a dilemma is reached. Hard disks today use the spin of electrons to determine whether the bit is a 0 or a 1. Creating a more compact system than this will require years of research into quantum computing, which as of now is possible, but not viable for common use. As the demand for more compact data storing systems continues, the ability and limits of traditional hard disks, and even solid state drives, to keep up with this
demand is getting slower. Another breakthrough in the storing of data is required to prevent the stunting of computer technology. The retrieval process is equally as complicated, and has a surprising amount of concepts rooted in physics than one might first guess. Including the deceptively simple way the disk arm moves left and right to find specific bits of data. The read process is made possible by what is known as the reciprocity principle. The read head picks up the magnetic flux produced by written magnetic transitions pass underneath the inductive recording head. This variation of magnetic flux creates an induced voltage in the read head. The reciprocity principle is based on the idea that "The mutual inductives between any two objects #1 and #2 is one quantity and the same: \( M_{12} = M_{21} \)." (Shan 1999) It is this principle that allows the process of reading the change of the magnetization of the bits on a track to be made possible. The read write heads typically float anywhere from 0.5 to 5 \( \mu \)-inches above the platter in a modern drive. As opposed to the early drive which floated 200-300\( \mu \)-inches above the platter. (Mueller 2002) The design if the read and write heads is expected to get even closer to the platter, some of which are expected to be in full physical contact with the disk platter. (Mueller 2002) Just as important as the principle that allows the read head to read written data, is the principles that allow the read head to know where and quickly search for where the data is written. The head actuator mechanism is the mechanical system that allows the heads to move. This process is incredibly important as the speed of which the read and write heads can reach the desired sectors, although the efficiency is not limited to speed. There exist two basic variations of the head actuator mechanism that all fall into. These two categories are: Stepper motor actuators and voice coil actuators, and each has different characteristics. (Mueller 2002) Stepper motors have a slow relative speed, a very high temperature sensitivity, are positionally sensitive, typically do not have automatic head parking, requires periodic preventive maintenance, and have a poor reliability. Whereas Voice coils have a relatively fast access speed, are not temperature sensitive, and are not positionally sensitive, do have automatic head parking, do not require preventative maintenance, and have excellent reliability (Mueller 2002) Stepper motors are far more applicable to less dense hard disks, such as floppy disks, and almost all hard disks today use voice coil actuators. (Mueller 2002) Stepper motors "step" from one predetermined position to the next. Which is only one of the major problems of stepper motor actuators. The greatest problem that affected these motors is the sensitivity to temperature, and the disposition to errors caused by temperature. (Mueller 2002) The far more advanced voice coil actuators automatically determines and adjusts the position of the head using a feedback signal from the drive. Voice coil actuators use pure magnetic force to move the head. An electromagnetic coil at the end of the head rack is near a stationary magnet. As the electromagnetic coils in the head rack are energized, the magnetic force produced either repels or attracts the head to the stationary magnet. (Mueller 2002) This system is similar to that of an audio speaker, hence the name voice coil actuator. How the disk arm detects where to look for data is just as complex as the reading/writing process itself. The voice coil uses what is called a servo to guide the heads and detect their position in relation to the platter. (Mueller 2002) This positioning system is sometimes called a closed loop feedback mechanism. Servo signals are sent and feedback signals are sent back, and it is this system (also called servo-controlled) that gives the servo accurate positioning of the read write heads. (Mueller 2002) The reason temperature was a big problem with stepper motors is the disk platters expanding and contracting with the change in temperature. A problem that occurs in all manner of construction, bridges on the macro scale, and hard drives platters on the micro scale. The way voice coil actuator
compensates is, instead of using predetermined positions like the stepper motor, uses a track following system. (Mueller 2002) Modern hard disks use what are called servo sectors (a.k.a servo wedges) to provide the Positional information of the data previously written on the hard disk by the writing heads. (Xu and Tomizuka 2011) Specially coded magnetic patterns are pre-written on the platter by the manufacturer, and it are these patterns that help the read heads know what sector (out of the tens of millions of sectors on a single disk platter) specific data is stored on. It is because of this continuous information from the servo that allows for the coil to follow the tracks. (Mueller 2002) In the category of voice coil actuators, two subcategories of the voice coil positioner mechanism exist. These two categories are called: Linear voice coil actuators and rotary voice coil actuators. These two types differ in the physical arrangement of the magnets and coils. In linear actuators the heads move in and out over the platters in a straight line, and the coil moves in and out on a track surrounded by stationary magnets. (Mueller 2002) The main advantage of using linear design is that it removes the head azimuth variations. Errors that are a problem in rotary positioning systems. Azimuth is described as "… the angular measurement of the head position relative to the tangent of a given cylinder." (Mueller 2002) Linear actuators heads do not rotate as they move from cylinder to cylinder. Which in turn removes the problem of azimuth variations from the system, but major flaws still exist in a linear system. The singular fatal flaw of this device is that they are incredibly heavy. (Mueller 2002) Far too heavy to be used in modern systems where lightness and compound systems are required to be efficient. Lighter mechanisms mean faster acceleration and deceleration as it moves from one cylinder to another. So despite the azimuth variation problem, rotary actuators became the most popular rotary actuator system by the early 2000's. (Mueller 2002) The device used to continually adjust the head positioner to precisely positioned above a specific cylinder on the disk is called the servo mechanism. (Mueller 2002) Three different designs of servo mechanisms exist: Wedge servo, embedded servo, and dedicated servo mechanisms. Each of these designs accomplishes the same basic task of enabling the head positioner to adjust continuously. The main difference between these designs is where the gray code information is written on the drive. The gray code is special information that is written on the disk during the manufacturing process. A gray code is defined as "… a special binary notational system in which any two adjacent numbers are represented by a code that differs in only one bit place or column position." (Mueller 2002) It is because of this system that the head can quickly and easily determine the precise position of information. This gray code is written by a servowriter. Servo writers are guided by a laser beam reference, that is able to calculate its own position using distances in wavelengths of light. (Mueller 2002) The first of these designs is the early technique called a wedge servo. In wedge servos the gray code is contained in wedges. In other words the drive platter is split up into slices. This design had many problems, including the fact that the servo information appears only one time every revolution, and was therefore a never popular design. (Mueller 2002) The wedge servo was improved upon and this improvement became known as an embedded servo. Embedded servos write information before the start of each sector, which allows the positioner circuits to receive feedback multiple times in a single revolution. (Mueller 2002) This creates a much faster and precise positioning system. Logically, if feedback being received multiple times in a single revolution improves efficiency, than the next advance would be a design which continuously feeds positional information to the positioner circuit. This design is called a dedicated servo. The reason for the name "dedicated servo" is that the design incorporates one side of one of the platters to be only used (dedicated) to contain servo positioning information. (Mueller 2002) The accuracy of the actuator is also reaching it's limit. Even with a continuous
stream of data, the limit of this principle will quickly be overtaken by the demand of evolving technologies. Unless massive investments in the research and development to the quick expansion of existing technologies and creation of new technologies.

Solid state drives (SSD's) are one alternative to hard disk drives. Solid state drive devices use a silicon based memory system for storing data, and have no moving parts. (Hesse 2016) This memory system uses non-volatile memory to store and access information. The most common SSD used today is the flash drive, and manufacturers have begun to use larger versions of these flash drives in personal computers as a replacement for hard disk drives. Solid state drives offer a faster and more reliable way to digitally store and access data on a computer. (Hesse 2016) But one major flaw of these devices is that, even though they are faster and more reliable, the cost outweighs the benefit for the typical consumer. The technology of solid state drives for storing information has yet to be perfected to the point that magnetic information has been, and the technology still suffers from the problem of reaching it's limit without satiating the ever growing data storage requirements. The solution for this dilemma of hard disks eventually reaching the physical limit for how small and compact they can become is the proposal of quantum data storage. Quantum computing, and quantum data storage, are mostly hypothetical devices that can perform certain calculations much more rapidly than conventional systems. (Hardesty 2016) Hard disk drives and solid state drives use bits to store data. These bits represent a 0 or a 1, quantum computers on the other hand use quantum bits, or qubits. (Hardesty 2016) Which can, basically, represent a 0 and a 1 simultaneously. Although this technology is very promising, it is very complex and will require miniaturization of the qubit technology. Once this qubit technology reaches a point to where it is feasible for commercial use. The obstacle of the limits of disk drives will be overcome. Proposed early uses of quantum computing include a hybrid of quantum storing drives and hard disk drives/solid state drives to ease the burden on the soon to be maxed out hard disk drive and solid state drive.

In conclusion, magnetic information storage was a incredibly important step in computer technology, and paved the way for the applicability of personal computer, laptops, and mobile phones. Without which we may still have had handheld calculators and computers may have still existed, but the power and feasibility of the internet would never be to the extent that it is now, and it is because of that that further investments in quantum computing is required as to not stunt the growth of technology for the future. Hard disk drives already hold trillions of bits, use the spins of electrons to hold data, and have near perfect read/write systems. But even with all this technology needs to advance, and the bottleneck expected by hard drives comes closer, we need to look to new and ever expanding technologies to satiate this ever growing demand for more efficient forms of storing data.
Figures
Figure #1
(Figure of a disk drive)

Figure #2

Longitudinal Recording

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Figure #3
References


The Chemistry Behind the Bhopal Gas Disaster

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ABSTRACT:
In 1984, forty tons of methyl isocyanate leaked from the Bhopal pesticide facility. This highly toxic gas traveled hundreds of miles, reaching hundreds of thousands of workers and unsuspecting citizens of the nearby Indian cities. The devastating impacts of the gas leak had a tremendous impact financially, legally, bureaucratically, physically, and emotionally. Decades later, the families of survivors, the involved corporations, and the Indian government are still dealing with the immeasurable consequences of the largest Indian industrial disaster. There are several chemical reactions that explain the complicated process of making pesticides and the hazards that inevitably follow. This paper will describe the chemical aspects that contributed to the severity of the gas leak and what the far-reaching and copious effects were.

The Bhopal pesticide facility was established in 1969 during India’s Green Revolution. This movement aimed to increase the productivity of crops, particularly in more rural areas. “Considered an essential factor in the effort to achieve self-sufficiency in agricultural production, pesticide production use increased dramatically during the late 1960's and early 1970's” (“Bhopal Disaster,” 1997). In an attempt to attain autonomy in the expanding field of agricultural production, a decision was made to produce pesticides within India, as opposed to relying on imports. Union Carbide Corporation (UCC), a United States based multinational company, led in this frontier by establishing a small pesticide factory in the city of Bhopal. They accomplished this through their subsidiary, Union Carbide India Ltd (UCIL). Many factors were taken into consideration when choosing the location for the pesticide plant. Bhopal, the capital city of the Indian state Madhya Pradesh, was favored for its central location, railway, proximity to a large lake, and sufficient electricity and labor forces.

In the early hours of December 3rd, 1984, hundreds of workers in the Bhopal pesticide plant as well as the hundreds of thousands of citizens in the surrounding towns were unaware of how drastically their lives were about to change. A few hours earlier, a faulty valve had allowed a large amount of water to seep into storage tank #610, which held several tons of methyl isocyanate. Despite the prior installation of six safety systems to prevent such a leak, none were operational. As the clock neared midnight, a supervisor at the facility was notified by several workers who complained of their eyes tearing up and burning. The supervisor doubted the severity of the situation and failed to take action quickly enough. In the following two hours, approximately forty tons of methyl isocyanate poured out of tank #610 and spread more than eight kilometers downwind, encompassing the city of nearly 900,000 people. The densely populated shanty towns surrounding the factory were immediately impacted. The devastating effects of methyl isocyanate exposure were particularly prominent in the tremendously poor populations of Jayaprakash, Nagar, Kazi Kamp, Chola Kenchi, and the Railway Colony. Figure 1 displays the layout of Madhya Pradesh and the various areas the toxic gas reached.

Methyl isocyanate (MIC) is an organic chemical compound with the molecular formula C2H3NO. It is a colorless, flammable liquid with a low boiling point of 39 degrees Celsius and a molar mass of 57.052 grams per mole. It can be absorbed through the skin and has a sharp, pungent odor when present in high concentrations. Methyl isocyanate has a water solubility level of 10 grams per 100 milliliters at 15 degrees Celsius. Figure 2 shows the combination of monomethylamine and phosgene at a high temperature to produce methylisocyanate and two moles of hydrogen chloride. N-methylcarbamoyl chloride (MCC) forms as the mixture is condensed, resulting in only one mole of hydrogen chloride left as a gas. The N-methylcarbamoyl chloride is converted to methyl isocyanate through the use of a
tertiary amine, such as N,N-dimethylaniline, pyridine, or through separation by distillation methods.

Methyl isocyanate has a high level of reactivity with several chemical functional groups. In particular, it is extremely likely to react with compounds containing a hydroxyl (OH) group and amine (NH) groups.

It is a little lighter than water but twice as heavy as air, meaning that when it escapes into the atmosphere it remains close to the ground. It has the ability to react with many substances: water acids, metals, and the small deposits of corrosive materials that accumulate in pipes, tanks, and valves (“Bhopal Disaster,” 1997).

When methyl isocyanate reacts with water at high temperatures, it can release more than 300 highly toxic chemicals. Water and methyl isocyanate react together, generating a lot of heat.

If the heat is not removed efficiently, the mixture quickly heats up and accelerates the reaction, producing even more heat. The methyl isocyanate, which has a low boiling point, soon begins to boil. When such reactions run out of control, they are known as runaway reactions or thermal runaways. And this is what happened at Bhopal. In addition, a number of other factors contributed to the runaway reaction. For example, the tank contained contaminants, some of which catalysed the reaction. The methyl isocyanate rapidly vaporised along with products of the reaction. The sudden rise of pressure inside the tank forced the tank’s emergency pressure release valve to open (Freemantle, 2016).

This allowed the discharge of vastly lethal chemicals such as hydrogen cyanide, nitrogen oxides, and carbon monoxide.

Methyl isocyanate is essential in producing carbamate pesticides such as carbaryl, the primary pesticide produced at the Bhopal facility. Carbaryl is used on a wide variety of fruits, nuts, poultry, livestock, and trees. It functions as a molluscicide to repel against slugs and snails, as well as an acaricide to repel ticks and mites. Carbaryl is more commonly known by its trade name, Sevin. Its proper chemical name is 1-naphthol N-methlycarbamate.

Carbaryl is formulated as a solid which varies from colorless to white to gray, depending on the purity of the compound. The crystals are odorless. This chemical is stable to heat, light and acids under storage conditions. It is non-corrosive to metals, packaging materials, or application equipment. It is found in all types of formulations including baits, dusts, wettable powder, granules, oil, molassas, aqueous dispersions and suspensions (“New approach to synthesis,” 2004).

There are several methods to synthesize carbaryl. One method utilizes the reaction of 1-napthol and phosgene. This produces chloroformate, which when treated with methylamine results in carbaryl. This method of preparation is believed to be less harmful to the environment because it bypasses methyl isocyanate in the reaction process. There is debate as to how environmentally friendly this synthesis actually is due to the use of the toxic phosgene which reacts with water. An alternative synthesis of carbaryl was the method used at the Bhopal pesticide factory. This process combines amidogen and phosgene to produce methyl isocyanate. During the second step, methyl isocyanate is subsequently treated with 1-napthol, thereby producing carbaryl, as demonstrated in Figure 3.

Many investigations were launched to determine the exact systems responsible for the gas leak.
UCC’s initial investigation showed that a large volume of water had been introduced into the MIC tank and caused a chemical reaction that forced the pressure release valve to open and allowed the gas to leak. A committee of experts, working on behalf of the Indian government, conducted its own investigation and reached the same conclusion. The incident occurred despite the fact that the system had been designed and operated to keep out even trace amounts of water and that no water had ever entered any of the tanks during the five years the plant had been in operation (Cause of the Bhopal Tragedy).

There were several safety systems, displayed in Figure 4, put in place in order to prevent such a leak from occurring. However, just months before the incident, Union Carbide Corporation scientists filed reports warning of multiple safety faults that could lead to a gas leak. “The reports were ignored outright and never made it to senior staff. Due to falling sales, staff had been laid off and safety checks became less and less frequent” (Gilbert 2015).

Slip-blind plates were supposed to have been installed in order to prevent the transfer of water between pipes. However, these were excluded from the cleaning checklist. Typically, a Freon refrigeration unit was functioning to cool the methyl isocyanate tanks. However, this had been shut down about six months prior to the incident in order to save money. The vent gas scrubber had also been turned off in the previous months. If this safety system had been functioning, the escaping methyl isocyanate would have been combined with sodium hydroxide, thereby lowering the concentrations down to a less toxic level. The sodium hydroxide acts as a buffer, neutralizing the acid and creating water as a byproduct. A pipe had been removed for maintenance from the flare tower that was intended to burn off gases before they spread too far. The last safety system set in place, the water curtain, was simply not high enough.

The water curtain that may have reduced the concentration of the gas was only set to 13 m and did not reach the gas; it was not designed to contain a leak of such magnitude. Though the audible external alarm was activated to warn the residents of Bhopal, it was quickly silenced to avoid causing panic among the residents. Thus, many continued to sleep, unaware of the unfolding drama, and those that had woken assumed any problem had been sorted out. (Gilbert 2015).

Had all, or even any, of these safety systems been operational at the time of the Bhopal gas leak, the devastating results could have been significantly reduced or even avoided completely.

The impact on people’s health following the Bhopal gas leak was far reaching and numerous. Immediate health problems presented in the forms of respiratory ailments, gastrointestinal problems, ophthalmic issues, neurological disorders, psychiatric illnesses, and musculoskeletal complications. Significant amounts of women suffered countless gynecological problems. The examination of 114 women in the field clinics in two of the gas affected slums in Bhopal three months after the disaster revealed that ninety percent had leucorrhoea, seventy-nine percent had pelvic inflammatory disease, seventy-five percent had some degree of cervical erosion, thirty-one percent suffered from excessive menstrual bleeding, and fifty-nine percent had suppression of lactation. These copious health issues that plagued not only the females directly exposed to the gas, but the future generations of their children. Children born after the disaster frequently had physical or mental deformities. There was a massive increase in chromosomal abnormalities that resulted in endless complications for both the children themselves and those responsible for their care. Many families’ inability to adequately care for their handicapped offspring resulted in those children facing twice the risk of death than children do elsewhere.
The vast release of chemical wastes in an attempt to dissipate the toxicity levels of the methyl isocyanate had a variety of negative repercussions. The parts of India surrounding Bhopal were exposed to contaminated drinking water. Many areas tested positive for benzene hexachloride and mercury in their water sources. A result of this was the poisoning and subsequent deaths of a large number of cattle, goats, buffaloes, dogs, cats, birds, and other animals. In addition, plant life was severely damaged as many trees shed leaves and the grass turned yellow without ever recovering.

The Indian government had been aware of the copious safety problems facing the Bhopal pesticide facility prior to the methyl isocyanate leak. However, they were hesitant to place heavy industrial safety and pollution control limitations for fear of creating a negative economic impact. The aftermath of the gas leak could have been managed much more efficiently if the government had a more extensive knowledge about certain toxic chemicals and their treatment. Despite this, the Indian government has continued to deny knowledge about the exact causative agent. When methyl isocyanate is exposed to 200-degree Celsius heat, it forms a degraded methyl isocyanate that contains hydrogen cyanide. There is clear evidence that the storage tank exceeded this temperature, largely due to the failure of the safety systems to function properly. People were immediately exposed to the hydrogen cyanide as the gas traveled, resulting in cyanide poisoning.

In the first few days, there was evidence that people could be suffering from cyanide poisoning—intravenous injections of sodium thiosulphate, an antidote, was found to be working on the patients. But soon, it was discontinued, many say, under pressure from UCC and its team of lawyers (“30 years of Bhopal,” 2014).

The responsibility to conduct medical research was given to the Indian Council of Medical Research (ICMR). They conducted twenty-four studies and found high incidence of lung disease, eye disease, and morbidity in victims. The studies were discontinued in 1994. All continuing research was left to the Centre for Rehabilitation Studies, an institution of Madhya Pradesh’s government. They were criticized for not doing much work. Their perceived lack of effort led to the insurgence of various studies through independent organizations. These independent studies also pointed to serious health problems including cancer, mental problems, and birth defects. Because there was no epidemiological study, these ailments were dismissed as a lack of hygiene and necessary health resources. This insistence from the government held ground amongst many because a large number of those exposed to the gas leak were extremely poor. Despite the Supreme Court’s repetitive requests for patient records to be computerized and official studies conducted to determine the health impacts of exposure, no significant movements were ever made towards this.

There has been an ongoing battle between the people affected by the Bhopal gas leak and those responsible for it. In 1989, the Union Carbide Corporation paid about $470 million for compensation. This amounted to only one-seventh of the original demand from the Indian government. In return, all civil and criminal cases against the company were terminated. Petitioners argued that the settlement was based on an estimated 40,000 severely injured when the number was closer to 400,000. The average amount paid to families of the dead was $2,200. This meant that each survivor received only $500 on average.

This means survivors have been given less than 5 cents per day – the cost of a cup of tea – to pay for decades of medical bills. Many have lost the ability to work because of their health problems and live in dire poverty (“What Happened in Bhopal,” 2014).

Many believe there has not been adequate compensation and continue to speak out against the unjustness of the circumstances.
Activists and victims consider the sum US $470 million agreed on in 1989 as inadequate to compensate the immense losses provoked by the terrible accident. Various petitions to hold accountable Dow Chemicals (which now owns UCC) have been presented to Indian and American courts. The company has systematically refused to own up to their liabilities in rehabilitating gas victims and cleaning up the toxic contamination left behind in the Bhopal site (Greyl 2015).

The United States courts decided that the Union Carbide Corporation and Dow Chemical cannot be held responsible for the management of the Indian subsidiary. One case that was filed through the Madhya Pradesh high court remains against the Union Carbide Corporation. There is still frantic lobbying urging the Indian government to withdraw the case. Most residents have moved away over the past thirty-three years. The civil rights groups that remain are intensely committed to the cause. There has been an enormous schism between activists and government that is still raging and the situation does not appear to be ameliorating in the near future.

Treatment of the victims has been a prominent focal point of the activist groups that remain in Bhopal.

In the case of medical relief, on paper, all has been provided to ensure that people get timely and best treatment. A super-specialty hospital has been set up. Treatment has been assured without payment. The Supreme Court even set up two committees—one to monitor the functioning of the medical system and the other to advise on what needs to be done for the best care of the victims. The state government has a separate department for gas relief and usually a senior minister is in charge of the department. Even at the Centre there is a clear mandate with the Ministry of Chemicals and Fertilisers to oversee all affairs. Yet, medical care is abysmal. The victims continue to say they do not even have water to drink (“30 years of Bhopal,” 2014).

Aside from the production of carbaryl, Union Carbide India Ltd previously manufactured Aldicarb, known by the trade name Temik, and Gamma-hexachlorocyclohexane (g-HCH), known by the trade name Sevidol. In the fifteen years leading up to the Bhopal disaster, Union Carbide India Ltd dumped waste products at dump sites both inside and outside of their pesticide plant, polluting soil and groundwater.

In 1999, local groundwater and well-water testing near the site of the accident revealed mercury at levels between 20,000 and 6 million times those expected. Cancer, brain-damage and birth-defect-causing chemicals were found in the water; trichloroethene, a chemical that has been shown to impair foetal development, was found at levels 50 times higher than EPA safety limits (“Union Carbide’s Disaster”). Many of these chemicals degrade at an extremely slow rate and consequently will remain in the environment for hundreds of years. “Land pollution due to uncontrolled disposal of industrial solid and hazardous waste is also a problem throughout India. With rapid industrialization, the generation of industrial solid and hazardous waste has increased appreciably and the environmental impact is significant” (Broughton, 2005). There is an ongoing argument about who is legally responsible for cleaning and decontaminating these sites. It has been proposed that a number of organizations should take on the responsibility, including the state government, the Centre, the successor buyer of the Bhopal factory, Dow Chemical, waste disposal companies, research institutes, and non-profits. A number of studies found groundwater surrounding the Union Carbide India Ltd site to be contaminated with chlorinated benzenes and HCH isomers. Carbaryl, aldicarb, carbon tetrachloride, and
chloroform were detected in a portion of these studies. All of these chemicals can be directly linked to the wastes dumped by the UCIL plant. Other studies claim there is only isolated contamination that can be attributed to the annual surface runoff during monsoon season. Regardless of the extent of polluted soil and groundwater, it is believed that there is a great risk for a “Bhopal 2.0” if nothing is done about the toxic waste.

Despite the numerous issues that have yet to be resolved following the Bhopal gas leak, there have been a number of attempts to prevent another industrial disaster. The way that chemical and hazardous waste management was reinforced was improved. Workers’ safety precautions were mandated on a larger scale. Legislation for environmental management was strengthened. The Environment Protection Act (EPA) was introduced in 1986. Amendments were made to the Factory Act of 1948. The Public Liability Insurance Act of 1991 came about. Although numerous legislations were either modified or brought into existence, environmental protection and management of hazardous waste has been steadily declining in India. There have been several cases of industrial accidents, with the suspicion of many more going unreported. Additionally, there is a growing toxic contamination of land and water. In 2010, ten toxic sites were identified, all of which contained thousands of highly toxic wastes.

The Bhopal disaster could have changed the nature of the chemical industry and caused a reexamination of the necessity to produce such potentially harmful products in the first place. However the lessons of acute and chronic effects of exposure to pesticides and their precursors in Bhopal has not changed agricultural practice patterns. An estimated 3 million people per year suffer the consequences of pesticide poisoning with most exposure occurring in the agricultural developing world. It is reported to be the cause of at least 22,000 deaths in India each year. In the state of Kerala, significant mortality and morbidity have been reported following exposure to Endosulfan, a toxic pesticide whose use continued for 15 years after the events of Bhopal (Broughton, 2005).

Despite the innumerable, horrific consequences following the Bhopal gas leak of 1984, I believe there are invaluable lessons to be taken away from the disaster. The events that occurred are proof that putting too much of an emphasis on the implementation of industrial growth in rural areas can have fatal consequences. Without the stringent regulations and continual mandates of proper safety protocol in industrial factories, things can go wrong in a matter of seconds. Much of this is due in large part to big corporations getting involved in growing markets. Because of their power, wealth, and team of expensive lawyers, they were able to get around regulations and avoid the consequences simply because they were operating in a developing country. Many turned a blind eye to Union Carbide Corporation’s wrongdoings and Union Carbide Corporation most certainly turned a blind eye to the safety of the workers that they employed. We need to hold companies such as Union Carbide Corporation responsible for the way they took advantage of India’s expanding pesticide market.

In addition to appropriately persecuting the large companies responsible for the gas leak, a number of precautions can be taken avoid another disaster like the Bhopal. Uniform regulations regarding safety measures in industrial factories should be implemented at a national level. Manufacturing plants should be placed in areas far away from large populations of people. There should be a standard for frequently checking the maintenance of these systems. This responsibility should fall on the government as opposed to the corporation that owns the plant. This would reduce any financial conflict of interest that might come from the repercussions of reporting any lack of properly following protocol.
These regulations should not be debatable and the failure to adhere to them should result in stringent consequences.

Several areas should be ameliorated at the national level of developing countries in order to lessen the impacts of another industrial disaster, should one occur. I believe that by placing an emphasis on improving public health infrastructure within developing nations, the results of gas leaks and other tragedies would be significantly less catastrophic. In areas surrounding manufacturing plants, fully functioning sewage systems should be mandated. There should be the adequate presence of hospitals with the necessary staff. The staff should be properly trained on the protocol following an industrial disaster as well as provided with the suitable medical equipment. An emergency response system must be put in place in order to respond to mass injuries at a moment’s notice. The government should work with industrial organizations in order to provide sufficient finances in communities that contain manufacturing plants. Should these communities not have the required public health infrastructure and safety systems in place, the industrial sites should be shut down immediately. If this were implemented in the city of Bhopal several decades ago, countless lives could have been saved. I consider it essential that we learn from the past and refuse to let history repeat itself.
Union Carbide India Ltd chose the location for the Bhopal pesticide factory due to its proximity to a number of necessities such as the railway, airport, and lake. However, this also meant these surrounding areas were densely populated, amplifying the disastrous consequences of the gas leak.

Kobayashi M. Case Details > Leakage of toxic methyl isocyanate stored in a tank at a chemical plant. Case Details > Leakage of toxic methyl isocyanate stored in a tank at a chemical plant. [accessed 2017 Apr 8].

Monomethylamine and phosgene are combined at a high temperature. This results in the production of methyl isocyanate and two moles of hydrogen chloride.

http://www.environmentalpollution.in/essay/air-pollution-essay/essay-on-air-pollution-meaning-sources-and-effects/2081
Figure 3: Chemical Synthesis of Carbaryl Using Methyl Isocyanate
Once methyl isocyanate has been successfully produced, it is treated with 1-naphtol. A catalyst is introduced, resulting in the production of carbaryl.
Methyl Isocyanate. Methyl Isocyanate. [accessed 2017 Apr 8].
http://www.ch.ic.ac.uk/rzepa/mim/environmental/html/menko.htm

Figure 4: Safety Systems to Prevent Toxic Gas Leak
Several safety systems had been installed in the Bhopal Pesticide Factory as a means of preventing and containing any gas leaks. However, none of these systems were fully operational at the time of the Bhopal disaster.
Union Carbide’s Disaster. THE BHOPAL MEDICAL APPEAL. [accessed 2017 Feb 11].
http://bhopal.org/what-happened/union-carbides-disaster/
References


Ironic Iodine: The Diversity and Dangers of Iodine Isotopes

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Abstract

The element Iodine has a variety of isotopes that make it useful, wasteful, and dangerous, giving it a paradoxical nature. Radioactive decay plays a key role in determining if Iodine is safe for our bodies, or better off in a nuclear waste facility. As with many isotopes, Iodine has a wide variety of half-lives, some in hours or days that make for great tracers in medical practice, and others that take millions of years to decay posing great environmental hazards but potentially useful for radioactive dating. Naturally, Iodine can be found in the atmosphere, in the oceans, and the human body as a primary component of hormone production in the thyroid. There are ways to use elements such as Tellurium to produce Iodine through distillation. The naturally occurring state of Iodine-127 is the only stable form of Iodine, the other 37 isotopes undergo radioactive decay. When iodine undergoes fission with elements like Ur, in nuclear power plants or from nuclear weapon detonation, it becomes a radioactive byproduct that can cause cancer or heavy environmental pollution. Nuclear fission weapons testing in the New Mexican and Utah deserts left large paths of radioactive fallout containing isotopes of Iodine and other radioactive isotopes. While the short half-life of many Iodine isotopes can be helpful to reduce exposure; the absorption by plants, then animals and finally human ingestion of radioactive Iodine proved to have severe consequences for many residents in these areas. In the perspective of nuclear power, I-131 is an undesirable product from Uranium fission after the split of the nucleus into nuclides that can decay into long half-life versions of Iodine. Despite disasters like Chernobyl and Fukushima that have released large amounts of radioactive Iodine into the environment, a new technology called hydro fracking is extending the environmental reach of Iodine, in this case as a tracer. While radioactive Iodine can cause health problems like cancer, certain isotopes like I-131 can treat that very cancer. I-131, and other isotopes, can cause cancer, cure cancer, they are considered waste from nuclear energy and weapons, and this is only the beginning of how ironic Iodine truly can be.

Introduction to Iodine

With any element, the question of its importance is posed? Rather than start with the question of why, this paper will demonstrate Iodine from universal origins, to its discovery, and its purpose today, all including how it plays a part in the human species and in the environment. Iodine’s abundance in the Universe is $1.0 \times 10^{-7}$ ($0.000001\%$), and $4.9 \times 10^{-5}$ ($0.000049\%$) in the Earth’s crust, the origins of every element contain ambiguity simply for the limited ability to measure greater portions of the Universe until meteoroids fall to earth. When a meteor contains minerals, it is called a chondrite. To understand chondrites, scientists use various forms of carbon and other radioactive dating techniques to classify where these minerals come from and how old they are. Data from the Pantar and Bjurbole Meteorites found Iodine in certain portions of the material, “I-Xe formation intervals for the Bjurböle chondrite and the dark and light fractions of the Pantar meteorite have been measured by activation techniques with the correlated release method. On the basis of the uniform synthesis model the intervals obtained are (60±2), (68±3), and (60±8), m.y.”. While these are relatively low numbers in terms of universal time, the particles observed were at least as old as the dinosaurs, only they did not come from planet earth. The Pantar Meteorite was what is known as an H5 chondrite, which are high in iron and very common; their parent chondrites classified LL (i.e. Chelyabinsk Meteor and Bjurbole) are less common, carbonaceous chondrites (even less common), all the way to primordial chondrites, the
basis of the Universe. This information goes to show where in the Universe Iodine can come from. Combinations of chondrites impacting the earth’s surface play a major role in creating conditions for life on planet earth. With Iodine being used by the human body and other highly specific applications it is fascinating to look deep into its origins.

The word Iodine comes from the Greek word *iodes* meaning violet, due to the metallic violet color of Iodine. Free Iodine, like the other Halogens, exists as a solid diatomic non-metal I₂, so it is placed as number 53 on the periodic table in group 17 (the Halogens). Iodine has an atomic weight of 126.90 g/mole and a density of 4.94 g/ml which is greater than water. It’s condensed ground state electron configuration is [Kr] 5s²4d¹⁰5p⁵, giving it a medium/large atomic radius 115pm and high ionization energy depending on the isotope of 1008.4-3180 kJ/mol. Iodine’s usefulness is due in part to its very high electronegativity of 2.66. The Iodine ion, Iodide [I⁻], which is found most commonly in sea water as it is very water soluble, has 53 protons, 54 electrons, 8 valence electrons, 46 core electrons, 74 neutrons and an effective nuclear charge of 7 (Figure 1.3 shows the structure of iodine). What does this mean for iodine, it’s ions, and isotopes?

Iodine is very common to humans, most directly in trace amounts from thyroxin in the thyroid, and in table salt (to prevent disease). Iodine can also be found as Potassium Iodide to make photographic film. The previously mentioned forms of Iodine do not require radioactivity for effectiveness however, after radioactive decay this element forms a variety of isotopes that have changed out world beyond photography film and table salt. Iodine currently is sourced from mines in Chile and Bolivia where it is found naturally bonded to a cation like sodium (Figure 1.5). Pure Iodine is caustic to the touch and poisonous if ingested.

The discovery of Iodine in many ways, was beyond remarkable if not only for the universal and planetary crust abundance of this element. French chemist and engineer Bernard Courtois discovered Iodine in 1811. While doing an experiment, Courtois was working with seaweed ash (a plant now commonly known to absorb Iodide) to extract potassium and sodium, and to continue the reaction he added H₂SO₄, after a liberal application a purple vapor developed, condensed on a couple metal objects in the room and Iodine was officially discovered. This experiment also showed Iodine’s ability to sublimate. In many ways, as with many great discoveries, Iodine was discovered partially on accident. These were the early days of Iodine, within a century and through forms of spectroscopy a new frontier for Iodine would emerge, and with more accidents.

**Production of Radioactive Iodine Through Beta Decay and Distillation**

As mentioned before there are different ways that Iodine can be produced, organically in the atmosphere, Tellurium distillation, and by fission products however, in this context only the last two are important. It cannot go without mention that the organic production of Iodine in the atmosphere is a mechanism for keeping Iodine distributed on the planet. “It is shown that OIO formation and its attachment to particles could account for the high enrichment of iodine in the small size fraction of marine aerosol, which is important for the transport of iodine from the sea to the continents. OIO may be a route to the formation of iodate, which is present in atmospheric precipitation.”

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Tellurium distillation is becoming a preferred method for $^{123}$I and $^{124}$I production as they have shorter half-lives than $^{131}$I allowing for smaller dosages in medical and environmental applications. “Dry distillation of radioiodine from tellurium dioxide targets has become the standard approach to producing these radioiodines” (Fonslet and Koziorowski). Simply per Figure 1.1, it is obvious why $^{123}$I and $^{124}$I are desired especially for bio kinetics and not excluding the fact that these radioisotopes sell for (10-50 $/mg) commercially. Distillation is never a short process, this reaction is not an exception, for clarity purposes it will be omitted. Dry distillation of radioiodine from TeO$_2$ is currently the safest and arguably most efficient means of acquiring iodine to aid in treatment of thyroid diseases and to move past $^{131}$I.

Now to focus on the man-made production of various radioactive isotopes of Iodine through fission. First the technical parts of half-life and radiation need to be detailed. An atom is radioactive when its nucleus, in an attempt to become more stable, emits a particle ($\alpha$ or $\beta$), a burst of energy ($\gamma$), or both. As particles, energy, are released the elements radioactivity decays by a factor of one half in (x) amount of time, thus the term half-life. (Figure 1.1 shows the half-lives of various Iodine isotopes). Particles differ in size, and are different from rays, giving each specialized substrates that can block or allow their passage (ie. lead, skin, houses). Alpha particles ($\alpha$), which are large, occur when a Helium nucleus (same size and weight) emits from an atom changing the mass and atomic number, whereas beta ($\beta$) particles, much smaller, emit an electron only changing the atomic number. Gamma rays are high energy photons, light energy, making them “fluid” and able to penetrate many types of mediums and are highly radioactive (ie. the Sun).

The equation $t_{1/2} = 0.693/k$ where $k$ is related to half-life and $0.693$ is derived from the natural log of $(1/2)$ (EQ 1.1). This equation demonstrates the half-life of an isotope. Radioactive decay is a first order kinetic process, meaning the rate of the reaction is directly related to the concentration of the reactant. Radioactive decay rates can be calculated by the following equation; $\ln[A] = -kt + \ln[A]_0$, where $[A]_0 = \text{original amount of a substance}$, $[A] = \text{amount of substance after } t \text{ which is the amount of time}$.

Equation 1.2 shows the decay equation for 100 grams of $^{235}$U after $4.9 \times 10^8$ years. It takes 49 million years to decay down to 5.1 grams of the original material. Gamma ($\gamma$) emission comes after a beta or alpha particle emission.

(Figure 1.2, 1.3, and 1.4) demonstrates the process of Uranium decaying in a fission reaction into Cerium and Zirconium also demonstrating some favorable short half-lives. In this fission reaction the original reactant is fragmented into nuclides, leaving behind Strontium and Barium. Fission as a mechanism relies on the breaking of one large nuclide like $^{235}$U (at least 232 protons), into many nuclides each with an originating atomic mass of another element, which then splits into more nuclides creating a chain reaction. Spontaneous fission is exceedingly rare in nature. Triggered fission, like that in a reactor or weapon relies on a slightly different mechanism. A hypervelocity neutron is jettisoned at the $^{235}$U atom, with incredible energy the neutron penetrates the nucleus, despite the atoms force keeping it spherical. The nucleus absorbs this energy and becomes “half-moon” shaped, this begins the division. Once the nuclear force weakens and electromagnetic repulsion kicks in, the two halves separate completely. The nucleus releases neutrons and an extremely large amount of energy. Ending with developing a few stable radioisotopes. This practice is used in the case of Uranium, however the half-lives in fission reactions for Uranium can lead into unpredictable isotopes such as; $^{129}$I, $^{131}$I, $^{133}$I, and $^{135}$I. Each of these radioisotopes played roles in high initial levels of radiation from reactor failures and nuclear weapons testing.
While iodine $\beta$ decay sounds as though it would only have $\beta$ emission, this is not the case. The primary form of decay for most iodine isotopes is $\beta$, there is sometimes gamma emission and $\alpha$ emission. Fig 1.1 also shows the different types of decay modes each isotope of iodine takes. The types of radiation are most important in cases where the radiation is not contained, Iodine isotopes are especially radioactive before their first half-life. Due to the nature of $\beta$ radiation and the nature of Iodine, binding to organic materials in the environment happens readily. While this may seem like an obvious statement in 2017, the residents of towns in Utah and New Mexico in the 1950’s were assured otherwise.

**WEAPONIZING IODINE**

While Iodine itself was not used in developing atomic bombs, there were a few bomb designs that sought out the production of radioisotopes of Iodine. During the kinetic acceleration towards super critical mass Uranium is trying to “throw off” a neutron, when this happens the Uranium nucleus splits forming not two, but three neutrons and a tremendous amount of energy along with the new nuclides belonging to their radioisotopes. This process is known as spontaneous fission. The purpose of this section of this paper is not to explain the details of a nuclear bomb, rather to ensure proper coverage of the nuclear tests done in the Nevada desert starting in the 1950’s by the United States Atomic Energy Council. So far it has been explained what iodine is and how it’s isotopes are radioactive, all information that has been culminated since the discovery of radiation. Unfortunately, this information was not available to the residents of what are now called the “downwinder” towns, partially including Las Vegas.

The very first test of a nuclear weapon this size was in New Mexico in 1945. It was a plutonium fission reaction called Trinity under the code name The Manhattan Project, Robert Oppenheimer was the lead scientist. A moment in history that always merits attention in this context. In terms of this project, ABC Studios “Turning Point” series did an episode they named Downwinders, a powerful documentary on the horrors that unfolded for towns in the nuclear proving ground areas. Mercury, Nevada, 75 miles NW of Las Vegas was the US Energy Commission: Nevada Proving Ground; from 1949-1962, over 124 atmospheric nuclear weapons and dozens of underground nuclear weapon tests were conducted. Local residents were encouraged to “gather around and watch history being made”. Meanwhile closer to the testing area, buildings, “crash test dummies”, and live animals were staged in view of cameras or simply as references to the incredible destructive force of a fission reaction. Atmospheric tests were dropped from bombers and detonated from varying heights just above the ground, the very first tests were set up on a large tower about 150 feet tall. The major danger associated with nuclear testing in a sand desert (or anywhere except space) is fallout. What the residents of these towns did not understand about fallout was how highly irradiated material that is drawn in by the initial implosive force of an explosion this size would be ejected out thereafter. It would be like depressurizing (popping) a balloon around a light powder, it would draw some of the powder to the area that just depressurized. Only in this case a massive explosion follows distributing “powder” high into the atmosphere and capable of entering global wind streams. Residents like Martha Layard recall each time a blast would go off, the immense cloud in the air, in pictures it looked like an Arizona dust storm or thunderhead, some reported it even glowing. Martha and her daughters would survive the fallout, but her two sons would not, one still-born with deformed legs, and the other died of leukemia at age six. One of her daughters has since
developed thyroid cancer, and the other has had multiple cases of melanoma skin cancer. Since radiation is invisible without special instruments or conditions, the residents played in the creeks, lived off their land, drank milk from their cows, completely unaware that $^{129}$I and other radioactive isotopes were permeating through the ground. Worse, iodine targeted the thyroid making it increasingly dangerous. Martha decided to right congressman to see why there had been no warning, one response from AEC Chairman Lewis L. Strauss stated “it is a small sacrifice to lose a son in the interest of national security”.

The neighboring community of St. George, Utah was predominantly Mormon religion, thus they did not drink or smoke and for all purposes lived very healthy lives mostly cancer free. Only three years after the tests began, dozens upon dozens of St. George residents developed a variety of cancers, including thyroid. The wife of Mayor Pickett of St. George, Viola Mae Jameson Pickett died within one week of showing symptoms of Hodgkin Lymphoma, which is radiation induced, on December 10, 1960. She was 38. Making matters worse the AEC persuaded newspapers to run headlines like; “A-Cloud Safe, Utah Told” and “Fallout? Not Enough to Worry about says AEC”, published days after one of their largest and most lethal tests called “Dirty Harry”.

“Dirty Harry” is noteworthy for many reasons:

1.) AEC Chief Medical Officer insisted that all tests conducted should be less than 12 kilotons, this calculation kept radiation within “acceptable” ranges.
   a. Dirty Harry was 32 kilotons per public record

2.) The AEC launched a film to “calm nerves”, showing people safe if they were indoors, even going to the lengths of having workers lie about how many counts they were receiving on their Geiger counters (or equivalent instrument).
   a. In many cases, they were maxing out their instruments at 350 milli ranks/hr

3.) Many people did not receive the bulletins or news to stay inside including schools who were not supposed to have recess.

4.) This bomb opened the door for even larger tests, broadening the umbrella of radioactive fallout.
   a. “Shot Simon” proposed yield = 23 kilotons
      i. Actual yield = 43 kilotons
   b. “Shot Simon II” proposed yield = 100 kilotons
      i. Actual yield = 5000 kilotons

(Source: ABC Downwinders)

Figure 1.8 Shows radioactive fallout in the United States from weapons testing and figure 1.7 shows a correlation between age of ingestion and exposure severity leading to absorption rates.

Though the government would not admit the extent of damage from nuclear testing, the radioactive particles showing up in milk in St. Louis, in wheat in the northern Midwest, and in the water in NY, could not deny the facts. Dr. Joseph Lyon an Epidemiologist for the University of Utah simply did a study of childhood leukemia death certificates for the applicable demographic that would have been exposed to radiation during this period. The correlation was beyond strong; it was disheartening especially since the damage has been done. Thyroid cancer correlations were more difficult to exact, however “eyewitness” accounts showed strong correlations. Today it is known why radioisotopes of iodine attack the thyroid and how to
prevent damage in instances of exposure. The world today sees chemical weapons used on innocent populations and is judged reprehensible, yet the United States knowingly irradiated parts of the south west and denied it until many of those involved have died, and beyond. The final upsetting aspect of this picture was the military exercise; soldiers were told to “rush” the enemy after the explosion. There was a waiting time and then they were to “engage the target”, between these soldiers and the workers who prepared the test sites, less than 2% of the approximate 300 soldiers and workers, are alive today. Many died within two decades or less of exposure.

Iodine was not the only culprit related to radiated deaths in the south west, however the isotope $^{129}$I was generated in many instances from these tests. This is now the time to dive further into why $^{129}$I is so important! Many of the Iodine isotopes are created by nuclear fission, however most of them have relatively short half-lives. $^{129}$I has the longest half-life of any fission product at 15.7 million years, while this incredible time frame can pose hazardous it also has practical application.

**Medical and Environmental uses for Iodine**

While weapons grade Iodine, or fallout Iodine from weapons, has the potential to kill via cancers and radiation poisoning partially due to their long half lives, however in medical purposes scientists have been able to exploit the shorter half lives of iodine isotopes making many viable tracers in the human body. Iodine-123 has a 13 hour half life, making it a very viable radioactive tracer for medical imaging, then dissipating in the body fast enough to prevent harm. Iodine-131 is used in thyroid cancer treatment because it, like all isotopes of iodine, has the ability to naturally seek out the thyroid due to thyroxin being made up partly of Iodine. Also the β emission that Iodine undergoes in order to decay is a small, exact, and aggressive molecule especially when attacking free radicals in the body. This makes it a very viable treatment for children with cancer as larger doses are readily absorbed by the foreign material (cancer) and the rest can be pushed out of the body. While no amount of radiation is gentle on the body, thyroid cancer has become increasingly easier to treat with the use of I-131 and now I-123.

A lesser known medical use of Iodine originated in the early 1900’s using aerosol iodine to treat the H1N1 virus. During this time almost 30 million people lost their lives to the influenza virus and iodine was “the most effective agent for killing viruses especially influenza viruses”. (Derry) It’s effectiveness came from iodine’s antiseptic properties, part of which make it caustic. However in low concentrations, toxicity can be avoided.

Iodine is so versatile in bio kinetics due to its decay nature and half-life that it is not possible to summarize it’s importance in a justifiable manner. Instead it is best to draw one main conclusion from the medical prescription of radioiodine, the nuclear weapons and subsequent ingestion of isotopes $^{129}$I, $^{131}$I, and $^{132}$I can undoubtedly be linked to cancer of the thyroid and other parasympathetic thyroid abnormalities. Yet it is possible that the very isotope that caused the cancer is there to treat it, bringing the irony of iodine full circle.

Again, despite the hazardous implications of using radioisotopes of iodine, humans have decided to use tracers like $^{125}$I in the quest for petroleum. Hydro fracking is a new method of fracturing ancient beds of fossil fuel layers to extract oil, in the process the size of an oil “vein”
must be assessed to determine viability and overall practicality of tapping into one reserve of an oil as opposed to another. Supposedly in small enough concentrations the radioactive iodine is able to help geologists and engineers navigate the paths of these reserves. However, as with any drilling or mining process there are risks, not only is it dangerous to accidentally fracture an aquifer next to an oil reserve, if $^{129}$I is used as a tracer element that aquifer is radioactively contaminated for 15.7 million years in the quantity it was initially put in. While this is not the only method for using iodine as a tracer, there are clearly pros and cons to using radioactive isotopes that originate most commonly from fission reactions and have millions of year-long half-lives.

Before hydro fracking was even a common practice, radioactive iodine had been released into the environment in great doses. When the Chernobyl nuclear power plant melted down in 1986, the plutonium reactor core spewed out fissile materials for over a week, including $^{129}$I and $^{131}$I, with the later dissipating in a matter of months, and of course others went on to circulate the globe. Chernobyl was a preventable “operator error” situation that has ripple effects beyond the life times of anyone involved. This would happen again in Japan at the Fukushima 1 Nuclear Power Plant after a devastating tsunami destroyed the cooling generators for the plant ultimately leading to a meltdown with an explosion of fissile materials being ejected and showing up in commercial cow milk and sea water on the North American Atlantic Coast and across the Eurasian continent. While these are only some of the popular examples of radioactive contamination, there are other examples that can be found with a little research.

CONCLUSION

Iodine is an incredible element with a diverse set of isotopes and with all the possibilities in the world for energy, medicine, and weapons it is no wonder that we use iodine the way we do today. While iodine was discovered during a time of lesser understanding of nuclear chemistry, the more we came to understand the more there were aspects of recklessness that emerged ultimately as a byproduct of weaponized Ur, even though the knowledge was available, bureaucracy and fear stood in the way of human life. As discussed, radioiodine was infinitely more dangerous than could be expected even if proper warning was given, due to its heavy beta emission thus giving it a soft tissue bombardment style destruction to the human body. Whatever tissue radioactive iodine touches it will try to destroy. With monumental advances in science, both in physics and nuclear chemistry the production and isolation of radioiodine is possible and effective. There are less instances of contamination from this radioisotope and more stories of successfully beating cancer, or simply having a properly functioning thyroid. The purpose of this paper was to expose the reader to more information about this diverse set of radioisotopes, and to cover some important historical and industrial mile markers for radioactive iodine. Finally, radiation is everywhere, as ubiquitous as oxygen, yet the human species seems to fear or overuse this incredible energy, rather than find it’s equilibrium.
Figures

Figure 1.2

Figure 1.4 (Fission of Uranium 235)

(Fig 1.2, 1.3, and 1.4 Source: http://hyperphysics.phy-astr.gsu.edu/hbase/NucEne/imgnuk/frag4.gif)

Figure 1.3

Figure 1.5

sodium (I) iodide
EQUATIONS:

(EQ 1.1) \( t_{1/2} = \frac{0.693}{k} \)

(EQ 1.2) \( \ln[A] = -kt + \ln[A_o] \)

\( t_{1/2} = \frac{0.693}{7.0 \times 10^8} \)

\( \ln[A] = \left(\frac{0.693}{7.0 \times 10^8}\right)(4.9 \times 10^{11} \text{ years}) + \ln[100.0 \text{ g}] \)

\( e\ln[A] = e\{(-9.9 \times 10^{-10})(4.9 \times 10^8) + \ln[100.0\text{g}]\} \)

\([A] = 5.1 \text{ grams Ur-235} \)
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<td></td>
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<td>¹⁰⁸&lt;sup&gt;Te&lt;/sup&gt;</td>
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<td>¹⁰⁷&lt;sup&gt;Te&lt;/sup&gt;</td>
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<td>α = 17%</td>
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<td>β+, p = 11%</td>
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<td>¹⁰⁶&lt;sup&gt;Sb&lt;/sup&gt;</td>
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<td>β⁻</td>
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* ε – refers to electron capture process that changes a nuclear proton to a neutron and emits a neutrino (fig. 3.3)

** MeV – megaelectron volts, used in high energy physics as a unit of momentum (1 Mev = 1.6021773e-13 Joules)
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Nano Robotic Surgery

Joylet Zuniga
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Physics 112
Dr. Casey Durandet
ABSTRACT:

This research paper will contain the following: The past, the present, and the future of how nano robotic surgery came about. It will about how nanotechnology was first introduced to us. Then it will about what is currently happening today and the research that is occurring. Leads us to what will happen in the future; the logic of what engineers, physicists, and surgeons are working on; and the ideas that will soon be developed for the years to come.

PAST:

This research paper concluded that many negative effects on the human body occur in the presence of microgravity when compared to humans in earths gravitational field. By outline the effects of gravity on the human body, organ systems, ageing, circadian rhythm, blood vessels, as well as twin astronauts, the current research illustrated these negative effects. As you can see, humans take gravity for granted on earth when traveling in space and living in microgravity. There are many adverse effects of spending extended timeframes in space. In order to eliminate the negative effects of microgravity, research scientist must continue to explore the causes and effects of gravity and microgravity on the human body.

The first documentation of a Nano robotic system was in 1985: the invention of the PUMA 560 [1]. The PUMA 560 was a surgical arm that appeared to be utilized in a delicate neurosurgical biopsy, and a non-laparoscopic surgery. Laparoscopies are originally frequently used to apply flexible fiber optic cameras. Here they potentially want to have a greater precision when using minimal invasive surgeries, granting the robotic system for successful robotic surgeries. In 1987, a cholecystectomy was performed by Nano robot that lead the first laparoscopic operation engaging a robotic surgery system. On the same year, the performance of a robotic surgery was transurethral resection used by the same PUMA 560 system. In the 1990’s, The Food and Drug Administration (FDA) approved the Automated Educational Substitute Operator AESOP Automated Educational Substitute Operator (AESOP) system for its production of the endoscopic surgical procedure [2].

The resolution to a Nano robotic surgery is to obtain the traditional open surgery to a minimal access technique. This means less money, shorter hospital stays, reduced postoperative pain, and lower risk of infection. A surgeon's favorite result to attempt and advance minimal invasive approach for surgical operations. However, performing laparoscopic surgeries is proven to be difficult to learn and perform due to technical limitations. In 1985, the PUMA 560, was used to place a needle for a brain biopsy using CT guidance. In 1988, the Imperial College London developed the PROBOT. Which was used to operate on prostatic surgery. In 1992, the ROBODOC was introduced remove precise fittings in the femur for hip replacement, developed by the Integrated Surgical Systems. Further development of robotic systems was completed by the Intuitive Surgical with the introduction of the famous da Vinci surgical system [3] that is still used today but more modernized. The da Vinci surgical system and computer motion with the AESOP and the ZEUS robots. Unfortunately, in 2003 the ZEUS was no longer actively marketed and bought by the Intuitive Surgical.
The da Vinci Surgical System contain three factors: a high-definition 3D, a surgeon’s console, and a patient-side robotic cart with four arms manipulated by a surgeon. We are introduced to the body through cannulas, by enunciating surgical instruments that are on the robotic arms. This robot is made to eliminate the shaky hands that are then transferred to micro-movements of the proper instrument filtered and scaled by the surgeon’s hands. The camera that is utilized in the da Vinci provides an accurate stereoscopic photo that is then transferred to a console that the surgeon will view. Since the da Vinci has been used to successfully perform surgeries. For example, it was used for mitral valve repair, prostate cancer, and hysterectomy which was then approved and cleared by the FDA. Ever since then the da Vinci System was used in 48,000 procedures in more than 800 hospitals in America and Europe. It sold for around $1.2 million.

In 2000, the da Vinci System broke new ground on camera/scopic utensils and encompassing systems of surgical instruments. The robotic surgery systems three-dimensional magnification screen helps the surgeons view and operate the areas that need high resolution and clarification. The arms represent significant advancement using the centimeter diameter representation. Similar are the large-armed systems for example like the PUMA 560. Intuitive surgical markers of the da Vinci robotic system eliminate the need for the surgical assistant and upgrades in the operating arms could potentially increase clinical applications. The “Endo-wrist” improves efficiency in the most minimal operating space, featuring operating arms that mimic the highly-experienced surgeon. This advancement allows for less contact between interior tissue that is exposed as well as surgical devices, minimizing risk of infection.

PRESENT:

The meaning of nanotechnology is the combinations of science, engineering and technology. It can manipulate and control materials at a molecular and atomic level. To give that a visual of how small a nanometer is; it is roughly the same size as a child’s small ball is to the Earth. Or the thickness that a normal 8 by 11.5 sheet of paper has. Another comparison of a cell which is roughly in the range of being 6,000-8,000 nanometers in diameter, or DNA that is 2.5 nanometers in width [7]. The nanorobotics system will rely on numerous motors on a sub-nanometer or nanometer resolution that will move in tiny increments. Targeting the exact location of whatever you are planning to remove or other such objects. On the other hand, where the surgeons would not be able to reach where that exact placement of whatever the surgeon is trying to locate. The measurement of a nanometer is .000001, and the nanotube is 1/1,000th of thickness of a human hair. Currently, there is a design being made that will create motion algorithms to prepare tests for the nabobs to perform different task. Nano robots are built with sensors and actuators taken from nanomaterials, like synthetic zinc oxide, quartz and gold, which have special faces in the nanoscale. The actuators disciple electrical energy into mechanical motion that move objects like the robot’s handle to grip an organ. This object has sensors to track motion, and the ability to rotate direction, called mechanical force, while producing electrical energy.
This machine will be able to be utilized in the following fields: microbiology, hematology, oncology, neurosurgery, cardiology, and dentistry. It also applies in the contrast agents for cell imaging. This is a liquid that is injected under Ultraviolet light and seeps where the cancer is located, making it easy for physicians to find medical applications of nanomaterials are used to fuse two pieces of meat into one single piece. Which could potentially solve blood leaks when surgeons are trying to re-stitch. Diagnostic devices were invented to help the use of arthroscopes. Drug delivery vehicles is a type of therapy in which a particle placed within the body will illuminate it with light from the outside. Once that light is absorbed by the particles and if the particles are metal, energy from the light will produce heat, which detects the particle and surrounding tissue. Neuro-electronic interfaces deal with the visionary goal and construction of Nano devices that permits a computer to be combined with the nervous system. Tissue repair will help patients by helping with the reproduction or repair of damaged tissue. Molecular nanotechnology is a machine that would be able to reorder matter at a molecular or atomic scale. What is Nano silver? Nano silver is used as an anti-infective material, that is proven to be extremely useful. This would prevent infections that could be caught in a hospital. Nano silver is proven to not be toxic, nor is the bacteria are known to be resistant towards it.

Due to destitute depth consciousness of a laparoscopic surgery is ambitious terms of the surgeon’s accomplishments It has barred range of view, clarified eye coordination and a decreased haptic cue. Surgeons then must have the patience of the repetitiveness that is required to perfect and reach the qualified skill level. Virtual reality touches base with the physicians. Virtual reality retains physicians in the art and science of their craft. In such a system, that us human’s users collaborate with virtual three-dimensional models of our organs, by using our five senses. For example, the model of the organ uses the sense of vision also using and wielding them to use our sense of touch. It has been demonstrated that there has been a form of use of simulators. Residents in training have unique liability to unusual situations. In extension, the physicians in training are offered the opportunity to be documented in action for equitable evaluation and customizing the training program for the upcoming physicians who will be working with these surgical robotic systems.

Recent studies show that surgical skills in the field take great memory and experience during training. Another recent study with thirty participation surgical residents at the Deaconess Medical Center in Boston showed that students performed 36% faster and 97% more accurately when given the feedback. The statistic did not even differentiate when the resident had a stronger memory. It is relevant to use all mechanics when soft tissue is being worked on in surgery. Now the simulator that uses physics still needs experimental data with modeling of mechanics of soft tissue response as well. Ongoing research is still occurring for Nano cell repair, where they send a small device smaller than a pill that detects the cells that need improvement and repairs them.

FUTURE:

Technology has done nothing but advance faster each year. The collaboration that happens between surgeon and technology is advancing, creating easier surgeries. This ease comes from the smoothness of using the arm. It essentially also removes the need for assistants as it is one. This does have a negative effect on future physician assistant careers though, even a
bigger issue in this will be the jobs affected in today’s time. The possibility of a person who has spent a significant amount of time of their lives in school for a profession being replaced by a robot is now not just a sci-fi possibility. This may be a necessary sacrifice, though, if we wish to increase success rates of surgeries.

As major advancements happen to the robotic surgical system they increase the ability to reduce the mistakes that happen with surgeons. Robotic advancements will greatly decrease the surgeon's motion on surgery so that the hardest of task can be done including surgery in a microscale setting on the body in high risk areas. Big groups in the medical field such as the National Science Foundation has stated “Nanotechnology has the potential to enhance human, performance, to bring sustainable development for materials, water, energy, and food. And even diminish the reasons for breaking the peace.” With more safe surgeries, just being the tip of the iceberg, breaking technology around the corner include Biocompatible surgical nanobots. With Biocompatible surgical nanobots surgeries trying to remove cancer and microvascular obstructions will no longer be major surgeries. They will also assist “noninvasive” organ and tissue transplants.

The 2020’s will be a huge stepping stone for nanotechnology due to increasing availability of diamondoid production of nanotechnology. The designs will scale parts in similarities to molecular microprocessors. The real task will be assembling the nanobots as they advance in technology because with advancements there can come more complex builds. Medics are hoping for these advancements sooner due to recent technology being implemented allowing for the nanobots to go straight to the targets areas. The United States Defense Advanced Research Project Agency (DARPA) is developing a more war friendly nanobot to help soldiers in the field by using the targeting technology to attack wounds and disease. Possibly getting rid of high uses of surgeons on the forefront since the robots manage to automatically inject.

Other than that, in the pharmaceutical field they are having the nanobots facilitate with neurosurgery, due to their micro size and their ability to move easily through delicate and complicated passageways. That way the diseases and illnesses will terminate. But that does not stop here: scientists and futurists have considered how to utilize and allow our bodies to achieve a physical upgrade. A robot named Respirocyte[4] designed by a nanotech pioneer Robert Freitas. This Respirocyte manage to hold 9 billion molecules of both oxygen and carbon dioxide oxygen. Commonly found in RBC (red blood cells) holding in 200 molecules of oxygen and carbon dioxide. Meaning we are able to run in full speed for a total of fifteen minutes after the absence of oxygen. This means we could utilize the same ability and hold our breath a lot longer underwater.

Nano robotic surgery will do great things for the years to come. Almost like saying that they found a cure for cancer. Having these Nano arms will help the surgeons to reach the unreachable, going as far as when they invented the PUMA 560, to AESOP, to ZEUS, to the Da Vinci, from now where robotic can be used in every field in medicine like neurosurgery, oncology, hematology and many more. And the future that we are looking at is to have nanobots repair our cells and more ideas that are still to come in the future.
FIGURES:


The picture above is the AESOP system.
   Representation of the first da Vinci system made.

   The image above shows the respirocyte

\[ V(\mathbf{r}_1, \mathbf{r}_2) = \frac{e_1 e_2}{4\pi\varepsilon_0 |\mathbf{r}_1 - \mathbf{r}_2|}, \]

   This equation is what has been used to calculate the length of a DNA strand.
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