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EDITOR: ELIZABETH MIRHAROON
FACULTY ADVISOR: MR. WYKES

Forward by Mr. G. Wykes

This year I had the opportunity to mentor a remarkably stellar constellation of young scientists. Not only were they bright and hard-working but they displayed an astonishing amount of creativity. True to the scientific process, our investigations evolved in complexity, interest and relevance. Some supported existing scientific theories, while others qualified established dogma. Still, others pushed the very boundaries of science: new directions, new ideas, new technologies. Furthermore, you couldn't imagine six investigations that collectively cover a wider expanse of science: From psychology to environmental science, from animal behavior to wearable technology, from citizen science to exobotany, from comparative anatomy to cognition. There was no room for 'cookie-cutter' science among our research cohort. As we wrap up this cycle already we are planning for the next: If you don't like inclement weather, best beware…sudden brainstorms are forming on the third floor.

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Gender Differences in High School Conformity: A Reapplication of the Asch Experiment By: Elizabeth Mirharoon and Avital Abramov

- **Background: Peer Pressure**

Merriam-Webster defines peer pressure as "a feeling that one must do the same things as other people of one's age and social group in order to be liked or respected by them" ("peer pressure"). Peer pressure is especially impactful among teens. In a Harvard article written by Emily Boudreau, it states, "Teens tend to be more susceptible to this pressure because it's a time in their life where they worry more about what others think of them" (Boudreau). Social psychological theories provide the basis for understanding how social conformity occurs and what variables may impact peer influence. This is the experiment that was conducted by Solomon Asch in 1951 at Swarthmore College. Asch's experiment was done to test whether or not the participants would conform to an answer that was obviously wrong. In this study, we re-apply the Asch Conformity Experiment to high school students to determine which gender capitulates more to peer pressure.

- **Abstract: The Asch Experiment**

In 1951, Solomon Asch hypothesized that when confederates or 'fake participants' uniformly gave a particular response in a group setting, the lone 'true participant' would feel pressure to conform to the group consensus. Asch's null hypothesis was that people wouldn't conform to something that is obviously wrong. In psychological terms, conformity refers to an individual's tendency to follow the unspoken rules or behaviors of the social group to which they belong (*Practical Psychology*). Pressure from a group, Asch concluded, could lead people to conform, even when they knew that the rest of the group was wrong. In this study, we re-apply the Asch Conformity Experiment to high school students to determine whether teenagers conform to a greater or lesser degree due to peer pressure and if there is a difference between males and females in their response to peer pressure. The conformity experiment that this study repeats are the "vision tests," in which study participants were found to be more

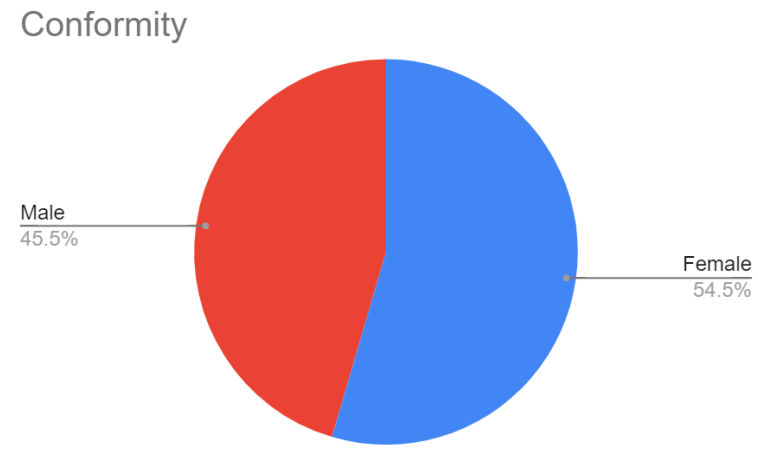
likely to conform to obviously wrong answers if these same wrong answers were voiced by other "participants," who were actually confederates of the experimenter.

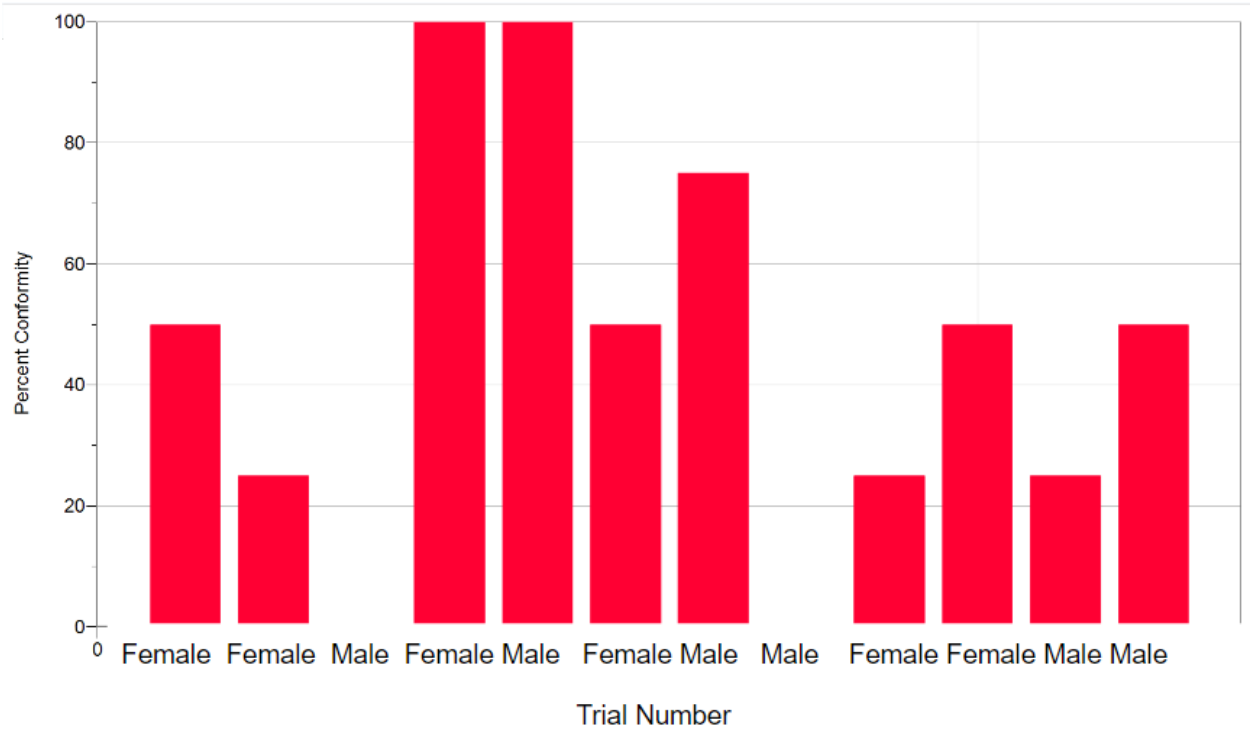
- **Methodology**

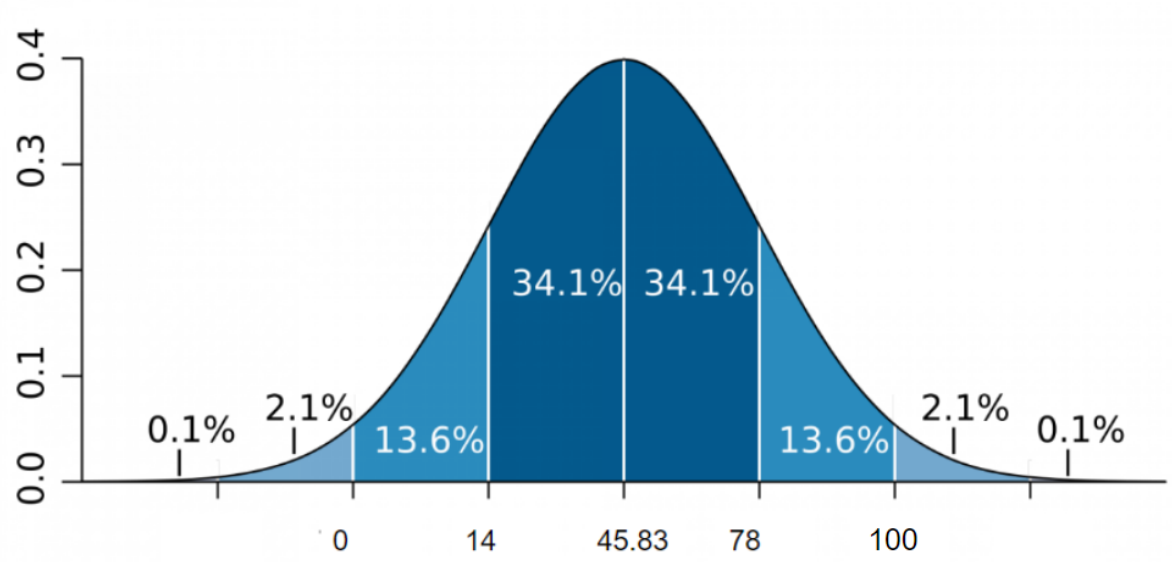
In our experiment, a total of twelve tests were conducted on groups of ten teenagers selected from grades nine through twelve from our high school. The 'true participant' was one individual chosen at random from the group. Nine 'confederates' in the group were given instructions and told the nature and purpose of the test, while the 'true participant' was taken to another room to sign a time-consuming non-disclosure agreement and was shown a separate slideshow with Asch's line test diagrams to confirm their accuracy in completing just four questions correctly in sequence. The intention here was to ensure that they were all clearly capable of reading the diagrams accurately. Meanwhile, the remaining nine students had the directions explained to them verbally. Confederates were seated all in the same row, leaving the second to last seat empty for the 'true participant'. The eight students responding before the 'true participant' would provide validation of the answers and the peer influence that we, the experimenters, were testing for. The 'true participant' would be seated in the second to last, not the last seat, to help eliminate ideas of contrivance. Assured that the 'true participant' was able to successfully read the diagrams, the experimenters were satisfied that as much control, causality and repeatability as possible was present without the 'true participant' suspecting any collusion. The only thing left was to execute the test to see whether or not he or she would conform to an obviously wrong answer under peer pressure. The 'true participant' was seated and a new slideshow of twelve slides was presented. An answer key to the slideshows was given to the first confederate in the row. The key had eight of the twelve answers correct, but four incorrect answers. These were shuffled randomly so as not to arouse suspicion in the 'true participant'. The first confederate sitting at the beginning of the row read from the scripted answer key as the experimenters presented the line test. The other confederates in sequence were instructed to repeat the answer of the first confederate, despite its truth value. When the question reached the 'true

participant', the responses were mixed. Some trials echoed Asch's results and some contrasted markedly. But in comparing trials the data presented a division along gender lines, and this outcome deserves attention as it may point to important sociological phenomena among teens.

- **Data**







- **Analysis:**

Over 75% of the participants in the conformity experiments went along with the rest of the group at least once when the answer was obviously wrong and the hardest question produced 75% conformity among participants, which is not really surprising since this question exhibits the smallest discrepancy between correct and incorrect choices.

In comparing males and females for conformity, our test results showed that they were more or less equal in how they conformed. Males conformed 45.5% of the time and females conformed 54.5% of the time. But the variance from these average percentages tells a bigger story: The test results showed that males either conformed 100% or 0%. This implies that males stayed consistent throughout the tests and never 'changed their minds'. This appears in stark contrast to females, who usually on the first test voiced what they believed to be the right answer but then went along with the confederates as the test progressed.

Does this reflect a sociological pattern? In terms of peer pressure, our data suggests that males will either give in to peer influence right away or not at all, while females may suspect peer influence but willingly capitulate to it anyway.

A teenage girl may be invited to a party suspecting that it is a 'bad' idea, but will go regardless in order to fit in. With more peer influence she may be pressured to drink or do drugs. According to Yale University, "Peer pressure is a well-documented sociological phenomenon: people tend to act how they see all of their peers acting" (Yale). Conformity is an important issue that was tested here, but this experiment begins to shine a light on the psychology behind teen conformity: It suggests that there are differences in male conformity, which the data suggests is more absolute in nature, and female conformity which tends to increase as the level of peer pressure increases. It is noteworthy that in this series, there was never a test where a female did not conform at least once.

- **Discussion and Relevance**

Asch performed his conformity experiment in the 1950s, a time when people were subject to more conformity, especially in the area of gender roles. In the 70's and 80's, people were encouraged to express themselves and their individuality. Therefore, many updates to Asch's tests have since been conducted to test whether conformity during Asch's time varies with conformity in our time and society. Conformity is a major component of teen peer pressure, which thanks to the internet and social media, seems more significant now than ever.

As teens this experiment was especially relevant to us. We were surprised by our results; at how easy it is for teens to give in to peer pressure. Teens are not fully mentally developed. They are much more impressionable and do not have the experience and sense of self from which adults can draw. To be part of a group, young males may go 'all in' and align their personalities with the group's in order to belong. Young women may act against their better judgment to be accepted by their peers. They are more likely to be influenced by social media or the opinions of others. Therefore a test of conformity, like the Asch test, can be very revealing when applied to teenagers. In a study entitled, "The gender difference of peer influence," Li Han, the author, states, "[..this study..] is compatible with the social psychology theories that females are more influenceable, especially by their friends and close peers." Creating programs or institutions for today's teens must be done with teen social psychology in mind.

A healthy environment is one where teenagers can express their opinions without fear of rejection, come to know themselves and build their personalities. Teenagers must learn how they relate to social groups without blindly conforming to the identity and policies of the group.

In an article that discusses gender differences in conformity, authors Diana Mattingly and Phillip M. Carter have results that showed that women were more likely to conform to gender role stereotypes, while men were more likely to conform to status interpretations (Eagly & Carli, 1981).

- **Post-Test Interviews of 'True Participants'**

"As the trial went on I felt more need to conform, as if I was doing something wrong." This participant succumbed to peer pressure. Even when the answer was obvious, she still conformed.

"I was seeing my peers who are really smart saying the answer was A so I went along with it." This participant wanted the validation of their peers and conformed.

"At first I was peer pressured to answer like everyone else but then I realized I was smarter" This individual has a lot of self confidence and went with her gut after she conformed once.

"I am so confused because everyone else was saying the wrong answer but at the time I wanted to be like everyone else and I was embarrassed to feel wrong." This participant was confused and did not want to feel embarrassed so she conformed.

"I don't know why I chose it, I just wanted to be the same as everyone else."
She gave into peer pressure.

"That test was easy. I don't know why everyone was getting them wrong. Like every single person down the line said the wrong answer. I started

second-guessing myself but it was obvious." This male participant did not conform once since he had the confidence to adhere to his beliefs.

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Novel Altometer Based on Acceleration and Pressure Changes by Abigail Rutta and Benjamin Zareh

- **Background [Identifying need]**

Children, due to their nature, easily get hurt climbing tall places: from where they are susceptible to falling. Current fall detection technology senses the fall and then calls emergency contacts. While summoning assistance and treatment for falling-related injuries, people still ultimately get hurt. A proactive and preventative solution would use the altitude of an individual to determine whether or not he/she is in a dangerous position (such as up a tree) and if so, to alert the appropriate contacts. This will allow someone to receive help before they fall and get injured, saving time, money, and potential life threatening injury. However, determining someone's change in altitude accurately is not easy since current altitude sensors are either expensive and/or are subject to large error. In just March of this year, Olivia Burgener's 11 year old daughter, Swayzie Blocker, climbed 100 feet up a tree and got stuck. By the time the authorities arrived to rescue her, she had climbed down to 80 feet, and the 55 foot ladder of emergency services couldn't even reach her. Luckily, Swayzie was brought down safely and recovered after a visit to the hospital. Swayzie was fortunate in that she was old enough to be alert and compliant with the authorities that came to save her. However, younger children that are not yet fully aware may not be able to prevent themselves from getting in these situations and don't know how to protect themselves. At just the age of two, Lee-Anne Maier's son Theo was able to climb to the top of the 12 foot net at the playground. Mathilde Duflos, a developmental psychologist, says that around age one or two, toddlers typically go through a phase where they want to climb everything (Milne). Climbing is often a child's first encounter with proprioception and coordination of their limbs. However, climbing is a major safety hazard for every curious child.

Accelerometers and barometers have shortcomings and therefore so are most altimeters that are based on one of these sensors. Current inexpensive accelerometers have large amounts of 'noise', which reduces their accuracy. Current accelerometers have a mass that presses against a crystal when

accelerating. Based on the current output by the crystal, the magnitude of the acceleration linearly can be measured. By having three of these along the x, y, and z-axis, the acceleration vector can be calculated from its axial components. However, gravity will always apply an acceleration vector along the z-axis despite no movement along the z-axis. This adds background interference to the accelerometer because the slightest inaccuracy in the measure of such a large acceleration will skew the displacement measurement dramatically.

In theory, one should be able to determine the change in vertical displacement (ie: height) of an accelerometer by integrating the acceleration values of the z-axis twice with respect to time. Some assumptions have to be made in order to use this method. First, one must assume that the accelerometer has no initial velocity with respect to the Earth. Second, one has to account for gravity by subtracting the gravitational acceleration from our Z axis, or else the accelerometer will appear to accelerate toward the center of the earth at 9.8 m/s^2. However, this method of finding the change in elevation is highly inaccurate at determining the displacement along the Z axis because the large interference of the accelerometer gets amplified significantly by the double integration. Ultimately, this makes most accelerometers an unreliable measure of elevation.

Changes in elevation can also be measured from pressure changes. Pressure changes, however, can be caused by changes in weather patterns, temperature, and humidity. Trying to derive the change in altitude of a device, using a traditional barometric pressure sensor alone, proves unreliable since the device will interpret any change in pressure for a change in altitude. This means that no matter how accurate the barometer is, there will be inherent noise when recording changes in height based on barometric data.

- **Abstract**

Due to their nature, children often get hurt climbing tall structures. Conventional fall detection technology senses a fall and calls for help. We aim to prevent this issue by calling for help when they are in such a situation before

they fall. However, current technologies that detect altitude changes are either expensive or inaccurate. In this project the cost and error of these sensors has been reduced by a multiplexing of two of them: an accelerometer and a barometer. First an accelerometer was used to determine sensor movement and if it was we assumed that any change in pressure would be caused by a change in altitude. However, if the accelerometer detected no significant changes in motion, the pressure sensor would be calibrated to negate external environmental pressure. The goal was achieved: the device displayed a constant altitude when stationary, while measuring the change in altitude when it was in motion. There are minor shortcomings in the design that will be mitigated upon future research.

- **Methodology**

Due to natural barometric drift and inherent inaccuracy of accelerometers, it is difficult to calculate changes in altitude using only one sensor. This project aims to resolve this by multiplexing two sensors to mitigate the 'noise' in each. If one sensor detects movement when the other sensor does not, the measurement is labeled a false positive and the sensors are recalibrated to show no movement.

First the barometer is allowed three seconds to measure and connect for current pressure. Pascal's law states that change in Pressure = density * acceleration * the change in height. With Gravity (acceleration) and the density of air treated as constants, in this equation the measured pressure can be used to determine current altitude. The successive differences between altitude values are then summed to calculate our total change in elevation.

Next, the change in vertical acceleration was measured to first determine whether or not the device was in motion. If the measurement exceeded an acceleration change of .15 meters/second/second, it was assumed that the device was in motion. Then, the barometric pressure was used to derive altitude change if the device was indeed in motion. If there is an insignificant change in acceleration, however, it is assumed that the change in altitude is zero and the barometer adjusts by subtracting the difference between the previous moving value of altitude and the current value of altitude. The same subtraction is done

to any later pressure altitudes. This should allow correction for any external pressure changes that occur when the device is not truly moving.

After collecting predicted altitude values, 100 consecutive elevations beyond threshold (set at one meter in altitude) were recorded. With 100 consecutive positive points, the device assumes movement beyond threshold and that it should trigger (In the case of this experiment a change to the background of the phone was triggered). This additional measurement delays the response to passing the threshold by 1.7 seconds but in doing so prevents many potential false positives.

This was coded onto an Android phone and the phone was used as the device for the purpose of this test. The phone's processor was able to record data about every 17 ms.

Next, the predicted altitude of our algorithm was compared to the barometric pressure alone and the acceleration alone. Two different types of trials were conducted: a control test where the phone was kept stationary and a motion test where the phone was lifted up and down. Going forward a solution to negate barometric drift should be undertaken.

- **Data**

After testing the device and comparing it to barometrically derived altitude and elevation from the accelerometer, the goal of creating a more accurate altitude sensor was achieved. After collecting and analyzing the data the device was able to adjust to measure no movement even when the barometric data suggested otherwise. This is shown in Figure 1 where the algorithm predicted a change in altitude of 0.0m when the barometric pressure data alone in the same test showed a fluctuating prediction of altitude throughout the test. In the up and down tests, as portrayed in Figure 2, our algorithm was able to properly detect a true change in height and measure its magnitude while at the same time recognizing when it was not moving.

Figure 1

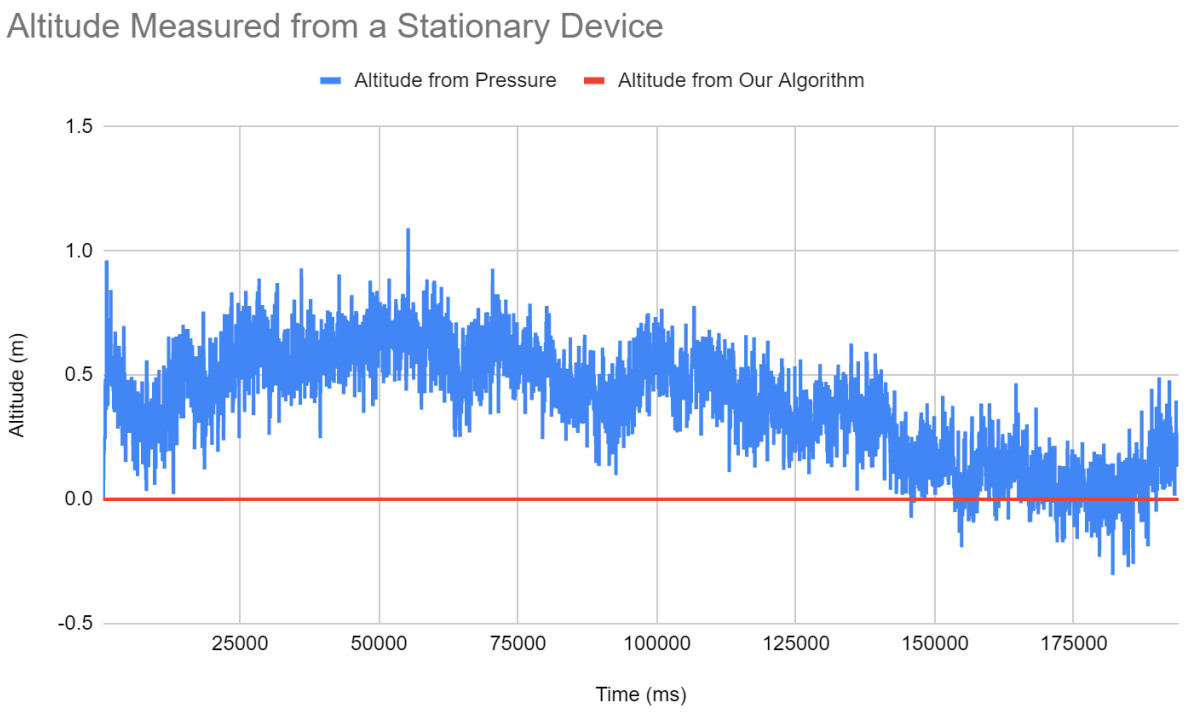
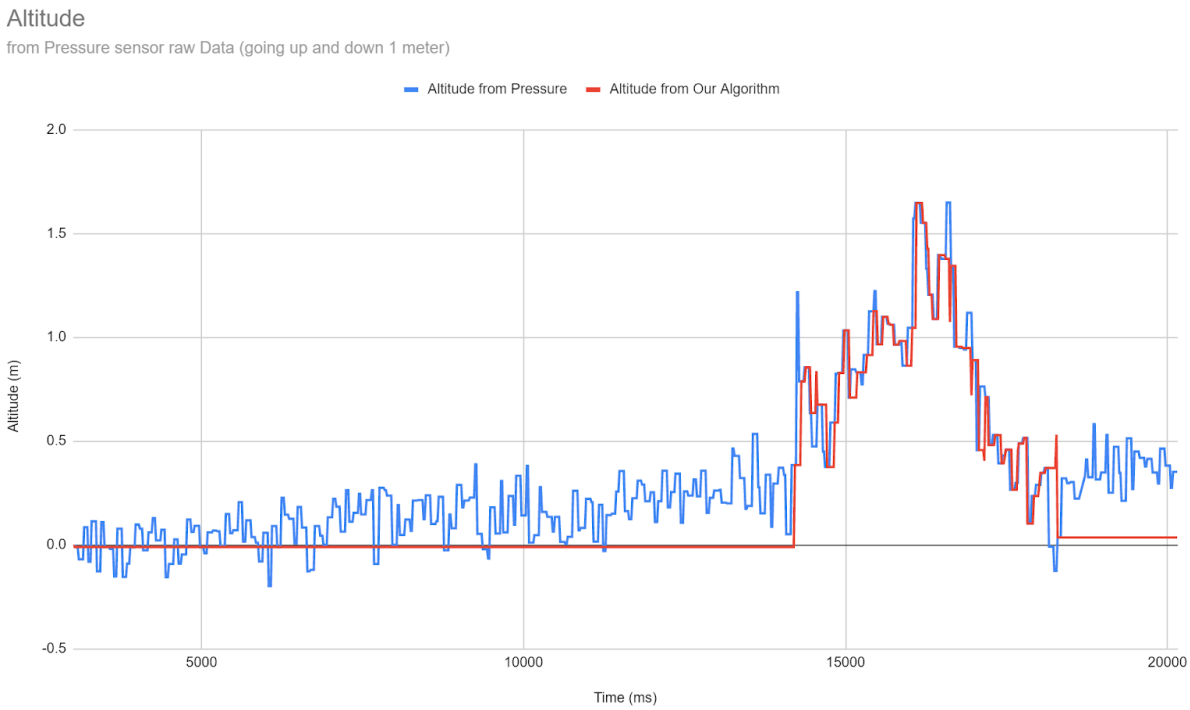


Figure 2



The altitude derived from acceleration, was inaccurate in its calculation such that finding the vertical displacement did not yield meaningful results. After one minute of recording data when the phone was stationary, the device calculated movement at 593 m/s, around 70% faster than the speed of sound, and 17.8 million meters from its starting position. This is evident in Figure 3 which displays the displacement prediction over the course of one minute. This can be remediated by subtracting the gravitational acceleration from the vertical acceleration. The calculated displacement after gravity is subtracted from the vertical acceleration is displayed in Figure 4.

Figure 3

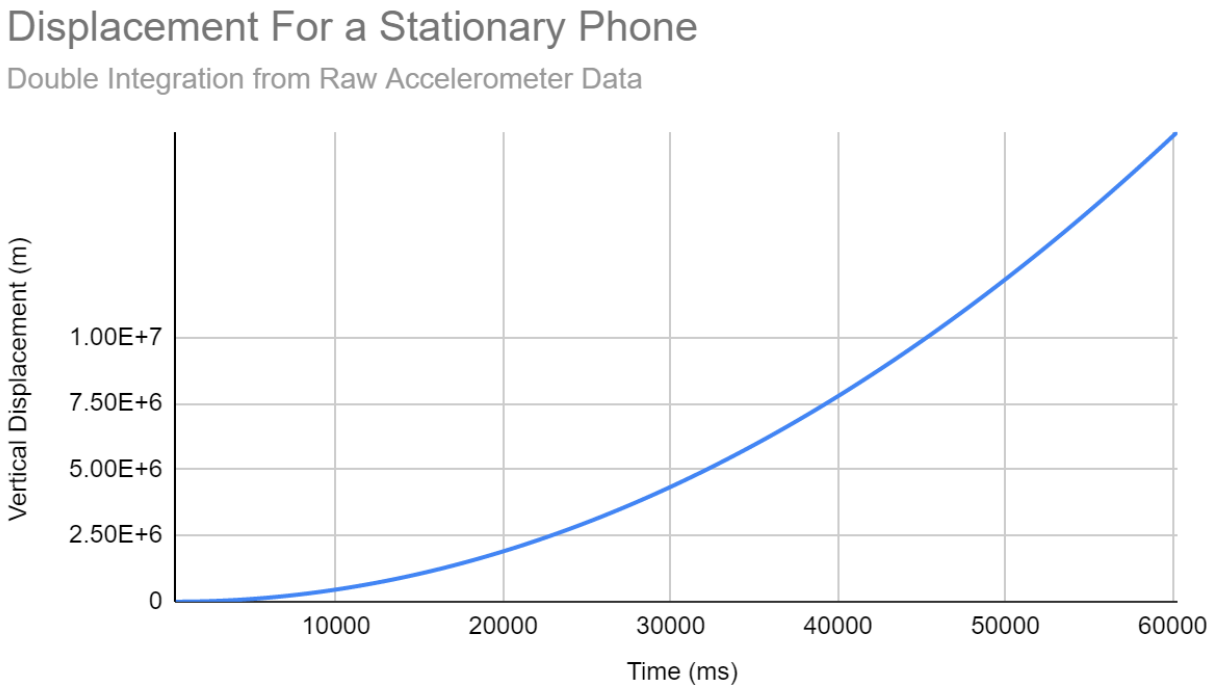
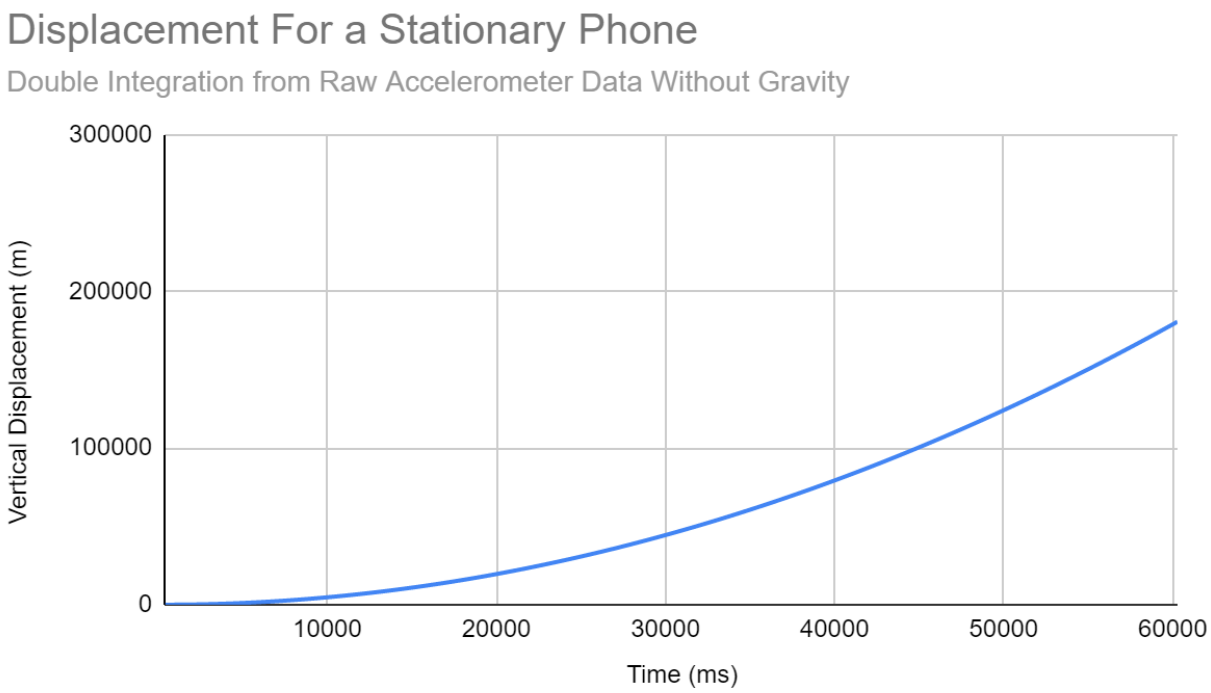


Figure 4



- **Discussion and Error Analysis**

Our project succeeds in reducing the uncertainty of an altimeter but still has a degree of inaccuracy. First, it records data every 17 ms. If a higher sample rate were implemented, it would yield a greater degree of accuracy which would reduce the margin of error. This could be accomplished in future research by either optimizing the code from which the algorithm runs or using a faster processor to run the program with a faster clock speed. Second, the device could mistake barometric drift for altitude changes if it were constantly in motion over a long period of time. Additionally, our algorithm still produces spikes in altitude which may interfere with the accuracy of new pressure values. This could be mitigated in future research by applying a low pass filter to the calibration algorithm. This filter would work by calculating the difference between the average of the previous few pressure values and the current pressure value. The magnitude of such an outlier would therefore become less significant because it would be averaged into part of the correct data set. Finally, our algorithm is still susceptible to some barometric drift over a long

period of time (>1 hour). While not as dramatic as the drift from the pressure sensor, alone it was found that given enough time, barometric drift would become prevalent. The barometric pressure from drift alone would be ~±8 meters while ours was a modest ~±2 meters.

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Flyers vs Fryers: Comparing the Wing Bones of Different Avian Species By: Elisheva Lemonik and Shana Monas

The effect of Calcium on bones strength

This experiment originally began to take shape in our freshman year of high school. We'd first heard about the idea from a presentation that included the idea of taking calcium out from chicken bones. Bird bones are relatively similar to the bones of humans. Bird bones have the same organ system as mammals. An example of convergent traits shared by birds and humans is that they are both "warm-blooded" (or endothermic), even though their most recent common ancestor was "cold-blooded" (or ectothermic). Birds and humans also both have an efficient, four-chambered heart rather than a two or three-chambered one. Bird bones help demonstrate the effect of Calcium in bones which is what this experiment is testing. Both mammals and birds have internal skeletons made of bones Since that presentation, the experiment underwent several changes. For one, we eliminated the chicken bones completely and substituted them with quails, because the densities of the bones were closer than that of pigeons and chickens. Once we had the densities for all the bones of both species, we set half aside to decalcify them. This was accomplished by soaking the bones in vinegar for four to five days. The decalcified bones were soft and bendable, meaning our breaking process took many different clamps and attempts to find the best possible way to suspend weights from the bones. After exhausting the regular weights from the lab, we discovered that the bones were much tougher than we thought, and adjusted our experiment to suspend sand instead. The overall process was long, but the results were rewarding after such a process. The results are shown in the tables.

Abstract:

Six sample bones from four different groups were obtained and cleaned. This project included six calcified Pigeon wing bones, six calcified quail wing bones, six decalcified pigeon wing bones, and six decalcified quail wing bones. A total of twelve bones were decalcified by soaking them in acetic acid. Stiffness and strength were measured by suspending weights midspan and identifying the angle of bend and the point of failure. In this way a comparison

was made between birds with flying wings and birds with vestigial wings, insofar as our two specimens would allow.

The purpose of the experiment is to study the differences in wing bones in flying birds vs non-flying birds. The experiment was conducted on quail and pigeon wings, due to their similar densities. To conduct this experiment, half of our obtained bones were decalcified, before each end of the bones were individually placed on a support, with weights suspended from the center until breakage or failure. The results found were fascinating - the quail bones broke at around the same weight range for both calcified and decalcified, while the calcium in pigeon bones had a much more visible effect.

The evolution of flying birds is a topic that greatly interests scientists studying evolutionary biology. It's believed that birds are descended from a group of dinosaurs called theropods, which lived during the late Jurassic period (Approximately 150 million years ago). While early birds were likely not very efficient fliers, they gradually developed various adaptations that allowed them to become better at flying, such as aerodynamic bodies, powerful wings, and more efficient respiratory and cardiovascular systems. However, while most birds are capable of flight, there are some that are not. Other species of birds evolved to their environments differently, such as quails. Quails adapted to live on the ground, with smaller, rounder wings that are unable to sustain flight. This evolution has aided them in foraging for food, and running and hiding from predators in low to the ground vegetation. The loss of flight has many possible factors, most likely being a change to their environment. The ongoing studies of avian evolution help uncover the mechanisms that drive evolutionary changes and adaptations. Currently, birds are among the most successful groups of animals on Earth, with over 10,000 species inhabiting virtually every environment on the planet.

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around the same weight range for both calcified and decalcified, while the calcium in pigeon bones had a much more visible effect.

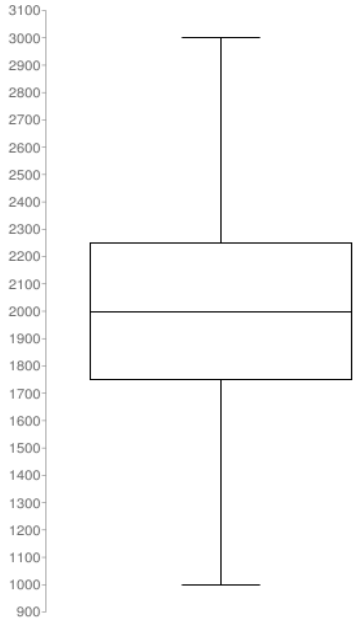
It is expected for the quail wings to break more easily when calcified and decalcified. Quails are terrestrial birds, and therefore would have less support and less calcium in their wings than that of Pigeons. Pigeons are flying birds which means that more calcium/support is needed in their bones. Therefore, it is expected that the wing bones of pigeons will be harder to break. Although, it is of course expected that the bones will break more easily when decalcified (just because the quail and pigeon bones are decalcified does not mean they will break with an equal amount of weight).

Bones of different species of birds were obtained, cleaned and labeled. Using surgical scissors, the wing bones were detached from the bird and boiled to remove any excess feathers that were remaining on the wing. The two specimens were Pigeon's (flying birds) and Quails (terrestrial birds). The bones were separated into left-side and right-side groups. One group (of twelve; six pigeon, six quail) was soaked in vinegar for four to five days to decalcify them, while the other group (of twelve; six pigeon, six quail) was left alone. To measure the strength of bones both calcified and decalcified, each end was placed on a support and weights were suspended at the center until the point of breakage or failure. Results were recorded and analyzed.

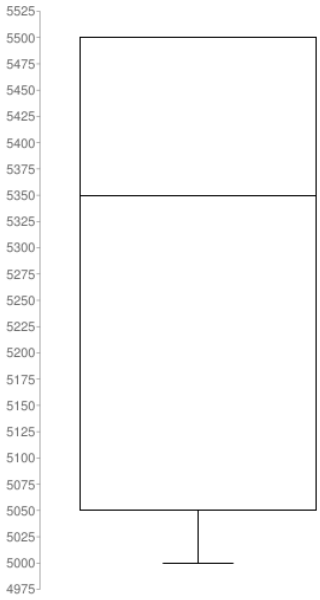
This type of research is used to test the integrity of structural components in building aerospace structures. Stress testing on bones is a useful tool for assessing the strength and density of bones, which was the aim of this experiment. Bones are composed of a complex mix of tissue and minerals, with calcium being the primary mineral component. Calcium plays a crucial role in the mineralization process of bone, which helps give it strength and rigidity. Studies like these are useful for gathering information and increasing the performance of aerospace structures. The skeletons of birds are universally described as lightweight as a result of selection for minimizing the energy required for flight. In fact, bird bones can adapt in response to mechanical stress. This could be useful in aviation engineering where lightweight structures are needed.

From this experiment we can conclude the hypothesis (Recall: If the strength of wing bones are tested between flying and relatively flightless birds, then the bones of the flying birds will be stronger) of this experiment is supported. The wing bones of the pigeons consistently held more weight than the quail bones, with and without calcium. Although statistics do not show a significant numerical difference in breakage points of decalcified wing bones, calcium did play a major effect on the rigidity of the bone (sample bones can show the softness in the bones after decalcifying). Results are shown in the graphs. There is a lot that can be gleaned from this experiment. This study can be adapted or continued to include more species of birds and assist in the future of human flight.

Decalc. Quail Wings

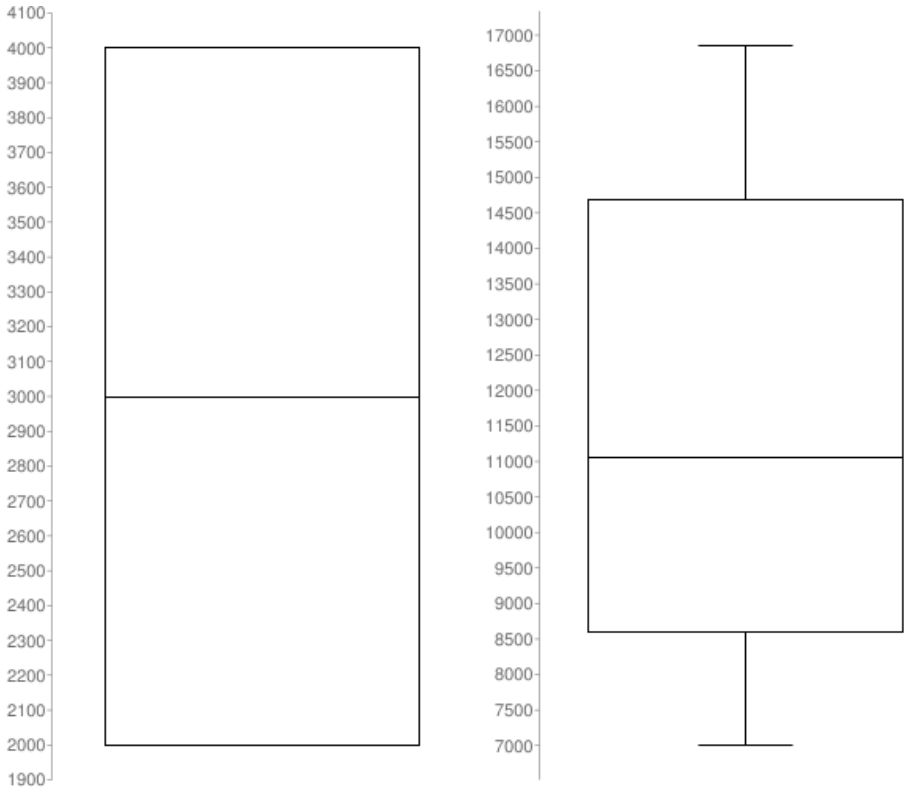


Decalc. Pigeon Wings

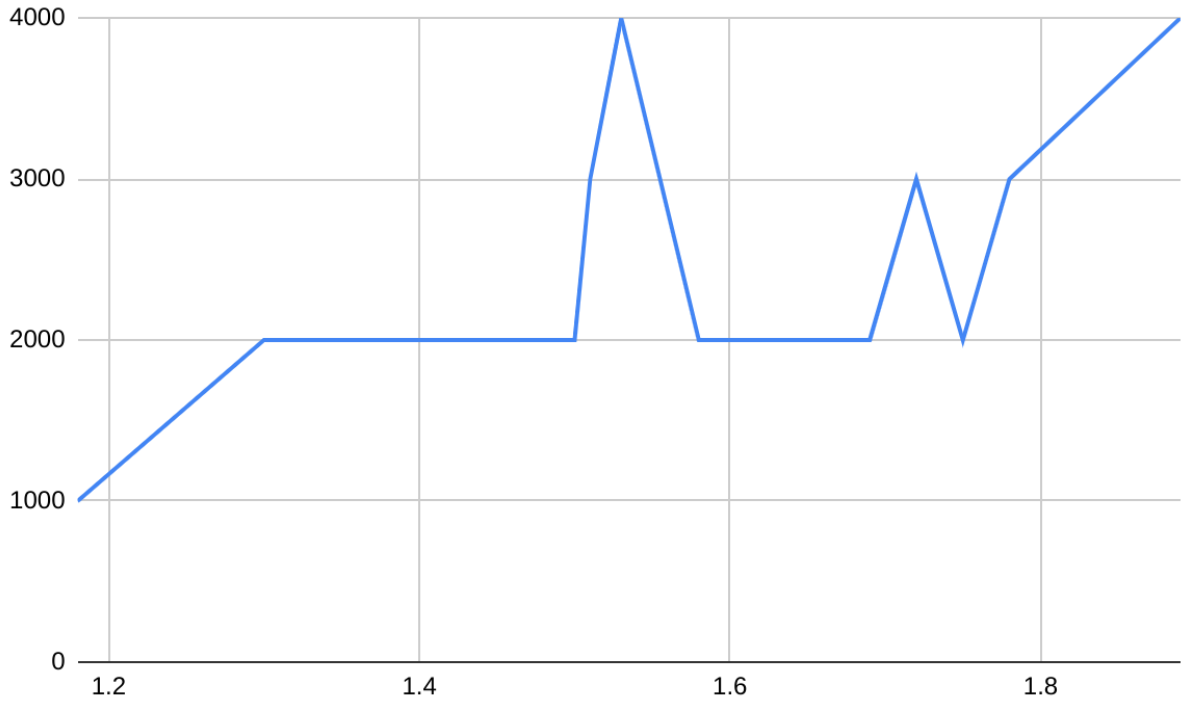


Calc. Quail Wings

Pigeon Wings



Quail Wing Strength Vs Densities



Pigeon Wing Strength Vs Densities

A Study On (simulated) Lunar Soil: Challenges to Biological Growth, Likely Soil Composition Variation, and Potential Remediation for Biological Disadvantages By: Abby Rutta

In May of last year, at the University of Florida, a team of three researchers worked together to plant Arabidopsis thaliana and successfully grow plants in lunar soil for the first time. Also known as Thale Cress, this crop has a short generation time of just 6 weeks, and can grow with limited amounts of light. These characteristics make it a very ideal crop to test with lunar soils, in addition to the fact that it's able to grow in small amounts of soil. Though the Arabidopsis thaliana plants that were grown were not nearly as robust as Earth-grown plants, the mere fact that they were able to grow is a breakthrough that has changed the world of lunar research. After this breakthrough, now that we know that real lunar soil can actually support plant life, it is crucial to figure out how to maximize and nourish these plants for the most optimal crops possible.

The driving questions behind my study - What are the challenges to growing crops on the moon? How will common variables of lunar soil come into play, and how can biological disadvantages be overcome? In this study, radish seeds were planted in a substrate regolith that has a similar soil composition to two predominant areas of the moon: lunar 'highlands' soil (LHS) and lunar 'mare' soil (LMS) to evaluate the potential for lunar soil to support basic crops, as well as in terrestrial potting soil (TS) as a control. Radish was chosen to be planted because it is a robust crop plant with a very quick maturation rate. Three radish seeds were planted in each pot.

Sources point out that silicon dioxide is a significant component of 'highland' soils (Lindsey, J., 1976). This silicon dioxide is formed from impacts on the surface of the moon, but its concentration varies with altitude. To account for this variation, three of the LHS plants were planted with glass fragments added in. To approximate the high iron content of the 'mare' soils, three of the LMS plants were planted with added iron filings.

To compensate for the lack of nutrient content in lunar regolith, lima bean seeds were planted as another variable. Lima beans, which are members of the legume family, host bacteria that can fix nitrogen into nitrate, which plants

use for protein synthesis. Three plants from the LHS, LMS, and TS groups were co-planted with two lima bean seeds in their soil. Three more plants from each of the three soil groups were planted with two lima bean seeds that were treated with rhizobium legume inoculant.

In addition to being individually watered, all of the plants had a wicking system that drew water up through the pot using capillary action. Water as a constant was never a limiting factor.

In total, there were 24 plants in TS, 24 plants in LHS, and 24 plants in LMS. All plants were planted on February 22nd, 2023 amongst 3 trays. An important detail to mention is that this study is limited to soil substrate and assumes an earth-like atmosphere and abundant water, which are concerns for future studies.

Error analysis: The artificial light that was used for the plants ran on a twelve hours on/twelve hours off schedule. On the moon, however, one day consists of about fourteen days of sunlight, and about fourteen days of darkness. Also, the sample size for the plants planted with lima or lima and inoculant was too small to draw truly reliable conclusions.

Results: Lunar highland soil (LHS) supports radish seed crops better than the lunar mare soil (LMS). ~23% of LHS pots grew at least one stem, with the stems reaching as tall as 53 mm, whereas 0% of LMS pots grew a stem. However, lunar mare soil supports lima bean growth better than lunar highland soil. 0% of the LHS planted with lima, with inoculant and without, grew lima stems, while the LMS planted with lima, with inoculant and without, had lima stem growth in ~16% of pots. The LHS with added glass simulating higher silicon dioxide at higher elevations on the moon produced no growth. The lunar mare soil (LMS) with added iron filings simulating the high concentration of iron in soils in varying areas on the moon produced no growth, and the soil became hard as the iron oxidized. Considering there are over one million lunar craters wider than 20 km with these iron-rich soils, remediation for this issue should be further studied.

Above all, however, the most significant takeaway of this study is that radish stems grew best when co-planted with lima bean seeds treated with rhizobium inoculant in soils previously described that otherwise did not sustain radish plant growth at all. The pots with lima and inoculant increased the growth

rate of the LHS by more than 43%. The combination of legume and nitrogen fixing symbionts may, as this study suggests, overcome the deficiencies in fertility evident in harsh lunar soils. On the moon, using legumes to bolster crop growth also serves as an additional food source, which is important considering the limited space and supplies that would be available for actually planting on the moon, in theory.

This discovery may establish a gateway, a first consideration, for further experimentation with other crops, to see how the benefits of lima seed and other nitrogen-fixing legumes affect other common crops. Further continuation of this study might include the examination and the comparison of the roots of each type of plant, as well as investigating productivity and possible changes in the nutrient content of the actual radishes and lima beans themselves.

Sofia LoPresti

Fixed Action Patterns in *Betta splendens*

Abstract

Animal behavior is broadly defined as observable muscular activity that is triggered by a stimulus (Campbell 2013). A fixed action pattern is an innate, instinctive, and automatic sequence of behaviors in response to a certain key stimulus. *Betta splendens*, more commonly known as Betta fish or Siamese Fighting Fish, are freshwater fish known for bright pigmentation, territorialism, and aggression in males. Aggressive posturing in these fish follows a modal-fixed action pattern. Research was conducted to document the fixed action pattern, and to test several variables to determine what exactly elicits the pattern in *Betta splendens*. Using a second male 'intruder' to elicit the fixed-action, an ethogram of the behavior was constructed. This baseline served as a control for comparison. Several cut-outs of different shapes and colors were used to determine what could reproduce the fixed-action pattern. It was determined that proximity and related color combined with movement best trigger the response. Shape it would seem has the least effect. Stimuli placed far from the fish failed to produce the response. Betta fish it would appear are near-sighted and have difficulty focusing on objects more than 2-4 feet away (Thomas 2022). This was evident in another observed behavior; classical conditioning. After repeated exposure to the pet owner, the fish began to recognize the owner's presence when close and, in a frenzy, swam up to the surface for food.

Fixed-Action Patterns

A fixed action pattern (FAP) is an innate, instinctive, and automatic behavior in response to a certain key stimulus (Mitchell 2013 Fig. 1). Once the response is triggered, a sequence of actions will follow, each of which must be completely executed in order to reach the end, even if the animal is exposed to other stimuli before it's finished. Fixed-action patterns allow researchers to

identify the ultimate cause or evolutionary reason for the behavior: How does the behavior improve the organism's chances of reproductive success?

Because it is innate, an organism can execute a fixed action pattern with no prior experience. It also does not require the animal to store new information on how to respond, which makes it optimal for animals with simple neural systems. The trade-off is that animals that have the ability to learn behaviors can adapt to new and changing environments, whereas those who are born with pre-programmed fixed-action patterns are not as flexible.

Betta splendens

Betta fish originated in shallow, fresh-water pools in Thailand over 400 years ago. The fish first appeared in Europe in the late 1800's. They are found in a variety of colors, and the males are generally more vibrantly-colored than females. This is common in nature where sexual selection is a strong genetic driving force. Betta fish were once bred for their fighting abilities to be used in sports competitions. Due to artificial selection, a more aggressive species of captive fish has been selectively bred. Thus doubly-selected, the fish soon began to be bred for ornamental purposes. Betta fish are now sought after for their bright colors and long, decorative fins, and now make cherished ornamental pets.

Male betta fish are extremely territorial and will instinctively fight another male that is within range. Combat can be avoided if the fixed action pattern is triggered resulting in a sequence of gill and fin deployments that constitute aggressive posturing that frightens away the intruder. This is in keeping with aposematic adaptations of other animal species that use color or display to frighten off would-be intruders, competitors or predators. FAP's are typically consistent and repeatable, as observed throughout the course of this experiment.

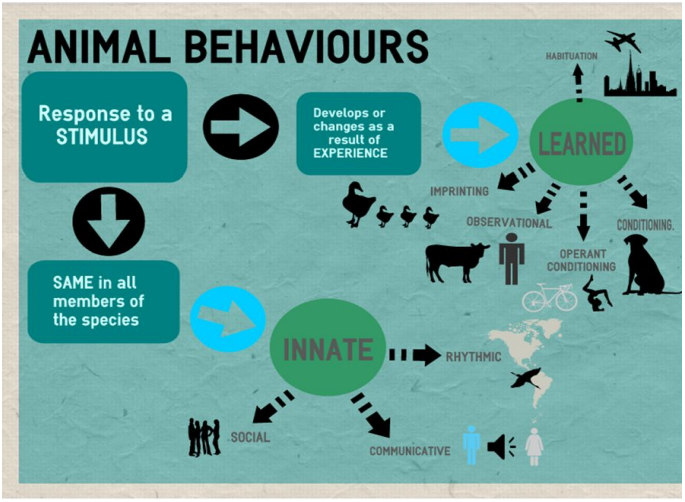


Fig. 1: The FAP is an Innate rather than a Learned Behavior

Betta Fish External Anatomy:

The primary purpose of fins is to aid in maintaining stability and balance, and provide motility through the water. *Betta splendens* have different types of fins, including a caudal fin, a ventral fin, a pectoral fin, a dorsal fin, and a pelvic fin. The caudal fin, also called the tail, provides the fish with a sudden burst of speed, which assists in propelling the fish forward. However, the caudal fins have lengthened over generations due to sexual and artificial selection, which has in turn resulted in slower movements. The dorsal and pectoral fins provide the fish with stability.

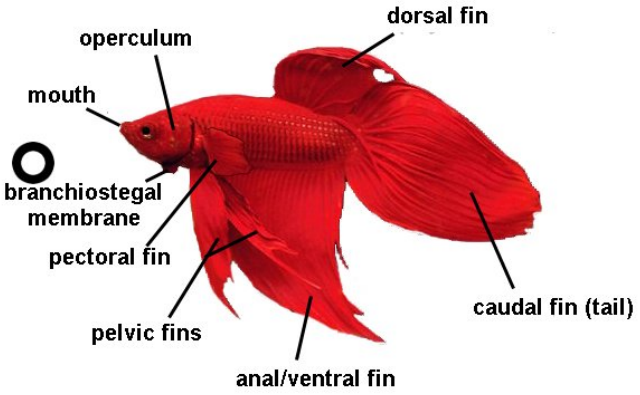


Fig. 2: *Betta splendens*, external anatomy

The Ethology of the Fixed-Action Pattern/The Observed Fixed-Action Pattern: Which one?

The observed fixed-action pattern was sequenced when the test fish was exposed to an intruder or to a mirror approximately 10 cm away:

1. Opercula (gill covers) open
2. The gills flare.
3. The ventral fin extends.
4. The pectoral fins begin to move rapidly.
5. The dorsal fin extends.
6. The caudal fin extends.
7. After an average of 7 minutes after stimulus removal, recovery begins.
8. The movement of the pectoral fins begins to slow down
9. The caudal fin begins to sag, and retracts completely.
10. The dorsal fin is still elevated, but begins to drop.
11. Gills and opercula retract

This pattern was found to be replicable and consistent when the fish were presented with the same stimuli: a second 'intruder' fish or a mirror within 10 to 20 cm. of the experimental Betta fish. This established a baseline or positive control for the study.

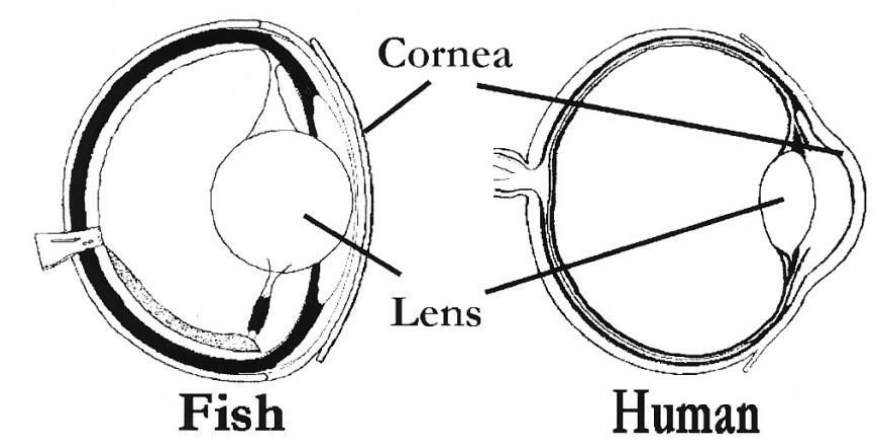


Fig. 3: Betta splendens can focus on objects up to a foot away.

Problem Statement and Hypothesis

Problem Statement: There is a pattern of behavior (FAP) exhibited by *Betta splendens* that is elicited by the visual stimuli associated with an 'intruder' fish.

Null Hypothesis: There is no correlation between the fixed-action pattern response of *Betta splendens* and the visual stimuli associated with an 'intruder' fish.

Experimental Hypothesis: A positive correlation between the response of *Betta splendens* and the visual stimuli associated with an 'intruder' fish will be observed as a fixed action pattern. The repeatability of the FAP will suggest that the response is innate, fixed, and sequential.

Isolating the components of the visual stimuli will shed light on exactly which variable(s) associated with the intruder is the stimulus.

Methodology:

Three blue and two red male betta splendens were observed over a period of 4 weeks. They were first monitored while alone during a one-week period of acclimatization. The fish were then tested against a mirror, with other 'intruder' fish, and with print-outs (colored and white) that were presented moving and stationary.

Negative Control: the isolated, acclimatized *Betta splendens* produced no response.

Positive Control: the test *Betta splendens* produced the sequential fixed-action pattern when exposed to both a mirror and an 'intruder' at a distance of approximately 10 cm.

Independent Variables: colored and white print-outs, some shaped like Betta fish, a mirror.

Dependent Variable: Elicitation of the fixed-action pattern.

With five fish to work with, each was alternated between the control group and being exposed to the independent variables.

Data

Stimulus	Response	Comments
None (Acclimatized)	None	Fish became habituated, therefore frustrated and pale in color. In order to prevent further boredom and stimulation from decreasing, new objects were added to their tanks.
Mirror	Full	Less aggressive than when exposed to another fish; pacing amount was the same. In addition, they began to build bubble nests upon seeing their reflections.
'Intruder' Fish	Full	Blue fish were more reactive than red fish– their reactions were more aggressive, and they paced more. However, no significant difference in gill and fin flaring.
White, Cut-Out Square (still)	None	
White, Cut-Out Square (mobile)	None	

White, Cut-Out Fish (still)	None	
White, Cut-Out Fish (mobile)	None	
Blue/Red Cut-Out Square (still)	Partial	The blue cut-out elicited a stronger reaction than the red one
Blue/Red Cut-Out Square (mobile)	Partial	The response was brief and fleeting.
Blue/Red Cut-Out Fish (still)	Partial	Both the red and blue fish were equally responsive. Both colors of the cut-outs elicited similar responses.
Blue/Red Cut-Out Fish (mobile)	Partial	Both red and blue fish were equally responsive; however, the red fish followed the cut-out less.

Discussion:

Upon exposing a betta fish to another one, there was no significant difference for gill and fin flaring between red and blue male betta fish detected. In addition, blue fish were found to exhibit more aggressive reactions, as well as 'pace' more than the red fish. However, red fish were found to be less reactive than blue fish. Upon introduction to the mirror, they were found to be less aggressive than when seeing another fish; however, the pacing was the same.

Also noted was the fish's ability to recognize its owner. After repeated exposure to the pet owner, the fish began to recognize and swim up to her as an example of classical conditioning.

An unexpected outcome of the experiment was habituation, which is decreasing responsiveness with repeated exposure to a stimulus. The habituation soon evolved into a confounding variable, as it interfered with the responses of the *Betta splendens*. The habituated fish, when exposed to another, briefly regarded the second fish and swam away without elicitation of a FAP.

Conclusion:

Betta splendens or Siamese fighting fish exhibit a fixed-action pattern– a pre-programmed, innate, and automatic response to a certain stimulus. Betta fish are responsive to other Betta fish and their own mirror reflection which formed a positive control for this investigation. The colored cut-outs elicited FAPs when moved regardless of the shape suggesting that Betta fish respond more to specific color and movement rather than the specific shape of the intruder fish. Want to avoid an aggressive encounter with a Betta fish? Wear white and stay still. It was concluded that the fixed-action pattern could indeed be artificially reproduced with various stimuli. Future research is warranted with more test fish.

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Lowest Lethality Dose (LDLO) of Various Seeds When Exposed to Detergent By: David Hanan

Abstract

This study determines the lowest lethal dose (LDLO) of detergent on various seeds. Plants provide food and countless ecological benefits but oversight in wastewater release contaminates natural and agricultural vegetation. Due to widespread pollution, plant survival is in danger, making food scarcity and climate change imminent threats. Detergent is a common pollutant in the environment which greatly contributes to water pollution and harms plants. A useful index for environmental testing is the LDLO, the lowest lethality dose that will begin to inhibit growth. In this study, a representative selection of seeds, cabbage (*Brassica oleracea*), beets (*Beta vulgaris*), yellow bush bean (*Phaseolus vulgaris*), and turnips (*Brassica rapa subsp*) are exposed to various concentrations of detergent ranging from .5 mL to .1 mL in an attempt to find the LDLO of detergent of each species. Results showed that cabbage seeds had the highest tolerance to detergent at .25 ml of detergent diluted in .25ml of water and beet seeds had the lowest tolerance at <.025 mL of detergent. Visual observations showed that the outer layer of bush beans became an abnormal shade of black from its usual light yellow hue. The results of this experiment reveal that cabbage seeds can tolerate higher doses of detergent as demonstrated by higher germination rates. The study suggests that cabbages can survive in areas exposed to higher concentrations of detergent. However, beets should not be planted in areas containing even small traces of detergent.

1.**Introduction**

1.1 Germination

Germination is the sprouting of seeds into plants after a period of dormancy. Germination will occur in a seed that has sufficient amounts of water, oxygen, light and correct temperature. The amount of time a seed takes

to germinate can vary based on its environmental conditions. Depending on the sensitivity of a seed to its environment, some seeds have the ability to germinate at a quicker rate than others. Before germinating, seeds conduct water imbibition which allows water to diffuse into the seed. In addition, proteins are synthesized and food is stored within the seed in the forms of lipids and carbohydrates. (Awatif S. Ali and Alaaeldin A. Elozeiri. 2017). The germination of a seed is visible when the cells in the seed's radicle, the seed's protrusion which develops into the root of the plant, elongates from absorption of water causing the radicle to penetrate the endosperm of the seed. Once a seed germinates, the lipid and carbohydrates stored prior to germination are used to support plant growth (Bewley. 1997).

1.2 Detergent's impact on plants

Detergent is a common pollutant in the environment making it dangerous to plant life. High levels of heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb) and mercury (Hg) are all found in detergent (McGrath 1990). These heavy metals inhibit a seed's ability to conduct photosynthesis and hinders enzymatic activity. Surfactants in detergent which aid in trapping dirt when clothes are being washed, cause soil to become water-repellent when released into the environment, preventing seeds from getting water needed to germinate (Shafran. Ronen. Weisbrod. Adar. Gross. 2006). Detergent has a pH of 10 making it a basic mixture. When high quantities of detergent are released into the environment the pH of water increases, becoming basic. water absorbed by seeds results in an inhibited ability to conduct photosynthesis which damages the seed prior to germination to its adult stage (Christensen 2017).

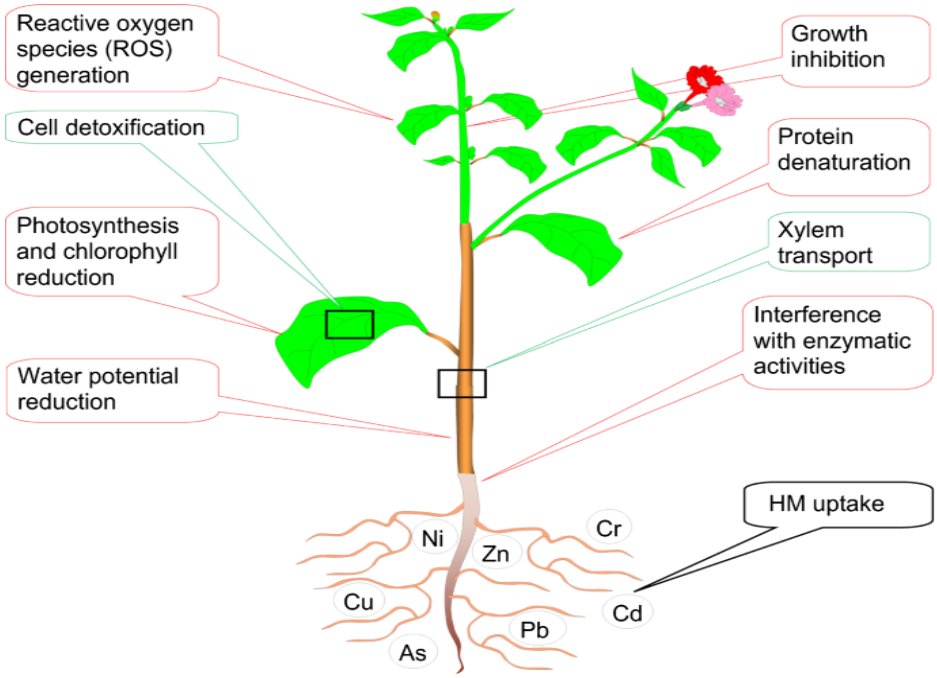


Figure 1: Absorption of Heavy Metals in Detergent. Heavy Metal uptake by seeds and plants from pollutants in the soil such as detergent hinder photosynthesis, growth and enzymatic activity which a seed requires to germinate and grow.
https://media.springernature.com/lw685/springer-static/image/art%3A10.1007%2Fs42452-021-04301-4/MediaObjects/42452_2021_4301_Fig1_HTML.png

1.3 Effect of decreased plant life on the environment

A decrease in plant life due to liquid pollutants negatively affects the environment. Plants absorb carbon dioxide for photosynthesis. The decrease in plant life results in an increase in the amount of carbon dioxide in the atmosphere. The high level of atmospheric carbon dioxide speeds up climate change because it is a greenhouse gas which traps heat emitted by the sun and releases it back to the earth (Fecht. 2021). As a result, abnormal natural disasters such as heat waves, wildfires, tornadoes and hurricanes occur more often. The increase in climate change causes further decrease in plant life, resulting in an unhealthy feedback cycle. The higher temperature dries out seeds preventing germination. Plants would be forced to grow longer stalks and

have smaller leaves in an attempt to cool themselves. The length of the stalks would leave the plant unsupported and unstable, eventually breaking (Marsh 2021).

1.4 Effect of decreased plant life on the economy

Agriculture is a major part of the United states economy. In 2019, the agriculture industry generated over a trillion dollars, 5.2 percent of the U.S. gross domestic product (GDP). As of 2020, 2.6 million jobs in the U.S. are direct on-farm employment. On-farm jobs, combined with all agricultural and food related industries add up to 19.7 million jobs, 10.3% of U.S. employment (Kassel. Martin. 2021). Agriculture is highly climate dependent, sensitive to sudden temperature and rainfall changes (Tun Oo. Van Huylenbroeck. Speelman. 2020). Harm to this sector would severely damage the economy. The probability of crop yield failures are projected to be 4.5 times higher by 2030 within many bread basket countries that are major producers of grains including the United States (Caparas. Zobel. Castanho. Schwalm. 2021). Crop failures will result in the loss of thousands of jobs and a sharp drop in the economy.

1.6 Purpose

The focus of this study was to find the lowest lethal dose (LDLO) of detergent to cabbage seeds (*Brassica oleracea*), beet seeds (*Beta vulgaris*), yellow bush bean seeds (*Phaseolus vulgaris*), and turnip seeds (*Brassica rapa subsp*). The lowest lethality dose (LDLO) is the amount of a substance that will begin to inhibit a population. Discovering detergent's LDLO to these seeds provides an understanding of which seed is most capable of growing in an environment with higher levels of pollution. Soil usage can be conducted efficiently as seeds which have a higher tolerance to pollutants such as detergent will be grown and have high germination rates in such areas. Pollutant sensitive seeds should not be grown in these areas as they will die out.

2. Hypothesis

Alternative Hypothesis (HA) **-** Detergent will have the highest LDLO to cabbage seeds and the lowest LDLO to turnip seeds.

Null Hypothesis (H0) - The germination of the various seeds will be unaffected by the detergent.

3. Materials and Methods

3.1 Plant Growth

Petri dishes were covered with two layers of filter paper. Ten seeds from a specific species were put into a petri dish for every experimental group and the control group as a representation of a population. Each dish received 10 grams of water via a pipette at the beginning of the experiment and none for the rest of the experiment. Seeds were grown at room temperature (22 °C) for 7 days.

3.2 Exposure to Detergent

Six experimental groups were created for each of the four types of seeds, each with a different concentration of detergent. Water was used as a diluent for the lower concentrations of detergent. Detergent and water were administered into each group via a micropipette. Group 1: 100% detergent (.5 ml). Group 2: 80% detergent (.4 ml) and 20% water (.1ml). Group 3: 60% detergent (.3 ml) and 40% water (.2 ml). Group 4: 50% detergent (.25 ml) and 50% water (.25 ml), Group 5: 40% detergent (.2 ml) and 60% water (.3 ml). Group 6: 20% detergent (.1 ml) and 80% water (.4 ml). In addition, a seventh control group was created.

3.3 Visual Observations

Visual observations such as abnormality in the color of each type of seed at different concentrations of detergent were recorded throughout the seven day period of germination.

3.4 Germination Rates

At the end of the seven day germination period, the amount of seeds that germinated in each petri dish were recorded.

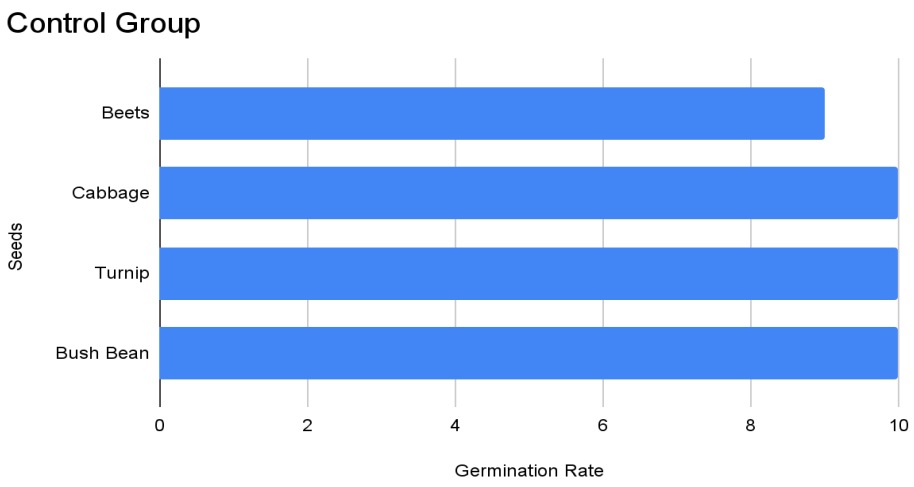
3.5 Further Experimentation of Beets

The LDLO of beets could not be found from the 7 original experimental groups. 3 additional petri dishes were made to find the lowest lethality rate of beet seeds. The amount of detergent administered in these petri dishes were .075 ml, .050 ml and .025 ml. After seven days the germination rates of the beet seeds in these additional experimental groups were recorded.

4. Results and Discussion

4.1 Control Groups Germination

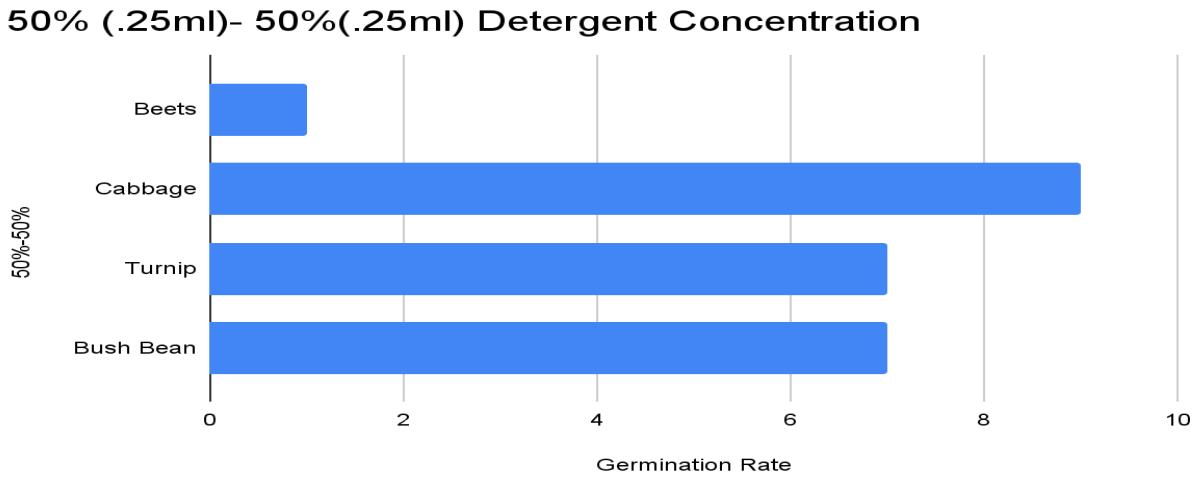
All the control groups had a 100% germination rate aside for the beet seed control which had a 90% germination rate.



Graph 1: Control Group Germination Rates. All seeds had a 100% germination rate aside for the beet seeds which had a 90% germination rate.

4.2 Cabbage Seed Germination

Cabbage seeds had the highest tolerance for detergent out of all the seeds. Detergent's lowest lethality dose to cabbage was a contraction of 50% detergent (.25 ml)-50 water%(.25ml). At 100% concentration of detergent (.5ml), cabbage had a higher germination rate then the other seeds at 50% while yellow bush bean and turnip seeds had a 10% germination rate and beet seeds had a 0% germination rate. The visual appearance of the cabbage seeds were normal - radicles were white and leaves had a light green hue, signifying a healthy germinated seed.



Graph 2: Germination rates of seeds to 50% detergent (.25ml) 50% water(.25ml) concentration. Cabbage seeds had a 90% germination rate, with only one seed out of the ten not germinating, elucidating detergent's LDLO on cabbage seeds at 50% detergent (.25ml) 50% water(.25ml).

4.3 Beet Seed Germination

Beet seeds had the lowest tolerance to detergent. When exposed to 100% concentration of detergent (.5ml) and 80% (.4ml) of detergent and (.1ml) of water beet seeds had a 0% germination rate. In all other experimental groups beet seeds had a 10% germination rate (one seed germinated). Further experimentation was conducted in an attempt to find detergent's lowest lethality dose to beet seeds. Additional experimental groups were created - .075ml, .05ml and .025ml of detergent within the 10 grams of water. Beet germination did occur at these lower concentrations, however only a 20% germination rate reached a contraction of .025 ml of detergent. Among the few beet seeds that did germinate, their leaves were shriveled and had brown colored patches signifying the severe damage caused by the detergent.

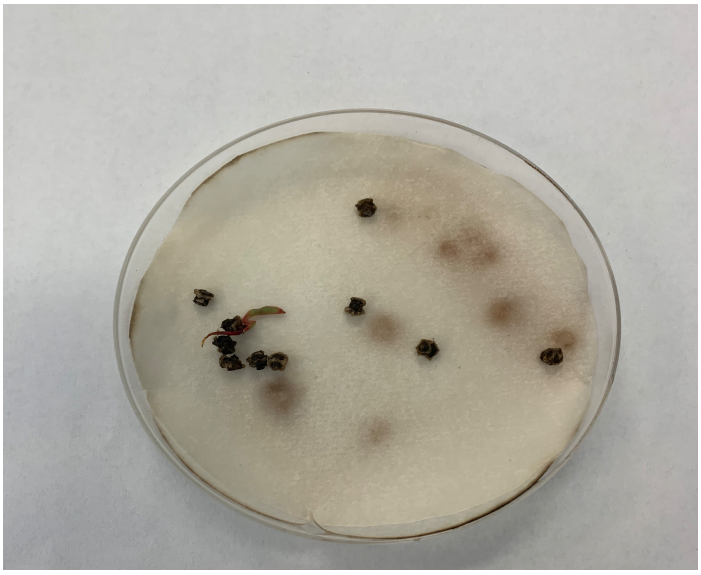
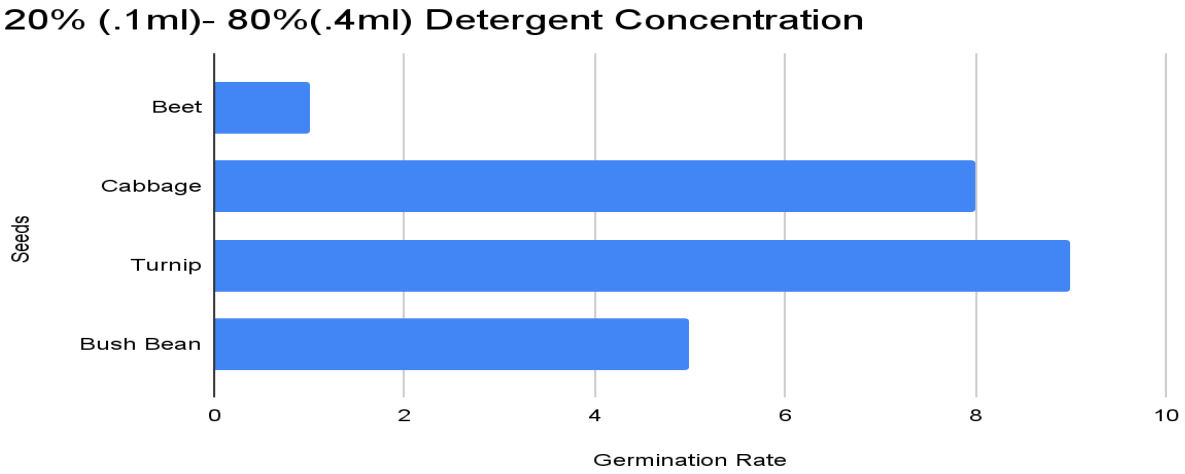


Figure 1: Petri dish of Beet seeds at a concentration of 20% detergent (.1ml) 80% water (.4ml). At the lowest contraction of detergent, beet seed germination was 10% as visible in Graph 2. The leaf of the single germinated beet seed is shriveled and has a brown hue, signifying the sensitivity of beet seeds to detergent.



Graph 3: Germination rates of seeds at a concentration of 20% detergent (.1ml) 80% water (.4ml). All seeds had a distinctly higher germination rate when administered with 20% detergent (.1ml) 80% water (.4ml), having a 50% and higher germination rate, excluding beet seeds which had a 10% germination rate.

4.4 Turnip Seed Germination

Turnip seeds had a high tolerance to detergent. Detergent's lowest lethality dose to turnips was at the lowest concentration at 20% detergent (.1ml) and 80% water (.4ml). In comparison with cabbage, the turnip seeds were not as successful at germinating, although a recognizable tolerance to detergent was recorded. During germination, the turnip seeds did not develop any abnormalities in shape or color, retaining the light brown hue of their sprouts and dark green colored leaves. The turnips had a moderately healthy and successful germination.

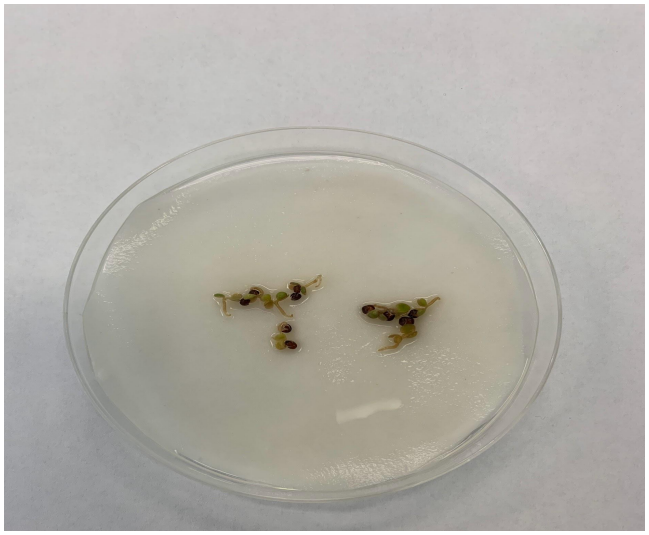


Figure 2: Petri dish of turnip seeds at a concentration of 20% detergent (.1ml) 80% water (.4ml). At the lowest contraction of detergent, turnip seed germination was 90%. The visual appearance of the seeds shows that the seeds were healthy post germinating

4.5 Yellow Bush Bean Seed Germination

Yellow bush bean seeds had a lower tolerance to detergent than cabbage and turnip seeds. Detergent's lowest lethality rate to yellow bush beans is >.1 ml of detergent diluted in .4 ml of water. At the lowest concentration of detergent at .1 ml of detergent diluted in .4 ml of water, yellow

bush beans had a 50% germination rate, while cabbage and turnip seeds had 80% and 90% germination rates. The outer layer of the seed turned from a light yellow hue to black and grew fuzz. In addition, the radicles of the yellow bush bean seeds developed brown patches.

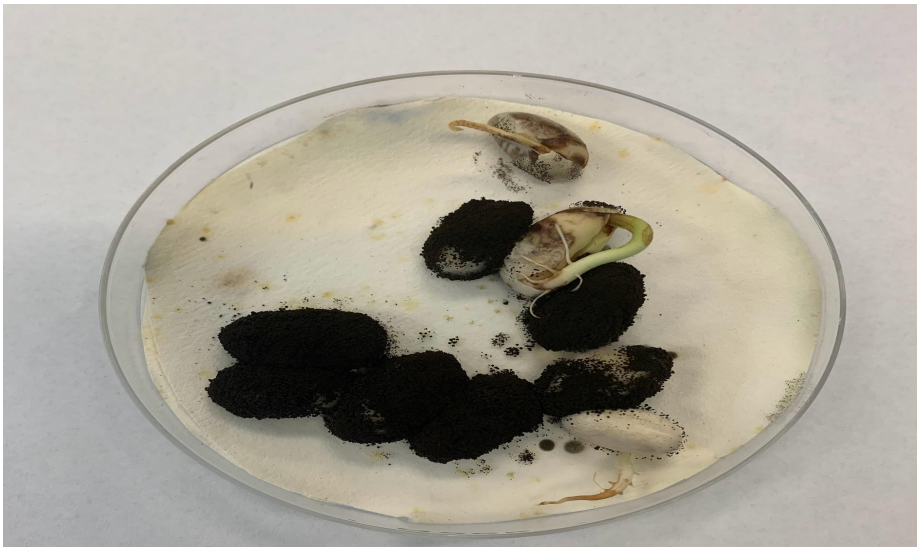


Figure 3 : Yellow bush bean seeds administered with a concentration of 60% detergent (.3ml) 40% water (.2ml). The majority of yellow bush bean seeds are covered with black fuzz and brown patches formed on the radicles.

5. Conclusion and Future Work

This study partially supported the experimental hypothesis of detergent's lowest lethality dose (LDLO) to various seeds. Detergent's LDLO to cabbage was the highest out of all the other seeds as hypothesized, being 50% detergent (.25 ml) and 50% water (.25 ml). Cabbage seeds demonstrated the greatest tolerance to detergent out of all the seeds with germination rates in all experimental groups ranging from 50% - 100%. The seeds had a healthy germination, not developing any abnormal colors.

Beet seeds had the weakest tolerance to detergent which was not hypothesized. The highest germination rate recorded in all the experimental groups of beet seeds was 10%. Additional petri dishes with lower concentrations of detergent, ranging from .075 ml of detergent to .025 ml of detergent resulted in a maximum germination rate of 20% out of 10 beet seeds. The visual

appearance of the few germinated beet seeds revealed shriveled sprout and abnormal color, signifying that although the seeds germinated, they were not healthy.

Turnip seeds had a high tolerance to detergent which proved the experimental hypothesis wrong. The LDLO of detergent to turnip seeds was 20% detergent (.1 ml) diluted in 80% water (.4 ml). Turnip seeds demonstrated germination rates close to cabbage seeds within all the experimental groups except the 100% concentration of detergent. Seeds had a healthy germination as observed from the sprouts having a dark shade of green and no other abnormal colors.

Yellow bush bean seeds were found to have a weak tolerance to detergent. Detergent's LDLO to yellow bush bean seeds was >.1 ml. In addition, seeds developed an abnormal coating of black fuzz on the outer layer. Seeds that did germinate developed brown patches on their radicles.

Future research on this study should investigate the reason why cabbage and turnip seeds had high germination rates when exposed to detergent. The development of black fuzz on the outer layer of yellow bush bean seeds should be investigated to determine metabolic processes that caused yellow bush bean seeds to develop visible abnormalities on their outer layer and radicles.

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