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Editor's Note

In our world of new materials, genetically-modified organisms, patented genes and elusive subatomic particles, it's worrisome that the communication surrounding these magnificent advances in the field of science pales in comparison to their importance to the world. The Higgs Boson was distilled down into the "god particle," in the hopes that the masses would understand it better that way. A recent study involving the effect of hydrogen sulfide on mitochondria was warped around to yield headlines that proclaimed that inhalation of flatulence could prevent cancer. It's no secret that science is a field with many interconnections and complex ideas, but are these absurd news items, reduced like so much red wine for a steak glaze, really helpful?

This note could read like an attack on the popular media; and indeed, I think that it should, in part, be that. Many news channels on television, radio and online have subscribed to a twenty-four-hour news cycle, so that they are broadcasting something all the time, regardless of what is actually going on. This results in "experts" on the air, providing "analysis" of the news. More often than not, this involves a host, who may or may not be particularly well-versed in the scientific topic being discussed, asking questions of a university professor who struggles to explain an idea which usually takes an entire semester to understand in the 45 seconds allotted to him or her. This model is designed to create convenient sound bites and balance out the "news" with commercials and other content, and ultimately make money for the news corporation.

By means of being two sides of the same coin, shouldn't that university professor be able to succinctly sum up what goes on in his or her lab on a daily basis in a way that everyone can understand? If the work that is being done all over our country on stem cells and cancer therapies (which is funded by billions of our tax dollars) is so important, don't the people doing that work have the responsibility to be able to tell the rest of us about it? I would argue that they do.

So the only logical conclusion to this discussion is that the population of our country must be able to understand science on a higher level than it currently does. From plumbers and carpenters (whose additions to our society are fantastic and whose services I would not dare live without) to professors and news reporters, we all need a better understanding of science. This allows the popular media to operate on a higher level of discourse, not having to worry about distilling ideas down for the "general population." And of course, the people doing the research need to be able to communicate with a minimum of jargon so that a reasonably scientifically-literate person might be able to understand the idea.

And how do we get there? Education, of course. It's saddening that bills are constantly tossed around in our government that propose to fund "emergencies" like a war overseas or an influx of immigrants. While these are pressing problems, we have an educational emergency on our hands, and one which, if we allow it to fester, will affect our country for generations. It's heartening to see the work submitted to this journal from teachers and students who are working to elevate the level of scientific discussion in this country. I hope that in the coming volumes we'll have even more great work to share.

D.M.S.
2014
Ithaca, NY

CHEMOTACTIC RESPONSES TO ARTIFICIAL SWEETENERS IN *TETRAHYMENA THERMOPHILA*

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The authors would like to thank Mr. Michael Stano for his support in terms of the progress of this project. They would also like to express their gratitude for his encouragement in the submission and publication of this paper.

ABSTRACT

Most companies in the food and drink industry use real sugar to sweeten their products, along with a "healthier" alternative that contains artificial sweeteners. The producers claim that artificial sweeteners, such as sweet 'n low or equal, help people lose weight because it's better for the body than real sugar. However, our experiment suggests that artificial sweeteners are not beneficial, but in fact, are detrimental to one's health. Tetrahymena were used to compare their reactions to different types of sweeteners to the reactions of humans.

Tetrahymena thermophila are organisms which are highly motile, large enough to be seen with a dissecting microscope (50 micrometers x 30 micrometers), and are very hardy. The sugar sensor, specifically the glucose sensor in Tetrahymena, is the enzyme glucokinase, which is the first enzyme in substrate level phosphorylation. As sucrose is a dimer of glucose and fructose, the fructokinase enzyme would also be expected to sense sucrose in Tetrahymena. We hypothesized that T. thermophila cells would migrate to high concentrations of sugar. With non-nutritive sweeteners, it would be expected that positive chemotaxis would not occur, as cells would produce no ATP from these molecules. T. thermophila were recorded on digital video cameras, and time-lapse videos were produced, which were used to measure chemotaxis time. Results showed that T. thermophila exhibited rapid chemotaxis towards both sucrose and stevia (ten and eight minutes respectively), while they exhibited negative chemotaxis towards aspartame and saccharin. An analysis of the differences between these groups generated p-values of less than 0.02, indicating high confidence and validation of our hypothesis. These results have implications for the widespread use of nonnutritive sweeteners.

Other experiments have determined that people who drink diet sodas are more likely to crave more because their bodies aren't using the sweetener as real sugar. These people end up gaining more weight than if they had consumed regular soda. Furthermore, foods that contain artificial sweeteners can cause diabetes because it lowers their blood glucose levels while sensitizing the hormone that produces insulin. These individuals are more likely to be diabetic.

INTRODUCTION

Obesity is a complex metabolic syndrome that has been linked to genes, diet, and behavior. It is estimated that over 60% of adults in the United States are overweight, with a body mass index (B.M.I.) of 25-29.9, and 33% of Americans are now obese, defined as a B.M.I. over 30 [13]. The dramatic increase in obesity rates is graphically illustrated in figures from the Centers for Disease Control comparing obesity rates in the U.S. from in 1995 to 2012 (Figure 1). Obesity is a public health epidemic in industrialized countries because it can be a contributing factor to type 2 diabetes, heart disease, and increased lipid accumulation in the blood [13].

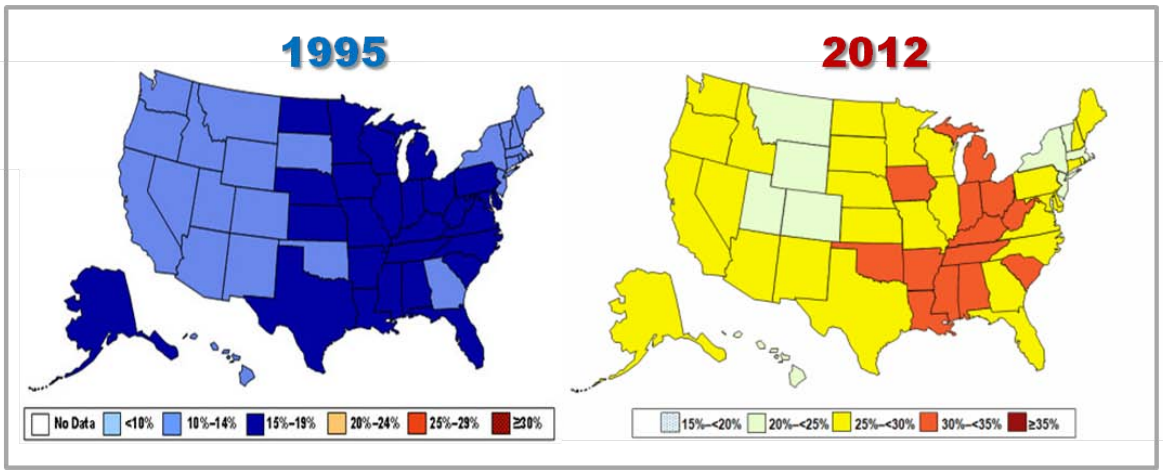

Figure 1. *The Increase in Obesity Rates in the United States from 1995-2012*. In 1995, no states had obesity rates that were ≥20%. By 2012, obesity rates in the United States of America were ≥30% in 12 states. Reproduced from reference 13

One of the leading risk factors for developing obesity and/or type 2 diabetes is the overconsumption of sugary beverages such as sodas and other corn syrup sweetened drinks [12]. High levels of fructose in the diet have been found to increase adipocyte, or fat cell number, and decrease responsiveness to insulin [10].

To provide sweetness without the calories, several artificial sweeteners are on the market. The aim of these products is to decrease the caloric content of the food, while still maintaining a taste that resembles what the consumer expects. However, research on the effect of artificial sweeteners on weight loss is often contradictory. Some studies report that aspartame can promote weight loss [2], while others concluded that aspartame actually increases caloric intake [11]. Even more troubling is a study finding that sucralose can cause increased blood glucose levels, elevated insulin levels, and decreased insulin clearance in healthy individuals [6]. Sugar substitutes are collectively known as non-nutritive sweeteners. These include aspartame (marketed as NutraSweet©), saccharin (marketed as Sweet-N-Low©), sucralose (marketed as Splenda©), and stevia from the leaves of the *Stevia rebaudiana* plant. Stevia is not chemically synthesized and it has been marketed as a healthier alternative to artificial sweeteners. While the

data on other sweeteners is inconclusive regarding any benefit, evidence has mounted that stevia is a promising class of nonnutritive sweetener that regulates caloric intake and in some cases increases feelings of satiety [4]. There is anecdotal evidence that at least one individual, Biz Markie, with type 2 diabetes has lost 140 pounds by replacing sugary sodas with stevia sweetened sodas, without increasing exercise, or implementing other dietary or lifestyle changes [3].

There are no reported studies examining the response of microorganisms to stevia. In contrast to humans, microorganisms have no preference for taste as we perceive it, as they lack the taste receptors that define our taste buds. Microorganisms do however sense whether a molecule is a viable carbon source for the production of ATP. When a molecule can be used as fuel, microorganisms exhibit a chemotactic response towards that food stimulus. The microorganism chosen for this study was the ciliated protist, *Tetrahymena thermophilia* (referred to from now on in this paper as *Tetrahymena*). Their ciliated structure allows them to quickly respond to changes in the presence of chemicals in their environment. These organisms are highly motile, large enough to be seen with a dissecting microscope (50 micrometers x 30 micrometers), and they are very hardy. The sugar sensor, specifically the glucose sensor in Tetrahymena, is the enzyme glucokinase, which is the first enzyme in substrate level phosphorylation [7]. As sucrose is a dimer of glucose and fructose, the fructokinase enzyme would also be expected to sense sucrose in Tetrahymena. As glucose or fructose binds to these enzymes and breaks down in the glycolytic pathway, ATP will be produced, the cell will undergo growth, energy needs will be increased, and a positive feedback cycle will begin in the cell that is fueled with more sugar. At this point, the cell will migrate to high concentrations and away from low concentrations of sugar. With non-nutritive sweeteners, it would be expected that positive feedback (increasing growth leading to increased energy consumption) would not occur, as cells would produce no ATP from these molecules. We asked the question of whether stevia, as it is a plant glycoside, or any artificial sweetener could be viewed by Eukaryotic cells as a food source? To answer this question, we developed an assay in which *Tetrahymena* would travel through a "Z" shaped maze towards water (negative control), sucrose (positive control), stevia, aspartame, or saccharin. The organisms were captured on video as they traveled from the start to the finish of the maze. With this setup in hand, the time course of cells through the maze, the density of cells at the start and finish of the maze, and the route that the *Tetrahymena* followed through the maze could be recorded. The results of this study could provide new insight into the fundamental difference in how stevia and other artificial sweeteners are perceived by eukaryotic cells.

MATERIALS AND METHODS

Agar plates were prepared using a solution composed of 5 grams of agarose sugar and 200mL of water in a 25 g/L ratio. The agarose solution was then heated to its boiling point for four minutes in a microwave, in order to dissolve all solute and to sterilize the agar. After being

heated, the agarose water solution was distributed into petri dishes to a depth of three millimeters and left to cool and solidify. When solidified, a scalpel was used to trace and cut out an indirect pathway for the Tetrahymena to follow. The dimensions of the grooves in the agar plates were 35mm by 3mm wide, and the dishes were sealed until ready to use.

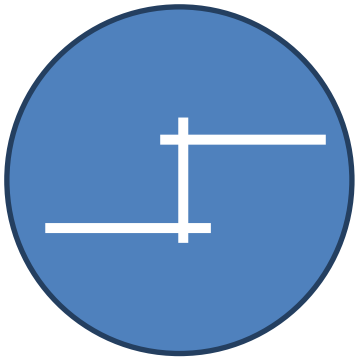

Figure 2. *Diagram of petri dish "agar maze".*

In order to prepare the Tetrahymena, a sterile pipette was used to transfer 6 mL of sterile NEFF media, a nutrient growth broth, into four Falcon tubes. A new sterile pipette was used to transfer 0.5 mL of Tetrahymena from a concentrated stock culture into each of the Falcon tubes to generate dilute working cultures. The tube caps were replaced loosely to ensure gas exchange and aeration in the stock and working culture tubes. The cultures tubes were stored at room temperature. When the Tetrahymena and agar plates were prepared, the Motic video camera was connected to a dissecting microscope in order to monitor the Tetrahymena. The grooves of the agar plates were flooded with NEFF media.

A cube (3mm by 3mm by 3mm) of agar was soaked in a solution of sweetener of 1g of sweetener to 10mL of water for fifteen minutes. Then 50 microliters of Tetrahymena were added to the start of the maze using a pipette, and their motions were observed through the Moticam camera. The timer was started just as the Tetrahymena were added to the start point and the sweetener –soaked agar cube was added to the end point. When the first organism reached the end point of the assay, the trial was over and the time recorded. This same procedure was performed with each trial, with the type of sugar placed at the end point as the experiment's only variable. A type of sugar and sugar substitute were used, as well as a control containing no sugar.

The videos were then analyzed and stacked using Image J. Two hundred consecutive frames of video were taken from each of the trials. This created a static image with Tetrahymena tracks. Their circular paths were analyzed for the average number of loops per frame.

RESULTS

After calculating the average times for a series of triplicate trials, a distinct correlation between chemotaxis length and associated sweetener type was revealed. The stevia solution had the highest average Tetrahymena count at the endpoint of the trial (Figure 3).

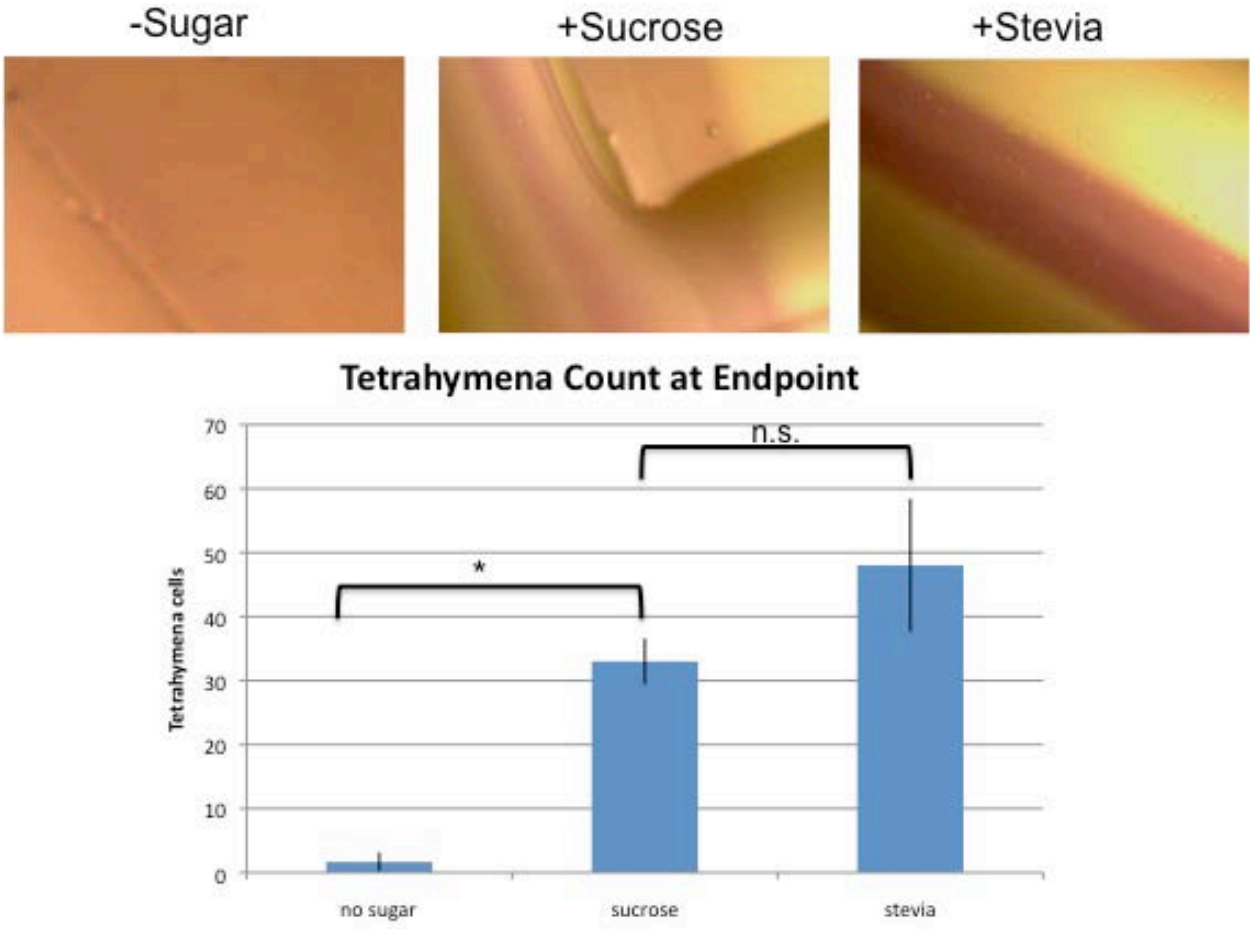

Figure 3. *Tetrahymena thermophilia chemotaxis in response to sucrose or stevia glycosides.* Agar plates were seeded with *T. thermophilia* at the start point of the assay. *Tetrahymena* were placed at the start of a series of three connected channels in the plate (forming a "Z" shape) which led to sweeteners placed in a well at the end of the "Z". Organisms were photographed and counted at the beginning of the assay. At the conclusion of the assay (20 minutes was chosen arbitrarily), all *Tetrahymena* had migrated to the endpoint of the assay in the presence of sweetener (images in upper panel of diagram). Organisms were photographed and counted at the end of the assay. Three frames were counted individually for each variable, and the average of those results are plotted. There were significantly less organisms in the negative control with no sugar after 20 minutes compared to either the sucrose or stevia conditions (*, p-value<0.01). There was no significant difference between the number of organisms observed at the endpoint of the sucrose and the stevia groups.

Therefore, it was concluded that the Tetrahymena had the highest affinity for stevia while it is in solution. The stevia signal molecule detected by the Tetrahymena appears to simulate and enhance the sugar signal molecule acceptor in a positive feedback model. The glucose ring in stevia's structure is integral to Tetrahymena, as well as human, cells' perception of stevia as a nutrient source. Protein receptors on the cells' surface recognize the glucose ring and employ chemical signaling within the cell in order to increase permeability to the sugar based substance through heightened phagocytic activity. An entirely different reaction was observed in the Tetrahymena during the aspartame and saccharin trials; both solutions' trials exhibited a longer duration than those of the sugar and stevia solutions'. Furthermore, it was also noted that a common component persisted in both the aspartame and saccharin molecule; dextrose. From this realization it was then speculated that this derivative of glucose was responsible for the similar results observed in the aforementioned trials.

A graphic representation of each trial provides a visual comparison of the length of each chemotaxis for the sugar substitutes. While the aspartame and saccharin trials seem to have a comparably similar duration, stevia's trial took a considerably shorter time even relative to natural cane sugar (Figure 4).

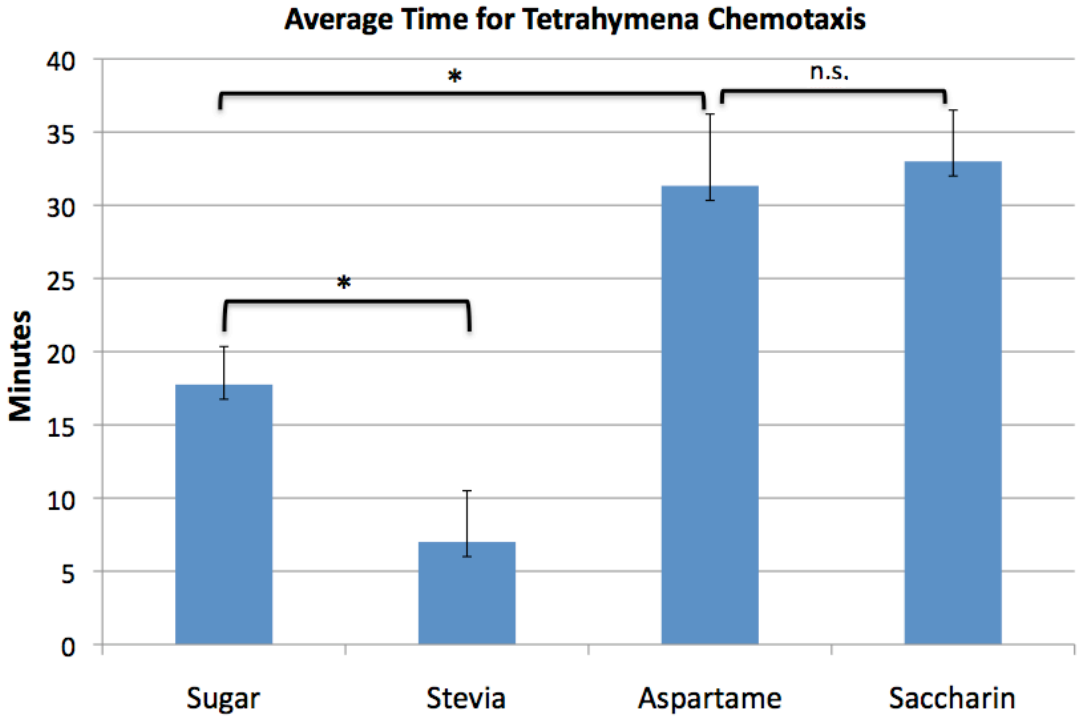

Figure 4. *Average time for Tetrahymena thermophilia chemotaxis in response to sucrose, stevia glycosides, or two artificial sweeteners aspartame and saccharin.* Agar plates were seeded with *T. thermophilia* at the start point of the assay. *Tetrahymena* were placed at the start of a series of three connected channels in the plate (forming a "Z" shape) which led to sweeteners placed in a well at the end of the "Z". Organisms were photographed and counted at the beginning of the assay. Organisms were then continuously monitored under the dissecting microscope using a

Motic brand digital camera. When all *Tetrahymena* had migrated to the endpoint of the assay in the presence of sweetener, the video of the assay was reviewed and the time at which the first organism reached the end of the maze was recorded. The experiment was repeated three times for each variable, and the average of those results are plotted. Interestingly, stevia glycosides are a more potent stimulus for chemotaxis than sucrose (*, p-value<0.05). There was no significant (n.s.) difference between the number of organisms observed at the endpoint of the aspartame and the saccharin groups. Organisms observed in the aspartame and saccharin groups after more than 30 minutes, were postulated to have randomly migrated to the end point of the maze, similarly to the negative control in the previous figure.

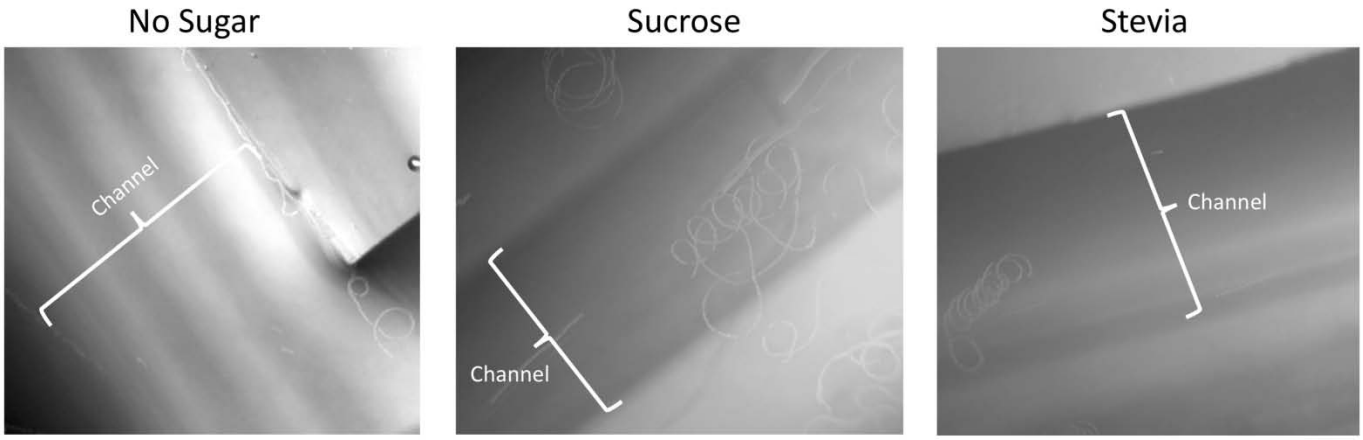

Figure 5. *Tetrahymena thermophilia chemotaxis paths in response to sucrose or stevia glycosides*. Agar plates were seeded with T. thermophilia at the start point of the assay. Tetrahymena were placed at the start of a series of three connected channels in the plate (forming a "Z" shape) which led to sweeteners placed in a well at the end of the "Z". Organisms were then continuously monitored under the dissecting microscope using a Motic brand digital camera. Over the course of the assay, the movement of Tetrahymena was tracked with ImageJ software available from the Research Sevices Branch of the National Institute of Health (http://rsbweb.nih.gov/ij/index.html). Tetrahymena moved in spiral patterns through the channel as they presumably fed on the sweeteners present in the assay. Tetrahymena produced noticeably more compact spirals in the presence of stevia, compared to sucrose. The difference in chemotactic response to different sweeteners is especially dramatic. No such behavior was observed in the absence of sugar, where the organisms traveled in a mostly straight line along the sides of the channel with single as opposed to multiple spirals at the channel junctions.

During the timed trials, Tetrahymena were actively tracking the sweeteners and engaged in looped motions (Figure 6).

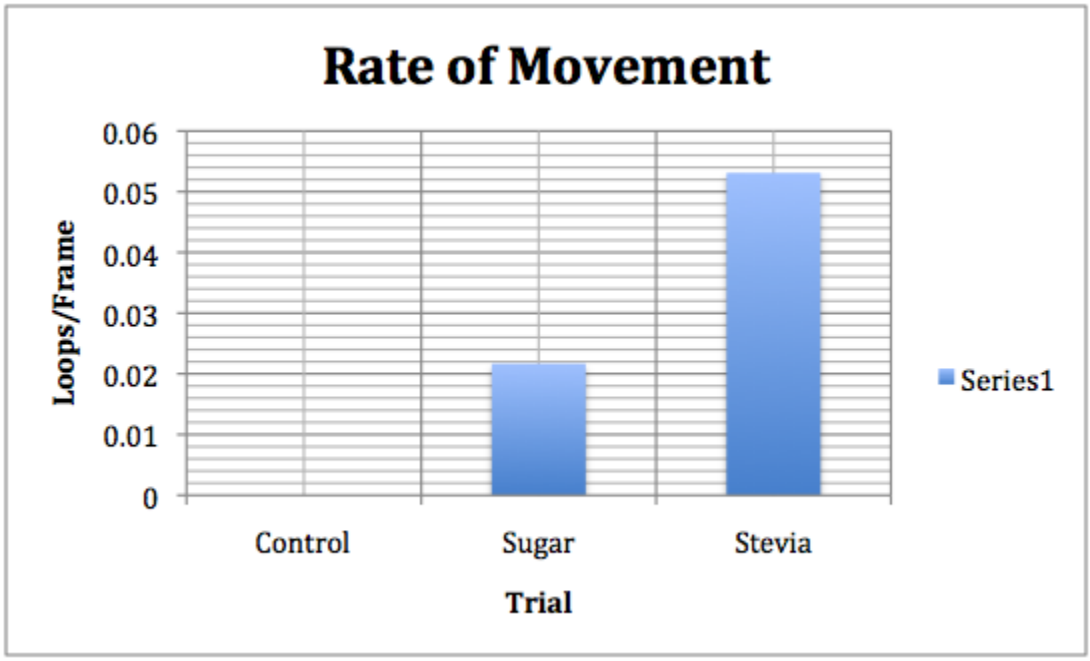

Figure 6. *Number of 360-degree revolutions made by Tetrahymena for each frame of video.*

DISCUSSION

The goals of this project were to compare the chemotactic responses of a Eukaryotic unicellular organism in the presence of nutritive and nonnutritive sweeteners. It was predicted that there would be chemotaxis towards sucrose and the naturally derived stevia glycosides but not towards nonnutritive artificial sweeteners. The results confirmed this hypothesis and additionally yielded the unexpected finding that *Tetrahymena* "prefer" stevia to even sucrose. This finding was supported by the observation of increased chemotaxis towards stevia, greater *Tetrahymena* cell density in areas where stevia was deposited, and increased "corkscrew" motion of *Tetrahymena* in areas where high concentrations of stevia were found. Similar, but less robust activity was found in the presence of sucrose but not in the negative control with no sweetener. It is unclear why *Tetrahymena* prefer stevia but the assumption is that they detect it as a beneficial carbon source for metabolism.

With these findings Anton et al. in 2010 constructed another experiment designed to test the effectiveness of a natural sugar substitute lacking the dextrose molecule in eliciting a response from the body similar to its response to glucose, while avoiding the negative side effects associated with aspartame and saccharin. In a comparative experiment between aspartame and stevia it was found that both, when taken as pre-prandial supplements, decreased food intake and, as a result, lowered postprandial blood glucose levels. However, stevia presented as the more favorable option because it kept blood glucose levels lower for a longer period of time

while maintaining the individuals' sensitivity to hormone stimulant by producing a moderate amount of insulin in response. As opposed to aspartame, stevia exhibited no negative side effects. This correlated to the chemotaxis results of the Tetrahymena experiment in that the use of stevia as a nutritional supplement elicited the most beneficial response from both its respective test subjects. From these results it was also speculated that the contradicting results observed in some researched aspartame trials may be connected to the opposing responses to dextrose observed in specific individuals.

From the results of this experiment it is clear that the Tetrahymena had the highest affinity for stevia, indicated by their short trial time and the heightened activity recorded. Upon detection of the stevia solution, many of the Tetrahymena exhibited cooperative behavior such as moving along the sides of the maze in straight lines and during further contact with the stevia, began to move in rapid corkscrew patterns calculated at 0.053 loops/frame. The higher level of activity observed in the stevia trial as opposed to the sugar trial suggests a correlation between each molecules' structural difference and its ability to be recognized by a eukaryote's nutrient surface receptor protein. The stevia molecule, though as nutritionally devoid as aspartame or saccharin, attracted Tetrahymena faster than even its nutritionally wholesome counterpart, sugar. A human body cell, whose surface receptor proteins are only marginally differentiable from those of a Tetrahymena's, arguably acts in much the same way.

Through multiple trials of a Tetrahymena Chemotaxis, conducted in order to compare the effects of different types of sugar supplements on a model species, results were obtained which correlated to studies done with human subjects. As suggested by the results of the timed trials, artificial sugars like the aspartame utilized in the experiment adversely affect metabolic processes involved in its consumption within the body [1]. It was speculated that the dextrose sugar included in the structures of both sugar molecules was responsible for the similar results of the aspartame and saccharin solutions' Chemotaxis; however, the current scope of this experiment cannot confirm such a conclusion. Further testing would be needed to substantiate the speculated toxicity of dextrose to Tetrahymena. Given additional time, a control trial would be conducted which would measure the level of nitrates released by Tetrahymena in a dextrose solution over an extended period of time. The nitrate level would vary directly with the rate of expiration of the Tetrahymena, confirming or negating the proposed hypothesis.

The results of this experiment also support the previously stated conjecture; similarities between the surface receptor proteins of Tetrahymena and other eukaryotes, coupled with the cooperative behavior observed, may allow for the facilitated development of a human dietary supplement through associated research in model organisms such as Tetrahymena. Biomedical Researchers can develop techniques which utilize stevia as a dietary supplement taken pre-prandially; this would reduce an individual's food consumption, and lower the subject's blood glucose levels while maintaining the body's sensitivity to insulin. Such a method would also decrease the probability of blood sugar spikes after food consumption for Type 1 Diabetics. Furthermore, it could prevent Type 2 Diabetes by promoting weight loss and increasing sensitivity to insulin.

CONCLUSIONS AND FUTURE RESEARCH

Through multiple trials of a Tetrahymena Chemotaxis, conducted in order to compare the effects of different types of sugar supplements on a model species, results were obtained which correlated to studies done with human subjects. As suggested by the results of the timed trials, artificial sugars like the aspartame utilized in the experiment adversely affect metabolic processes involved in its consumption within the body [1]. It was speculated that the dextrose sugar included in the structures of both sugar molecules was responsible for the similar results of the aspartame and saccharin solutions' Chemotaxis; however, the current scope of this experiment cannot confirm such a conclusion. Given additional time, a control trial would be conducted which would measure the level of nitrates released by Tetrahymena in a dextrose solution over an extended period of time. The nitrate level would vary directly with the rate of expiration of the Tetrahymena, confirming or negating the proposed hypothesis.

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In conclusion, our findings indicate that Eukaryotic unicellular organisms respond to stevia in much the same way as they do to sucrose. This was not the case for other nonnutritive sweeteners tested. Stevia has been reported to increase feelings of satiety, just as nutritive sugars [4]. In contrast, sucralose is a very prevalent nonnutritive sweetener has been reported in a small study to have detrimental effects [6]. It is impossible to extrapolate results from protists to humans, however this is the first study of its kind to show that protists "prefer" stevia as much, if not more than sucrose. From a public health standpoint, the ideal course of action would be to limit, curb, or prevent the public's consumption of sugary beverages. However, where this is not desirable or politically or logistically possible, the increased use of safe, inexpensive, naturally derived non-nutritive sweeteners such as stevia may in fact decrease the toll in human suffering and health care spending that arises from the obesity epidemic.

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REDUCTION OF CHEMICAL FERTILIZERS IMPACTING GROUNDWATER CONTIMATION

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ABSTRACT

The purpose of my project was to test the height of plants using different types of fertilizers. We also based this off of groundwater contamination from chemical soils and fertilizers. Small plastic starter pots were 63.5 mm tall. The pots were each filled with 236.59 grams of a different material. The materials that were used were: chemical soil, organic soil, regular dirt, dirt with organic fertilizer, and our own substance, which was composed of dirt and coffee grounds. The soil compositions were placed in five cups each, for a total of 25 cups. Three Cosmo seeds were placed in each pot, at a depth of 3 cm, and covered loosely with soil. The plants were placed under a grow light, which gave the plants sixteen hours of sunlight. The plants were watered 50 ml of water for the first three days. 50 ml of water was too much for the plants so we reduced the amount of water to 30 ml every day. The process of watering the plants lasted seven days. The plant's heights by measured from the top of soil level to the top of the plant. The daily data we collected showed us the height of each plant in each pot. Our data showed us that the organic soil grew the tallest. The chemical soil grew very well, being the tallest plant. The soil with organic fertilizer didn't grow at all. My group found that the organic soil grew very well compared to some of the other substances. This shows that organic soil/organic farming is definitely a viable option to using chemical fertilizers that contribute to groundwater contamination.

BACKGROUND INFORMATION

A chemical fertilizer is an inorganic material that contains synthetic materials that are added to soil to sustain plant growth. Chemical fertilizers consist of many harmful substances that can cause death. They can contain very small amount of harmful substances such as: Urea, Lead, Cadmium, Chromium, and Sulfuric Acid (Groundwater). Many deaths are caused by water contamination.

An organic fertilizer is a substance that is acquired from remains or byproducts of natural organisms (Organic). An organic fertilizer is different from chemical fertilizers because they contain naturally formed substances rather than manufactured chemical concentrates such as: Potassium, Nitrogen, and Phosphorus (Soil). Organic fertilizers do not cause groundwater contamination and are a healthy alternative to chemical fertilizers.

Groundwater contamination is when man made products get into groundwater and cause it to be unsafe to human use (Groundwater EPA). Groundwater contamination can be caused by

leakage of oil, gas, chemicals, or road salts (Groundwater EPA). Groundwater isn't only dangerous to humans but also to animals and plants (Groundwater EPA). Groundwater contamination is known to cause Blue Baby Syndrome, hypertension, and stomach cancer (Groundwater).

MATERIALS

The materials used for our project were: Cosmos (a flowering plant that grows 457.2-609.6 mm), tap water, measuring cups, Moxie Java's coffee grounds, 2 cm gravel, plant pots that were 63.5 mm tall, a grow light, a water tray, and a ruler.

Name of Medium	Composition	Notes
Commerical Organic soil	Soil, compost, organic matter, etc.	Purchased from Zamzows
Commerical Chemical soil	Soil, chemical based fertilizers, bark, etc.	Purchased from Zamzows
Regular Dirt	Local silt, clay, sand, etc.	Found in a field with no rocks or plants in it
Commerical Soil with Organic Fertilizer	Soil, chicken manure, and cow manure	Purchased from Zamzows
Our Own Substance	Regular dirt with coffee grounds	N/A

Table 1. Names and compositions of growth media used.

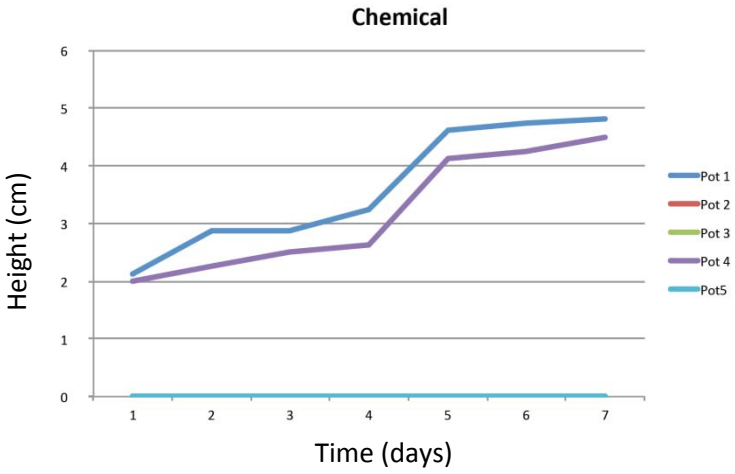
PROCEDURE

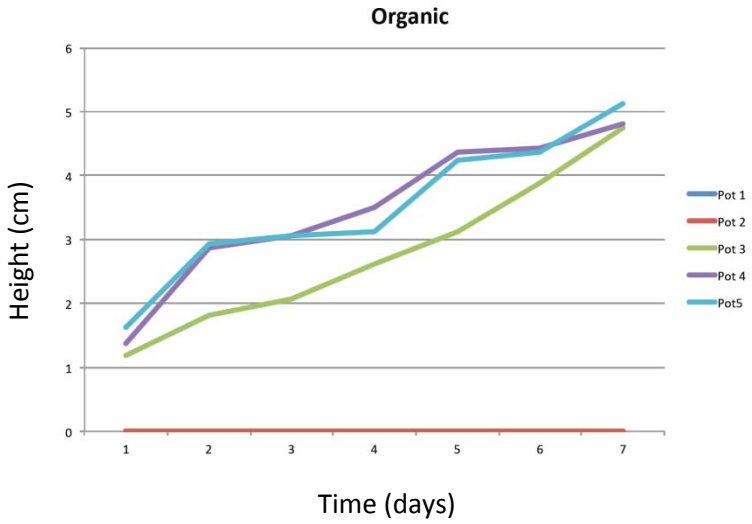
Small plastic starter pots were 63.5 mm tall. The pots were each filled with 236.59 grams of a different material. The materials that were used were: chemical soil, organic soil, regular dirt, dirt with organic fertilizer, and our own substance, which was composed of dirt and coffee grounds. The soil compositions were placed in five cups each, for a total of 25 cups. Three Cosmo seeds were placed in each pot, at a depth of 3 cm, and covered loosely with soil. The plants were placed under a grow light, which gave the plants sixteen hours of sunlight. The plants were watered 50 ml of water for the first three days. 50 ml of water was too much for the plants so the amount was reduced to 30 mL every day. The process of watering the plants lasted seven days. The plant's heights were measured from the top of soil level to the top of the plant.

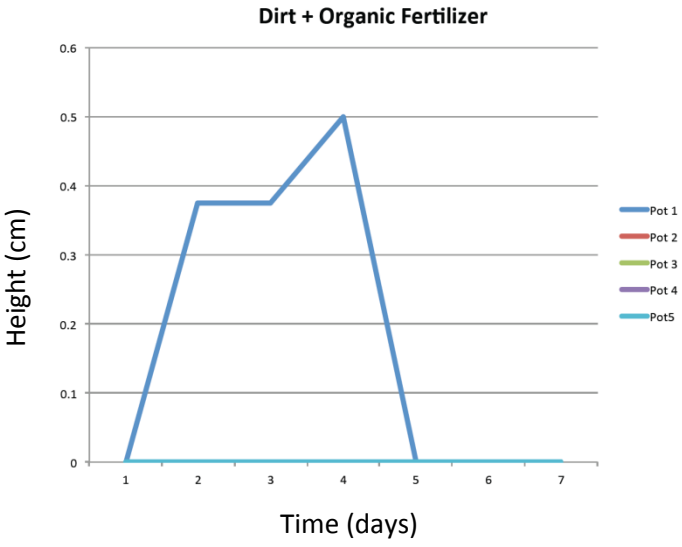
RESULTS

Our data showed us that the organic soil grew the tallest. The plants in the chemical soil grew well but not well as the organic fertilizer. The plants in our own substance grew in very close relation to the chemical soil. The dirt with organic fertilizer didn't grow at all, and the regular dirt grew small flower starts but never grew very tall. There was a much larger difference

between the dirt and organic soil, compared to chemical soil or our fertilizer. My group found that the organic soil grew very well compared to some of the other substances. This shows that organic soil/organic farming is definitely a viable option to using chemical fertilizers that contribute to groundwater contamination.







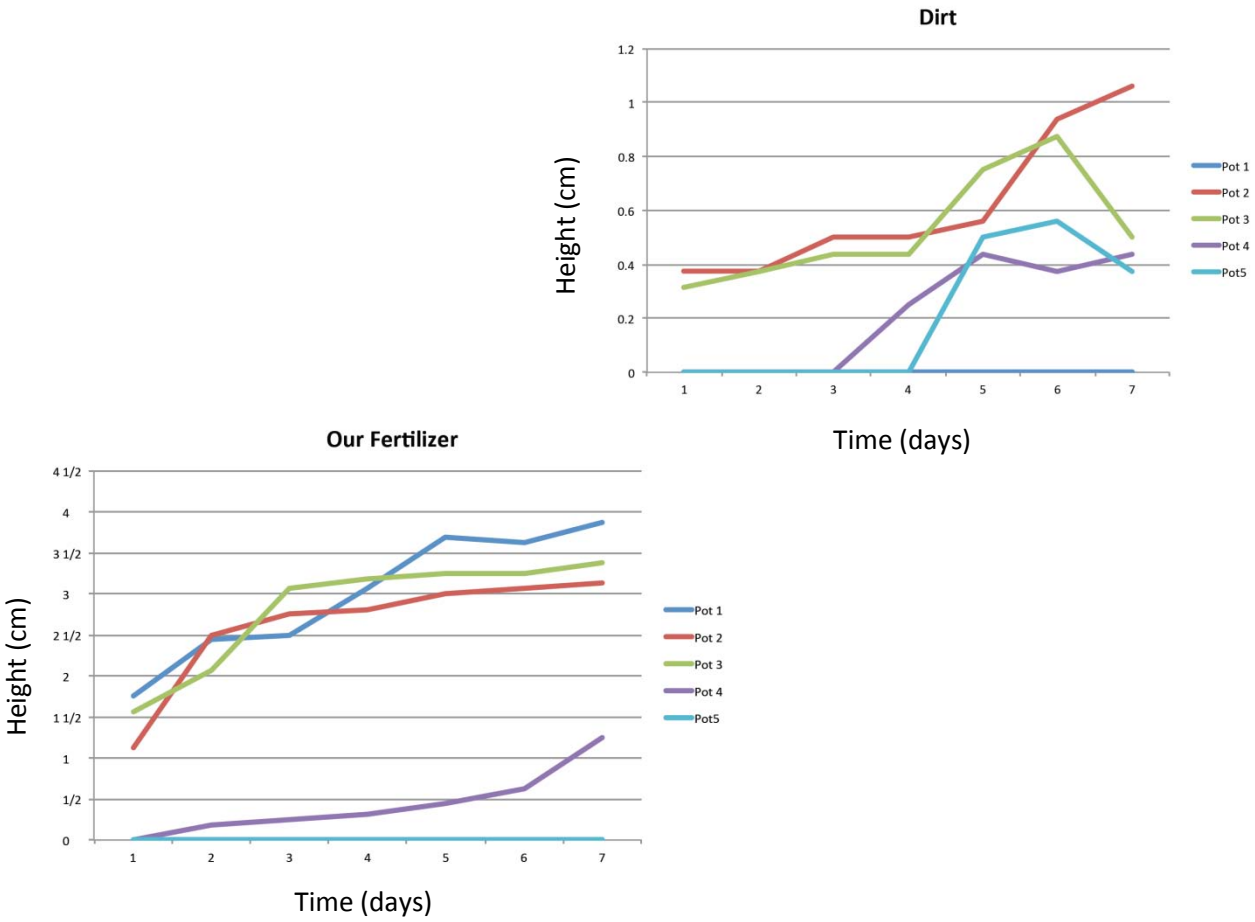


Figure 1. Growth of plants in various types of soils over seven days.

CONCLUSIONS

My conclusions followed my hypothesis. My hypothesis was: If I use an organic fertilizer it will make the plants grow larger because the natural substances will cause the plants to grow healthier than using chemical soil/fertilizer. The organic soil grew the tallest and this helps us reduce groundwater contamination with the use of chemical soil/fertilizers. The chemical soil grew in very close relation to the organic soil but it contains some chemicals that aren't good for human or animal consumption. In the future I would test a similar project but have a larger sample size and I would test the amount of groundwater contamination is related to plant soils and fertilizers. The only problems that I had with this project was finding the correct soil and fertilizers that varied from each other.

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SUNLIGHT VERSUS HEAT LAMP WATER DESALINATION

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ABSTRACT

The purpose of this investigation is to create a desalination model to demonstrate one way of creating freshwater needed to sustain human life. We created two desalination plants to show how effective sunlight versus a heat lamp was in desalinating saltwater. We took two identical bowls and filled them with the same amount of water and salt. We placed a small cup in the middle of each bowl and covered them both with plastic wrap. One small weight was placed on top of the plastic wrap in the center of both bowls. One bowl was placed outside under sunlight and the other under a heat lamp. We then waited six hours and recorded the amount of water in each small cup. In plant A, we collected 1.2 mL and in plant B we collected 6.1 mL. It was concluded from this project that desalination is not the best way to create freshwater. This conclusion was reached on the fact that using the sunlight and even the heat lamp, a very small amount of water was desalinated in the six hour period allowed. This relates to the real issue of desalination plants. The plants today use large amounts of energy to convert the saltwater to freshwater. In one aspect desalination plants take advantage of the vast supply of saltwater, but on the other hand they use huge amounts of energy to achieve this accomplishment.

INTRODUCTION

The purpose of this project was to create two desalination plants to compare which method would be most effective in creating freshwater. Earth has an abundance of ocean water and lacks freshwater that is used effectively in areas of the world with absences of fresh sources of water. Most of all the water found on Earth is from the oceans and is not suitable for human consumption. Our bodies depend on sodium chloride to maintain a healthy chemical equilibrium, but the salt content is too high in ocean-water to be potable. Drinking water with too much salt could potentially be fatal. Most of the freshwater on Earth is found in lakes, rivers, and underground reservoirs. Freshwater only makes up about 2.5% of overall water found on Earth. Building desalination plants to desalinate seawater is one way of generating additional freshwater to be fit for human consumption.

Desalination is the process of extracting the salt and minerals from saltwater to make it acceptable for human intake and irrigation of crops. It is very important today because there is a worldwide need for freshwater, in areas that do not have access to lakes or rivers. The increase in population and consumption of freshwater is causing parts of the world to experience freshwater shortages which have the potential to suppress economic advancement worldwide

("Environmental"). Desalination is one of the earliest known water treatment options. Many ancient ships used this method of water treatment to create freshwater ("Saline Water"). Desalination is mainly used today as a way to generate freshwater on ships, in regions with sparse fresh water resources, and where water has been contaminated.

There are three widely known methods of desalination which include natural water desalination, thermal desalination, and membrane desalination ("Ocean Water"). Natural water desalination is the water cycle. The other two types of desalination, thermal and membrane, are manmade systems that recreate the water cycle to generate large amounts of freshwater. It is expensive to process seawater because large amounts of energy and special equipment are required to transform seawater to freshwater. Presently, it costs $650 per 1233.5 kiloliters to desalinate seawater ("Ocean Water").

Natural Desalination: This occurs when water evaporates in result to the sun's exposure. After the water is evaporated it rises to Earth's atmosphere where the air temperature is cooler. As a result, the water vapor condenses and forms clouds that eventually produce precipitation. Once the water falls as precipitation, it can be collected as freshwater.

Thermal Desalination: This is the man made version of the water cycle. It occurs when salt water is heated and transferred into different pressured chambers. Water boiling in the high pressure chamber is moved to the low pressure chamber to decrease the boiling point, causing the evaporation process to quicken. The freshwater created is then collected after it condenses.

Membrane Desalination: Reverse osmosis and electro-dialysis are two methods of membrane desalination. Reverse osmosis is the process of forcing the seawater through layers of membranes at 4,136,854.4 Pa to 6,894,757.3 Pa to catch the salt ions as the seawater passes through. Electro-dialysis is when an electric potential is inserted in the membrane to attract the positively and negatively charged ions to opposite poles of the electric potential as the seawater passes through the membrane.

Despite the fact these manmade desalination plants produce vital freshwater, they have their consequences. Large amounts of energy are required to run the desalination plants, so the increased use of fossil fuels and greenhouse gas emissions is the result. Another conflict comes from when the water is extracted from the ocean to desalinate. Intake screens are used to filter out the larger particles in the water and as a result small marine life like plankton, fish eggs, and larvae are killed ("Pacific Institute"). After the water is desalinated, brine is deposited back into the ocean as waste. Brine is a sludge with double the salt concentration of normal seawater and contains many chemicals ("Ocean Water").

The benefits of desalination would include reducing the stress on the natural freshwater resources, higher water inventory availability, and excellent water quality (Seawater Desalination"). Desalination of seawater is not the only and definite solution to freshwater

shortages. It has many economical and environmental drawbacks but, it is leading the way towards the acme goal of creating more freshwater the world vitally needs.

MATERIALS

1. 14.8 g of Iodized Salt
2. 236.6 mL of Drinking Water
3. 2 Small Cups (177.4 mL each)
4. 2 Glass Bowls (1 L)
5. Volume Measuring Tool
6. Plastic Wrap (two sections of .1 m)
7. 2 Small Rocks (10 g each)
8. Metric Ruler
9. Heat Source:
   a. Sunlight
   b. Heat Lamp

PROCEDURES

1. Two large glass bowls were placed on a level surface and labeled *Sunlight* and *Heat Lamp*.
2. 236.6 mL of distilled water was added to each bowl.
3. 14.8 g of iodized salt was added to both bowls. The water was stirred with a stirring rod until the salt was dissolved completely.
4. The small cup was placed directly in the center of each glass bowl.
5. Plastic wrap was placed on the top of each glass bowl and secured tightly around the edges.
6. One rock was placed on top of the plastic wrap of each bowl directly in the center over the small cup.
7. The desalination plant labeled *Sunlight* was placed on a level surface outside under direct sunlight.
8. The desalination plant labeled *Heat Lamp* was placed underneath the heat lamp on a level surface about .3 m from the bulb of the heat lamp.
9. The heat lamp was turned on.
10. The desalination plants were exposed to the heat sources for six hours.
11. The amount of water desalinated from each plant was collected after the six hours.

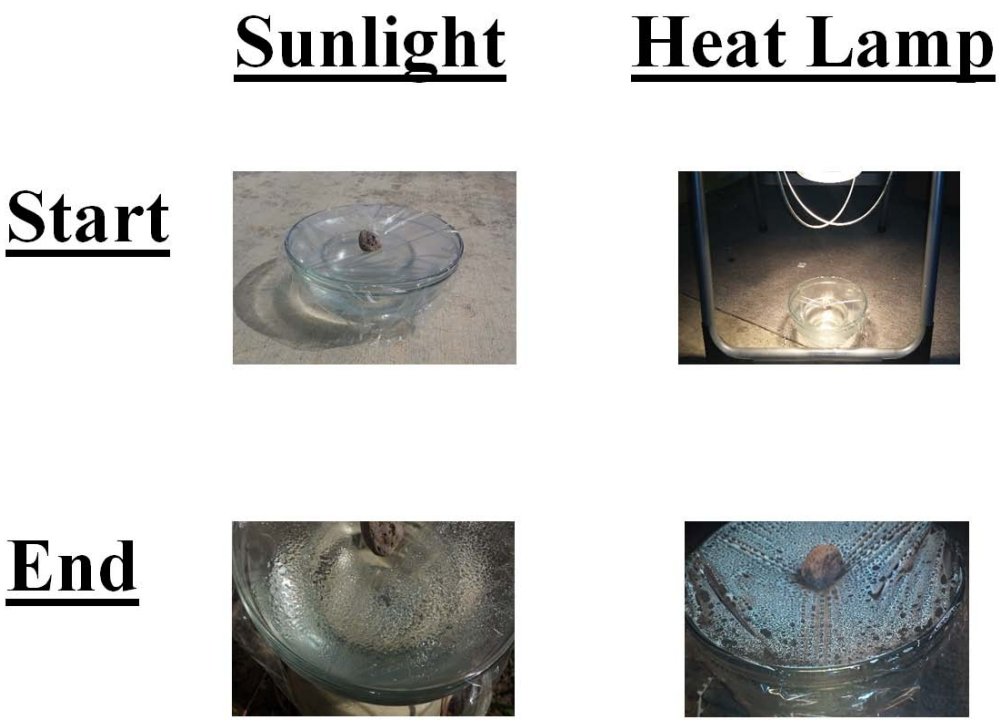

Figure 1. Photographs of desalination plants at 0 h and at 6 h.

RESULTS

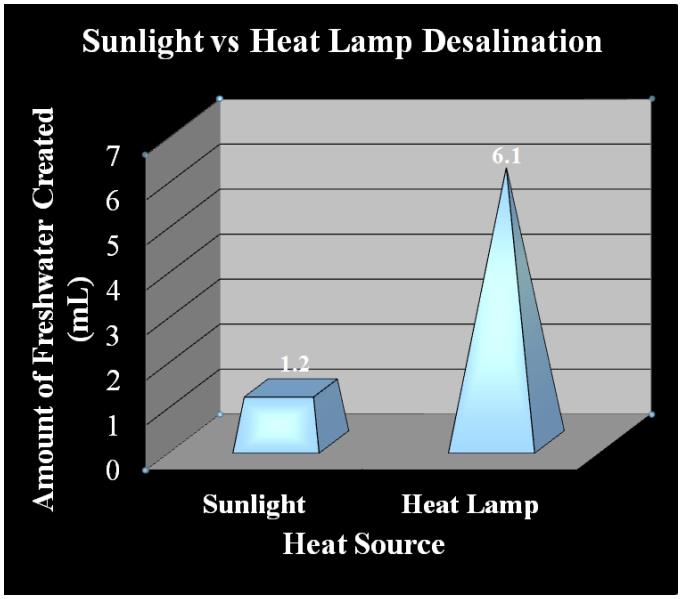

Figure 2. Amount of freshwater created via two different types of desalination plants.

After we conducted this experiment, we found that the salt was left behind when we collected the freshwater. The water evaporated and then condensed back into freshwater due to the plastic wrap covering and blocking the water from escaping. When the water condensed on the plastic wrap it fell into the small cup creating fresh water. This is a good example of the water cycle. When the water heats up it evaporates then it condenses together and the water falls into the bowl as precipitation. For this experiment we put one bowl in the sunlight and the other under a heat lamp. We waited six hours for the water to evaporate. The heat lamp produced 6.1 mL of freshwater. The heat lamp was the best source because it exposed the desalination plant to direct light for six hours. The sun produced 1.2 mL of freshwater. The sun was not as good due to weather conditions and directness of sunlight.

CONCLUSIONS

Based off the results, we concluded that the heat lamp was the most effective way of desalination compared to sunlight. This experiment proved that it takes a lot of energy to even desalinate a small amount of water. When we compared the amounts of water desalinated from both plants, we found that the heat lamp worked the most efficiently over the six hours, versus the sun. Although the heat lamp worked better than the sun, in the end we only desalinated 6.1 mL after six hours. This relates to the actual desalination plants because like our small scale plants, they need large amounts of energy to power and convert the saltwater. The world needs more fresh water and this would definitely help with this problem but, desalination has its drawbacks. One problem is that it makes us more reliant on the already diminishing fossil fuels and increases the greenhouse gas emissions into our atmosphere. If we were to rely on this method of generating freshwater in the future, engineers would have to make the desalination plant more energy efficient and limit waste products created when the water is treated. To make the plants work better, they would have to expose the water to the heat source longer and build the plants bigger to make it worth the money. If we were to do this experiment again we would make sure the day we conducted this experiment was a sunny day with no clouds so it had less effect on our results. This experiment helped us learn about how energy intensive desalination is and how it is not a cost efficient solution in producing additional freshwater.

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