

The Extraction of Heat from Elodea Cells Decreases the Rate of Intracellular Movement of Chloroplasts.

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(Elodea Plant)

Introduction:

Actin filaments play an important role in the movement, relocation and anchoring of chloroplasts (Takagi). Chloroplasts change their positions within cells in response to light irradiation and this is referred to as photo-relocation movement (Sato, Wada, Kadota). Chloroplasts move in plant cells to position themselves in the most optimal position for the absorption of light to be used for efficient photosynthesis (Sato, Wada, Kadota). Chloroplasts also move away from regions of light that could be hazardous. This photo relocation of chloroplasts is a well-known process that occurs within cells and plays an important role in the vitality of plants. The role of the movement of chloroplasts increases the photosynthetic activity within the cells of plants (Takagi). In this study, I exposed plant cells to ice to

investigate its effect upon the rate of movement of chloroplasts within the cell.

Chloroplasts have faces and profiles and in response to light irradiation, chloroplasts move their faces towards dim light and their profiles towards strong light (Takagi). The regulation of movement of chloroplasts is due to the wavelength of the light that it is exposed to. Light has an effect on the movement of chloroplasts, and it would be interesting to see if there are any other factors that could either negatively or positively effect a chloroplast's movement. I decided to investigate the cellular behavior of the intracellular movement of chloroplasts within cells in response to a decrease in temperature. Intracellular movement is the movement of organelles and other particles within a cell. I wanted to see if the decrease in temperature would effect the rate of movement of chloroplasts within plant cells. To perform this experiment, I used the cells of an Elodea plant. Elodea, or Elodea Canadensis, is a freshwater plant that is found in freshwater streams and ponds. It is a multiple branched, aquatic plant, with numerous thin, bright green, serrated leaves (Elodea Canadensis)

Will exposing the cells of an Elodea plant to a temperature well below room temperature effect upon the rate of movement of chloroplasts within the cell? When I thought about this question, I developed my hypothesis upon the fact that exposing an object to temperatures lower than its own temperature causes heat to be extracted from the warmed object. Since the relative motion of particles is influenced by heat, an increase in temperature, the measure of heat, will increase the kinetic energy of the object that is being exposed to the increase in temperature (Chemistry). Consequently, the lowering of the temperature of an object will cause the motion of the particles with in it to slow down. The extraction of heat will cause the motor proteins that move along microtubules within the cell to slow their movement. This would cause the slowed movement of the chloroplasts, because the motor proteins that move along the microtubules are the proteins that move the chloroplasts within the cells. Taking this into consideration, I hypothesized that if Elodea leaves are cooled on ice, then the rate of movement of the chloroplasts within the cells will decrease to a rate slower than that of the rate of movement of the chloroplasts at room temperature. To test my hypothesis, I performed an experiment that involved taking Elodea leaves, exposing them to ice to extract their heat and then observing the intracellular movement of the chloroplasts within the cells. My experiment involved the preparation of a control condition in which I observed the rate of movement of chloroplasts at room temperature, and an experimental condition, in which I observed the rate of movement of chloroplasts after having extracted the heat from the cells.

The process of motor proteins moving along microtubules is a type of chemical reaction and every chemical reaction is effected by the addition or extraction of heat. Since every chemical reaction is effected by the change in heat, then this suggests that the extraction of heat from the Elodea leaves will cause a slowed movement of chloroplasts within its cells. This experiment is physiologically relevant to Elodea cells. The significance of the effect of temperature upon the cells of Elodea plants can provide information that can lead to finding the optimal living conditions for these plants. It can also lead to answering questions about photosynthesis and whether the chloroplasts that are involved in this process are affected by temperature, thus effecting photosynthesis in Elodea plants.

Materials and Methods:

Materials:

- * Elodea plants (in a container of the pond water in which they thrive, maintained in a green house when not being utilized in lab)
- * Four slides and four slip covers.
- * A plastic pipette.
- * Razor blade
- * Chem wipes
- * Ice
- * One Millex GV 0.22 micrometer filter unit
- * Tube for filtering pond water
- * Macintosh computer
- * Nikon Eclipse E200 light microscope
- * Digital Interface camera manufactured by Sony Corporation
- * Computer programs
 - BTV pro
 - ImageJ
- * Test tube
- * Ice and container to hold the ice
- * Thermometer

Methods:

Prior to collecting data, note that data from a control and its corresponding experimental should be obtained and collected on the same day. If for some chance data collection happens over a period of days, a new control and a new experimental should be prepared and data should be collected from both conditions. This will ensure consistency and accuracy in the obtained data.

Before preparing slides.

- 1) I obtained the elodea plants from the green house, which were still in their original pond water and brought them to the lab.

- 2) I took a large tube and sucked up some pond water.
- 3) I placed a 0.22 micrometer Millex GV micrometer filter unit on the tip of the tube.
- 4) The I filtered the water by draining out the water through the filter. This allowed the water to be clear, filtered pond water.
- 5) Next I took a thermometer and recorded the temperature of the water. The temperature should be about room temperature.

A. Preparation of control slides

- 1) I brought to my lab bench a slide, cover slip, razor blade and a pipette.
- 2) I took the elodea plant and pulled off a leaf. Since leaves are several layers of cells thick, I took a razor blade and carefully shaved off a thin layer of the leaf in order to obtain a sample that was clear under observation due to the decreased layers of cells.
- 3) I took the leaf shaving and placed it on the middle of the slide. Taking a plastic pipette, I placed a few drops of the pond water, from the bucket containing the plants, onto the leaf on the slide. Then I took the cover slip and carefully placed it onto the leaf, making sure not to capture any air bubbles under the slipcover. The best method of this is to take one edge of the slipcover, place it on the slide and then slowly lower the slip cover over the sample on the slide. This should produce a slide that does not have any air bubbles. If there is any excess water on the slide, take a chem wipe and remove it carefully.
- 4) This slide was the control in this experiment

B. Using the microscope and digital camera of view the cells.

- 1) I turned on the Macintosh computer, Nikon Eclipse E200 microscope and the attached Sony Digital Interface camera that are located at the lab station.
- 2) I placed control 1 on the microscope stage.
- 3) Using the 4x objective lens first, I observed the cells with the microscope. I obtained a focused view of the cells, and then switched to the 10x objective lens and focused that view of the cells as well. Once that is viewed as clear and focused, I switched to the 40x objective lens and once more, observed the cells and obtained a focused view of the Elodea cells.
- 4) Once there was a clear and focused view of the cells with the use of the 40x objective lens, I observed them on the computer with the use of the Sony Digital Interface camera.
- 5) To view the image that is seen with the microscope, a computer program called BTV pro was used.
- 6) I clicked on the BTV pro icon at the bottom of the desktop. Clicking on this icon opens BTV pro.
- 7) Once BTV pro was open, I clicked on the option at the top of the desktop that read Video Size. I clicked on it and then choose a desired resolution size. If planning on making a website upon completion of this experiment, the best choice for resolution is 640 x 480 pixels
- 8) There is a silver lever-like attachment on the upper right portion of the microscope. To move the view of the cells from the microscope to the computer screen, I pulled the lever out as far as it would go. This put the camera to use, allowing the view of the cells under observation to be seen on the computer screen with the use of the camera and the BTV pro computer program.
- 9) Once the image of the cells appeared on the computer screen, a picture or movie of the cells was

captured. (Note: Even though the image of the cells appears on the computer screen, the microscope can still be utilized, as before, in the focusing and movement of the view of the cells. The only aspect that changes is that the view of the cells cannot be seen through the eye piece of the microscope.)

10) After observing and focusing the image of the cells on the slide, it was then time to capture and collect data.

C. Capturing Data

- 1) To obtain and capture data, I first made sure that BTV pro was being utilized to observe the cells on the computer screen.
- 2) Once a desired view of the cells appeared on the computer screen, I moved the cursor to the option on the top of the desktop that read Capture. I clicked on Capture and then clicked on Capture Movie. For the purpose of this lab, only a short movie was needed. I captured a movie anywhere between 5-15 seconds in length. I used a stop watch to regulate the capturing time.
- 3) Once the desired time length was reached, I clicked on Capture and then Stop Capturing.
- 4) I saved the movie with an appropriate name so to easily distinguish it from the rest of the data. The name should be followed by .mov and it should be saved to the server in a folder with the rest of the collected data. (Note: Movies that are too long take up more memory and take longer to save. It is safest to capture a short movie because saving large files can cause the program to crash.)

Repeat Procedures A, B and C for a second control.

D. Preparation of Experimental Slides

- 1) To prepare an experimental slide for this lab, I followed the same procedure for A.
- 2) After preparing the slide the same way as the control slide, a variable was introduced to the slide.
- 3) Since this experiment tested the effect of the extraction of heat from Elodea cells upon the movement of the chloroplasts within the cell, the slide was exposed to a source of cold.
- 4) To expose the slide and the Elodea cell upon the slide to a temperature vastly lower than that of room temperature, I took a plastic container and filled it with crushed ice.
- 5) I took the container of ice and flattened the top layer of ice so that it became a flat and even cold surface. There are a number of ways to flatten the surface of the crushed ice. One technique would be to fill the container to the brim with ice and then flatten the edge by taking a ruler or the edge of a lab bench and run the container across the surface, which will make the top flat and even.
- 6) I placed the prepared slide onto the flattened ice layer and allowed the slide and the cells within the leaves to become cold. I allowed the slide to lay on the ice for about 15 minutes prior to observing the cells on the slide.
- 7) Once the heat from the cells and the slide were extracted due to their exposure to ice, I observed the cells with the microscope.

E. Observing the experimental slides with the Nikon Eclipse E200 microscope and Digital Interface Camera

- 1) I followed the procedure for part B and C exactly, with the exception of one additional step.
- 2) After placing the slide on the microscope stage, I placed pieces of ice onto the sides of the slide, to keep the slide as cold as possible for as long as possible, making sure not to allow any melting water to drip all over the microscope.
- 3) Note: Since this experimental is testing the effect of lack of heat upon cells, it is necessary to perform this procedure as quickly as possible to ensure that the cells do not heat up during the process of observing the cells and capturing the data.

Repeat procedures D and E for a second experimental.

F. Quantifying Data

- 1) At this point in the experiment, all of the data has been collected in the form of a movie captured in the program BTV pro and saved in a single folder in a .mov format.
- 2) There are four movies all together. Two controls and two experimentals.
- 3) To quantify the data, I took one of the movies captured and followed the movement of about 4 random chloroplasts within the cells and determined their rate of movement within the cell in micrometers per second.
- 4) The use of the computer programs BTV pro and ImageJ are needed in the quantification of collected data.
- 5) In order to determine the rate of movement, I took a movie and observed the chloroplasts' positions initially and then after about 5 seconds. This cannot be done using the movie itself. To observe and compare the positions and relative movements of chloroplasts after five seconds, specific frames of the captured movie needed to be examined. Frame 1 and frame 73 of the movie are the two frames that were examined in order to find its rate. Frame 1 shows the initial position of the chloroplasts because that is the first frame that was captured, and frame 73 is the position of the cells after 5 seconds into the movie.
- 6) To remove these frames from the movie and observe and compare them individually, they needed to be exported from the movie itself
- 7) To export a frame, I first opened the desired movie in BTV pro.
- 8) I went to Window and selected Frame Positions.
- 9) A box will appear on the screen in which the desired frame number or time(in seconds) could be entered. I typed in the desired frame number.
- 10) Once the desired frame number was typed in, the program jumped to that frame in the movie and that image that was desired appeared on the computer screen.
- 11) I went to file, and clicked on Export Frame. I saved this frame with an appropriate name so to be able to distinguish it from the rest of the frames that were exported. I saved this as a JPEG in the folder with the rest of the data.
- 12) For each movie, I exported and saved frame 1 and frame 73.
- 13) I opened the folder, clicked on the icon of the saved frame and draged it onto the ImageJ icon

located on the bottom of the desktop. This opened the image in the ImageJ program. To observe and compare the two frames, I opened both frames in ImageJ so that I could have both of the pictures present on the computer screen.

14) I positioned the frames so that they were side by side and observed the positioning of the chloroplasts. I picked a random chloroplast on one of the frames and identified it on the second frame. To determine how much that specific chloroplast moved from the first frame to the 73rd frame, I went to the toolbar that comes up on the top of the screen and clicked on the Straight Line selection.

15) Selecting the straight line option allowed for the ability to find the x and y coordinates of a particular point on the frame. This was done by simply placing the cursor on top of the point on the frame whose location was desired. I took the cursor and placed it over the center of the chloroplast being observed. I recorded its x-y coordinates. I went to the other frame and found the same chloroplast and again placed the cursor over the center of the chloroplast and then recorded the x-y coordinates that appeared on the toolbar.

16) Once the locations of the chloroplasts were identified, the two points were used to find the distance that the chloroplast moved in pixels over the five second interval. To find the distance, I took the cursor and placed it on the coordinate that was recorded for the location of the chloroplast in frame one. I clicked on that point, holding down on the mouse, and dragged the cursor until it reached the coordinate of the location of the chloroplast that was on frame 73. Once the cursor had reached that coordinate let go of the button on the mouse. This produced a line on the frame. This line was the distance that the chloroplast moved, in pixels, from frame one to frame 73.

17) To find how many pixels long the line was, I clicked on Analyze, and then clicked on Measure. A box appeared on the computer screen and in the box there was a number. This number was the number of pixels the chloroplast had moved in a 5 second period. I recorded this distance in pixels/5 seconds.

18) I repeated steps 14-17 for three other chloroplasts on the frames that were opened in ImageJ.

19) I took the four distances that were obtained, converted each of them in micrometers per second and found the average rate of movement.

1. I took the distance found, which is in pixels per 5 seconds and divided it by 5. This gave a value in pixels per second.
2. I took the value in pixels per second and multiplied it by 1.52 micrometers per pixel, which gave the distance in the desired units of micrometers per second.
3. I converted all of the four distances of the four different chloroplasts and then added them together and divided by four. This produced the average rate of movement in micrometers per second for that particular condition.

20) I repeated steps 3-19 for the rest of the movies that were captured. I recorded and labeled all the data that was quantified.

21) I then took the rawdata of from both of the controls located on table one, averaged the rates together and came up with an overall average rate of movement for the control. I did the same calculations with the raw data obtained from the two experimentals as well.

Results:

I collected my data initially in the form of movies. With the data in this form, it was easy to interpret qualitatively. I captured movies of four different slides, two experimental and two controls. My data collection occurred over a two day period. I obtained data from one control and one experimental condition on the first day and one experimental and one control on the second day. Looking at the data qualitatively, I noticed how there was variation between the appearance of the cells, varying in the amount of chloroplasts present in each cell. There was also variation among the observed rate of motion of the chloroplasts among the two controls and the two experimentals. When observing the rate of movement of the chloroplasts within the cells was quite different between the control cells and the experimental cells. By just watching the movies that I captured of each condition, I was able to observe that the chloroplasts in the control cells moved at a faster rate than the chloroplasts in the experimental cells.

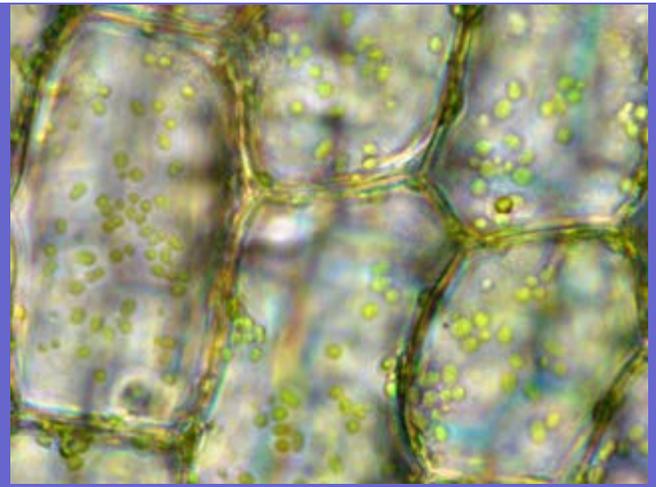
I quantified my data to obtain the rate of movement of the chloroplasts within each of the controls and each of the experimentals. From each control and each experimental movie, I collected data that allowed me to calculate the rate of movement in micrometers per second. The average rate of movement of the chloroplasts in the first control is 7.51 micrometers per second. The average rate of movement within the cells of the second control is 10.01 micrometers per second. The average rate of movement of the chloroplasts in the first experimental is 3.95 micrometers per second, and the average rate for the second control is 1.46 micrometers per second. Combining all of the control data and all of the experimental data, the average rate of movement of the chloroplasts for all the control cells is 10.05 micrometers per second. The average rate of movement of the chloroplasts for all the experimental cells is 2.87 micrometers per second. Below is a data table of the rates of movement of the four chloroplasts obtained from each of the controls and experimentals and the averages that they produced for each condition. The rates of the four chloroplasts and the average rate of movement for each of the four movies is in Table 1 below. The average rates of movement of all of the experimental cells and all of the control cells is located in Table 2.

Table 1:

Rate of Movement (micrometers/sec) of Chloroplasts Within Elodea Cells

Control 1

	Control 1	Control 2	Experimental 1	Experimental 2
Rate of Chloroplast 1	8.35	13.05	5.68	1.52
Rate of Chloroplast 2	7.07	9.43	2.87	1.52
Rate of Chloroplast 3	6.52	5.40	3.80	1.28
Rate of Chloroplast 4	8.09	12.50	3.46	1.52
Average Rate	7.51	10.01	3.95	1.46



Experimental 1

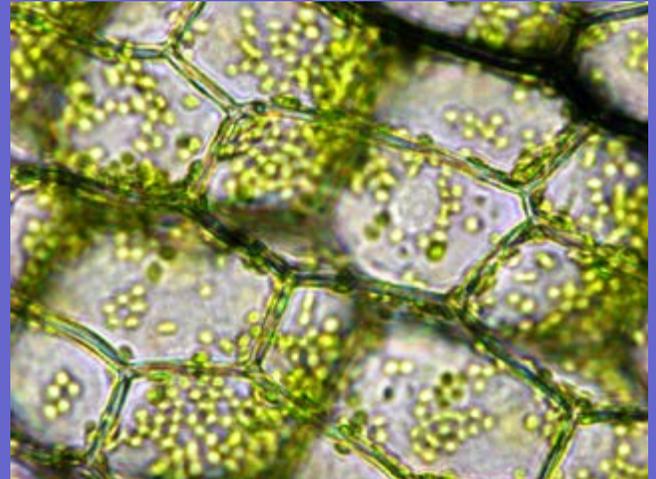


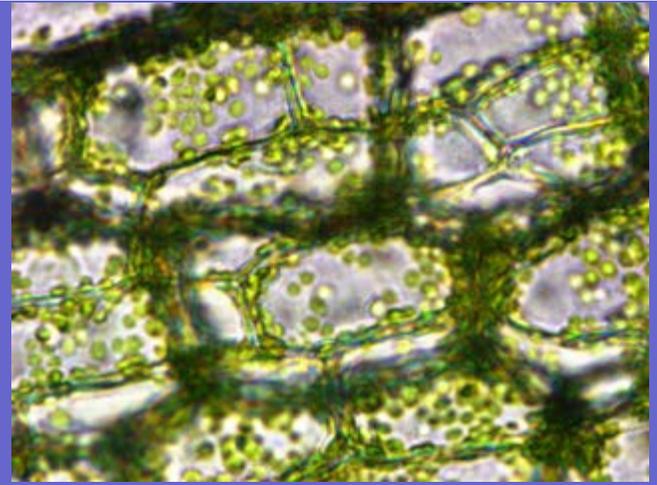
Table 2:

Average Rate of Movement of Chloroplasts of the Controls and Experimentals

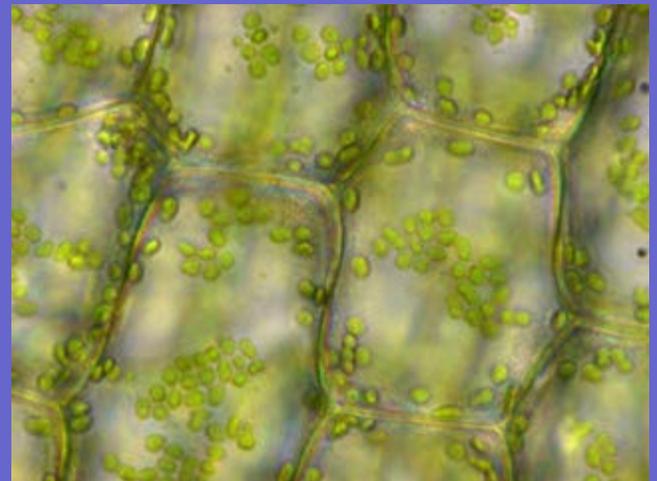
Control 2

	Control	Experimental

Average Rate (micrometers/sec)	10.05	2.87



Experimental 2



Discussion and Conclusion:

The data collected in this experiment indicate that the temperature in which elodea cells are exposed to, has a negative effect upon the rate of intracellular movement of chloroplasts within the cell. After quantifying the data, I was

able to take my results and determine the average rate of movement within the cells for each of the controls and each of the experimentals. I made sure that I had an experimental and a control for each day. This ensured that my data would be consistent and would eliminate any chance of adding another variable into the equation. I compared the control from the first day to the experimental from the first day and my data showed that the rate of movement of the chloroplasts drastically changed due to the exposure of the cells to ice. The average rate of movement of the cells in the control was 7.51 micrometers per second, while the average rate of movement of the chloroplasts in the experimental was 3.95 micrometers per second. Looking at the two rates, it is apparent that the rate of intracellular movement within the cells decreased by about 50% when heat was extracted from them. Taking the data from the second day of data collection, I obtained a rate of movement for the second control and experimental as well. The average rate of movement of the cells in the second control was 10.01 micrometers per second, while the rate of movement in the experimental was 1.46 micrometers per second. Looking at these two rates, it was also apparent that the rate of movement of the chloroplasts decreased to a high degree when they were exposed to ice. The rate of the experimental on the second day decreased by just under 90% from that of the control rate of movement.

The data that was collected for this experiment support my hypothesis that if elodea leaves are cooled on ice, then the rate of movement of the chloroplasts within the cells will decrease to a rate slower than the rate of movement of the chloroplasts at room temperature. The two rates of movement that were calculated from the two experimental conditions were both significantly lower than that of the rates of movement within the two control conditions. It was expected that my results would show a decrease in the rate of movement of the chloroplasts in the experimental cells that were exposed to ice. Since kinetic energy increases with an increase in heat, it only makes sense that a decrease in heat will cause there to be a decrease in kinetic energy. If there is a decrease in kinetic energy, then that will cause the intracellular movement of the cell to slow down from that of the intracellular movement of the cells that were observed at room temperature. The cells in both experimental conditions were exposed to ice, which extracted heat from the cells, causing them to have less kinetic energy. The fact that less kinetic energy causes a slowed rate of movement in the cell is why it was expected that my results would show a slowed rate in the experimentals. This is based upon the change in kinetic energy of the motor proteins that aid in the movement of the chloroplasts. Motor proteins move along microtubules within the cell, and the movement of these motor proteins causes there to be a movement of organelles, and in this case, the chloroplasts. Similar to the mechanism of kinetic energy in terms of molecules and atoms, the increase of heat of a chemical reaction causes the rate of the reaction to increase. The process of motor proteins moving along microtubules is, in itself, a chemical reaction. Since rates of all chemical reactions increase when they are heated, this chemical reaction within the cell will increase its rate as well. Consequently, this chemical reaction will decrease its rate if heat is removed from it. When the heat is extracted from the cells, the motor proteins will move slower along the microtubules, causing the movement of the chloroplasts to slow as well.

When I compared the rates of both of the controls to each other, I was surprised to find that the rates were different. I had expected that the rates of the movement of the chloroplasts would have been the same because they were at the same temperature of about 25 degrees Celsius. Since the cells were maintained in the same temperature water, I had expected that the rates of movement would have been a lot closer than they were. I expected to see this based on the fact that the cells were kept at the same temperature, implying that they would have the same amount of energy available for the chloroplasts to utilize in the movement within the cells. The procedure for these controls was performed on different days, which could imply that cells behave differently on different days. The differences in the rates of movement could also be due to the fact that when I captured each movie, the amount of time elapsed between removing the leaves from the pond water and viewing the leaf sitting with the microscope, could effect it. Since the microscope releases some heat, especially in the area of the slide that is exposed to the light from the bottom of the microscope, the longer the cells were exposed to the light before I captured the movie could have caused an increase in temperature of the cells, thus increasing the rate of movement of the cells. This could also be true for my experimentals, because the rates of the two experimentals were also very different. This was also unexpected for the same reason as the fact that the control rates of movement were different from one another. I exposed each of the experimentals to ice for the same 15-20 minute period.

In terms of the experimental, I feel that my method of attempting to keep the cells and the entire slide cold during the process of capturing the movie could have been better. When I observed the cells of the experimental conditions with the microscope, I made sure that I performed the observing and then capturing of those movies as quickly as possible, making sure, however, that my data were going to be accurate and understandable. I tried to work with the

experimentals as quickly as possible so to not allow the cells and the slide to heat up too much. I also placed chunks of ice upon the edges of the slide to help keep the slide and its contents cold. If I were to perform this experiment again, I would definitely search for another technique that may be a little more accurate than just placing ice on the slide and working as quickly as possible. Although I feel that my method was not the best that I could have used, I do feel that it was accurate and sufficient enough for me to collect accurate and usable data. I determined this because of the fact that the average rate of movement of the chloroplasts in both experimental conditions were extremely slower than that of the control conditions' rates of movement. Another factor that could have caused for this difference in rates, as well as the difference in rates for the controls is that different leaves from the plant were used in each of the four conditions. This suggests that cells behave differently in different parts of the plant and that there may not be a constant rate of movement of chloroplasts within the cells of Elodea plants.

Another reason why the rates vary could be due to the way that I determined the rate of movement within each of the cells. The way I determined the rate of the cells was by randomly picking four chloroplasts within the cell under observation and measuring its movement over a five second period. This did allow me to quantify my data, but I think that if I were to perform this experiment again, I would choose to observe and measure the movement of more than just four chloroplasts. It would give me a more accurate determination of the average rate of movement within the cells. Only having found the rate of four chloroplasts could have made my results inaccurate. The rates were so different between the experimentals and the controls, that I do not believe my overall conclusion would be altered, but my average rates would be more accurate. The reason why I believe that the rates would be more accurate is because, as I had mentioned earlier, not all of the chloroplasts moved at a consistent rate compared to one another. Therefore, if I had found the rates of more chloroplasts, I would have been more apt to include the varying rates of the majority of the chloroplasts. I would also try to collect all of my data on the same day. One other change I would make to my data collection would be to have a set time period in which the movie must be captured from the time that the slide was prepared to the time that I start the capturing of the movie. I would try to make sure that I took the movies as soon as possible for every condition, the controls and the experimentals.

My results, although not as accurate as I would have liked, did support my hypothesis. If I were to perform this experiment again, another aspect of my procedure that I would change would relate to the amount of data collected. I would definitely collect more data if I performed this experiment again. Although both sets of my data supported my hypothesis, I would feel more certain about my findings if I had five or even six sets of experimentals and controls. This would make my data and results more concrete and accurate. Analyzing my results further, a few questions arose that would take my results and extend them in a new direction. The first question that arose was, if the decreasing of heat slowed the rate of movement of chloroplasts within Elodea cells, would the increase in heat increase the rate? What is the cells threshold for heat before the effect of the increase of temperature of the cell changes from increasing the rate of movement, to decreasing the rate of movement due to the decomposition or death of the cells? Can the results of this experiment tell us anything about the optimal temperature in which Elodea plants can thrive in? I would perform this experiment similarly to my previous experiment, with the desired changes in my procedure for collecting and quantifying the data. I would prepare the control the same way I did in my experiment, but I would change the condition that I would expose the experimental cells too. I would heat the cells to varying temperatures above room temperature. I would expose them to temperatures that were slightly above room temperature, as well as extremely high temperatures. I would expose the experimentals to varying temperatures like that to test and see whether heat does increase the rate of intracellular movement and whether or not the cells have a heat threshold, which would be observed by the death of the cells characterized by no movement at all. Other possible experiments that could take my results and extend them in different directions include an experiment that would test to see whether the rate of the movement of chloroplasts has an effect on the growth of plants, and whether the decrease in temperature of the cell has a similar effect upon the intracellular movement of other organelles within the plant cell besides chloroplasts.

Based on my results, the extraction of heat from Elodea cells causes a decrease in energy within the cells, further causing the intracellular rate of movement of the chloroplasts to decrease. When looking at my collaborators results, I realized that they didnt exactly relate to my results. My collaborator tested to see what the effect of changing the pond waters pH of 8.42 to 6.1. He was unable to make a conclusion from his results because, unlike my results, one of his experimentals showed a slower rate of movement, while the other showed and increase in the rate of movement. All of my data supported my hypothesis. The data revealed that the rate of movement of the chloroplasts in cells that were exposed to ice decreased significantly from the rate of movement of the chloroplasts that were observed at room

temperature. The quantification and analysis of the data collected clearly supports my hypothesis that the extraction of heat will cause the rate of movement of the chloroplasts in Elodea cells to be slower than the chloroplasts in Elodea cells that were at room temperature.

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Picture of Elodea plant found at
<http://science.exeter.edu/jekstrom/WEB/CELLS/Elodea/Elodea.html>

