**Osmosis Across a Selectively Permeable Membrane**

**Introduction**

What does it mean to be alive? From a biology viewpoint, the cell is a necessary requirement in order to be considered living. It is the smallest unit of life. There are two basic types of cells: prokaryotic cells and eukaryotic cells. Prokaryotic cells are the simplest organisms that lack a membrane-bound nucleus and any other membrane-bound organelles. Eukaryotic cells, on the other hand, do contain these membrane-bound organelles. This makes them more complex. Despite these important differences, there are similarities between these two types of cells. They both contain cytoplasm, DNA, ribosomes, and the plasma membrane. This last common feature, the plasma membrane, is vital to an organism’s survival.

 The plasma membrane is a phospholipid bilayer that separates the inside of the cell from the extracellular matrix, or the outside of the cell. According to OpenStax College (2013), it is composed of two layers (bilayer) of phospholipids. These phospholipids contain a polar phosphate head and two nonpolar fatty acids tails. When placed in a water environment, the hydrophilic polar heads face outward, while the hydrophobic nonpolar tails face inward, forming the phospholipid bilayer (147-148). Figure 1 below shows this explanation.



**Figure 1.** The phospholipid bilayer cell membrane. Image found online at Boundless.com, the publisher of *Boundless Biology.*

It is essential that substances, such as nutrients and molecules, are able to move in and out of the plasma membrane. How does a cell do this? As stated by OpenStax College (2013), there are mechanisms that require no outside source of energy where particles are able to flow freely (passive transport), but there are also molecules that require outside energy in order to move (153). These molecules are too large or unable to move across the concentration gradient, therefore they use active transport (161). Diffusion and osmosis are two types of passive transport that are crucial to a cell.

 Diffusion is the passive, directional movement of molecules from an area of high concentration to an area of low concentration. Like Vodopich (2014) describes, the rate of diffusion can be affected by many factors, including the steepness of the concentration gradient along with the size, polarity, and solubility of the molecules (94). For example, the rate of diffusion increases when temperature is increased due to the faster movement of particles in the air.

 Osmosis is a specific type of diffusion characterized by water moving across the plasma membrane. Plasma membranes are selectively permeable, meaning that they only allow certain substances in and out. In situations where the water can move and molecules and other particles cannot, the water will move from areas of high concentration to areas of low concentration. According to Vodopich (2014), there are three different types of solutions that a cell can be surrounded by: hypotonic, hypertonic, and isotonic*. Hypotonic solutions* have a lower concentration of solutes and a higher amount of water than the cell. *Hypertonic solutions* have a higher concentration of solutes and a lower amount of water than the cell. Finally, *isotonic solutions* have the same concentration of solutes and water compared to the cell (97). When describing the direction of the movement of water (osmosis), the water moves from areas of high concentration to areas of low concentration. This means water moves from hypotonic to hypertonic solutions because hypotonic solutions have more water and less solute, and hypertonic solutions have less water and more solute. In order for equilibrium to be reached, water will follow its concentration gradient (high to low) and flow from hypotonic solutions to hypertonic solutions.

 There are scientists who are currently testing the idea that water moves from hypotonic to hypertonic solutions to make more efficient vaccines. Immunizations play a vital role in the prevent and eradication of widespread diseases. Various methods have been examined in order to eliminate numerous shots and ensure maximum immunity against the pathogen. De Geest et. al came up with the idea to use osmotic pressure “as the triggering mechanism to cause physical rupture of a vaccine-containing capsule” (Melchels et. al). In order to test the concept of osmotic pressure, the scientists in this experiment used polymer tubes and glucose to control the rate of water, ultimately resulting in bursting of the membrane as the hydrostatic pressure overcame the burst pressure of the capsule, thus instantaneously releasing the payload. The results of their experiment show that “the behavior of the osmosis-driven delayed burst-release devices can be expected to be mostly independent of external factors, thus presenting a reliable platform for vaccine delivery” (Melchels et. al).

In order to test the hypothesis that water moves from hypotonic solutions to hypertonic solutions when solute particles are not able to move due to the selectively permeable plasma membrane, an experiment involving various sugar solutions and dialysis tubing will be tested. If the hypothesis is supported, the tubing placed in hypotonic solutions will increase in weight due to water moving into the tubes; the tubing placed in hypertonic solutions will decrease in weight due to water leaving the tubes; and the tubing placed in isotonic solutionsshould have no change in weight because there will be no net movement of water.

**Materials and Methods**

*Setting up the Experiment*

The dialysis tubing was cut into 15 cm long pieces and soaked in water. Four different pieces were made into bags containing sucrose solutions. Bag A contained 1% sucrose solution, Bag B also contained 1% sucrose solution, Bag C contained 10% sucrose solution, and Bag D contained 25% sucrose solution. Each bag had precisely 10 mL of their particular solution. A 15 cm string was cut and securely tied around one end of Bag A. One person held the tubing while the other individual did the tying. A piece of paper was labeled “A” with a permanent Sharpie in order to differentiate between each bag. Tweezers were used to slip the little piece of paper into the opened end of the tubing. A 10-mL pipette was then used to obtain 10 mL of the 1% sucrose solution held in the flask. This solution was then released into the dialysis tubing. The opened end was loosely folded over and slightly pressed to push the fluid up in order to get rid of any air bubbles. It was then folded over and securely tied with another 15 cm long string. This procedure was repeated for all four bags with each containing their appropriate type of solution.

Once the pieces of tubing had the appropriate type and amount of solution, the beaker and container were prepared. A 250 mL beaker was obtained and filled with 150 mL of the 10% sucrose solution. The large Tupperware container was filled up roughly halfway with 1% sucrose solution.

The tubing was now weighed. The electronic scale was plugged into the outlet, and a small plastic tray was placed on top of it. After being zeroed out by pressing the “zero” button, each bag was separately weighed in grams. Bag A was placed on the tray, weighed, taken off, and the scale was zeroed again. This was completed for the rest of the bags, B, C, and D. Table 9.1 in the Biology 105/106 Lab Manual, found on page 98, was copied and made into an excel data sheet. The initial weight for each bag was recorded in its appropriate location.

*Beginning the Experiment*

Since all the materials were now ready and the initial weight of each bag had been recorded, the pieces of tubing were placed into their appropriate containers. Bag A was placed into the 10% sucrose solution in the 250 mL beaker, and Bag B, C, and D were all placed into the large Tupperware 1% sucrose solution. The timer was set for fifteen minutes, and the start button was pressed.

*During the Experiment*

Once 15 minutes had passed and the timer went off, the bags were taken out of their containers and patted with a paper towel in order to ensure there was no extra weight due to the outside being wet. Each bag was then individually weighed by being placed in the plastic tray on the electronic scale. The scale was always zeroed out before anything was weighed. After each tubing was weighed, they were placed back into their respective containers for another fifteen minutes. Their weight was recorded on the excel data sheet. This procedure was repeated every fifteen minutes, for a total of sixty minutes.

 To keep track of how the bags were being affected, the total weight and change in weight (measured in grams) were recorded on the excel data sheet for each time interval. The change in weight was found by subtracting the total weight for the specific time interval from the initial weight taken at 0 minutes.

*After the Experiment*

After an hour had passed and the tubing had been weighed five times, (one initial weight and four times representing each time interval), the experiment had reached an end. All the materials were cleaned up by throwing away the tubing and discarding the solutions found in the containers down the sink. The beaker and Tupperware were thoroughly washed out, and everything was put back to its appropriate location.

**Results**

 Dialysis tubing was used to represent a cell membrane in order to test the concept of osmosis. As stated in the hypothesis, water should move from hypotonic solutions to hypertonic solutions when the solute particles are unable to move. This is because water flows from areas of high concentration (hypotonic solutions) to low concentration (hypertonic solutions). The weight for each bag was initially recorded at 0 minutes and then every fifteen minutes along with its change in weight. This information is presented below in Table 1.

 As can be seen in table 1, bag A had a total weight change of -1.0 gram in the 60-minute time interval. Bag B had a total weight change of +0.3 grams. Bag C had a total weight change of +1.7 grams. Finally, Bag D had a total weight change of +3.8 grams. When looking at the individual time intervals for each bag, it can be noted that they follow a trend. Bag A had a relatively slow decrease in weight over time, Bag B stayed roughly the same weight with only a slight increase over time, and Bag C and D had a larger increase in weight over the 60 minutes. In particular, Bag D had the largest change in weight compared to any of the other bags.

**Table 1**. The initial weight of each dialysis tubing along with the total weight and change in weight in 15-minute intervals over a 60-minute time period.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 0 Mins | 15 Mins | 30 Min | 45 Min | 60 Min |
| (all in grams) | Initial Weight | Total Weight | Change inWeight | Total Weight | Change in Weight | Total Weight | Change in Weight | Total Weight | Change in Weight |
| **Bag A** | 10.1 | 10 | -0.1 | 9.7 | -0.4 | 9.2 | -0.9 | 9.1 | -1 |
| **Bag B** | 10.3 | 10.6 | 0.3 | 10.5 | 0.2 | 10.3 | 0 | 10.6 | 0.3 |
| **Bag C** | 10.7 | 11.5 | 0.8 | 11.7 | 1 | 11.9 | 1.2 | 12.4 | 1.7 |
| **Bag D** | 12.5 | 14.1 | 1.6 | 14.7 | 2.2 | 15.5 | 3 | 16.3 | 3.8 |

 Figure 2 represents the data through a scatter plot graph. It shows how time affected the change in weight of each bag. This graph was made by using Excel and listing the appropriate information in the entry cells. The lines were made by using a trend line, which is also commonly known as a best fit line. Each bag is represented by a particular symbol that can be noted in the figure’s legend. This graph shows the relationship between time and change in mass of the bags in a more visual way. It also compares each bag to one another, showing which bags increased in weight (C and D), stayed the same (B), or decreased in weight (A) over the 60-minute time interval. The graph shows that increases or decreases in weight followed a linear trend.

**Figure 2**. Scatter plot graph that shows the change in weight (g) of each bag over time (mins).

**Discussion**

Each bag was placed in a solution that was either hypotonic, hypertonic, or isotonic. Bag A contained 1% sucrose and was placed in a 10% sucrose solution. This means the bag was hypotonic and the sucrose solution was hypertonic. According to the hypothesis, water flows from hypotonic to hypertonic solutions, meaning that the water should have moved out of Bag A and caused it to decrease in weight. This occurred based on the results, for the bag decreased -1.0 grams in weight.

 Bag B contained 1% sucrose and was placed in a 1% sucrose solution. Because these solutions contain the same amounts of sucrose and water, it is an isotonic solution. In isotonic solutions, there should be no net movement of water, which means that the rate of the movement of water should be equal and there should be no change in weight of the bag. This is true for Bag B, because it only increased in weight by +0.3 grams, which is a very minimal difference.

 Bag C contained 10% sucrose and was placed in a 1% sucrose solution. This means the bag is hypertonic and the sucrose solution is hypotonic. Again, the predicted result was that water flows from hypotonic solutions to hypertonic solutions. If this is the case, then water should have entered the bag and caused it to become larger. This happened as the bag increased in weight by +1.7 grams.

 Bag D contained 20% sucrose and was placed in a 1% sucrose solution. This means the bag is hypertonic and the sucrose solution is hypotonic. Because it was hypothesized that water moves from hypotonic solutions to hypertonic solutions, the water should have moved into the bag and caused an increase in weight. This seems to be the case, because the bag increased in weight by +3.8 grams. Bag D had the largest increase in weight, which is due to it having the largest concentration gradient, or the highest difference for the water particles to reach equilibrium.

 According to this analysis, the results support the hypothesis that water moves from hypotonic solutions to hypertonic solutions when solute particles are unable to move due to the selectively permeable plasma membrane. This is an important concept in cell biology and is the stepping stone of many new experiments and discoveries. As mentioned earlier, scientists have used this concept of osmotic pressure and the movement of water from high concentrations to low concentrations to create new technology. In the case of Melchels et. al, more efficient vaccines are being created by incorporating this well-known concept of biology.

 This particular experiment had its limitations for it was performed by using dialysis tubing, not real cells. In real life, other substances other than water will be able to move in and out of the cell. These may include macromolecules and other smaller molecules, such as gases. This was not mimicked in this experiment, because only water was able to move in and out of the tubing. It would be interesting to see what takes place within a plasma membrane as other particles are able to move through. Will this affect osmosis? If particles are able to move, then the concentration of the solutions is going to change, therefore directly affecting osmosis. The experiments in science are endless.

 Osmosis is a vital process that plays a huge role in many different areas of life. Even though it may be as simple as movement of water across a selectively permeable membrane, its applications in the world are complex and unending. It is so crucial to understand this process and other cellular activities in order to be well educated about the cell and, of course, life itself.

**References**

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