Teacher's Manual

Osmosis and Diffusion

IS3001

Next Generation Science Standards

MS-LS1-2. Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.

[Clarification Statement: Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.]

LS1.A: Structure and Function

- Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell.

MS-LS1-3. Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

[Clarification Statement: Emphasis is on the conceptual understanding that cells form tissues and tissues form organs specialized for particular body functions. Examples could include the interaction of subsystems within a system and the normal functioning of those systems.]

LS1.A: Structure and Function

- In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions.

HS-LS1-2. Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

[Clarification Statement: Emphasis is on functions at the organism system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. An example of an interacting system could be an artery depending on the proper function of elastic tissue and smooth muscle to regulate and deliver the proper amount of blood within the circulatory system.]

LS1.A: Structure and Function

- Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.

HS-LS1-3. Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

[Clarification Statement: Examples of investigations could include heart rate response to exercise, stomate response to moisture and temperature, and root development in response to water levels.]

LS1.A: Structure and Function

- Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.

Aligned to the Next Generation Science Standards (NGSS)*

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Osmosis and Diffusion

IS 3001

INTRODUCTION

Diffusion is the movement of molecules, at random, from one area to another. Diffusion occurs when there is an unequal concentration of molecules in an environment, known as a concentration gradient. These molecules have energy and are constantly in motion, bouncing off of each other and moving in random directions. In an area of high concentration, which therefore contains more molecules, the chances of collision are higher. Over time, the molecules distribute themselves equally throughout the environment; the rate at which this occurs being dependent on both the concentration gradient and the size of the environment.

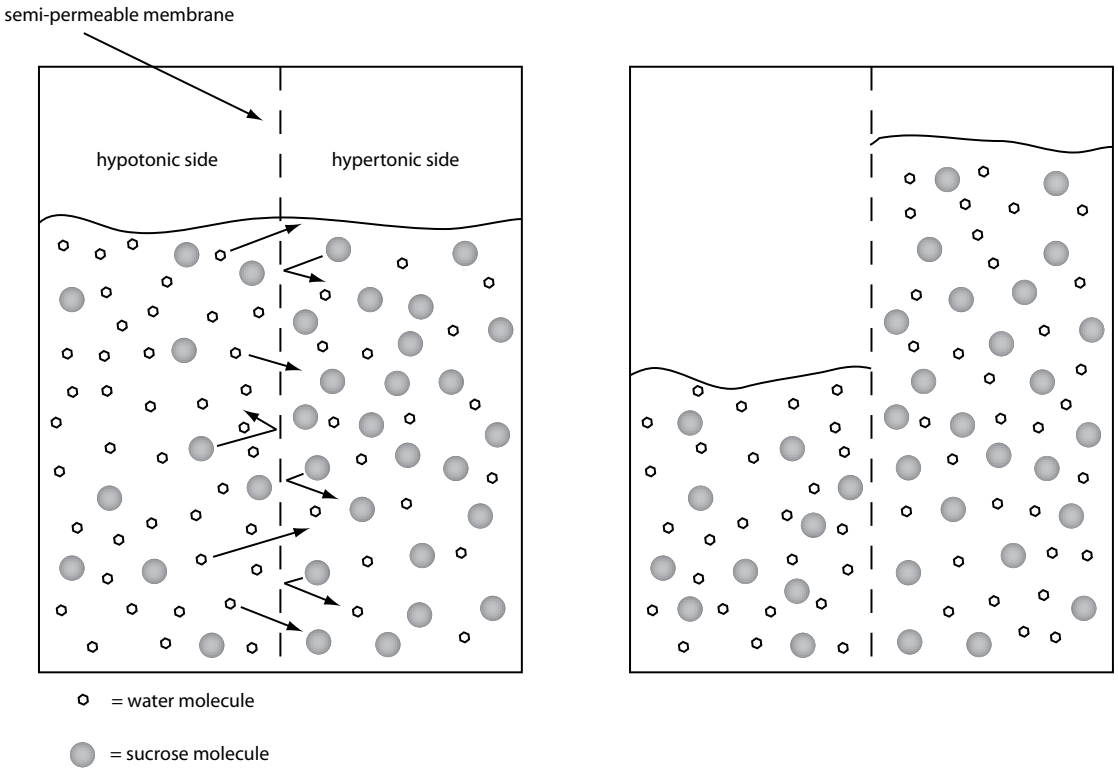
To illustrate this, consider a natural gas leak. Natural gas, used in forced-air heating, is odorless. For safety reasons, a special chemical is added to natural gas, giving it a distinctly unpleasant smell. If a home were to develop a natural gas leak, it may not immediately be noticeable unless one was in close proximity of the leak (area of high concentration). Over time, however, the molecules distribute themselves throughout the environment, alerting someone in another part of the home to leave the house and call for help.

Osmosis is a special form of diffusion. Osmosis is the diffusion of water across a concentration gradient. This is a very important concept to note. Osmosis is always a form of diffusion but diffusion is not always a form of osmosis. Another factor necessary for osmosis to occur is the presence of a barrier, known as a semi-permeable membrane, which will allow water molecules to cross but will not allow solutes (substances dissolved in the water) to cross. Diffusion may involve movement across a membrane or it may not. Osmosis always involves movement across a membrane. Diffusion may involve the movement of water and/or solutes; osmosis only involves the movement of water.

The direction water moves during osmosis is dependent on the concentration of solutes on either side of the semi-permeable membrane. The three key terms to understand when discussing osmosis are *hypertonic*, *hypotonic*, and *isotonic*.

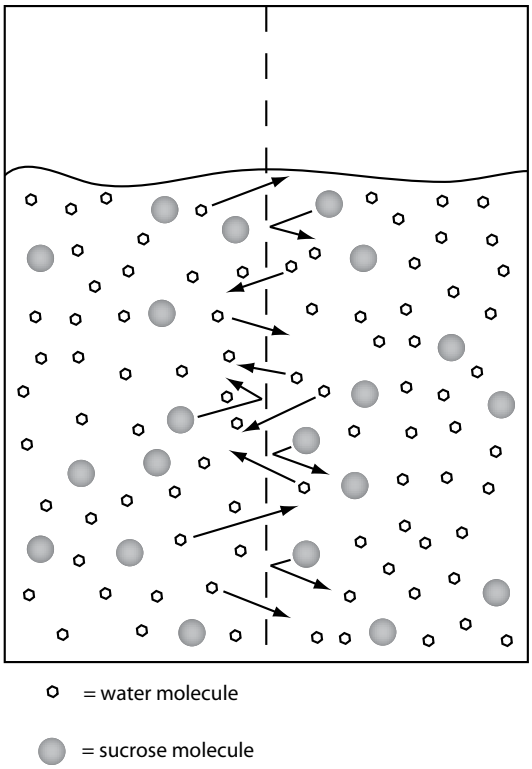
If two solutions differ in concentration, the solution with the higher concentration of solutes is said to be **hypertonic** (*hyper-* meaning greater or more). The solution with the lower concentration of solutes is known as **hypotonic** (*hypo-* meaning less or under). If both solutions have the same concentration of solutes, they are said to be in an **isotonic** (*iso-* meaning same or equal) state.

To illustrate the concept, consider a simple solution of only water and sucrose molecules, separated by a membrane that allows water molecules to pass, but not sucrose molecules. The illustration below represents what happens when two solutions of differing concentration are separated by the membrane, the solution on one side having more sucrose molecules (hypertonic) and the solution on the other having less sucrose molecules (hypotonic):



Notice above that since the sucrose molecules cannot pass through the membrane, the water molecules pass from the hypotonic side to the hypertonic side in an attempt to create an equal ratio of water-to-sucrose molecules. Also note that in the end result there is an increase of volume on one side of the system. This is because the hypertonic side gained more water molecules as both sides eventually reached the same concentration. Remember, concentration is a ratio of solute to solvent.

Now look at the diagram below representing two solutions of equal concentration (isotonic) separated by the same membrane:



As illustrated above, just because two solutions are isotonic relative to one another does not mean that water molecules do not move across the membrane. Through random motion, water molecules move through the membrane equally in both directions, the result being that, over time, neither side of the system shows a net gain of water molecules.

Diffusion, Osmosis, and Cells

All living cells are surrounded by a membrane, called the plasma membrane. The membrane is vital for controlling what enters and exits cells. The cell membrane is semi-permeable, meaning that only certain molecules can pass freely across the membrane. In other words, the cell membrane is responsible for regulating what moves into and out of cells.

Both diffusion and osmosis are vital mechanisms for cell survival. Cells need to bring in nutrients or remove waste material (diffusion) and need to regulate water levels both within the cell and surrounding the cell (osmosis). While diffusion and osmosis are the focus of this investigation, it should be noted that these two methods are by no means the only processes in which materials may cross a cell membrane.

Diffusion and osmosis are both forms of transport known as passive transport. The word passive is used because these forms of transport do not require energy to move the materials across the membrane. As mentioned previously, materials naturally move in an attempt to balance the concentration of solutes and/or water, which in this case would be balance between the inside and outside of the cell. The advantage of passive transport is that the cell, or organism, does not have to expend energy to meet a cell's needs. The generation and storage of energy is vital to the survival of all living organisms. Any energy expended in one process is less energy that may be available for another process. Energy used must be replaced. While saving energy is truly a benefit, there are a couple of disadvantages to passive transport.

Firstly, passive transport can be a slow process. This is a cost of the fact that no energy is being employed. If there was a higher concentration of nutrients outside of a cell than inside, and the cell needed the nutrients to survive, a passive process such as diffusion may not allow the nutrients to enter the cell as quickly as needed. Secondly, sometimes removing a solute or water imbalance may harm a cell. Consider the following scenarios:

- If a cell has a high solute concentration within the plasma membrane and there is a high water content surrounding the cell, the process of osmosis would cause water to move into the cell. As more water moves in, the cell expands and pressure is placed on the cell membrane. Eventually the pressure may become so high that the cell bursts in a process called *lysis*.

- Conversely, if the solute level outside the cell is higher than inside the cell, osmosis will draw water from the cell and into the external environment. This causes the cell membrane to contract and the cell to reduce in volume. Eventually, the cell may completely shrivel and be unable to function properly. This process is called *crenation*.

Fortunately, cells can also engage in forms of active transport. Active transport can cause solutes and water to move opposite the direction they would under passive conditions. However, the expense is that moving materials in this fashion requires the input of energy. While the goal of cells is to generate and store energy, having to use some of their energy is certainly preferable to cell death. Again though, the primary purpose of this investigation is to examine passive transport in the form of both diffusion and osmosis.

Objectives

- Learn about two forms of passive transport: diffusion and osmosis.
- Compare and contrast similarities and differences in the processes of diffusion and osmosis.
- Use a colorimetric test to demonstrate the movement of a solute across a semi-permeable membrane.
- Set up an environment likely to facilitate osmosis.
- Gather data to determine whether or not osmosis may have occurred.

Materials Included in the Kit

30 pc. Dialysis tubing
1 Starch capsule (to make 100ml of 1.0% solution)
1 btl. Sucrose (to make 100ml of 0.5M solution)
1 btl. Iodine/potassium iodide solution, 15ml
30 Plastic cups

Materials Needed but not Supplied

Electronic balances (0.01g or better)
Distilled or deionized water
Small funnels
Paper towels

Safety

Safety goggles
Gloves
Lab apron

Chemical Disposal: *All used solutions may be poured down the drain with copious amounts of water. Used dialysis tubing may be disposed of in the general trash.*

Pre-lab Preparation

Both stock solutions may be prepared up to two days prior to performing the lab. If they will not be used the same day, cover and refrigerate. Be sure to remove both solutions from the refrigerator far enough in advance to allow the solutions to reach room temperature before performing the experiment.

Preparation of 1.0% Starch Solution

1. Add 100ml distilled or deionized water to a 250ml beaker or flask (or similar container).
2. Place beaker or flask on a hot plate/stirrer.
3. With stirring, add the starch capsule to the water and turn on the heat to help dissolve the starch (no more than 100°C).
4. Allow the solution to mix with heat until the starch is completely dissolved.
5. Label the container “1.0% Starch.”

Preparation of the 0.5M Sucrose Solution

1. Add 50ml distilled or deionized water to a 250ml beaker or flask (or similar container).
2. Place the beaker or flask on a hot plate/stirrer.
3. With stirring, add the entire contents of the sucrose container to the water.
4. Allow the solution to mix (heat is not necessary) until the sucrose is completely dissolved.
5. Turn off stirring and add enough water to the container to bring the volume up to the 100ml marking.
6. Stir the solution briefly to mix.
7. Label the container “0.5M Sucrose.”

Prepare Dialysis Tubing

1. Approximately 15-30 minutes prior to performing the lab, place all of the dialysis tubing pieces in a large container containing distilled or deionized water.

Instructor’s Notes

This lab is composed of two activities performed successively. Part I of this activity should take students approximately 10-15 minutes to set up. They will then make observations during a 30 minute period. Part II also takes approximately 10-15 minutes to set up and students will gather data over a 60 minute period. Depending on the length of the lab period, you may wish to have students set up Part I and make their initial observation and then immediately set up and begin Part II, while continuing to make their observations of Part I. If students will be running both exercises simultaneously, be sure they read both procedures in advance to help them organize the time and set up.

Procedure

Materials Needed per Group

2 pc. Dialysis tubing
2 Plastic cups
Electronic balance
Small funnel
Paper towels

Shared Materials

1.0% Starch solution
0.5M Sucrose solution
Iodine/potassium iodide solution
Distilled or deionized water

Safety

Safety goggles
Gloves
Lab apron

Part I: Diffusion

1. Fill your plastic cup approximately ¾ full with distilled or deionized water.
2. Obtain one piece of dialysis tubing. Gently rub both ends of the dialysis tubing between your fingers to open the tubing.

Note to Students: *Dialysis tubing is composed of cellulose, a derivative of plants. The cellulose tubing contains microscopic pores. In other words, dialysis tubing is a semi-permeable membrane.*

3. Tie a knot in one end of the dialysis tubing as close to the end as possible.
4. Using a small funnel, add enough 1.0% starch solution to the dialysis tubing to fill it about halfway (approximately 5ml).

5. Tie a knot in the other end of the dialysis tubing, again tying the knot as close to the end of the tubing as possible. Both ends of the tubing should be completely sealed (no starch solution leaking out).

6. Rinse the sealed tubing under the tap briefly to wash away any starch solution that may have gotten on the outside of the tubing.

7. Set the sealed, rinsed tubing on some paper towels and gently blot dry.

8. Add one to two drops of iodine/potassium iodide to the water in your plastic cup and gently swirl to mix. The solution in the cup should be amber to light brown in color. If not, add one more drop and swirl again.

Note to Students: *Iodine and some iodine compounds are often used to test for the presence of starch. When iodine reacts with starch it displays a blue to purple-black color, depending on the amount of iodine and starch present. If no starch is present, the iodine will remain the same color.*

9. Observe the color of the solution in the cup and the color of the solution in the dialysis tubing and record your observations in the Data Analysis section of the lab.

10. Note the time and place sealed dialysis tubing in the cup containing the water/iodine solution.

11. Continue to make observations every ten minutes for the next 30 minutes. Be sure to note both the color of the solution in the cup and the color of the solution in the dialysis tubing. Be sure to record your observations in the Data Analysis section after each observation.

12. After 30 minutes, record your final observation. Remove the dialysis tubing from the cup and dispose of all materials according to your instructor.

Part II: Osmosis

1. Fill your other plastic cup approximately ¾ full with distilled or deionized water.
2. Obtain a second piece of dialysis tubing. Gently rub both ends of the dialysis tubing between your fingers to open the tubing.
3. Tie a knot in one end of the dialysis tubing as close to the end as possible.
4. Using a small funnel, add enough 0.5M sucrose solution to the dialysis to fill it about halfway (approximately 5ml).
5. Tie a knot in the other end of the dialysis tubing, again tying the knot as close to the end of the tubing as possible. Both ends of the tubing should be completely sealed (no sucrose solution leaking out).
6. Rinse the sealed tubing under the tap briefly to wash away any sucrose solution that may have gotten on the outside of the tubing.
7. Set the sealed, rinsed tubing on some paper towels and gently blot dry.
8. After blotting the dialysis tubing dry, use an electronic balance to determine the mass, to the resolution of the balance, of the dialysis tubing containing the sucrose solution. Record the mass, in grams, in the Data Analysis section of the lab.
9. Note the time and place the sealed dialysis tubing in the cup containing the water.
10. Continue to make mass measurements every ten minutes for the next 60 minutes. Be sure to thoroughly blot the dialysis tubing dry before determining the mass with each measurement and place the dialysis tubing back in the cup immediately after taking each measurement. Be sure to record all of your measurements in the Data Analysis section.
11. After 60 minutes, record your final mass measurement. Dispose of all materials according to your instructor. Be sure to wash your hands before leaving the lab.
12. Using the blank graph in the Data Analysis section, graph your results of mass readings against time. You will have to determine the mass range to place on the y-axis and place time values on the x-axis.

Name:	Instructor:
Date:	Class/Lab Section:

DATA ANALYSIS

Part I: Diffusion

Time	Color Solution in Cup	Color Solution in Tubing
Initial	**light brown**	**clear**
10 Minutes	**light brown**	**clear**
20 Minutes	**light brown**	**light purple**
30 Minutes	**light brown**	**purple-blue**

Part II: Osmosis

Time	Mass (g)
Initial	**7.301**
10 Minutes	**7.722**
20 Minutes	**8.213**
30 Minutes	**8.563**
40 Minutes	**8.927**
50 Minutes	**9.298**
60 Minutes	**9.395**

Sample Data only. Student results will vary.

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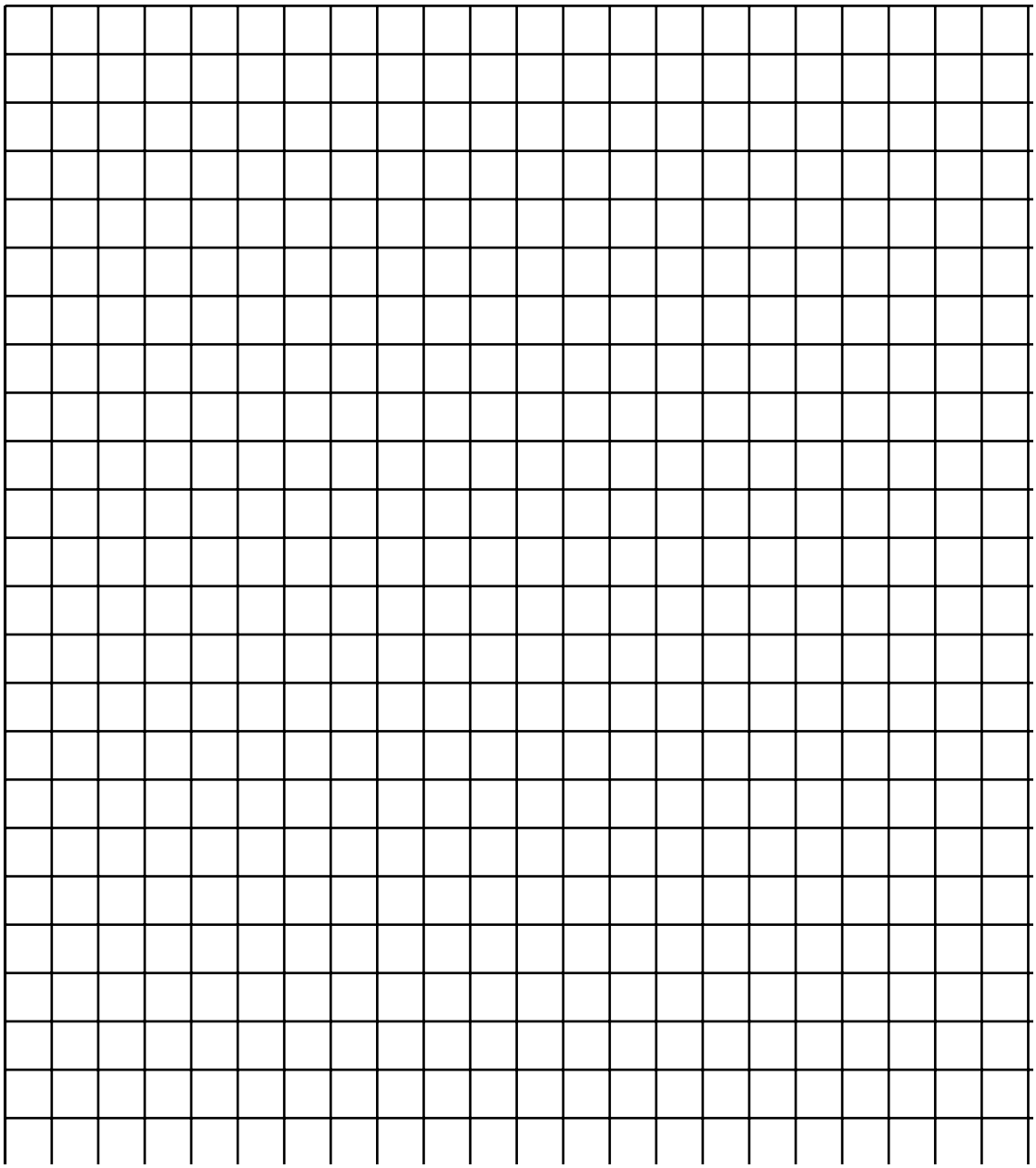
Name:	Instructor:
Date:	Class/Lab Section:

DATA ANALYSIS

Title:_____



Name:	Instructor:
Date:	Class/Lab Section:

DATA ANALYSIS

Questions

1. Based on your observations for Part I, do you think diffusion was occurring? Explain.

Students should conclude that diffusion was occurring due to the fact that the starch solution in the dialysis bag was changing color, indicating that the iodine/ potassium iodide was moving into the bag and reacting with the starch.

2. The solutions used in Part I had two solutes: starch in the dialysis tubing and iodine/ potassium iodide in the cup. Based on the results, do you believe iodine/potassium iodide was moving into the tubing, starch was moving out of tubing into the cup, or both? Explain.

Students should conclude that iodine/potassium iodide was moving into the cup due to the fact that the color changed in the tubing so the iodine must have entered the tubing to react with the starch. They should also conclude that the starch was not moving out of the dialysis tubing because if it did, it would have reacted and changed the color of the solution in the cup.

3. Based on the results for Part II, do you believe osmosis was occurring? Explain.

Students should conclude that osmosis was occurring due to the increase in mass of the dialysis tubing. To increase in mass, something had to enter the dialysis tubing and since the only thing in the cup was water, the water must account for the increase in mass.

Name:	Instructor:
Date:	Class/Lab Section:

DATA ANALYSIS

4. Do you think any of the sucrose diffused out of the dialysis tubing and into the cup? Explain. (Hint: sucrose molecules have more mass than water molecules).

Unlike part I, where a color indicator could provide confirmation of the direction of movement of solutes, part II involved two clear liquids and the liquid in the cup was not tested for the presence of sucrose at the conclusion of the exercise. Without experimentally confirming the presence or absence of sucrose in the cup one cannot be absolutely certain. Based on the fact that the dialysis tubing increased in mass, most likely only water was moving because if heavier sucrose left the tube, the tubing would probably decrease in mass. While not 100% conclusive, it is probably a reasonable assumption that only water was moving into the tubing.

5. Based on your graph from your results in Part II, did water move into the dialysis tubing at a constant rate? Explain the reason for your answer.

Exact answers will vary based on actual student data but student graphs should indicate that the rate of mass increase (and therefore water movement into the dialysis tubing) was beginning to decrease with time. This is due to the fact that as more water moves into the dialysis tubing to dilute the sucrose solution inside, the concentration gradient is decreasing between the solutions. This leads to a slowing in the rate of osmosis.

6. If you cut a potato in half and placed a few drops of the iodine/potassium iodide solution on it, what do you think would happen?

As potatoes contain a great deal of starch, the iodine-potassium iodide drops would turn blue/purple on the potato.

7. In the background information, the concept of cell lysis was discussed when osmosis caused a cell to take in too much water and eventually burst the cell. This is more of a risk for animal cells than plant cells. Why do you think this is?

While plant cells contain a membrane, they also contain a rigid cell wall not found in animal cells. This makes plant cells more structurally resistant to cell lysis.

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