Diffusion Confusion
Examining Osmosis and Selective Diffusion

MATERIALS AND RESOURCES

EACH GROUP
- balance
- 2 beakers, 250 mL
- corn syrup solution
- 12 cm dialysis tubing
- glucose test strip
- graduated cylinder, 100 mL
- 10 mL iodine solution
- spoon, plastic
- 15 mL starch/glucose solution
- syringe, 10 mL
- weigh boat

TEACHER
- 2 beakers, 600 mL
- cork borer
- corn syrup
- dental floss
- 500 mL iodine solution
- other solutions for Extension
- potato
- 200 ml starch/glucose solution
- water, distilled

ABOUT THIS LESSON

This investigative lesson examines the process of diffusion and osmosis through a selectively permeable membrane. The lesson also explores the change in the mass of a potato piece through the process of osmosis depending on the concentration of corn syrup.

OBJECTIVES

Students will:
- Explain how membranes are semipermeable and how that relates to plasma membranes
- Differentiate between hypertonic, hypotonic, and isotonic conditions and how they relate to the process of osmosis
- Collect data and determine the percentage of corn syrup that is isotonic to a raw potato piece

LEVEL

Biology
COMMUNITY CORE STATE STANDARDS

(LITERACY) RST.9-10.3
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

(MATH) A-CED.2
Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

(MATH) S-ID.4
Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

ASSESSMENTS

The following types of formative assessments are embedded in this lesson:

• Sharing class data

The following assessments are located on our website:

• Short Lesson Assessment: The Gate Keepers
• Cells Assessment

REFERENCES


NEXT GENERATION SCIENCE STANDARDS

PLANNING/CARRYING OUT INVESTIGATIONS
ANALYZING AND INTERPRETING DATA
USING MATHEMATICS

CAUSE AND EFFECT
STRUCTURE AND FUNCTION
SCALE, PROPORTION, AND QUANTITY

B.1 Cell membranes are selectively permeable due to their structure.

B.2 Growth and dynamic homeostasis are maintained by the constant movement of molecules across membranes.

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TEACHING SUGGESTIONS

This activity is designed to supplement a unit on the cell, cell transport, and homeostasis.

Part I of this lab is a demonstration of the semipermeable nature of cell membranes. In Part II, students investigate the relationship between osmosis and varying concentrations of corn syrup. This part of the lab includes finding the percent change in mass.

If this is the first time your students have been exposed to diffusion and osmosis, a quick review of hypotonic, hypertonic, and isotonic relationships may be needed. The Khan Academy also has a video that explains this process along with the basics of solutes, solvents, and solutions at www.khanacademy.org/science/biology/human-biology/v/diffusion-and-osmosis.

For students that are having difficulty with the concept of permeability, you may want to have them complete Part I with different cheap bags and dental floss to tie off the top. For advanced students, Part I may be demonstrated by the teacher and then students could design and implement their own experiments in Part II and the extension.

If several classes are performing this experiment at the same time, it is advisable to use clear plastic cups that can be labeled with the class period and initials of the lab group.

PREPARATION OF SOLUTIONS

500 ML LUGOL’S IODINE SOLUTION
Dissolve 10 g of potassium iodide in 100 mL of distilled water. Add 5 g of iodine crystals to this solution. Add an additional 400 mL of distilled water. Stir until the iodine dissolves. Store the solution in an opaque or dark brown bottle. Be sure to use rubber gloves when making this solution.

200 ML OF 15% GLUCOSE-1% STARCH
Dissolve 30 g of glucose and 2 g of soluble starch in enough distilled water to make 200 mL of solution.

HINTS

The dialysis tubing must be soaked in water prior to use to make the tubing pliable enough to be opened. If dialysis tubing is not available, cheap plastic bags can be used.

To save on the expense of the glucose test paper, you may want to perform the test as a demonstration. Show the students that the iodine water does not have glucose and that the 15% glucose-1% starch solution does. Also, the glucose test strips can be cut in half.

If you do not have enough 250 mL beakers, use clear plastic cups that can be purchased at the local store.

Students can supply the potatoes and corn syrup. The potatoes are easily made uniform in size if you use a french fry cutter or a cork borer.

Use weigh boats or Petri dishes on the balance.
ANSWER KEY

ANALYSIS

Percent Change in Mass of Potato in Various Sucrose Solutions

Figure A. Graph of class data
**DATA AND OBSERVATIONS**

**PART I**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Present in the Beaker</th>
<th>Present in the Dialysis Tubing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beginning</td>
<td>End</td>
</tr>
<tr>
<td>Water</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Iodine</td>
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<td>No</td>
</tr>
<tr>
<td>Glucose</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Starch</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**PART II**

<table>
<thead>
<tr>
<th>Percent Syrup</th>
<th>Final mass (g)</th>
<th>Initial mass (g)</th>
<th>Change in mass (g)</th>
<th>Percent change in mass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>15.15</td>
<td>13.59</td>
<td>+1.56</td>
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<td>90%</td>
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<td>12.05</td>
<td>-7.38</td>
<td>-61.24</td>
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</table>
ANSWER KEY (CONTINUED)

CONCLUSION QUESTIONS

PART I

1. Water was permeable because the amount of liquid increased in the dialysis tubing.
   Glucose was permeable because the test tape showed no glucose in the water in the beaker initially but, at the end of 30 minutes, the water tested positive for glucose.
   Iodine was permeable because it crossed the dialysis tubing and reacted with the starch, turning it purple/black.
   The starch was impermeable because it would have reacted with the iodine in the water outside the dialysis tubing if it was permeable.
2. If a membrane is selectively permeable, this means it has pores that allow some substances in while keeping others out that are too large to pass through these pores. The dialysis tubing is selectively permeable because substances such as water, glucose, and iodine were able to pass through the tubing but the starch molecule was too large to pass.
3. Sucrose is a disaccharide and therefore much larger than the glucose, a monosaccharide, that was used in the experiment. Sucrose would be too large to pass through the dialysis tubing, so the water in the beaker should not test positive for sugar in the end result.

PART II

1. Answers will vary but should be where the line of the graph is at zero percent change in mass.
2. Prepare a solution of corn syrup that is equal to the interpolated value of what would be isotonic to the potato. Determine the mass of the potato and put it in the corn syrup solution. After 24 hours, determine if the mass of the potato remained the same. If there was no change, the solution is isotonic to the potato.
3. As the percent concentration of corn syrup increases, the percent change in mass increases.
4. Answers will vary. However, the potato should be shriveled, which would indicate that the potato was hypotonic to the solution.
5. Answers will vary. However, the potato in the distilled water should have gained mass, which indicates that the potato was hypertonic to the distilled water.
6. The results would occur at a faster rate because the surface area of the potato increases.
7. The apple should be divided into equal pieces and each piece weighed. The apple pieces should then be put in various concentrations of a solution. After 24 hours, the pieces should be removed and weighed. The solution in which the apple did not gain or lose weight is isotonic to the apple. This result would correlate to the solute concentration of the apple.
8. The seawater is hypertonic to human blood and contains many more different types of salts. When we drink seawater, our cells are taking in salt at a much greater concentration than can be processed by the human body. The kidneys are not able to produce urine with solute concentration levels that are as great as seawater, therefore they must keep diluting it using water from the body, causing excessive urination.
**Diffusion Confusion**

**Examining Osmosis and Selective Diffusion**

The cell membrane is a selectively permeable membrane that regulates what materials enter and leave the cell. There are some substances that are permeable to the cell membrane, such as water, oxygen, and carbon dioxide. Their ability to move into and out of the cell is a function of the second law of thermodynamics and free energy.

If a skunk sprays its “perfume” in a classroom, a student walking into the room can smell this odor. The student will be able to locate the source of the odor by tracing the odor along an increasing gradient to its source, the skunk. However, after enough time has passed another student entering the room may be able to detect the odor but will not be able to locate the skunk.

The preceding example is an illustration of the second law of thermodynamics and free energy. When the spray is first released, it forms a small cloud of molecules that is relatively ordered. These molecules are in constant random motion and now have the freedom to move in any direction. It seems intuitive that out of all the possible directions that the spray molecules will take, they will move away from the center of the cloud rather than toward it. These molecules are moving from an area of greater concentration to an area of lesser concentration. It is true that a small percentage of the spray molecules will move toward the center of the cloud, but the majority will move away from the center.

The net movement of the molecules is away from the center of the cloud. In doing so, the spray forms a concentration gradient that the first student could follow to locate its source. As the molecules continue to move, they become more randomized and relatively equidistant from one another, and a concentration gradient will no longer exist. Eventually, this system will reach a state of equilibrium in which the perfume molecules will continue to move but there will be no net movement of the molecules. As a result, the second student entering the room will not be able to locate the skunk.

This example follows the second law of thermodynamics because over time, this system becomes more disorderly as the molecules randomly move. The free energy of the molecules then decreases as they become more randomized and disorganized.
Scientists summarize the movements of diffusion in a rule: Substances tend to move from areas of greater concentration to areas of lesser concentration. This difference in concentrations between two places is called a **diffusion gradient**, or **concentration gradient**.

When a substance is able to pass through a membrane, we say that the membrane is **permeable** to that substance. Membranes may be more permeable to some substances than to others. These membranes are referred to as **selectively** or **differentially permeable**. In other words, these membranes have different permeability to different substances; perhaps a small urea molecule will pass easily but not a large starch molecule. Sometimes membranes do not permit substances to pass through at all. They are said to **impermeable** to that substance.

Cell membranes are typically permeable to small, uncharged molecules such as water, carbon dioxide, and oxygen. **Osmosis** is the special process of water moving across a membrane along a concentration gradient. Whether the net movement of water is into or out of the cell is a function of the osmotic gradient. When materials are impermeable to the cell membrane and are not in equilibrium, there is a net movement of water across the membrane. The rule of thumb is, “Water likes to dilute.” Like other substances, water will cross the membrane from where the water is most concentrated to an area where it is least concentrated.

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**Figure 1. Semipermeable membrane**

- **Solute that is impermeable to the membrane**

  Side A is hypotonic relative to side B. Side B has more impermeable solutes than side A. The net movement of water will be from side A to B.

  Movement \( \text{H}_2\text{O} \)

- **Both sides now have an equal concentration of solutes and are said to be isotonic. Water will still move across the membrane but at equal rates. There is no net movement of water from one side to the other.**

  Movement \( \text{H}_2\text{O} \)
If a semipermeable membrane separates two solutions and those solutions are different in their concentrations, one can expect that there will be a net movement of water. The solution that has the greatest concentration of solutes is said to be **hypertonic** relative to the other side. The solution that has the least concentration of solutes is said to be **hypotonic** relative to the other side. The net movement of water will be from the hypotonic side of the membrane to the hypertonic side of the membrane as “water dilutes” the side with greater amount of solutes (Figure 1).

**PURPOSE**

The purpose of this lab is to investigate the process of diffusion and osmosis through a semipermeable membrane. It also explores the change in the mass of a potato piece through the process of osmosis, with a change in the concentration of corn syrup. Your teacher may direct you to complete either Part I or Part II or both, depending on the amount of time available to the class.

**SAFETY ALERT!**

» Lugol’s iodine solution is a poison if ingested. It is also a strong irritant and can stain clothing. Avoid skin/eye contact; do not ingest.

» If contact occurs, flush affected area with water for 10 minutes; rinse mouth with water. Notify your teacher immediately.
PROCEDURE

PART I

1. Obtain one piece of dialysis tubing and tie a knot in one end. Open the other end of the tubing. This is best done with wet fingers rubbing the end of the tubing.

2. Use the syringe to put 10 cc of 15% glucose-1% starch solution into the dialysis tubing bag (note that 10 cc = 10 mL). Using glucose test tape, test the solution in the dialysis tubing for the presence of glucose. Record your findings in Table 2.

3. Tie the open end of the bag shut, and wipe off the outside of the bag. Make sure you leave enough room for the bag to swell.

4. Fill a 250 mL beaker with 200 mL of water. Add 10 mL of iodine solution or enough that the water appears golden yellow. Using glucose test tape, test the solution in the beaker for the presence of glucose. Record your findings in the data table.

5. Submerge the bag into the beaker of iodine and water. Allow the bag to remain in the solution for 30 minutes and observe the results. After the time has elapsed, test the beaker and the dialysis tubing for the presence of glucose.

6. Observe the dialysis bag and the solution in the beaker for evidence of the presence of starch. Remember that a blue to blue-black color indicates the presence of starch in an iodine-containing solution. Record your findings in Table 2 on your student answer page.
PROCEDURE (CONTINUED)

PART II

1. Obtain a piece of raw potato. Measure its mass to the nearest 0.1 of a gram.
2. Your teacher will assign you a percentage of corn syrup solution to use. If
the solution you are assigned is not made, make the assigned solution by
following the appropriate recipe as shown in Table 1. Use a 250 mL beaker
for your solution.

<table>
<thead>
<tr>
<th>Percent Corn Syrup</th>
<th>Corn Syrup (mL)</th>
<th>Water (mL)</th>
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<tbody>
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<td>90%</td>
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</table>

3. Mix the solution thoroughly until the solution is homogeneous. If you are
using a high concentration of corn syrup (80% or 90%), it is easier to mix
20 mL of the corn syrup with the water and then add the remaining corn
syrup.

4. Carefully measure the mass of your piece of raw potato. Record this value as
the original mass in Table 3.

5. Carefully place your piece of potato into your assigned corn syrup solution
and cover it with foil.

6. After 24 hours, determine the mass of the potato piece and record this value
as the final mass.
ANALYSIS

1. Determine the percent change in mass by using the formula,

\[
\% \text{ change in mass} = \left( \frac{\text{final mass} - \text{original mass}}{\text{original mass}} \right) \times 100 \quad \text{(Eq. 1)}
\]

2. Collect the class data for all the potato pieces in the class in Table 3.

3. On your own graph paper, prepare a properly titled graph of the class data. Be sure to label it with the correct units and measurements. Be able to identify the dependent variable and the independent variable.
DATA AND OBSERVATIONS

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<td>Iodine</td>
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<td>Starch</td>
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PART II

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</table>
CONCLUSION QUESTIONS

PART I

1. Using evidence from your experiment, determine which substances were permeable and which were impermeable to the dialysis tubing. Be specific.

2. Explain the concept of a selectively permeable membrane, and how this relates to the dialysis tubing.

3. Sucrose is impermeable to the membrane (dialysis tubing). Sucrose is a disaccharide. Explain why sucrose is impermeable to the membrane and how the results of the experiment would change if sucrose were used.
CONCLUSION QUESTIONS (CONTINUED)

PART II

1. Using evidence from your graph, predict the percent solute of the potato cells. Justify your answer using data from your experiment.

2. Design a procedure to support the idea that the percentage of corn syrup isotonic to the potato, as interpolated from the graph, is correct.

3. What is the relationship between the percent change in mass and increasing amounts of corn syrup?

4. For 90% corn syrup solution, was the potato hypertonic or hypotonic relative to the corn syrup? Use data from your data table and your graph to justify your answer.
CONCLUSION QUESTIONS (CONTINUED)

5. In distilled water, was the potato hypertonic or hypotonic relative to the corn syrup solution? Use data from your data table and your graph to justify your answer.

6. Predict how the results would change if your potato piece were cut into multiple smaller pieces instead of leaving it as a whole piece.

7. Your teacher gives you an apple and asks you to design an experiment to determine the percent solute for it. Describe what steps you would take to make this determination. Based on your knowledge of the potato data, indicate what you would predict for the solute concentration.

8. A ship sinks off the coast of the United States, leaving its passengers stuck in life rafts. After several days, the passengers begin to become dehydrated and several of them drink the seawater. The passengers that drank the seawater all died of dehydration. Provide an explanation for the seawater “poisoning.”
EXTENSION

You or your group gets to ask your own question and then make a hypothesis. Use the protocol from Part II to test your hypothesis.

You may choose to a different material other than potatoes, or use another substance other than corn syrup. Consult your teacher before performing your experiment. Make a mini-poster of your results and communicate your conclusion to the class.