3. OSMOSIS

Background

Osmosis is the movement of water through a semipermeable membrane. During osmosis, water molecules may move from outside a cell to the inside or vice versa. The direction of the net movement of water depends on the concentration of water and solutes inside the cell compared to outside the cell.

A number of terms in biology describe the state of the extracellular fluid compared to the intracellular fluid. One set of terms is: *hypertonic*, *hypotonic*, and *isotonic*. In an isotonic situation, there is a state of dynamic equilibrium. Water molecules cross the membrane in both directions, but there is no net movement of water. In hypertonic and hypotonic situations, there is a net movement of water driven by a difference in water concentration on the two sides of a membrane. Water concentration is lower in a fluid with a high amount of dissolved solutes, and higher in a fluid with a low amount of dissolved solutes.

In this investigation, you will be given two pairs of solutions. In each pair, one solution represents extracellular fluid. The other solution will be put into a bag made from dialysis tubing, and will model the intracellular fluid of a cell. From your observations, you should be able to determine whether the extracellular fluid is hypertonic or hypotonic to the model cell.

Driving Question

Which extracellular fluid represents fluid that is hypertonic to the cell? When blood becomes hypertonic, how does the body respond to maintain homeostasis?

Materials and Equipment

Use the following materials to complete the initial investigation. For conducting an experiment of your own design, check with your teacher to see what materials and equipment are available.

- Data collection system
- Colorimeter
- Cuvettes (4)
- Cups or beakers (2), 250-mL
- Small funnel
- Graduated cylinders (2), 25-mL
- Dialysis tubing (2), 12-cm pieces
- Solution A, 100 mL
- Solution B, 20 mL
- Solution C, 100 mL
- Solution D, 20 mL
- Plastic pipets (2)
- Small binder clips (2)
- Kimwipes®

Safety

Follow these important safety precautions in addition to your regular classroom procedures:

- Wear safety goggles at all times.

Investigation

Record all observations, data, explanations, and answers in your lab notebook.

1. Put on your safety goggles.

2. Prepare the 2 beakers of "extracellular" fluid: Add 100 mL of Solution A to a 250-mL beaker or cup. Add 100 mL of Solution C to a different beaker or cup.

3. Open the 3 ABI Osmosis lab file. Connect the colorimeter to your device.

   NOTE: If the lab file is not available, create a table display after you calibrate the colorimeter in the next step. Title the first column Solution. Select the Green (550nm) Transmittance (%) measurement for the second column. Change the sampling mode from Periodic to Manual.

4. Calibrate the colorimeter.

   NOTE: Always wipe cuvettes with a lint- and scratch-free wipe before placing into the colorimeter. Orient the cuvette in the colorimeter so the light path is not blocked by labels or ridges.

5. Obtain two graduated cylinders. Pour 20 mL of Solution B into one cylinder and pour 20 mL of Solution D into the other cylinder.

6. Use a plastic pipet to transfer Solution B from the graduated cylinder to the cuvette until the cuvette is about ¾ full, then remove enough of Solution B from the cylinder until 15 mL remain.

7. Place the cuvette into the colorimeter and start data collection. Record the transmittance of green light. Remove the cuvette.

8. Use a different pipet to fill a clean, dry cuvette with Solution D. Reduce the volume of the graduated cylinder to 15 mL.

9. Measure and record the transmittance of green light through the solution.

10. Obtain a piece of dialysis tubing that has been soaked in water. Rub the tubing between your fingers to open it. Twist the tubing at one end and tie a tight knot in it. Place a funnel in the opening at the opposite end. Pour 15 mL of Solution B into the tubing. Twist the tubing at the top and use a binder clip to keep it closed.

11. Place the dialysis tubing with Solution B into the beaker with Solution A as shown in Figure 1. The tubing should be mostly submerged but it should rest upright, with the binder clip remaining above the surface of the solution.

12. Prepare another dialysis tubing bag using 15 mL of Solution D. Place this bag into the beaker with Solution C. Label the cups or beakers, or place them on a labeled paper towel, to keep track of which solutions are present in each arrangement.

13. Let the dialysis bags remain in the beakers, undisturbed, for 30 minutes. While you wait, answer the questions that follow.

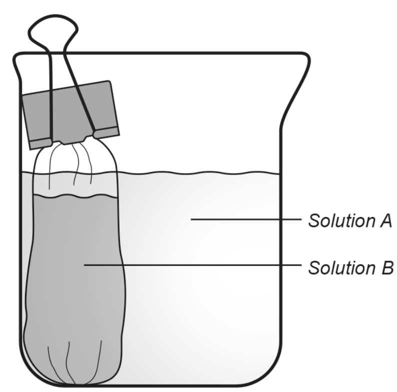
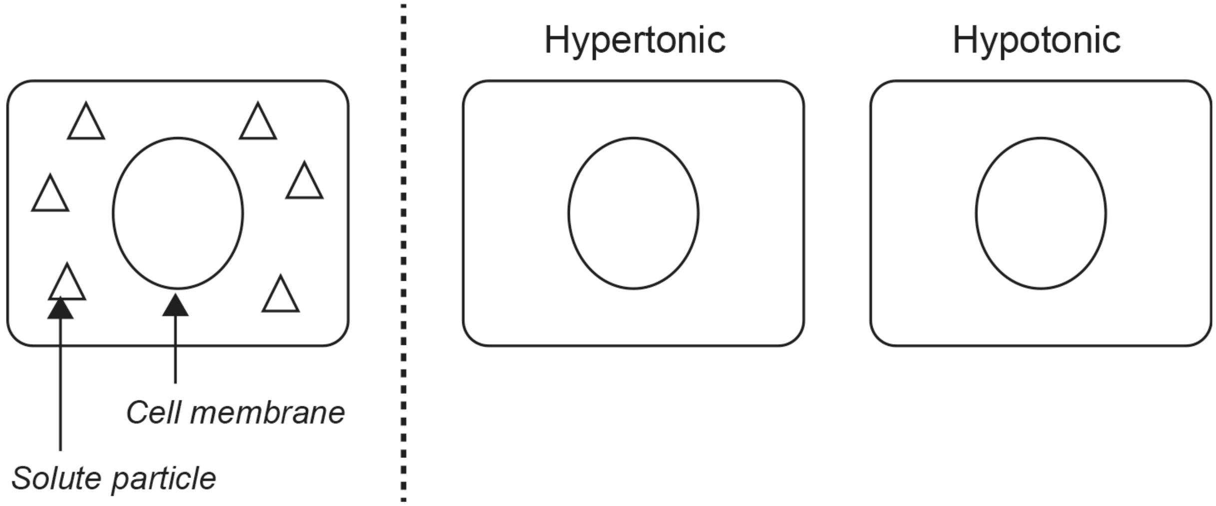


Figure 1: Dialysis bag submerged in beaker

❓ 14. The diagram below represents a cell surrounded by extracellular fluid that is isotonic to the cell. Based on this model, draw solute particles in the other two diagrams to represent fluids that are hypertonic and hypotonic to the cell.

NOTE: Draw the diagrams in your lab notebook.



❓ 15. a. In which situation will there be a net movement of water into the cell?

b. Draw an arrow on the diagram to indicate this.

c. Imagine that the cell contains a colored solution. If osmosis causes water to move into the cell, what should happen to the transmittance of light through that solution? Explain your reasoning.

❓ 16. For the remaining diagram, explain the net movement of water expected and describe the expected change in transmittance.

17. After 30 minutes, remove the binder clip from the dialysis bag soaking in Solution A. Untwist and open the dialysis bag so you can pipet solution out of the bag.

18. Use a pipet to fill a dry, clean cuvette about ¾ full of Solution B from the bag. Place the cuvette into the colorimeter and record the transmittance of green light through the solution. Compare this to the initial transmittance for Solution B and calculate the change.

19. Open the dialysis bag in Solution C and fill a cuvette with a sample of Solution D from the bag. Determine the transmittance of green light for Solution D and compare this with the initial transmittance. Calculate the change.

20. Create a data table to organize the measurements of transmittance of green light. Include a column in your table for percent change in transmittance. For Solutions B and D, record transmittance data and calculate the percent change.

$$\text{Percent change} = \frac{(\text{Final value} - \text{Initial value})}{\text{Initial value}} \times 100$$

Data Analysis

1. a. Which solution experienced a decrease in transmittance?

   b. If transmittance decreased, did the solution become lighter in color or darker in color?

   c. In this situation, did water move into the model cell or out of the model cell?

   d. Was the extracellular fluid in this situation initially hypertonic, hypotonic, or isotonic to the model cell? Explain your choice.

2. Solution A is tap water and Solution B is a 0.8 M sucrose solution. Based on this information, explain the change in transmittance for Solution B.

3. A student carries out this experiment and adds the following to the setup: a dialysis bag containing distilled water submerged in a beaker with distilled water. Explain the purpose of this dialysis bag and the value of the results, if any.

Table 1: Transmittance of light through a blue-colored solution

Condition	Transmittance (%) and % Change
Initial	15.4
Final	15.5
Percent change	0.6%

Synthesis Questions

Consider a hot day in which you have to run a mile in P.E. class. As you run, your body sweats to help maintain proper body temperature. Sweating leads to minor dehydration due to water lost from the sweat droplets that evaporate off the skin.

In this investigation, you monitored the water content of a model cell by detecting changes in transmittance of light through a colored solution. In the body, the water content of plasma (the liquid portion of blood) is monitored by specialized cells called *osmoreceptors*. These osmoreceptors are located in the hypothalamus.

1. When dehydration occurs, what change in the blood is able to be detected by osmoreceptors?

2. The osmoreceptors help regulate the inhibition or stimulation of anti-diuretic hormone (ADH). In the case of dehydration, the hypothalamus signals the pituitary gland to release ADH.

   a. What effect does releasing ADH have on the kidneys?

   b. Specifically, the target cells that ADH binds to add aquaporins to their cell membranes in response to the hormone. How does this explain the change that occurs in the kidneys to counter dehydration?

   c. ADH is a short peptide hormone that triggers a cAMP signal pathway in target cells. Why wouldn't ADH move directly into cells?

3. Describe the negative feedback system that prevents overcorrection of dehydration.

4. Caffeine is a diuretic. Explain the effect caffeine has on urine production and explain why excess caffeine consumption leads to dehydration.