Name____Period_____Assignment#_____

Lab 04 Diffusion and Osmosis: What is the slute potential of potato cells?

See Lecture Questions 32-34, 42-46

Pre-lab: Annotate Text and Answer Questions 1-21

_____Teacher initials procedures_____Teacher initials data collection

Annotating Text
☐ **UNDERLINE** concepts you think might be useful for understanding or solving the problem
☐ Box information you think might be helpful for designing your investigation
☐ ← Write **notes** in the left margin
☐ → Write **questions and answers** in the right margin
Each paragraph (including each step of the procedures) must have something underlined or boxed, **AND** have something written in the margins (a question and/or note).

Cells must move materials through membranes and throughout the cytoplasm in order to maintain homeostasis. The movement is regulated because cellular membranes, including the plasma and organelle membranes, are selectively permeable. Membranes are phospholipid bilayers containing embedded proteins; the phospholipid fatty acids limit the movement of water because of their hydrophobic characteristics.

The cellular environment is aqueous, meaning that the solutes (e.g., salts, organic molecules) dissolve in water, which is the solvent. Water may pass slowly through the membrane by osmosis or through specialized protein channels called aquaporins. Aquaporins allow the water to move more quickly than it would through osmosis. Most other substances, such as ions, move through protein channels, while larger molecules, including carbohydrates, move through transport proteins.

The simplest form of movement is diffusion, in which solutes move from an area of high concentration to an area of low concentration; diffusion is directly related to molecular kinetic energy. Diffusion does not require energy input by cells. The movement of a solute from an area of low concentration to an area of high concentration requires energy input in the form of ATP and protein carriers called pumps.

Water moves through membranes by diffusion; the movement of water through membranes is called osmosis. Like solutes, water moves down its concentration gradient. Water moves from areas of high potential (high free water concentration) and low solute concentration to areas of low potential (low free water concentration) and high solute concentration). Solutes decrease the concentration of free water, since water molecules surround the solute molecules. The terms *hypertonic, hypotonic,* and *isotonic* are used to describe solutions separated by selectively permeable membranes. A hypertonic solution has a higher solute concentration and a lower water potential as compared to the cell; therefore, water will move into the hypertonic solution through the cell membrane by osmosis. A hypotonic solution has a lower solute concentration and a higher water potential than the cell; water will move down its concentration gradient into the other solution. Isotonic solutions have equal water potentials.

In non-walled cells, such as animal cells, the movement of water into and out of a cell is affected by the relative solute concentration on either side of the plasma membrane. As water moves out of the cell, the cell shrinks; if water moves into the cell, it swells and may eventually burst. In walled cells, including fungal and plant cells, osmosis is affected not only by the solute concentration, but also by the resistance to water movement in the cell by the cell wall. This resistance is called turgor pressure. The presence of a cell wall prevents the cells from bursting as water enters; however, pressure builds up inside the cell and affects the rate of osmosis.

Water movement in plants is important in water transport from the roots into the shoots and leaves. You likely will explore this specialized movement called transpiration in another lab investigation.

Understanding Water Potential

Water potential predicts which way water diffuses through plant tissues and is abbreviated by the Greek letter psi (ψ). Water potential is the free energy per mole of water and is calculated from two major components: (1) the solute potential (ψ_s), which is dependent on solute concentration, and (2) the pressure potential (ψ_P), which results from the exertion of pressure—either positive or negative (tension) — on a solution. The solute potential is also called the osmotic potential.

$$\psi = \psi_P + \psi_S$$

Water Potential = Pressure Potential + Solute Potential

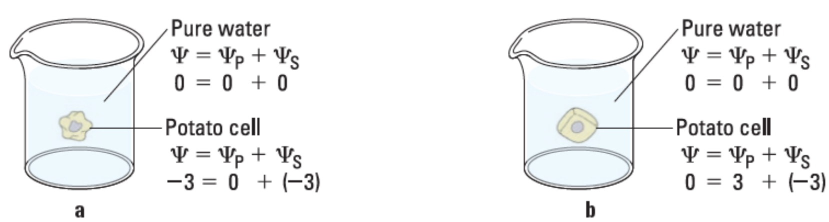
Water moves from an area of higher water potential or higher free energy to an area of lower water potential or lower free energy. Water potential measures the tendency of water to diffuse from one compartment to another compartment.

The water potential of pure water in an open beaker is zero ($\psi = 0$) because both the solute and pressure potentials are zero ($\psi_S = 0$; $\psi_P = 0$). An increase in positive pressure raises the pressure potential and the water potential. The addition of solute to the water lowers the solute potential and therefore decreases the water potential. This means that a solution at atmospheric pressure has a negative water potential due to the solute.

The solute potential (ψ_S) = – iCRT, where i is the ionization constant, C is the molar concentration, R is the pressure constant (R = 0.0831 liter bars/mole-K), and T is the temperature in K (273 + °C). A 0.15 M solution of sucrose at atmospheric pressure ($\psi_P = 0$) and 25°C has an osmotic potential of -3.7 bars and a water potential of -3.7 bars. A bar is a metric measure of pressure and is the same as 1 atmosphere at sea level. A 0.15 M NaCl solution contains 2 ions, Na^+ and Cl^-; therefore i = 2 and the water potential = -7.4 bars.

When a cell's cytoplasm is separated from pure water by a selectively permeable membrane, water moves from the surrounding area, where the water potential is higher ($\psi = 0$), into the cell, where water potential is lower because of solutes in the cytoplasm (ψ is negative). It is assumed that the solute is not diffusing (Figure 1a). The movement of water into the cell causes the cell to swell, and the cell membrane pushes against the cell wall to produce an increase in pressure. This pressure, which counteracts the diffusion of water into the cell, is called turgor pressure.

Over time, enough positive turgor pressure builds up to oppose the more negative solute potential of the cell. Eventually, the water potential of the cell equals the water potential of the pure water outside the cell (ψ of cell = ψ of pure water = 0). At this point, a dynamic equilibrium is reached and net water movement ceases (Figure 1b).



Figures 1a-b. Plant cell in pure water. The water potential was calculated at the beginning of the experiment (a) and after water movement reached dynamic equilibrium and the net water movement was zero (b).

If solute is added to the water surrounding the plant cell, the water potential of the solution surrounding the cell decreases. If enough solute is added, the water potential outside the cell is equal to the water potential inside the cell, and there will be no net movement of water. However, the solute concentrations inside and outside the cell are not equal, because the water potential inside the cell results from the combination of both the turgor pressure (ψ_P) and the solute pressure (ψ_S). (See Figure 2.)

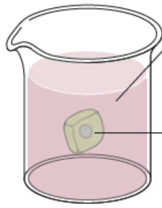


Figure 2. Plant cell in an aqueous solution. The water potential of the cell equals that of surrounding solution at dynamic equilibrium. The cell's water potential equals the sum of the turgor pressure potential plus the solute potential. The solute potentials of the solution and of the cell are not equal.

If more solute is added to the water surrounding the cell, water will leave the cell, moving from an area of higher water potential to an area of lower water potential. The water loss causes the cell to lose turgor. A continued loss of water will cause the cell membrane to shrink away from the cell wall, and the cell will plasmolyze.

1) Calculate the solute potential of a 0.1 M NaCl solution at 25°C. Show your work.

2) If the concentration of NaCl inside the plant cell is 0.15 M, which way will the water diffuse if the cell is placed into the 0.1 M NaCl solution? Explain and illustrate.

3) What must the turgor pressure equal if there is no net diffusion between the solution and the cell? Show your work.

4) What factors determine the rate and direction of osmosis?

Design an experiment to identify the water potential of potato cells. Use the following questions to guide your investigation:

5) How can you measure the plant pieces to determine the rate of osmosis?

6) How could you determine the water potential in the cells?

7) How would you know if a solution had the same water potential as the cells?

8) What would your results be affected if the potato were placed in a dry area for several days before your experiment?

9) When potatoes are in the ground, do they swell with water when it rains? If not, how do you explain that, and if so, what would be the advantage or disadvantage?

10) Where is the cell membrane in relation to the cell wall (explain and illustrate)? Can you see the two structures easily? Why or why not?

11) What changes do you expect to see when the cells are exposed to the solutions?

12) How will you know if a particular treatment is increasing turgor pressure? If it is reducing turgor pressure?

13) Why are most cells small, and why do they have cell membranes with many convolutions?

14) What organelles inside the cell have membranes with many convolutions? Why?

15) Do you think osmosis occurs when a cell is in an isotonic solution? Explain your reasoning.

16) You are in the hospital and need intravenous fluids. You read the label on the IV bag, which lists all of the solutes in the water. Why is it important for an IV solution to have salts in it?

17) What would happen if you were given pure water in an IV?

18) How would you determine the best concentration of solutes to give a patient in need of fluids before you introduced the fluids into the patient's body?

19) What would happen if you applied saltwater to the roots of a plant? Why?

20) What are two different ways a plant could control turgor pressure, a name for internal water potential within its cells? Is this a sufficient definition for turgor pressure?

21) Will water move into or out of a plant cell if the cell has a higher water potential than its surrounding environment?

Materials:

1) Potato corers of various diameters
2) Dowel (for removing potato core from corer)
3) Plastic cups
4) 1M sucrose stalk solution
5) 1M NaCl stalk solution
6) Balance
7) Ruler
8) Aluminum foil
9) Distilled water
10) Scalpel

Procedure:

1) Prepare solutions from stalk solution
2) Use corer to prepare potato cores (minimum 6 per solution)
3) Add enough solution to the cups to submerge potato cores
4) Cover the cup with aluminum foil
5) Place in a safe place for overnight storage

Your Task:

Design and experiment to determine the solute potential of potato cells

To determine *what type of data* you will need to collect, think about the following questions:

1) What will serve as your independent variable during your experiment?

2) What will serve as your dependent variable during each of your experiments?

3) What type of measurements or observations will you need to record during your experiment?

To determine *how you will collect your data*, think about the following questions:

4) What types of treatment conditions will you need to set up and how will you do it?

5) How many trials will you need to conduct?

6) How often will you collect data and how will you do it?

7) How will you make sure that your data are of high quality (how will you reduce measurement error?)

8) How will you keep track of the data you collect and how will you organize the data?

To determine *how you will analyze your data*, think about the following:

9) How will you determine if there is a difference between the treatment condition and the control condition? What statistics will you use?

10) What type of calculations will you need to make?

11) How will you present your data?

Connections to Crosscutting Concepts and the Nature of Science

As you work through your investigation, be sure to think about the following:

- the importance of identifying the underlying cause for observations,
- how models are used to study natural phenomena,
- how matter moves within or through a system,
- the difference between data and evidence in science, and
- the nature and role of experiments in science.

Guiding Question:

Claim:

Alternative claims:

Method:	What data will you collect? How will this data help you answer the guiding question? What safety precautions will you follow?

Data table(s) and chart(s)

Guiding Question:

Our Claim:

Our Evidence:

Analysis: break it down (Illustrate and describe your data)

Interpretation: What does the analysis mean?

Our Justification of the Evidence:

Use your scientific knowledge and analysis to support your interpretation