TRANSPORT IN CELLS

Why?

Water accounts for over 70% of the human body. If water levels are not regulated and maintained there can be disastrous consequences. Cells and tissues can swell, blood cells burst and your brain expands so much it pushes on the skull, leading to brain damage and death. So what exactly is the process that allows organisms to regulate and maintain their water content?

MODEL 1: Movement of Water – a type of diffusion.

Schematic Diagram of Transport of Water in a Sugar Solution:

| Key: | Sugar molecules (solute) | Water molecules (solvent) | Selectively permeable membrane |

For each question use the above diagram:

1. Complete the following table:

<table>
<thead>
<tr>
<th></th>
<th>Left side of membrane</th>
<th>Right side of membrane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of water molecules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of sugar molecules</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio of water to sugar</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. a. What is the **solvent** in the diagram?

   b. What is the **solute** in the diagram?

3. Using the terms from Question 2, define a solution (use complete sentences).
Read This!

A concentrated solution (strong solution) is one where the ratio of solute to solvent is high. A dilute solution (weak solution) is one where the ratio of solute to solvent is low. Note: for Model 2, the diagram in Model 1 was modified so that the molecules on the left side of the membrane are inside the cell, and the molecules on the right side of the membrane are outside the cell.

MODEL 2: Movement of Water in and out of Cells.

4. Model 2 shows a cell bounded by a selectively permeable membrane. There is a sugar solution inside the cell and outside the cell. (Circle the correct responses.)

   a. Which side of the membrane has a more concentrated sugar solution?
      Inside/outside

   b. In a concentrated solution there is more/less water.

   c. Which side of the membrane has a more dilute sugar solution?
      Inside/outside

   d. In a dilute solution there is more/less water.

5. Looking only at the diagram and key:

   a. Which molecule(s) will be able to move through the membrane? Explain your reasoning.

   b. Which molecule(s) will NOT be able to move through the membrane? Explain your reasoning.
Read This!

Molecules are in constant random motion, moving in all directions. However, depending on the concentration of molecules there can be an overall direction of movement, called the NET direction.

6. Predict the net direction of movement of the molecule that crosses the membrane by drawing an arrow into or out of the cell on the diagram in Model 2.

7. How will the concentration of the sugar solution on each side of the membrane change as this molecule moves?
   a. On the inside it will become ….
   b. On the outside it will become…

8. Applying what you already know about diffusion and the random movement of molecules, what will eventually happen to the concentration on both sides of the membrane?

9. Using your responses to the questions above, summarize what your group has learned so far about the movement of water through a selectively permeable membrane.

10. Osmosis is the term used for this movement of water across a selectively permeable membrane. Using your response to the previous question to develop a definition of osmosis with your group.

11. As instructed by your teacher, review the definitions from other groups in your class. Once the class has agreed on a definition, write it in the box below.

OSMOSIS is
**MODEL 3: Osmosis in Plant and Animal Cells**

<table>
<thead>
<tr>
<th>External solution:</th>
<th>Hypertonic</th>
<th>Isotonic</th>
<th>Hypotonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal Cell</td>
<td><img src="image" alt="Diagram A" /></td>
<td><img src="image" alt="Diagram B" /></td>
<td><img src="image" alt="Diagram C" /></td>
</tr>
<tr>
<td>Crenated</td>
<td><img src="image" alt="Diagram D" /></td>
<td><img src="image" alt="Diagram E" /></td>
<td><img src="image" alt="Diagram F" /></td>
</tr>
<tr>
<td>Cell membrane</td>
<td><img src="image" alt="Diagram G" /></td>
<td><img src="image" alt="Diagram H" /></td>
<td><img src="image" alt="Diagram I" /></td>
</tr>
<tr>
<td>Cell wall</td>
<td><img src="image" alt="Diagram J" /></td>
<td><img src="image" alt="Diagram K" /></td>
<td><img src="image" alt="Diagram L" /></td>
</tr>
<tr>
<td>Plant Cell</td>
<td><img src="image" alt="Diagram M" /></td>
<td><img src="image" alt="Diagram N" /></td>
<td><img src="image" alt="Diagram O" /></td>
</tr>
<tr>
<td>Plasmolysed</td>
<td>Turgid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Read This!**

The diagram above shows how cells can be altered due to osmosis. Water is constantly moving across cell membranes by random motion. The relative amount of water movement into and out of the cells is indicated by the size of the arrows. Note that both plant and animal cells are surrounded by a selectively permeable membrane, and that plant cells are also surrounded by a permeable, rigid, outer cell wall.

12. For each question use diagrams A-F above. Which cells have:

   a. Taken in water?

   b. Lost water?

   c. No change in water?
13. If osmosis is the movement of water from a high concentration of water (dilute solution) to an area of lower concentration of water (concentrated solution), then

   a. Describe the concentration of the solution surrounding cells A and D (extracellular), relative to the concentration of the solution inside cells A and D (intracellular).

   b. Describe the concentration of the solution surrounding cells C and F (extracellular), relative to the concentration of the solution inside cells C and F (intracellular).

   c. Describe the concentration of the solution surrounding cells B and E (extracellular), relative to the concentration of the solution inside cells B and E (intracellular).

14. Using the answer to the previous question, develop definitions for the following words:

   a. A hypertonic extracellular solution is…

   b. A hypotonic extracellular solution is…

   c. An isotonic extracellular solution is…

15. Describe what has happened to a plant cell that is placed in a hypertonic solution.

16. What word is used to summarize these changes to the plant cell?
17. What word would be used if the cell were from an animal?

18. Describe the changes to the plant cell when it is placed in a hypotonic solution.

19. What word summarizes these changes?

20. What is different about a plant cell placed in a hypotonic solution and an animal cell?

21. Considering the difference in the structure of plant & animal cells, do you think that if water were continually added, the plant cell would eventually undergo lysis? Use complete sentences to explain your answer.

22. Using the concept of osmosis, explain why water is sprayed over produce in a grocery store and what change in appearance this might cause to the produce and why it is desirable.

23. Plants that live near the sea can often get flooded with seawater. This causes them to wilt. Using the principals of osmosis explain why this happens.
Extension Problems

24. The street drug Ecstasy can lead to repetitive behavior such as drinking up to 20L of water over a two hour time period. This can lead to brain edema and death. Explain what is happening at the level of the brain cells and include the role of osmosis in this process.

25. The diagram shows a single-celled organism called Paramecium, which lives in freshwater environments. This organism contains a specialized organelle called a contractile vacuole that helps maintain osmotic balance. Predict how this organelle might help the organism survive given that it is constantly immersed in a hypotonic solution.
Learning Objectives:
After completing the activity the students should be able to:

1. Define and understand the term osmosis.
2. Understand that both the random movement of water molecules and concentration gradient help maintain water balance across cell membranes.
3. Correctly use the terms hypotonic, isotonic, hypertonic, plasmolysed, turgid, and crenated, when discussing relative solution concentrations and cell appearance.

Prerequisites:
Students should already understand the concept of diffusion.

Evaluation Questions:
1. The diagrams show plant cells in two different external solutions, isotonic and hypertonic. Explain IN DETAIL what happens when the plant cell in the isotonic solution is placed in the salt solution. Use the scientific words listed where appropriate.

   **Word Bank:** Concentrated, Flaccid, Turgid, Plasmolysis

   **SUGGESTED RESPONSE:** When the cell is placed in the salt solution the concentration on the outside is stronger than the inside, so water will move out by osmosis, causing the cell to become flaccid. Eventually plasmolysis may occur when the cell membrane pulls away from the cell wall.

2. The diagrams below represent animal cells placed in a solution. The concentration of the solutions inside and outside of the cells is shown. (The higher the value of M, the more concentrated the solution.)

   a. Draw an arrow on each diagram showing the direction of water movement either into or out of the cell. **Out of cell in A; into cell in B.**

   b. Which cell could eventually burst? A or B? **B would**
3. During osmosis:
   a. Water moves from a concentrated solution to a dilute solution.
   b. Solutes move from a concentrated solution to a dilute solution.
   c. Water moves from a dilute solution to a concentrated solution.  Correct answer
   d. Solutes move from a dilute solution to a concentrated solution.

Support Materials:
None needed

Facilitation suggestions:
Students are cued to wait for your instructions for Question 12. There are several ways to come to a class-wide definition of osmosis. All groups could post their definitions on the board, and the class could vote; one group could write their definition on the board, and each successive group could suggest changes/improvements to it; three or four groups could get together to agree on a common definition and these larger groups could share with the entire class, etc.

Students may need some basic explanation of molarity in order to understand that a 2M solution contains more solute per unit volume compared to a 1M solution, i.e. is more concentrated.

Target Responses

1. Complete the following table:

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of water molecules</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>Number of sugar molecules</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Ratio of water to sugar</td>
<td>4:1</td>
<td>1:1</td>
</tr>
</tbody>
</table>

2. a. What is the solvent in the diagram? water

   b. What is the solute in the diagram? sugar
3. Using the terms from question 2, define a solution (use complete sentences)
   
   A solution is a mixture of a solvent and a solute

4. Model 2 shows a cell bounded by a selectively permeable membrane. There is a sugar solution inside the cell and outside the cell. (Circle the correct responses.)
   a. Which side of the membrane has a more concentrated sugar solution? 
      Inside/outside
   b. In a concentrated solution there is more/less water.
   c. Which side of the membrane has a more dilute sugar solution? Inside/outside
   d. In a dilute solution there is more/less water.

5. Looking only at the diagram and key:
   a. Which molecule(s) will be able to move through the membrane? Explain your reasoning. Water because of their size
   b. Which molecule(s) will NOT be able to move through the membrane? Explain your reasoning. Sugar because they are too large

6. Predict the net direction of movement of the molecule that crosses the membrane by drawing an arrow into or out of the cell on the diagram in Model 2. Out of

7. How will the concentration of the sugar solutions on each side of the membrane change as this molecule moves?
   a. On the inside it will become …. more concentrated
   b. On the outside it will become… more dilute

8. Applying what you already know about diffusion and the random movement of molecules, what will eventually happen to the concentration on both sides of the membrane? It will eventually reach dynamic equilibrium; the concentration will be the same inside and out, and water will move across the membrane equally in both directions.

9. Using your responses to the questions above, summarize what your group has learned so far about the movement of water through a semi-permeable membrane.
   See target response for Question 11

10. Osmosis is the term used for this movement of water across a selectively permeable membrane. Using your response to the previous question to develop a definition of osmosis with your group. See target response for Question 11

11. As instructed by your teacher, review the definitions from other groups in your class. Once the class has agreed on a definition, write it in the box below.

   OSMOSIS is the movement of water across a semi-permeable membrane from an area of high water concentration (dilute solution) to an area of lower water concentration (concentrated solution).
12. Which diagrams show cells that have:
   a. Taken in water? C & F
   b. Lost water? A & D
   c. No change in water? B & E

13. If osmosis is the movement of water from a high concentration of water (dilute solution) to an area of lower concentration of water (concentrated solution), then
   a. Describe the concentration of the solution surrounding cells A and D (extracellular), relative to the concentration of the solution inside cells A and D (intracellular). The extracellular solution surrounding A/D is more concentrated than the intracellular solution inside cell A/D.
   b. Describe the concentration of the solution surrounding cells C and F (extracellular), relative to the concentration of the solution inside cells C and F (intracellular). The extracellular solution surrounding C/F is less concentrated than the intracellular solution inside cell C/F.
   c. Describe the concentration of the solution surrounding cells B and E (extracellular), relative to the concentration of the solution inside cells B and E (intracellular). The extracellular solution surrounding B/E is the same concentration as the intracellular solution inside cell B/E.

14. Using the answer to the previous question, develop definitions for the following words:
   a. A hypertonic extracellular solution is more concentrated than the intracellular solution.
   b. A hypotonic extracellular solution is less concentrated than the intracellular solution.
   c. An isotonic extracellular solution is equally as concentrated as the intracellular solution.

15. Describe what has happened to a plant cell that is placed in a hypertonic solution. The cell membrane has pulled away from the cell wall. [The central vacuole has shrunk in size.]

16. What word is used to summarize these changes to the plant cell? Plasmolyzed

17. What word would be used if the cell were from an animal? Crenated

18. Describe the changes to the plant cell when it is placed in a hypotonic solution. The entire plant cell swells [and the central vacuole increases in size].

19. What word summarizes these changes? Turgid

20. What is different about a plant cell placed in a hypotonic solution and an animal cell? The animal cell swells but eventually bursts whereas the plant cell does not.
21. Considering the difference in the structure of plant & animal cells, do you think that if water were continually added, the plant cell would eventually undergo lysis? Use complete sentences to explain your answer. **No because it has a rigid cell wall that will prevent it from bursting.**

22. Using the concept of osmosis, explain why water is sprayed over produce in a grocery store and what change in appearance this might cause to the produce and why it is desirable. **As water is sprayed over produce the water moves into the plant cells by osmosis. This causes the cells to swell and look larger/firmer and so improve their appearance.**

23. Plants that live near the sea can often get flooded with seawater. This causes them to wilt. Using the principals of osmosis explain why this happens. **As the plants get surrounded by seawater the concentration outside the cells is stronger than inside, so it causes water to move out of the cells by osmosis, causing the plants to wilt.**

**Extension Questions**

24. The street drug Ecstasy can lead to repetitive behavior such as drinking up to 20L of water over a two hour time period. This can lead to brain edema and death. Explain what is happening at the level of the brain cells and include the role of osmosis in this process. **As the body takes in water, osmosis causes the water to move into the blood. If excessive water is taken in, the blood eventually becomes less concentrated, so is hypotonic to the cells. As it passes over the body tissues it causes water to move into the more hypertonic cells by osmosis, causing the cells to swell (brain edema). This damages the brain cells. Furthermore, the increase in water content in and around brain cells causes the brain itself to expand. It cannot expand indefinitely due to the surrounding skull. The rising pressure inside the skull can eventually lead to death.**

25. The diagram shows a single-celled organism called Paramecium, which lives in freshwater environments. Explain how this organism maintains osmotic regulation given that it is constantly immersed in a hypotonic solution. **Paramecium removes water through the contractile vacuoles by active transport. In addition paramecium can release salts from inside crystals when their cytoplasm becomes excessively dilute.**