From Gummy Bears to Celery Stalks: Diffusion and Osmosis

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Part I – Introduction to Diffusion and Osmosis

Sue: "Hey Jude, what did we learn in Mr. Phillotson's biology class today? I missed it because I wasn't feeling well."

Jude: "Today we mostly discussed diffusion and osmosis."

Sue: "What are diffusion and osmosis?"

Jude: "Well, diffusion is the movement of molecules of a substance from an area of high concentration to an area of lower concentration. When molecules do that it's called moving down a concentration gradient. Mr. Phillotson demonstrated diffusion in class by placing a few drops of green food coloring in a glass of water. At first most of the water was clear with a small amount of dark green food coloring concentrated in the center where he had placed the drops, but over a few minutes the molecules of food coloring spread out in the water until they were evenly distributed among the water molecules and the entire glass appeared a light green color. He said the same thing happens in the air when someone sprays perfume inside a room. At first the molecules of perfume are concentrated and strong-smelling in a small area, but over time they diffuse through the air in the room until they are evenly distributed and the entire room smells weakly of perfume."

Sue: "Where does the energy come from to move the molecules during diffusion? Did Mr. Phillotson mention that?"

Jude: "Yes, actually, he did. He said that molecules move down their concentration gradient spontaneously, without any work being done, so no energy input is required. Diffusion of molecules can even occur through a membrane, as long as the membrane has holes or pores that will allow those molecules to pass through. Mr. Phillotson said that if molecules diffuse down their concentration gradient through a biological membrane, such as the plasma membrane of a cell, that is called passive transport. Passive transport does not require energy input from the cell.

Sue: "So, passive transport moves molecules across a cell membrane and does not require energy input from the cell because the necessary force is provided by the concentration gradient?"

Jude: "Correct. Molecules can also be moved across a cell membrane against their concentration gradient, but that would require energy input. Mr. Phillotson said that process is called active transport, and that we would learn more about it later. "

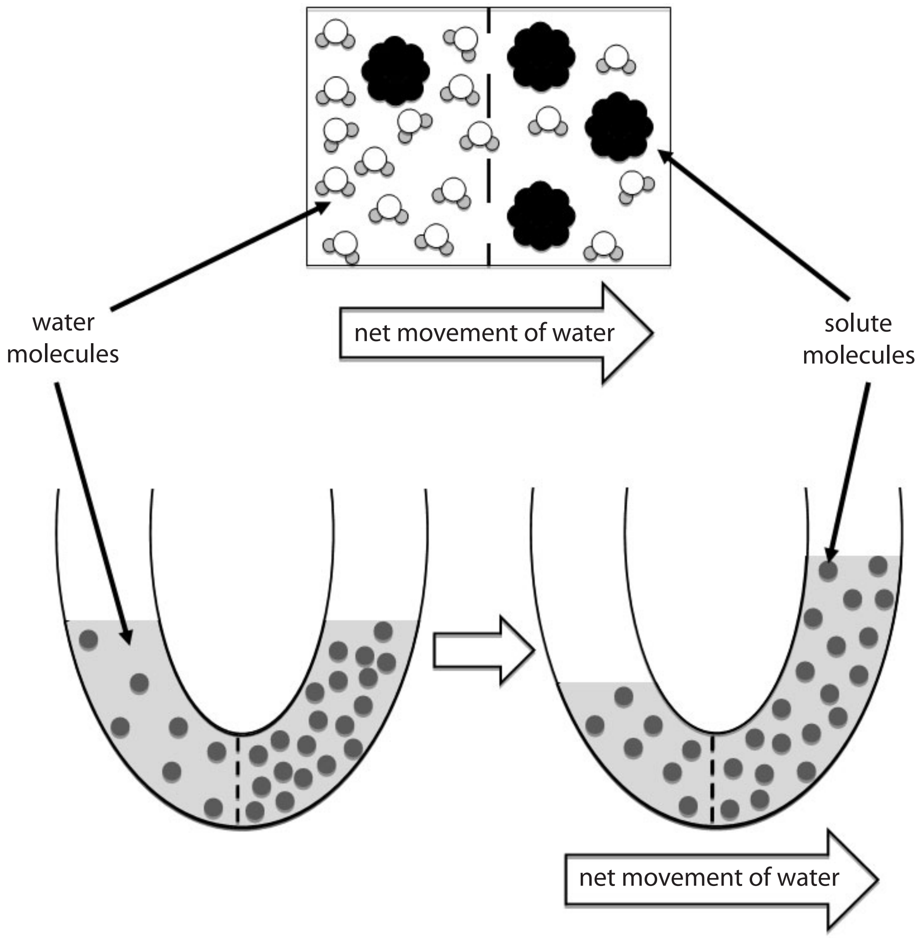
Sue: "Ok. I think I understand diffusion now. So, what is osmosis?"

Jude: "Osmosis is the diffusion of water across a selectively permeable membrane. During osmosis water moves from an area of higher concentration of water molecules to an area of lower concentration of water molecules.

Sue: "If water molecules are moving down their concentration gradient during osmosis, that must happen spontaneously and not require energy input, right?"

Jude: "Correct."

Figure 1. Osmosis



Sue: "I'm confused, though. I thought all water was the same. How can there be different concentrations of water?

Jude: "Mr. Phillotson explained that often, whether inside a living organism or in a laboratory experiment, water contains other molecules, or solutes. The higher the concentration of solutes, the lower the concentration of water. Do you understand, Sue?"

Sue: "I think so… but… did Mr. Phillotson happen to do a demonstration of osmosis?"

Jude: "Actually, he gave us a homework assignment to help us understand osmosis, and said we will go over another example in class next time, after we discuss the homework."

Questions

1. Define the terms *diffusion, passive transport, active transport,* and *osmosis*. In each of your definitions, describe the role of a concentration gradient.
2. Biological membranes are said to be selectively permeable (or semi-permeable). What does this term mean, and how does this affect the way that molecules are able to move through cellular membranes?
3. Which type of molecule is more likely to quickly pass through a cellular membrane via simple diffusion, polar or non-polar? Why? (You may need to use information from your textbook and class discussions to answer this question.)

Part II – Osmosis and Gummy Bears

Sue: "Homework?! Ugh. What is the assignment?"

Jude: "Each of us was given three gummy bears and these instructions:

Step 1. Measure and record the starting length, width, and depth of all three gummy bears. Estimate the starting volume of each gummy bear using the formula: volume = length × width × height.

Step 2. Gather three glasses of the same size, and label them #1, #2, and #3.

Step 3. In glass #1, add one inch of water at room temperature and place one of the gummy bears inside.

Step 4. In glass #2, add 1/4 inch of salt and ¾ inch of water at room temperature, as well as one gummy bear.

Step 5. In glass #3 add nothing except the third gummy bear.

Step 6. Cover all three glasses with plastic and leave overnight.

Step 7. The next day, measure the final length, width, and depth of each gummy bear, and calculate the ending volume.

Step 8. Determine the change in volume of each gummy bear and record your results.

Mr. Phillotson said we could weigh the gummy bears instead of measuring them with a ruler, but that it is easier to provide everyone with rulers than scales."

Sue: "That's all we have to do?"

Jude: "We are also supposed to answer the following questions....

Questions

Answer the questions below *before* conducting the experiment.

1. Record the following observations:

Gummy bear measurements	*#1*	*#2*	*#3*
Starting length (mm):			
Starting width (mm):			
Starting depth (mm):			
Estimated starting volume (mm^3): (length × width × height)			

2. Predict what will happen to the size of each of the gummy bears overnight.

3. Explain how osmosis is related to the predictions you made in Question 2.

4. Use your textbook or other resources to define the following terms: *hypertonic solution, hypotonic solution,* and *isotonic solution.*

5. Which of the terms from Question 4 describes the solutions in each of the glasses that the gummy bears were placed into?

Answer the questions below *after* conducting the experiment.

6. Record your results in the tables below.

Gummy bear measurements	*#1*	*#2*	*#3*
Final length (mm):			
Final width (mm):			
Final depth (mm):			
Estimated final volume (mm^3): (length × width × height)			
Change in volume (= final volume – starting volume)			

7. Did your observations match your prediction? If no, explain what you think accounts for the difference.

Part III – Osmosis in Animal Cells

The experiment that Mr. Phillotson's class conducted simulates what happens when living cells, such as your own red blood cells (RBCs), are placed in solutions of different tonicities. The gelatin in gummy bears forms a structural matrix that acts somewhat like a selectively permeable membrane, allowing passage of certain molecules but not others. Water will move in or out of the gummy bear matrix when placed in solutions of different tonicities in order to obtain equilibrium. The plasma membrane that surrounds RBCs and other animal cells is similarly selectively permeable; water will move across the membrane more readily than will solutes such as sodium chloride (NaCl).

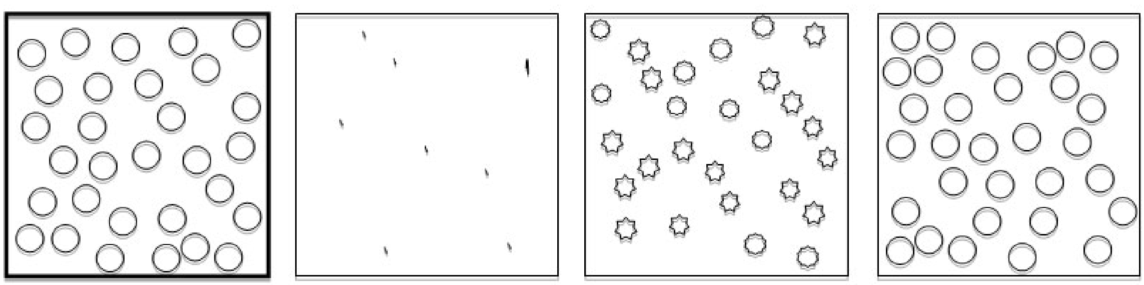
Similar to a gummy bear, the plasma membrane of an animal cell will shrivel up if there is a net loss of water from inside the cell. However, unlike a gummy bear, if there is a large net influx of water into the cell, the plasma membrane may break, and the cell will be destroyed. The bursting of the cell in that situation is called lysis.

Questions

The solute concentration in blood is equivalent to 0.9% NaCl. In the lab section of Mr. Phillotson's class, students viewed a sample of blood with a microscope. Next, several drops of blood were added to three different solutions: 0.09% NaCl, 0.9% NaCl, and 9% NaCl. (Solutions can be made by adding 9.0 g of NaCl to 100 ml of water to produce 9% NaCl, then mixing 10ml of this solution with 90 ml of water to produce 0.9% NaCl, and mixing 10ml of this solution with 90ml of water to produce 0.09% NaCl).

1. In the figure below, the panel on the left shows how the RBCs appeared in the blood when viewed at 400× magnification. Label the three other panels by indicating which shows RBCs added to 0.09% NaCl, to 0.9% NaCl, and to 9% NaCl. Below the panels, indicate whether each solution is isotonic, hypertonic, or hypotonic in relation to RBCs.

RBCs in: ___blood___ #1 = ______% NaCl #2 = ______% NaCl #3 = ______% NaCl



Tonicity: ____________________ ____________________ ____________________

2. Hospital patients often receive medications, nutrients, and water intravenously (IV), which means they are injected directly into the patient's veins through a needle. IV fluid is not pure water, but is instead a saline solution (water containing NaCl). What do you think is the appropriate NaCl concentration for IV fluid? Why?

3. What would happen if pure water was used as IV fluid instead of saline solution?

Part IV – Osmosis in Plant Cells

Unlike gummy bears and animal cells, the cells of plants are surrounded by rigid cell walls. These cell walls will prevent cells from bursting if there is a large net movement of water into the cell. However, when a plant cell swells due to a net influx of water, the cell wall can only expand so far before exerting pressure back on the cell, which is called *turgor pressure*. Many plants depend on turgor pressure and the firm, or turgid, state it creates to provide structural support. If you have ever seen a houseplant or a stalk of celery go limp after not receiving water for a while, you have observed plant cells that have lost turgor pressure and become flaccid. Conversely, a significant net loss of water from inside a plant cell can cause its plasma membrane to pull away from the inside of the cell wall; this state is called *plasmolysis*.

Questions

1. In the boxes below, draw three plants cells: one that is turgid, one that is flaccid, and one that is plasmolyzed. Indicate with arrows the direction of the net movement of water across the cell membrane.

2. Underneath each cell you drew above, label whether the plant that cell represents was placed in a hypertonic, hypotonic, or isotonic solution.
3. Design and describe an experiment using celery stalks to demonstrate how certain conditions will cause a loss or gain of turgor pressure. In order to follow the scientific method, your description should start with an observation and be followed by (i) a testable hypothesis, (ii) an outline of the experiment that will test the hypothesis, (iii) a description of the type of data that will be collected, and (iv) a possible conclusion that could likely be made after completing the experiment and analyzing the data.

References

McKinley, M., and O'Laughlin, V.D. (2006) *Human Anatomy.* Student Edition (online) McGraw-Hill High Education. http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

Pruitt, N.L., and Underwood L.S. (2006) *Bioinquiry: Making Connections in Biology*. 3rd ed. John Wiley & Sons, Inc.

Reece, J.B., et al. (2009) *Campbell Biology*. 9th ed. Benjamin Cummings.