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Case Study: From Gummy Bears to Celery Stalks: Diffusion and Osmosis

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From Gummy Bears to Celery Stalks: Diffusion and Osmosis

By Kevin M. Bonney

This is an interrupted case study that intersperses information about diffusion and osmosis with content review and knowledge application questions, as well as a simple experiment that can be conducted without the use of a laboratory. This case study was developed for use in an introductory undergraduate biology course. The case would also be appropriate for use in a high school biology course and could be adapted for use with elementary or middle school students. To successfully complete this case study, students require prior knowledge and instruction about basic cell structure (including cell membrane composition and the presence of cell walls in plant cells but not animal cells), as well as access to information about how polarity affects membrane solubility.

Objectives

After completing the case, students will be able to

- define the following terms: *diffusion, active transport, passive transport, osmosis, selectively permeable, hypertonic, hypotonic,* and *isotonic*;
- explain and identify what will happen to animal cells and plant cells when placed in a hypertonic, hypotonic, or isotonic solution;
- apply knowledge of the above concepts to designing and conducting simple experiments that will demonstrate osmosis, diffusion, and tonicity; and
- explain at least two examples of how tonicity and osmosis are relevant to their everyday lives.

Classroom management

The case is designed to be presented and discussed over two to four hour-long class periods, with at least one overnight break given during Part II so that an experiment can be conducted. The entire case should be discussed as a class, but the experiments and questions in the case can be conducted individually or in groups of two to five.

The case begins with a narrative followed by a set of review questions used to introduce background information about diffusion and osmosis and define the terms *active transport* and *passive transport*. The second part of the case includes instructions for a simple experiment using gummy bears soaked in different solutions to demonstrate osmosis that can be conducted by students at home or in a classroom. This is followed by an explanation of how the principles of diffusion and osmosis affect animal and plant cells. Review questions and a discussion of two other simple experiments that further demonstrate osmosis, one of which can be conducted by students at home, comprise the last two sections of the case study.

CASE STUDY

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, it is called *passive transport*. Passive transport does not require energy input from the cell.

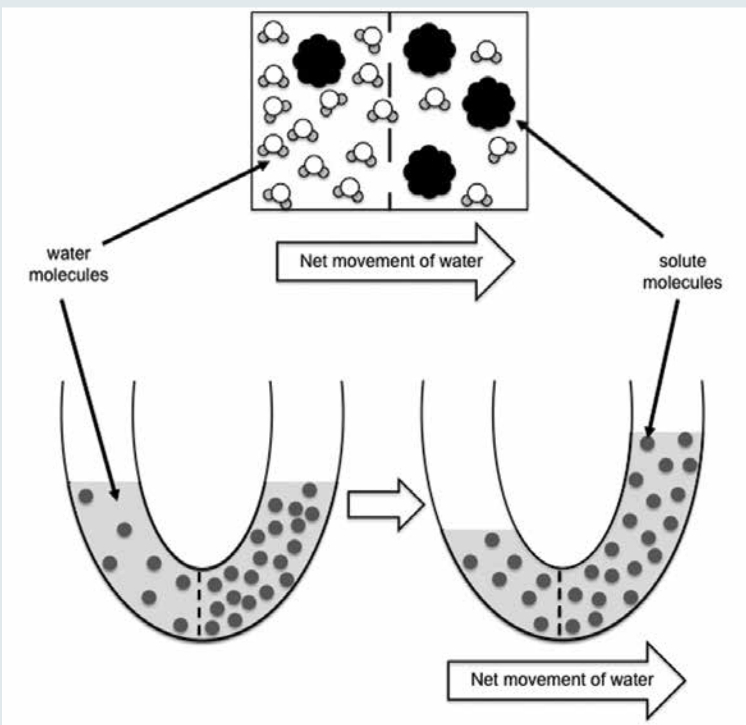
Sue: So, passive transport moves molecules across a cell membrane and does not require energy input from the cell because the necessary force is provided by the concentration gradient?

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 [see Figure 1].

FIGURE 1



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

Jude: Correct.

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 semipermeable). 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 nonpolar? Why? (You may need to use information from your textbook and class discussions to answer this question.)

Part II: Using gummy bears to demonstrate osmosis

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 x width x height.
- *Step 2.* Gather three glasses of the same size, and label them #1, #2, and #3.
- *Step 3.* In glass #1, add 1 inch of water and place one gummy bear inside.
- *Step 4.* In glass #2, add ¼ inch of salt and ¾ inch of water, 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 following questions *before* conducting the experiment:

1. Record your observations in Table 1.
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 terms from Question 4 describe the solutions in each of the glasses that the gummy bears were placed into?

Answer the following questions *after* conducting the experiment:

1. Record your results in Table 2.
2. Did your observations match your predication? 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

TABLE 1

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

TABLE 2

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

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 10 ml of this solution with 90 ml of water to produce 0.9% NaCl, and mixing 10 ml of this solution with 90 ml of water to produce 0.09% NaCl.)

1. Figure 2 shows how the RBCs appeared in the blood when viewed at 400X 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.
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?

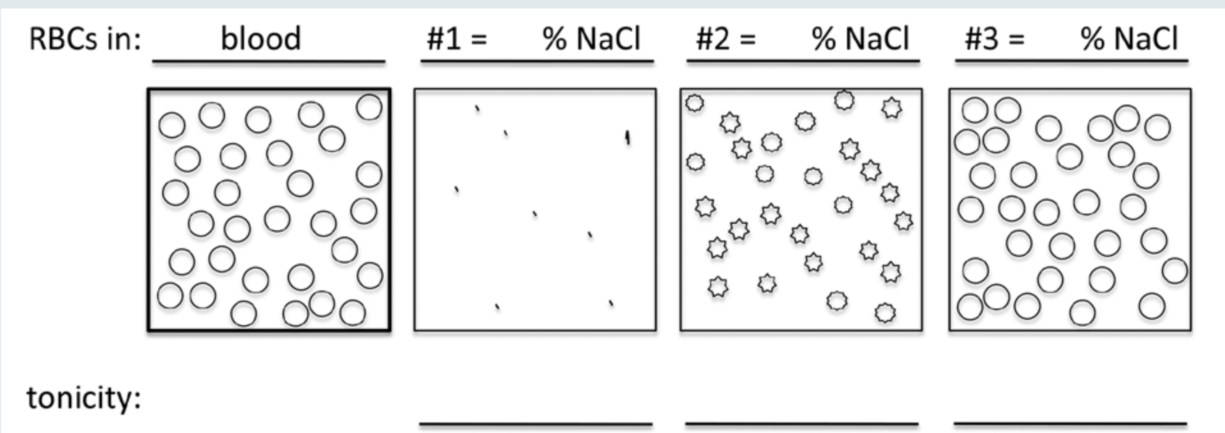
Part IV: Osmosis in plant cells

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 because of 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. On a separate sheet of paper, draw three plant 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,

FIGURE 2



write 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 (a) a testable hypothesis, (b) an outline of the experiment that will test the hypothesis, (c) a description of the type of data that will be collected, and (d) a possible conclusion that could likely be made after completing the experiment and analyzing the data.

Note: Detailed teaching notes and the answer key may be found at the National Center for Case Study Teaching in Science at http://sciencecases.lib.buffalo.edu/cs/collection. ■

Resources

McKinley, M., & O'Laughlin, V. D. (2006). *Human anatomy* (Student ed.). New York, NY: McGraw-Hill Higher Education. Available at http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

Pruitt, N. L., & Underwood L. S. (2006). *Bioinquiry: Making connections in biology* (3rd ed.). New York, NY: Wiley.

Reece, J. B., Urry, L. A., Cain, M. L., Wasserman, S. A., Minorsky, P. V., & Jackson, R. B. (2009). *Campbell biology* (9th ed.). San Francisco, CA: Benjamin Cummings.

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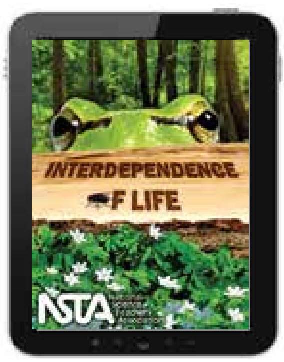

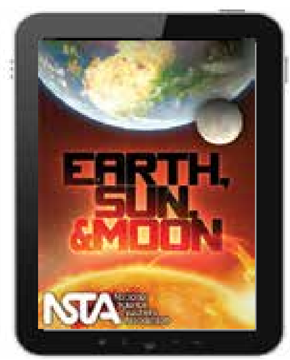

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