A learning cycle to explore the concept of osmosis

Brook Carlsen and Edmund A. Marek

Why does an athlete reach for a sports drink after a tough game or practice? The learning cycle presented in this article helps students answer this question. Learning cycles (Marek 2009) are designed to guide students through direct experiences with a particular concept. In this article, students learn about osmosis, or the moving of water into and out of cells through semipermeable membranes.

The lesson presented here follows the 5E Learning Cycle—Engage, Explore, Explain, Elaborate, and Evaluate (Bybee 1993)—and begins by engaging students in a data-gathering exploration. This article describes the lesson and how we use it in the high school biology classroom.
Engage

We begin the lesson by inviting students to predict what will happen when limp celery stalks are placed in beakers or glasses of water, and turgid stalks are placed in colored water. (It is important to make fresh cuts at the base of each stalk so that water is absorbed easily.) Whether or not students are familiar with osmosis and how it applies to this demonstration, we do not ask them to draw conclusions.

Students observe the limp celery stalks becoming turgid and the colored dye moving up the vascular system of the turgid stalks, coloring their “veins.” This sets the stage for the next part of the learning cycle.

Explore

In groups of three to four, students then place two raw chicken eggs (with the shell on) into a vinegar bath and soak them for three or four days (though we often soak them ourselves several days prior to save class time). Each group needs the following materials:

- safety goggles,
- a measuring balance,
- paper towels,
- three 400 ml beakers,
- 150 ml of corn syrup,
- 150 ml of distilled water,
- a spoon,
- plastic wrap,
- rubber bands, and
- a calculator.

We review proper safety procedures before students begin the investigation and remind them to always wear safety goggles and gloves in the lab; they must also use caution with the eggs—though they seem rubbery after soaking in the vinegar, they break easily. We remind students too that the eggs are raw, which means they might carry Salmonella, as recent outbreaks demonstrate. If an egg breaks, students should not clean it up. They must wash their hands with soap and water if they touch an egg or a surface an egg has come in contact with (even though they are wearing gloves). Students must also be careful not to touch their eyes, nose, or mouth after handling the eggs or corn syrup. Guidelines for glassware safety also apply.

### Figure 1

**Exploration data.**

Remember to complete each step for both of your group’s eggs, solutions, and beakers.

<table>
<thead>
<tr>
<th>Steps</th>
<th>Mass (g) Beaker 1, Egg 1 (Corn syrup)</th>
<th>Mass (g) Beaker 2, Egg 2 (Pure water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mass of shell-less egg from vinegar bath and paper towel</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Mass of paper towel</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Mass of egg (Step 1 – Step 2)</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Mass of beaker</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Mass of solution and beaker before egg is added</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Mass of solution before egg is added (Step 5 – Step 4)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Total mass of egg and solution before egg is soaked overnight (Step 3 + Step 6)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Mass of egg, solution, and beaker after egg is soaked overnight</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Mass of egg after it is soaked in the solution overnight and paper towel (take the egg out of the beaker)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Mass of paper towel</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Mass of egg (Step 9 – Step 10)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Mass of solution and beaker after egg is removed</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Mass of solution (Step 12 – Step 4)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Total mass of egg and solution after egg is soaked overnight (Step 11 + Step 13)</td>
<td></td>
</tr>
</tbody>
</table>
**Suggested procedure**

After soaking the eggs in vinegar, students follow these instructions to complete the lab:

1. Label each beaker with your group’s name, class block, and solution (i.e., corn syrup [beaker 1] or distilled water [beaker 2]).
2. Remove the eggs’ shells and discard them. Place each egg on a paper towel and record your observations.
3. Measure the mass (in grams) of each egg while it is on the paper towel and write the results in Figure 1 (p. 49). Remember the beaker number of each egg (keep egg 1 with beaker 1). Determine the mass of the paper towel under each egg.
4. Subtract the mass of each paper towel from the mass of each egg. Record these measurements in Figure 1.
5. Pour 125 ml of corn syrup into beaker 1 and 125 ml of distilled water into beaker 2. Gently place the eggs in their corresponding beakers (egg 1 in beaker 1 and egg 2 in beaker 2).
6. Cover the beakers with plastic wrap and secure them with rubber bands to prevent evaporation. Allow the beakers to sit overnight. (Sometimes an additional night is needed for the eggs to show noticeable changes.)
7. Observe what has happened to the eggs in your group’s beakers.
8. Remove the rubber bands, plastic wrap, and eggs from the beakers and place each egg on a paper towel. Carefully measure the mass of each egg (in grams) while on the paper towel. Write your results in Figure 1. Measure the mass of the paper towel separately and record it in Figure 1. Subtract the mass of the paper towel from the mass of each egg while on the paper towel and record your data in Figure 1.
9. Weigh and record the remaining solutions’ masses. Complete the remaining steps in Figure 1.

**Explain**

We then collect each group’s data and record it in a chart that shows class averages and general trends. We discuss the results as class. It is important to scaffold questions so that students can develop the concept of osmosis on their own. We use the following questions to help guide the discussion (the suggested answers are italicized):

- Why do you think you weighed the eggs after the shell dissolved (before it was placed in other fluids)? The eggs were weighed to determine their original masses—to see if they changed after the eggs had soaked.
- How did the egg masses compare between the “before” and “after” soakings in the beakers? The water egg’s mass increases; the corn syrup egg’s mass decreases.
- How did the “before” and “after” mass of the corn syrup solution compare to the mass of the egg after it had soaked? The mass of the egg soaked in corn syrup decreases, and the mass of the corn syrup solution increases by the same amount the egg decreases. (Teachers may be able to incorporate conservation of mass into the discussion since the beakers were covered with plastic wrap and the masses changed because the water moved from the egg to the corn syrup solution [or from the water to the egg, in the case of the egg in the distilled water].)
- What is the function of a chicken egg’s shell? The shell provides structure and water retention and keeps out bacteria.
- Why does the shell need to be semipermeable? In a fertilized egg, the shell must allow the exchange of gases, such as oxygen and carbon dioxide (from the developing embryo), but still be impermeable to water.
Do liquids move back and forth from the outside to the inside of an egg while it is in a nest? Little, if any, movement occurs back and forth from the outside to the inside of the egg.

Would this experiment have the same results if we did not remove the eggs’ shells before we soaked them in different solutions? If the shells were not removed, little change would occur between the masses of the eggs and their solutions because eggshells are not very permeable to water.

When you break a shell-less egg, you see that a membrane contains the egg white (cytoplasm). If fluids were able to freely pass through the “skin” surrounding the shell-less egg, how would the fluids (solutions) move in each situation? Fluids in the egg would move out of the egg and into the corn syrup. Distilled water would move directly into the egg.

Draw arrows to show the path of the fluid (Figure 2). What are the differences between pure water and corn syrup? Corn syrup has sugar particles (molecules) in combination with water; pure water is just that.

If there were tiny holes in the “skin” surrounding the eggs, which one (water or corn syrup) would be more likely to pass through? Water is more likely to pass through because water molecules are smaller than sugar molecules. In cells, proteins called aquaporins embedded in the cell membrane help facilitate and regulate the flow of water.

What could be the reason for the fluid moving into or out of cells? Any answer that demonstrates understanding of osmosis is a good one.

At this point in the learning cycle, we develop a concept statement with students and identify our terms, which should look something like this: “Water moves into and out of the eggs through a semipermeable membrane in a process called osmosis.” (Scientific terms for concept development include semipermeable membrane and osmosis.)

**Elaborate**

At this point, we return to the focus of the lesson: Why do athletes drink sports drinks? The “elaborate” activity is a real-life application of osmosis, and we begin by having students collect information about a particular sports drink—Gatorade—through assigned reading or internet investigations. (Note: Any sports drink can be used; we chose Gatorade because of its interesting history.)

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**Sample assessment.**

(Note: The correct answers to each question are italicized.)

In the diagram below, a cell with a semipermeable membrane is placed in a container of solution. Only water can pass through this cell’s membrane. The dots represent large particles suspended in water.

1. How will the water move in the scenario above?
   A. Water will move out of the cell because the particles will push the water out of the cell.
   B. Water will move out of the cell because water molecules are attracted to each other and more water is located outside the cell than inside the cell.
   C. Water will move into the cell to reach equilibrium of particles-to-water ratio inside the cell and outside the cell.
   D. Water will not move because it cannot pass through the cell membrane.

2. Fill in the blank: In Figure 1 (p. 49), the mass of the solution outside the cell ________ during the first few hours after the cell is placed in the solution.
   A. increases
   B. decreases
   C. stays the same

3. Explain how the overall mass of the container (the mass of the cell and the solution surrounding the cell) changes because of osmosis. The law of conservation of mass states that the overall mass of a closed system cannot change. The overall mass of the container includes the mass of the cell and the mass of the outside solution, so the solution’s mass will be measured with the rest of the masses, regardless of its location.

4. What is osmosis?
   Osmosis is water moving into and out of cells through semipermeable membranes.
Why Do Athletes Drink Sports Drinks?

Through their research, students discover that University of Florida (UF) researchers created Gatorade to help their struggling football team—the Florida Gators. In 1965, the Florida heat was causing many players to become dehydrated. That year, Dwayne Douglas, the assistant football coach at the time, asked Robert Cade, a kidney disease specialist at the university, why his athletes were losing so much weight after games and practices, but urinating so little. Cade quickly determined that the players were sweating so much that they had little fluids left to urinate. The UF researchers developed a new drink that seemed to help counteract this dehydration: Gatorade. And in 1967, the Florida Gators won the Orange Bowl for the first time!

To relate osmosis to sports drinks and facilitate discussion about students’ findings, we use the following questions (the suggested answers are italicized):

- What is dehydration? What is sweat? List the components of sweat. Dehydration occurs when an organism has lost significant body fluids and usually essential cellular particles. Humans sweat to cool the body by releasing energy when sweat evaporates. Sweat is comprised of water and dissolved particles called electrolytes. The solute particles, or electrolytes, are primarily sodium and potassium. If there are more of these particles inside the cell than outside the cell, water moves into the cell through a semipermeable membrane. If more sodium and potassium particles are outside the cell than inside the cell, water moves out of the cell through the cell membrane. This process is called osmosis.

- If electrolytes (primarily sodium and potassium) are sweated out of the body from inside its cells, how does this affect osmosis? The remaining water may leave the cells since the sodium and potassium concentrations inside the cells have decreased—increasing the cells’ water concentration and making movement of water out of the cells more likely.

- Why might drinking water not be enough to alleviate dehydration (taking place on a cellular level) in this situation? Cells need solute particles (electrolytes) inside them to facilitate the water entering. When electrolyte particles exit the cells as sweat, the osmotic pressure inside the cells increases—making it more difficult for water to enter the cells and rehydrate tissue.

- What is in a sports drink that helps alleviate dehydration? The solute particles (electrolytes) and water in sports drinks alleviate dehydration. Replacing solute particles inside the cells helps facilitate the movement of water back into the cells. (Editor’s note: For most shorter workouts and other daily activities, drinking just water is enough to rehydrate you, so remember to drink plenty of water every day!)

Evaluate

Depending on the teacher, authentic assessment for this activity can take many forms. Evaluation should take place throughout the learning cycle so that the content and the science processes can be assessed. In Figure 3 (p. 51), we offer five items to help assess students’ understanding of osmosis (suggested answers are italicized.)

Conclusion

Biology students gain more from direct experiences with science concepts. By providing students with tangible, concrete experiences with osmosis, they are better able to understand the movement of particles through a membrane (thanks to the change in egg mass and size). An inquiry experience with osmosis helps students better understand this concept!

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On the web

Standards addressed: www.nsta.org/highschool/connections.aspx

References


