Secondary & College Biology Students' Misconceptions About Diffusion & Osmosis

Arthur Louis Odom

The diagnosis of students' misconceptions and the identification of reasons for those misconceptions is a prerequisite to developing lessons that result in conceptual change. In recent years, research on students' misconceptions has been of considerable interest to science educators and cognitive psychologists. It is now generally agreed that every student brings to science class his/her conceptions of the world, and because of students' wide variety of experiences, each concept will hold a somewhat different meaning. Further, many of the conceptions will be different from those generally accepted by the scientific community. In this article the term misconception refers to students' ideas that are different from those generally accepted by scientists.

Diffusion and osmosis are widely taught in many secondary and college biology curriculums. There are several reasons why we should focus on diffusion and osmosis concepts in biology. Diffusion and osmosis are key to understanding many important life processes. Diffusion is the primary method of short distance transport in a cell and cellular systems. An understanding of osmosis is key to understanding water uptake by plants, water balance in aquatic creatures, turgor pressure in plants, and transport in living organisms. In addition, diffusion and osmosis are closely related to key concepts in physics and chemistry such as permeability and the particulate nature of matter (Friedler, Amir & Tamir 1987).

Purpose

Because of the diversity of diffusion and osmosis concepts and their importance in understanding science/biological systems, an evaluation of biology students' understanding is needed so more effective teaching methods can be developed. The purpose of this study was to determine the following among secondary biology students, college nonbiology majors and biology majors:

1. To identify students' misconceptions about diffusion and osmosis.
2. To determine whether students differ in their understanding of diffusion and osmosis concepts.
3. To determine whether males and females differ in their understanding of diffusion and osmosis concepts.
4. To determine if there is any interaction between class (secondary, nonmajor and major) and gender with regard to understanding diffusion and osmosis concepts.

Methods & Procedures

The Diffusion and Osmosis Diagnostic Test (DODT) was used to detect misconceptions (Odom & Barrow, in press). The diagnostic test was developed using procedures that have been used in earlier research by Treagust (1985), Peterson (1986), Haslam and Treagust (1987), Gorjanc-Barthel (1989), and Kio-kaew (1989).

Items for the diagnostic instrument are based on the two-tier, multiple-choice format. The first tier consists of a content question with two, three or four choices. The second tier consists of four possible reasons for the first part: three alternative reasons and one desired reason. The alternative reasons were based on misconceptions previously detected during a multiple-choice test with free response reason and interview sessions.

The content boundaries of the final instrument were defined by a list of propositional knowledge statements (Figure 1). A specification grid (Figure 2) was constructed to determine the face validity and whether the test questions matched all of the validated content specified by the propositional knowledge statements. Two major questions were addressed while determining face validity:

1. Does the question assess the content as defined by the validated propositional knowledge statements?
2. Is the question at a level of sophistication appropriate for college freshman biology students?

If the above criteria were not met, then the item was dropped. All 22 propositional knowledge statements were matched to the items on the Diffusion and Osmosis Diagnostic Test.
1. All particles are in constant motion.
2. Diffusion involves the movement of particles.
3. Diffusion results from the random motion and/or collisions of particles (ions or molecules).
4. Diffusion is the net movement of particles as a result of a concentration gradient.
5. Concentration is the number of particles per unit volume.
6. Concentration gradient is a difference in concentration of a substance across a space.
7. Diffusion is the net movement of particles from an area of high concentration to an area of low concentration.
8. Diffusion continues until the particles become uniformly distributed in the medium in which they are dissolved.
9. Diffusion rate increases as temperature increases.
10. Temperature increases motion and/or particle collisions.
11. Diffusion rate increases as the concentration gradient increases.
12. Increased concentration increases particle collisions.
13. Diffusion occurs in living and nonliving systems.
14. Osmosis is the diffusion of water across a semipermeable membrane.
15. Tonicity refers to the relative concentration of particles on either side of a semipermeable membrane.
16. A hypotonic solution has fewer dissolved particles relative to the other side of the membrane.
17. A hypertonic solution has more dissolved particles relative to the other side of the membrane.
18. An isotonic solution has an equal number of dissolved particles on both sides of the membrane.
19. Osmosis is the net movement of water (solvent) across a semipermeable membrane from a hypotonic solution to a hypertonic solution.
20. Osmosis occurs in living and nonliving systems.
21. A semipermeable membrane is a membrane that selectively allows the movement of some substances across the membrane while blocking the movement of others.
22. Cell membranes are semipermeable.

Figure 1. Propositional knowledge statements required for understanding diffusion and osmosis.

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<table>
<thead>
<tr>
<th>Item</th>
<th>Propositional Knowledge Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2, 4</td>
</tr>
<tr>
<td>2</td>
<td>2, 4, 5, 6, 7, 12</td>
</tr>
<tr>
<td>3</td>
<td>2, 3, 4, 11, 12</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>4, 5, 6, 8</td>
</tr>
<tr>
<td>6</td>
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<td>7</td>
<td>9, 10</td>
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<td>14, 19, 21</td>
</tr>
<tr>
<td>9</td>
<td>15, 16, 17, 18</td>
</tr>
<tr>
<td>10</td>
<td>14, 19, 22</td>
</tr>
<tr>
<td>11</td>
<td>13, 20</td>
</tr>
<tr>
<td>12</td>
<td>21, 22</td>
</tr>
</tbody>
</table>

Figure 2. Specification grid of the propositional knowledge statements matched with items in the Diffusion and Osmosis Diagnostic Test.

Subjects

The DODT was administered to 116 secondary biology students, 123 nonbiology majors, and 117 biology majors. The secondary students attended a suburban high school located in a large metropolitan area in the Midwest. Each student was enrolled in either Biology I or Biology II. The grade levels ranged from 10th to 12th grade. The college nonbiology and biology majors attended a large Midwestern university. The nonbiology majors were enrolled in a course specifically designed to meet the general education science requirements for nonscience majors. The biology majors were enrolled in a first year general biology course for science/biology majors. Prior to administration of the test, each type of student participated in seven different laboratory exercises based on the propositional knowledge statements that defined the content boundaries of the DODT. The exercise included activities on the following:

1. Diffusion of a solid in a liquid
2. Effect of temperature and concentration on diffusion rates
3. Diffusion through membranes
4. Osmosis
5. Consequences of osmosis in a closed system
6. Water uptake by plant cells
7. Observations of the central vacuole in Elodea

(Summers 1988). The labs were followed by discussions.

All of the students who participated in the study were selected with a random number table. The secondary students were taught by a secondary biology teacher who was also a Presidential Awardee. The university students were taught by graduate teaching assistants in the laboratory sections and biology professors in the lecture sections.
Table 1. The percentage of secondary biology students, nonbiology majors and biology majors selecting each response combination for item 3 on the Diffusion and Osmosis Diagnostic Test.

As the difference in concentration between two areas increases, the rate of diffusion:
- (a) Decreases
- (b) Increases
Reason
- (a) There is less room for the particles to move.
- (b) If the concentration is high enough, the particles will spread less and the rate will be slowed.
- (c) The molecules want to spread out.
- (d) The greater likelihood of random motion into other regions.

<table>
<thead>
<tr>
<th>Choice on first tier</th>
<th>Reason</th>
<th></th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Secondary Biology</td>
<td>9.5</td>
<td>19.8</td>
<td>5.2</td>
<td>2.6</td>
<td>37.1</td>
</tr>
<tr>
<td></td>
<td>8.6</td>
<td>5.2</td>
<td>13.8</td>
<td>35.3*</td>
<td>62.9</td>
</tr>
<tr>
<td>Nonbiology Majors</td>
<td>8.9</td>
<td>18.7</td>
<td>4.9</td>
<td>5.7</td>
<td>38.2</td>
</tr>
<tr>
<td></td>
<td>8.9</td>
<td>4.1</td>
<td>27.6</td>
<td>21.1*</td>
<td>61.8</td>
</tr>
<tr>
<td>Biology Majors</td>
<td>5.1</td>
<td>12.8</td>
<td>5.1</td>
<td>2.6</td>
<td>25.6</td>
</tr>
<tr>
<td></td>
<td>1.7</td>
<td>3.4</td>
<td>29.1</td>
<td>40.2*</td>
<td>74.4</td>
</tr>
</tbody>
</table>

* Correct choice and reason

Results

The split-half reliability of the DODT among the sample population was 0.74. Majors had fewer misconceptions than nonmajors and secondary students on the DODT. A two-way analysis of variance indicated a significant difference between classes [secondary students, nonbiology majors and biology majors (p = 0.000)]. There was no significant difference between gender and no interaction between gender and class. A post hoc-Tukey test of significance indicated that there was no significant difference between secondary students and nonbiology majors (p = 0.961). There was a significant difference between biology majors and secondary/nonbiology majors (p = 0.000).

According to Gilbert (1977), if a multiple-choice item has four to five distractors, understanding is considered satisfactory if more than 75% of the students answer the item correctly. In a typical multiple-choice test with four possible selections, there is a 25% chance of guessing the correct answer. For a two-tier item with two selections on the first tier and four selections on the second tier, there is a 12.5% chance of guessing the correct answer combination.

The range of correct answers for the first tier of the test was 36% to 87% for secondary students, 36% to 98% for nonbiology majors, and 38% to 96% for biology majors (Table 2). When both tiers were combined, the correct responses were reduced to a range of 32% to 75% for secondary students, 15% to 81% for nonbiology majors, and 23% to 92% for biology majors.

The DODT results suggest that students at all levels did not acquire a satisfactory understanding of diffusion and osmosis concepts. Secondary students scored 75% on one out of 12 items, nonmajors scored above 75% on two out of 12 items, and majors scored above 75% on three out of 12 items on the DODT.

Major misconceptions were detected in six of the seven conceptual areas covered by the test: the particulate and random nature of matter, concentration and tonicity, the influences of life forces on diffusion and osmosis, the process of diffusion, and the process of osmosis. Table 3 is a list of the most common misconceptions detected by the DODT.

Table 2. Percentages of secondary biology students, college nonbiology and biology majors selecting the desired content choice and combination content choice and reason on the Diffusion and Osmosis Diagnostic Test.

<table>
<thead>
<tr>
<th>Item</th>
<th>Secondary Biology</th>
<th>Nonbiology Majors</th>
<th>Biology Majors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>content reason*</td>
<td>content reason*</td>
<td>content reason*</td>
</tr>
<tr>
<td>1</td>
<td>78.4</td>
<td>59.5</td>
<td>72.5</td>
</tr>
<tr>
<td>2</td>
<td>86.5</td>
<td>38.8</td>
<td>90.2</td>
</tr>
<tr>
<td>3</td>
<td>62.9</td>
<td>35.3</td>
<td>61.8</td>
</tr>
<tr>
<td>4</td>
<td>81.0</td>
<td>35.3</td>
<td>89.9</td>
</tr>
<tr>
<td>5</td>
<td>39.7</td>
<td>34.5</td>
<td>37.4</td>
</tr>
<tr>
<td>6</td>
<td>83.6</td>
<td>50.0</td>
<td>88.6</td>
</tr>
<tr>
<td>7</td>
<td>85.4</td>
<td>75.0</td>
<td>97.6</td>
</tr>
<tr>
<td>8</td>
<td>67.2</td>
<td>33.6</td>
<td>51.2</td>
</tr>
<tr>
<td>9</td>
<td>72.4</td>
<td>45.7</td>
<td>69.9</td>
</tr>
<tr>
<td>10</td>
<td>84.5</td>
<td>43.1</td>
<td>80.5</td>
</tr>
<tr>
<td>11</td>
<td>36.2</td>
<td>31.9</td>
<td>35.8</td>
</tr>
<tr>
<td>12</td>
<td>84.5</td>
<td>71.6</td>
<td>95.1</td>
</tr>
</tbody>
</table>

* content and reason combination
Table 3. Percentages of responses by secondary biology students, college nonbiology and biology majors with specific misconceptions detected by the Diffusion and Osmosis Diagnostic Test.

<table>
<thead>
<tr>
<th>Misconceptions</th>
<th>Secondary Biology</th>
<th>Nonbiology Majors</th>
<th>Biology Majors</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Particulate &amp; Random Nature of Matter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Particles move from high to low concentration because:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. They tend to move until the two areas are isotonic and then the particles stop moving.</td>
<td>22.4</td>
<td>32.5</td>
<td>33.3</td>
<td>2</td>
</tr>
<tr>
<td>b. There are too many particles crowded into one area, therefore they move to an area with more room.</td>
<td>18.9</td>
<td>31.7</td>
<td>26.5</td>
<td>2</td>
</tr>
<tr>
<td>2. As the difference in concentration increases between two areas, rate of diffusion:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Increases because the molecules want to spread out.</td>
<td>13.8</td>
<td>27.6</td>
<td>29.1</td>
<td>3</td>
</tr>
<tr>
<td>b. Decreases because if the concentration is high enough, the particles will spread less and the rate will be slowed.</td>
<td>19.8</td>
<td>18.7</td>
<td>12.8</td>
<td>3</td>
</tr>
<tr>
<td>3. When a drop of dye is placed in a container of clear water the:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Dye molecules continue to move around because if dye molecules stopped, they would settle to the bottom of the container.</td>
<td>26.7</td>
<td>13.0</td>
<td>6.0</td>
<td>6</td>
</tr>
<tr>
<td>b. Dye molecules continue to move around because this is a liquid; if it were solid the molecules would stop moving.</td>
<td>3.5</td>
<td>6.5</td>
<td>11.1</td>
<td>6</td>
</tr>
<tr>
<td>Concentration &amp; Tonicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. A glucose solution can be made more concentrated by adding more glucose because the more water there is, the more glucose it will take to saturate the solution.</td>
<td>26.7</td>
<td>22.0</td>
<td>20.5</td>
<td>4</td>
</tr>
<tr>
<td>2. Side 1 is 10% salt solution and side 2 (15% salt solution).</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Side 1 is hypotonic to Side 2 because water moves from high to low concentration.</td>
<td>19.8</td>
<td>15.4</td>
<td>6.0</td>
<td>9</td>
</tr>
<tr>
<td>b. Side 1 is hypertonic to Side 2 because the water moves from high to low concentration.</td>
<td>7.8</td>
<td>10.6</td>
<td>3.4</td>
<td>9</td>
</tr>
<tr>
<td>The Influence of Life Forces on Diffusion &amp; Osmosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. If a plant cell is killed and placed in a salt solution, diffusion and osmosis will not occur because the cell will stop functioning.</td>
<td>25.0</td>
<td>26.8</td>
<td>22.2</td>
<td>11</td>
</tr>
<tr>
<td>The Process of Diffusion</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. The process responsible for a drop of blue dye becoming evenly distributed throughout a container of clear water is:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Diffusion because the dye separates into small particles and mixes with water.</td>
<td>17.2</td>
<td>18.7</td>
<td>20.5</td>
<td>1</td>
</tr>
<tr>
<td>b. Osmosis because there is movement of particles between regions of different concentrations.</td>
<td>11.2</td>
<td>14.6</td>
<td>5.1</td>
<td>1</td>
</tr>
<tr>
<td>2. When sugar is added to water, after a very long period of time the sugar will be more concentrated on the bottom of the container because:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. There will be more time for settling.</td>
<td>10.3</td>
<td>25.2</td>
<td>7.7</td>
<td>5</td>
</tr>
<tr>
<td>b. The sugar is heavier than water and will sink.</td>
<td>26.7</td>
<td>22.0</td>
<td>40.2</td>
<td>5</td>
</tr>
<tr>
<td>c. Sugar dissolves poorly or not at all in water.</td>
<td>11.2</td>
<td>8.9</td>
<td>12.8</td>
<td>5</td>
</tr>
<tr>
<td>The Process of Osmosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Two columns of water are separated by a membrane through which only water can pass. Side 1 contains dye and water; Side 2 contains pure water. After two hours, the water level in Side 1:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Will be higher because water will move from the hypertonic to the hypotonic solution.</td>
<td>13.8</td>
<td>22.0</td>
<td>16.2</td>
<td>8</td>
</tr>
<tr>
<td>b. Will be higher because water moves from low to high concentration.</td>
<td>18.9</td>
<td>13.0</td>
<td>15.4</td>
<td>8</td>
</tr>
<tr>
<td>c. Will be lower because water will move from the hypertonic to hypotonic solution.</td>
<td>12.1</td>
<td>14.6</td>
<td>14.5</td>
<td>8</td>
</tr>
<tr>
<td>d. will be the same because water will become isotonic.</td>
<td>1.7</td>
<td>17.1</td>
<td>13.7</td>
<td>8</td>
</tr>
<tr>
<td>2. If a freshwater plant cell was placed in a beaker of 25% salt water solution, the central vacuole would decrease in size because salt absorbs the water from the central vacuole.</td>
<td>31.9</td>
<td>35.8</td>
<td>19.7</td>
<td>10</td>
</tr>
</tbody>
</table>

Discussion & Conclusions

This study provides evidence that even following instruction secondary biology students, nonbiology and biology majors continue to have misconceptions about diffusion and osmosis. The identification is of direct relevance for secondary and college biology teachers since this knowledge can be used to develop instructional approaches to hopefully correct these misconceptions.

Similarly, Zuckerman (1993) identified 12 accurate conceptions of osmosis. In addition, she identified eight misconceptions about osmosis held by high school science students. It was reported that misconceptions about osmosis blocked problem solving of
osmosis-related questions. Two misconceptions were specifically linked with blocking meaningful problem solving: the rate of osmosis is constant, and the concentrations of water across the membrane must be equal at osmotic equilibrium. Of the 12 accurate conceptions, two were especially important in enabling problem solvers to generate correct answers: increasing the height of the column of a solution increases the hydrostatic pressure on the membrane; and when a solution and water are separated by a selectively permeable membrane, pressure against the solution side of the membrane opposes osmosis.

Odom and Settlage (1994) reported that formal reasoning played a significant role in understanding diffusion and osmosis concepts. They found that formal high school students out performed preformal high school students on five out of seven concepts related to diffusion and osmosis: particulate and random nature of matter, concentration and toxicity, membranes, the process of diffusion, and the process of osmosis. In addition, they found grade level to be an insignificant covariate, and in most cases formal 10th grade students out performed preformal 11th and 12th grade students. Similarly, Renner and Marek (1998) noted that the large majority of high school students were preformal reasoners. In their study, 90% of the 10th graders, 76% of the 11th graders, and 68% of the 12th graders were preformal. The results of these two studies suggest that specially designed instructional approaches should be used if diffusion and osmosis are going to continue to be part of the secondary curriculum. Further, the approaches should include instructional strategies that allow students concrete interaction with diffusion and osmosis concepts and should follow a sequence that focuses on the learning cycle model of instruction.

Christianson and Fisher (1994) reported that college students in a “constructivist” course learned significantly more diffusion and osmosis concepts than students in a more traditional biology course. It was suggested that motivation and learning in biology could be enhanced by:

1. Allowing teacher-student and student-student discussion.
2. Allowing time for prediction. Once students have been presented with a body of information, they need opportunities to apply that information in order to weed out misconceptions, reinforce understanding, and make predictions.
3. Using concept mapping to anchor concepts and construct meaning.
4. Using the best teaching method—a variety of methods. Lecture, discussion, laboratory demonstration, prediction, consensus building, and computer organization of knowledge all contrib-

ute to learning. Different students will respond to different techniques.

In conclusion, an important outcome of this research study is the extent to which biology concepts in diffusion and osmosis are not being comprehended by students from secondary and university campuses. Based on the results of this study, biology teachers appear not to be teaching for comprehension of diffusion and osmosis concepts, but rather for emphasizing the acquisition of facts (although there were no direct observations of instruction). Further, the DODT can be a valuable tool that can aid teachers in assessing both their teaching methodologies and students’ understanding and reasoning about diffusion and osmosis.

References


Appendix A

Diffusion & Osmosis Test

Directions: DO NOT WRITE ON THE ASSESSMENT. This assessment consists of 12 pairs of questions that examine your knowledge of diffusion and osmosis. Each question has two parts: a multiple choice response followed by a multiple choice reason. On the answer sheet provided, please circle one answer from both the response and reason sections of each question.

1a. Suppose there is a large beaker full of clear water and a drop of blue dye is added to the beaker of water. Eventually the water will turn a light blue color. The process responsible for blue dye becoming evenly distributed throughout the water is:
   a. Osmosis
   b. Diffusion
   c. A reaction between water and dye
1b. The reason for my answer is:
   a. The lack of a membrane means that osmosis and diffusion cannot occur.
   b. There is movement of particles between regions of different concentrations.
   c. The dye separates into small particles and mixes with water.
   d. The water moves from one region to another.
2a. During the process of diffusion, particles will generally move from:
   a. High to low concentrations
   b. Low to high concentrations
2b. The reason for my answer is:
   a. There are too many particles crowded into one area, therefore they move to an area with more room.
   b. Particles in areas of greater concentration are more likely to bounce toward other areas.
   c. The particles tend to move until the two areas are isotonic and then the particles stop moving.
   d. There is a greater chance of the particles repelling each other.
3a. As the difference in concentration between two areas increases, the rate of diffusion:
   a. Decreases
   b. Increases
3b. The reason for my answer is:
   a. There is less room for the particles to move.
   b. If the concentration is high enough, the particles will spread less and the rate will be slowed.
   c. The molecules want to spread out.
   d. The greater likelihood of random motion into other regions.
4a. A glucose solution can be made more concentrated by:
   a. Adding more water
   b. Adding more glucose
4b. The reason for my answer is:
   a. The more water there is, the more glucose it will take to saturate the solution.
   b. Concentration means the dissolving of something.
   c. It increases the number of dissolved particles.
   d. For a solution to be more concentrated, one must add more liquid.
5a. If a small amount of sugar is added to a container of water and allowed to set for a very long period of time without stirring, the sugar molecules will:
   a. Be more concentrated on the bottom of the container
   b. Be evenly distributed throughout the container
5b. The reason for my answer is:
   a. There is movement of particles from a high to low concentration.
   b. The sugar is heavier than water and will sink.
   c. Sugar dissolves poorly or not at all in water.
   d. There will be more time for settling.
6a. Suppose you add a drop of blue dye to a container of clear water and after several hours the entire container turns light blue. At this time, the molecules of dye:
   a. Have stopped moving
   b. Continue to move around randomly
6b. The reason for my answer is:
   a. The entire container is the same color; if the dye molecules were still moving, the container would be different shades of blue.
   b. If the dye molecules stopped, they would settle to the bottom of the container.
   c. Molecules are always moving.
   d. This is a liquid; if it were solid the molecules would stop moving.
7a. Suppose there are two large beakers with equal amounts of clear water at two different temperatures. Next, a drop of green dye is added to each beaker of water. Eventually the water turns light green (see Figure 1). Which beaker became light green first?
   a. Beaker 1
   b. Beaker 2

7b. The reason for my answer is:
   a. The lower temperature breaks down the dye.
   b. The dye molecules move faster at higher temperatures.
   c. The cold temperature speeds up the molecules.
   d. It helps the molecules to expand.

8a. In Figure 2, two columns of water are separated by a membrane through which only water can pass. Side 1 contains dye and water; Side 2 contains pure water. After two hours, the water level in Side 1 will be:
   a. Higher
   b. Lower
   c. The same height

8b. The reason for my answer is:
   a. Water will move from the hypertonic to hypotonic solution.
   b. The concentration of water molecules is less on Side 1.
   c. Water will become isotonic.
   d. Water moves from low to high concentration.

9a. In Figure 3, Side 1 is ____ to Side 2.
   a. Hypotonic
   b. Hypertonic
   c. Isotonic

9b. The reason for my answer is:
   a. Water is hypertonic to most things.
   b. Isotonic means “the same.”
   c. Water moves from a high to a low.
   d. There are fewer dissolved particles on Side 1.

10a. Figure 4 is a picture of a plant cell that lives in fresh water. If this cell was placed in a beaker of 25% salt water solution, the central vacuole would:
   a. Increase in size
   b. Decrease in size
   c. Remain the same size

10b. The reason for my answer is:
   a. Salt absorbs the water from the central vacuole.
   b. Water will move from the vacuole to the salt water solution.
   c. The salt will enter the vacuole.
   d. Salt solution outside the cell cannot effect the vacuole inside the cell.

11a. Suppose you killed the plant cell in Figure 4 with poison and placed the dead cell in a 25% salt water solution. Osmosis and diffusion would:
   a. Not occur
   b. Continue
   c. Only diffusion would continue
   d. Only osmosis would continue

11b. The reason for my answer is:
   a. The cell would stop functioning.
   b. The cell does not have to be alive.
   c. Osmosis is not random, while diffusion is a random process.
   d. Osmosis and diffusion require cell energy.

12a. All cell membranes are:
   a. Semi-permeable
   b. Permeable

12b. The reason for my answer is:
   a. They allow some substances to pass.
   b. They allow some substances to enter, but they prevent any substance from leaving.
   c. The membrane requires nutrients to live.
   d. They allow ALL nutrients to pass.