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Freshman Biology Non-Majors
Misconceptions about Diffusion and Osmosis

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INTRODUCTION

Every student brings to science class their conceptions of the world. Because of students wide variety of experiences, each concept will hold a somewhat different meaning for each student. The general meaning of some conceptions will be shared, while others will be unique. Many of the conceptions are scientific misconceptions associated with intuitive ideas or preconceptions acquired prior to school (Driver, 1987). Wandersee (1986) noted that many of the misconceptions students hold are the same as conceptions held by pre-Newtonian scientists, and younger students are more likely to hold out-dated scientific conceptions.

Misconceptions research has compiled large volumes of research during the past fifty years. Misconceptions have been detected from preschool through college. Recent sources have shown that even science teachers have misconceptions about science (Lawrenz, 1986). One particularly alarming interview session found deep rooted scientific misconceptions held by Harvard graduates and professors (Private Universe, 1988). One of the most important results of research on science misconceptions has been a better understanding of difficulties in science learning and an awareness of the need for significant changes in the teaching/learning process (Gil Perez & Carrascosa, 1987).

PURPOSE

Diffusion and osmosis are the 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 concepts is key to understanding water intake by plants, water balance in land and 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, solutions, and the particulate nature of matter (Friedler, Amir, & Tamir, 1987). Because of the diversity of diffusion and osmosis concepts and their importance in understanding biological systems, an evaluation of non-biology major students understanding was needed to detect student misconceptions so more effective teaching methods can be developed.

The purpose of this study was to determine the following:

1. To identify non-biology major college students' common misconceptions about diffusion and osmosis.
2. To determine whether males and females are different in their understanding of concepts concerning diffusion and osmosis.
3. To determine whether the number of science courses taken in high school is a significant covariate when assessing understanding using the Diffusion and Osmosis Diagnostic Test.

METHODS AND PROCEDURES

The diagnostic test was developed using procedures that have been previously utilized in earlier research by Treagust (1985), Perterson (1986), Haslam & Treagust (1987), Gorjanc-Barthel (1989), and Kiokaew (1989). The development involves three general areas: defining the content boundaries of the test, obtaining information about students' misconceptions, and developing the instrument.

DEFINING THE CONTENT BOUNDARIES

Propositional knowledge statements were used to define the content boundaries of diffusion and osmosis concepts. The propositions were derived from two college level biology textbooks (Starr & Tarrgart, 1987; Wolfe, 1977), and one college level biology laboratory manual (Summers, 1989). A list of 22 propositional knowledge statements required for understanding diffusion and osmosis at a level of sophistication appropriate for freshman college biology students were identified (Figure 1). The validity of the propositional knowledge statements was determined by a panel of two professors of science education and one professor of biology.

IDENTIFYING STUDENTS' MISCONCEPTION

To assess students' conceptions of diffusion and osmosis a total of 20 introductory college biology students were interviewed. All of the interviewees were students who had completed a two hour laboratory followed by a one hour discussion of diffusion and osmosis concepts. Following instruction, students were asked to volunteer to be interviewed about their knowledge of diffusion and osmosis concepts. The interviews contained open ended questions. All of the students interviewed had partial misconceptions, complete misconceptions, or no understanding of diffusion and osmosis concepts. All of the interviews were audio tape recorded and were used to develop a list of student misconceptions about diffusion and osmosis concepts.

Based on the validated list of propositional knowledge statements, a 15 item multiple choice test with free response answers was developed. The first tier of the test was in multiple choice format with two, three or four choices. The second tier was the statement "The reason for my answer is because:" with a blank space provided. Students were asked to explain the reason for their multiple choice selection. This test was administered to 171 non-science major introductory college biology students who had previously received instruction on diffusion and osmosis concepts. The free response data provided further evidence of biology students' misconceptions about diffusion and osmosis.

INSTRUMENT DEVELOPMENT

Items for the diagnostic instrument were based on the two-tier multiple choice format described by Treagust (1985). 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 detected

Figure 1. Propositional Knowledge Statements Required for Understanding Diffusion and Osmosis.

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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.

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during the multiple choice test with free response reason and the interview sessions. A pilot study was conducted to refine the items on the diagnostic instrument.

The Diffusion and Osmosis Diagnostic Test consists of 12 items

(Appendix A). The conceptual areas covered by the test are: the particulate and random nature of matter, concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion and the process of osmosis. Table 1 is an example of an item that tests understanding of the particulate and random nature of matter.

For the final instrument, a specification grid was constructed to determine whether the test matched all of the content specified by the propositional knowledge statements. All 22 propositional knowledge statements were matched to the items on the Diffusion and Osmosis Diagnostic Test. All of the questions, except one, incorporated more than one of the propositional knowledge statements. Item number 4 matched only propositional knowledge statement number 5, which is concerned with concentration as measured by the number of particles per unit volume.

SAMPLE OF THE POPULATION STUDIED

The Diffusion and Osmosis Diagnostic Test was administered to 123 non-biology major students enrolled in a freshman biology laboratory course. The sections were selected using a random number table. The composition of the sample by gender and class was 41 male and 82 female students. Prior to the administration of the test, each student received two hours of laboratory instruction followed by one hour of discussion of diffusion and osmosis concepts.

Table 1. <u>The percentage of Biology non-majors selecting each response combination for items 3 on the Diffusion and Osmosis Diagnostic Test</u>.

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.

	Choice on first tier		Reason a	Reason b	Reason c	Reason d	Total
Non-majors	a	8.9	18.7	4.9	5.7	38.2	
		b	8.9	4.1	27.6	21.1*	61.8

* Correct choice and reason

SCORING THE ITEMS

An item was scored correct on the Diffusion and Osmosis Diagnostic Test if both the desired content and reason answer were selected. Items were evaluated for both correct and incorrect response combinations selected. For example, response combinations selected in an item dealing with the particulate and random nature of matter is shown in Table 1. The desired content answer was selected by 61.8% of the students, while only 21.1% selected the desired content answer and reason combination.

SUMMARY OF THE FINDINGS

The split-half reliability of the test was 0.74. The difficulty indices ranged from 0.23 to 0.95, providing a wide range of difficulty items. The discrimination indices ranged from 0.21 to 0.65. A 0.20 value was established as a minimum and those greater than 0.20 were considered acceptable without need for further revision of the test items.

There was no significant difference between genders and no interaction between gender and major ($p>0.05$). Number of science courses taken in high school was a insignificant covariate ($p>0.05$).

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. With a typical multiple choice test with four possible selections, there is a 25% chance of guessing the correct answer. With 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. For the first tier of the test, the range of correct answers was 35.8% to 97.6% (Table 2).

When both tiers were combined, the correct response were reduced to a range of 14.6% to 95.9%. The Diffusion and Osmosis Diagnostic Test results suggests that non-biology major students did not acquire a satisfactory understanding of diffusion and osmosis concepts. They scored above 75% only on 2 out of 12 items.

Table 2. Concepts Assessed by the Diffusion and Osmosis Diagnostic Test. Percentage of Freshmen Non-Science Majors Selecting the Desired Content Choice and Reason.

Concept Assessed	Item Number	Content Choice	*Reason
Kinetic Energy of Matter	7	97.6	95.9
The Particulate Nature and Random Motion of Matter	2	90.2	22.0
	3	61.8	21.1
	6	88.6	65.9
Concentration and Tonicity	4	89.9	50.4
	9	69.9	44.7
The Influence of Life Forces on Diffusion and Osmosis	11	35.8	31.7
Membranes	12	95.1	81.3
The Process of Diffusion	1	72.5	52.8
	5	37.4	34.1
The Process of Osmosis	8	51.2	14.6
	10	80.5	40.7

* students selecting the desired content and reason answers.

Discussion

Understanding of the particulate nature of matter and the random interaction of molecules is key to understanding diffusion and osmosis concepts. Furthermore, numerous studies have suggested that the understanding of the particulate nature of matter requires formal reasoning skills. Researchers have also noted that understanding diffusion and osmosis concepts requires formal reasoning skills (Simpson & Marek, 1988; Arnold & Simpson, 1982), which may account for the difficulty students have learning these concepts.

Previous research has documented that comprehension of diffusion and osmosis also requires mastery of complex concepts and phenomena. An understanding of macro- and micro-systems is required (Johnstone & Mahmond, 1980), and students must have a working knowledge of several concepts: concentration, gradient, membrane, semipermeable, kinetic motion of particles, and particulate interaction. Okeke and Wood-Robinson (1980) noted that the majority of high school biology students fail to appreciate the continuous random movement of molecules. Murray (1983) noted that concentration is key to understanding osmotic problems and also reported that college students had difficulty distinguishing between the concepts "permeable", "semipermeable", and "impermeable".

Bishop and Anderson (1990) reported the number of previous biology courses taken by college freshman biology students had no influence on misconceptions about evolutionary concepts. In this study, the number of science courses taken in high school was not a significant covariate when assessing students' understanding using the Diffusion and Osmosis Diagnostic Test.

The next section of the discussion will focus on possible reasons for students selecting alternative responses on the Diffusion and Osmosis Diagnostic Test.

Kinetic Energy of Matter

This concept was examined through item 7. Analysis of alternate responses revealed few misconceptions. Over 90% of the students selected the correct content and reason answer. In the question, green dye was added to two different beakers, one containing water at 25 C (beaker 1) and the other containing water at 35 C (beaker 2). Students were asked to determine which beaker would become light green first. The correct answer was "beaker 2" because "the dye molecules move faster at higher temperatures".

The Particulate Nature and Random Motion of Matter

This concept was examined through items 2, 3, and 6. Analysis of responses revealed students' had several alternative conceptions about the particulate nature and random motion of matter.

The desired response to item 2 was "during the process of diffusion, particles will generally move from high to low concentrations" because "particles in areas of greater concentration are more likely to bounce toward other areas." About 23% of the students selected the desired answer combination.

The most common alternative response may have been due to a misunderstanding of terminology. For example, many students selected "particles generally move from high to low concentration because particles tend to move until the two areas are isotonic and then the particles stop moving". These students may have memorized the prefix "iso" which means "the same" and interpreted this item to mean that particles would continue to move until they are "the same" concentration throughout. It is possible that these students had a partial understanding of diffusion, because an end result of the process of diffusion is an uniform distribution of particles (or, the particles are "the same" throughout).

The second portion of the alternative response suggests that particles stop moving. Students may have interpreted "stop moving" as equivalent as "no net movement", thereby, demonstrating a partial understanding of kinetic theory of matter.

Another common alternative selection for item 2 was the that "there are too many particles crowded into one area and therefore they move to an area with more room". This selection could represent an anthropomorphic view of matter, that is, the need for molecules to move into another area. Friedler, Amir, and Tamir (1987) noted secondary students used explanations that movement of molecules is due to a desire or drive toward equalizing concentration. Zuckerman (1993) reported that high school students explained that water anthropomorphically osmoses to equalize either the amounts or concentrations of water.

In item 3, students were asked to determine the rate of diffusion as a result of a concentration gradient. The desired response was that "as the difference in concentration between two areas increases, the rate of diffusion increases" because of "the greater likelihood of random motion into other regions". While 61.8% of the students chose the desired content answer, only 21.1% had the desired combination of content and reason.

The most common alternative response for item 3 was "the molecules want to spread out". This is another anthropomorphic view of matter. Another common alternative response was "the rate of diffusion will decrease because if the concentration is high enough, the particles will spread less and the rate will be slowed." It is reasonable that students were imagining a cramped area, like a large number of people having difficulty moving in a crowded room. It is equally possible that these student had no appreciation of the random motion of molecules.

In item 6, students were to determine what would happen to blue dye molecules after they had been evenly distributed throughout a large container of clear water. The desired response was "that molecules of dye continue to move around randomly" (rather than stop moving) because "molecules are always moving." A majority of students (88.6%) did understand that the molecules would continue moving randomly. While 65.9% chose the desired reason (i.e. molecules are always moving).

Many students selected that "if dye stopped moving it would settle to the bottom of the container". This may be because students believed that movement is necessary to oppose gravity. Another alternative response for item 6 was that "the dye and water are liquids, therefore, their molecules would continue to move randomly; if it were solid the molecule would stop moving". It is possible that students had an understanding of the underlying processes and were confused by the wording of the alternative response, that is, whether the response was referring to the macro or micro level. There is relatively little molecular movement in solids compared to liquids. Furthermore, students may believe liquids as having molecular motion because the shape of liquids can be easily manipulated. Thus, the shapes of solids are not as easily manipulated. Simpson and Marek (1988) reported high school students failed to recognize that matter is in a constant state of random motion and that mixtures result in them evenly dispersing as a result of random movement.

Concentration and Tonicity

These concepts were examined through items 4 and 9. Analysis of responses revealed that students had alternative conceptions about concentration and tonicity of solutions.

In item 4, the desired pair of responses was a glucose solution can be made more concentrated by "adding more glucose" because "it increases the number of dissolved particles" (50.4% selected this combination). The most common alternative response was "adding more glucose" because "the more water there is, the more glucose it takes to saturate the solution." While the reason is true standing alone, it is an incorrect reason for the phenomenon described in the item.

Item 9 assessed students' understanding of the concept of tonicity. A diagram on the test showed two columns separated by a semipermeable membrane. Side 1 contained 10% salt water and side 2 contained 15% salt water. The desired answer combination to the item was side 1 is "hypotonic" to side 2 because "there are fewer dissolved particles on side 1" (44.7% selected this combination).

The question involves the prefixes hypo-, hyper-, and iso-. Each refer to the relative concentration of dissolved particles in solutions separated by a membrane. The most common alternative response was "hypotonic" because "water moves from a high to a low concentration." It is possible that students memorized the terms with little understanding of the concept. Another common alternative response was side 1 is "hypertonic" to side 2 because "water moves from a high to a low concentration". Water moving for high to low concentration is a possible result of two different solutions being separated by a membrane, but it is not the reason one solution has a greater tonicity than the other. This selection may represent at least a partial understanding of the process of osmosis (net direction of movement).

The Influence of Life Forces on Diffusion and Osmosis

This concept was examined through item 11. In this item a plant cell was killed and placed in 25% salt water, then the question asked whether diffusion and osmosis would continue. The desired response combination was "diffusion and osmosis would continue" because "the cell does not have to be alive" (31.7% selected this combination). Analysis of alternate responses revealed numerous misconceptions.

The most common alternative response was diffusion and osmosis would stop after a plant cell was killed because the cell was no longer functioning. It is reasonable that students would compare a cell with a living organism such as a person. When a person dies, many observable physiological functions stop, such as the heart beat and breathing. At the macro-level, when an organism dies it stops functioning, but at the micro-level, processes may continue for hours or days.

Friedler et al (1987) noted among secondary students that a high level of reasoning as well as an understanding of macro-and micro-systems is required to understand the concepts associated with diffusion and osmosis.

Membranes

This concept was examined through item 12. Students were asked about the permeability of a cell membrane. Over 80% of the students characterized that cell membranes as semipermeable because they allow some substances to pass. The large majority of students (81.3%) selected "all cell membranes are semipermeable" because "they allow some substances to pass." Analysis of alternate responses revealed few misconceptions.

The Process of Diffusion

This concept was examined through items 1 and 5. In item 1, a drop of blue dye is place in a container of clear water and over time the dye becomes evenly distributed throughout the water. A majority of students selected "the process responsible for blue dye becoming evenly distributed in the water is "diffusion" because "there is movement of particles between regions of different concentrations" (52.8% selected this combination).

The most common alternative conception was that the process is "diffusion" because "the dye separates into small particles and mixes with water." It is reasonable that students view dye as one large particle (e.g. drop of dye) and when a drop of dye is added to water it breaks into small particles. Furthermore, when the "dye" is added to the water, students may have been using the word "dye" level (e.g. "dye" molecules).

Another common alternative response was that the process is "osmosis" because there is movement of particles between regions of different concentrations. It is possible that these students had an understanding of the underlying processes with little understanding of the terms diffusion and osmosis.

In item 5, 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 desired response combination was "the sugar molecules will be evenly distributed throughout the container" because "there is movement of particles from a high to low concentration." A minority of students (about 37%) selected the correct content. Almost all of these also chose the correct reason (34.1%). The most common alternative responses were "the sugar molecules will be more concentrated on the bottom of the container" because "the sugar is heavier than water and will sink " and "there will be more time for settling." One interpretation of these results is that students integrated gravity concepts into solution chemistry. Students can see sugar granules sink to the bottom of the container. If students ignored the condition (that the sugar was allowed to set for a very long period of time), their response would describe what happens when sugar granules are first place in the container.

The Process of Osmosis

This concept was assessed through items 8 and 10. Analysis of responses revealed numerous alternative conceptions. In each item students were asked to determine the net direction of water movement through a membrane.

In item 8, the two columns of water are separated by a semipermeable membrane through which only water can pass. Side 1 contains water and dye and side 2 contains water.

A minority of the students selected "after two hours the water level in side 1 will be higher than side 2" because "the concentration of water molecules is less on side 1" (14.6% selected this combination).

A majority of the students determined the correct net direction of water movement, but less than 30% selected the correct reason. The most common alternative response was the water on side 1 will be higher because "water will move from the hypertonic to the hypotonic solution". It is likely that students had memorized the tonicity terms with little understanding of their meaning. Students may have recalled that there is a "rule" to determine the net direction of water movement. The correct rule is water moves from hypotonic to hypertonic solutions, thus students may have remembered the rule incorrectly.

The terms for tonicity appear to be difficult for students to apply. The prefixes hypo-, hyper-, and iso- refer to the relative concentrations of solute. In cases of osmosis, students need to know the relative concentration of the solvent water. This knowledge cannot be obtained from the terms for tonicity directly. For example, the prefix hypo-means "less" or "under". If a solution is hypotonic, the solution has a smaller concentration of solute than the hypertonic solution with which it is compared. Water concentration, then, is greater in the hypotonic solution than in the hypertonic one. The tonicity terms provide the relative concentration of the solvent that is needed to decide in which direction water will diffuse so that net movement is from greater concentration to lesser concentration.

Another alternative response for item 8 was "water moves until it becomes isotonic". Memorization of the term isotonic with little understanding of the process of osmosis could result in this misconception. "Iso" means "the same", and it is possible that students consider osmosis as continuing until the concentrations are the same on each side. As was the case in item 2.

It is equally reasonable that students who selected the alternative response "water will become isotonic" had a partial understanding of the process of osmosis. In the context of the teaching osmosis, many examples are used that suggest that particles tend to move until there is even distribution. Furthermore, it is likely that students will develop a personal theory based on limited information. Zuckerman (1993) reported that high school students indicated that concentration of water across a membrane must be equa at osmotic equilibrium.

Item 10 assessed the process of osmosis in a plant cell. This item shows a picture of a plant cell that lives in fresh water, the cell is then placed in 25% salt water and asks what happen to the size of the central vacuole. The desired response was "the central vacuole would decrease in size" because "water will move from the vacuole to the salt water solution". A majority of students (80.5%) determined the correct direction of water flow. Less than half of the students (40.7%) selected the desired reason.

The most common alternative response was "salt absorbs water from the central vacuole". The meaning of "absorb" may be different in a science context than in a non-scientific context. Common everyday experiences in a non-science context are sponges absorb water and paper towels absorb water. If "absorb" is viewed as the "taking away" of water, then students may have believed that the salt water solution absorbs the freshwater. In a scientific context, absorption is capillary action caused by adhesion. Salt solutions do not cause capillary action. Similarly, Johnstone and Mahmond (1980) noted students described plasmolysed cells as "sponges" that draw water from turgid cells. To confuse the issue even further, instructors and textbooks will refer to capillaries in villi absorbing digested food from the small intestine.

The large intestine absorbs excess water. In this case, absorption refers to diffusion and /or active transport of molecules across cell membranes.

Conclusions and Implications for Teachers

This study provides evidence that even following instruction non-biology majors continue to have alternative concepts on diffusion and osmosis concepts. The Diffusion and Osmosis Diagnostic Test appears to provide a feasible approach for evaluating students' understanding and for identifying alternative conceptions of diffusion and osmosis concepts. The identification is of direct relevance for college biology teachers since this knowledge can be used to develop instructional approaches to hopefully neutralize misconceptions about diffusion and osmosis.

Similarly, Zuckerman (1993) identified 12 accurate conceptions of osmosis. In addition, she identified 8 inaccurate conceptions about osmosis held by high school science students. It was reported that misconceptions about osmosis blocked problem solving of osmosis related questions. Of the 12 accurate conceptions, two were especially important in enabling problem solvers to generated correct answers (i.e. the rate of osmosis is constant; the concentrations of water across the membrane must be equal at osmotic (equilibruim).

Identification of misconceptions about diffusion and osmosis is vital to make meaningful problem solving accessible to more students. Further, identification of misconceptions is needed to develop strategies to provide students with the accurate conceptual knowledge required for scientific problem solving.

The analysis of the items on the Diffusion and Osmosis Test demonstrates the role that language plays in teaching and learning. Misconceptions can arise from differences between common uses of terms and their scientific use. Within a science class, words may be used in either way without clear differentiation. Analogies and metaphors are often used to describe objects and events in science. Such analogies and metaphors have their experiences inside and outside the classroom, they do not necessarily understand these words, analogies, and metaphors in the same way as the teacher intended. Students will create meaning from their own understandings and interpretations of their experiences.

The same issue arises when teachers attempt to assess students' understanding of science concepts and principles learned in class. Students will interpret test questions in light of their own use of language, their own understanding of the meaning of analogies and metaphors. These may or may not be congruent with the instructor's view of these items. Just as students can misinterpret the teachers meaning, the teacher can misinterpret the meaning of what the students intends to convey.

Another issue arises from the teacher's efforts to make scientific concepts and principles simpler and easier to understand. This often involves providing a fair and appropriate approximation of reality that is sufficient for an appropriate level of understanding for the age and/or developmental level. As students progress through their education, new layers of meaning are added to a concept. Each experience with a concept adds new meaning. A novice learner cannot be expected to appreciate all the various nuances of a concept that an advanced learner or an expert might have. What might be appropriate understanding of a concept at one level would be inappropriate at another.

APPENDIX A
The Diffusion and Osmosis Diagnostic Test

Directions: DO NOT WRITE ON THE ASSESSMENT. This assessment consists of 12 pairs of questions which 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 because:
a. the lack of a membrane means that osmosis and diffusion can not 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 because:
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 because:

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 because:
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 because:
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 because:
a. the entire container is the same color; if they 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?

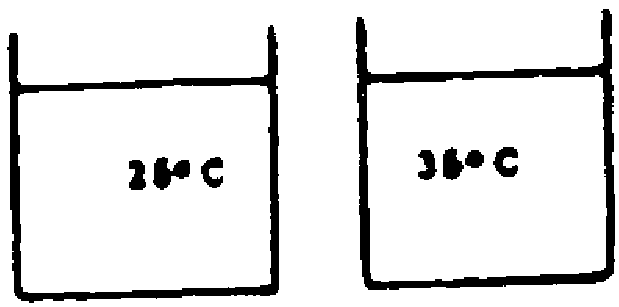

Figure 1

Figure 1

a. Beaker 1
b. Beaker 2

7b. The reason for my answer is because:
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

Figure 2 (See Below)

8b. The reason for my answer is because:

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 because:

Figure 3 (See Below)

a. water is hypertonic to most things.
b. isotonic means "the same".
c. water moves from a high to a low concentration.
d. there are fewer dissolved particles on side 1.

10a. Figure 4 is a picture of a plant cell that lives cell in fresh water. If 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

Figure 4 (See Below)

10b. The reason for my answer is because:

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 can not affect 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 because:
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 requires cell energy.

12a. All cell membranes are
a. semipermeable
b. permeable

12b. The reason for my answer is because:
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.

Figures 2 - 4.

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