Research Experiences for Teachers (RET) – 2012

LESSON PLAN TEMPLATE

MODULE TOPIC: Inquiry based learning- Osmosis and Diffusion
The acquisition of biochemical and life sustaining compounds is a major theme in life science. This lesson provides students with an interactive experience in which they will investigate dynamic homeostasis as it applies to permeability. Upon completion of this lesson, students will have an increased understanding of membrane function, water potential, and inquiry based learning including proper laboratory operations.

RATIONELE:
While working in the York center, I was made very much aware of the deterioration of my math skills. I required extensive help to calculate what would be considered simple conversions and discovery of unknowns. I realized that I was leaving out a huge part of my students scientific education. With this knowledge, I set out to develop a lesson that not only applies the principles learned this summer, but integrated mathematic principles and scientific inquiry. Our RET project included several principles that apply to Biology, but I chose to focus on the reasoning behind developing the freeze-dried films with DOD delivery. The medications being used are not easily absorbed into the human body. The module will incorporate the mathematic skills, and laboratory practices that were the cornerstones of my summer research.

STANDARD(S) & INDICATOR(S):
- 5.1.12.B.1: Design investigations, collect evidence, analyze data, and evaluate evidence to determine measures of central tendencies, causal/correlational relationships, and anomalous data.
- 5.1.12.B.3 Revise predictions and explanations using evidence, and connect explanations/arguments to established scientific knowledge, models, and theories.
- 5.2.12.A.5 Describe the process by which solutes dissolve in solvents.
- 5.3.12.A.3 Predict a cell's response in a given set of environmental conditions.

OBJECTIVE(S): SWAT
- **Predict** rates of diffusion based on calculated surface area-to-volume ratios
- **Distinguish** between diffusion and osmosis in one sentence.
- **Explain** how cell shape and size affects waste removal and nutrient intake
- **Utilize** models and representations to create scientific questions about the properties of cell membranes and permeability as it applies to molecular properties and structure
- **Identify** the roles of solutes and solvents in solutions in two sentences.
- **Employ** proper laboratory protocol and observe all safety rules.

MATERIALS:
<u>Inquiry 1</u>
• 2% agar containing the pH indicator
dye phenolphthalein
• 1% phenolphthalein solution
• 0.1M NaOH
• 0.1M HCl

• Squares of hard, thin plastic (from disposable plates); unserrated knives; or scalpels from dissection kits
• Metric rulers
• Petri dishes or test tubes to hold the agar cubes

Inquiry 2

• Distilled or tap water
• Benedict's Solution
•Potassium Iodide
• 1 M glucose
• 20 cm-long dialysis tubing

Part B:

- Dialysis Tubing
- Distilled Water
- 0.2 M sucrose
- 0.4 M sucrose
- 0.6 M sucrose
- 0.8 M sucrose
- M sucrose
- Beakers

Part C:

- Potato
- Cork Borer
- Scale
- Distilled Water
- 0.2 M sucrose
- 0.4 M sucrose
- 0.6 M sucrose
- 0.8 M sucrose
- M sucrose
- Beakers

Independent Inquiry

• Potatoes, sweet potatoes, or yams
• Cork borers or french fry cutter
• Balances
• Metric rulers
• 8 or10 oz. drinking cups
• Sucrose solutions of different concentrations (0, 0.2, 0.4, 0.6, 0.8, 1.0 M)

LIST OF HANDOUTS (attach original copies of each handout - teacher & student edition)
Water Potential Review
3 Laboratory Practices
Independent Laboratory Exercise

BACKGROUND INFORMATION:
While working in the York center, I was made very much aware of the deterioration of my math skills. I required extensive help to calculate what would be considered simple conversions and discovery of unknowns. I realized that I was leaving out a huge part of my students scientific education. With this knowledge, I set out to develop a lesson that not only applies the principles learned this summer, but integrated mathematic principles and scientific inquiry. Our RET project included several principles that apply to Biology, but I chose to focus on the reasoning behind developing the freeze-dried films with DOD delivery. The medications being used are not easily absorbed into the human body.

Cells do not act as closed systems. They are consistently interacting with their environment in attempt to meet the cells need, and to maintain homeostasis. This process is controlled by the selectively permeable plasma membrane. These membranes are composed of phosphol ipids and various embedded proteins. It is the hydrophobic characteristics of the phospholipid bilayer that helps to limit movement in and out of the cell.

Cells exist in an aqueous environment. This means that cells are surrounded by a solvent (water) in which various solutes are dissolved in. Water freely passes in and out cellular membranes through specialized protein channels referred to as aquaporins in a process known as osmosis. Charged particles such as ions must also be moved in and out of the cell through specialized integral proteins known as protein channels. Larger molecules must make use of specialized transport proteins in order to pass through the plasma membrane.

The most basic form of intracellular movement is diffusion. In this process, solutes move from areas of high concentration to areas of low concentration without the input of energy (ATP) and is solely based on the natural kinetic movement of the molecules.

Osmosis is the diffusion of water through the aquaporins of a membrane. Much like diffusion, water moves with the concentration gradient (from a high concentration (high potential) to a low concentration(low potential)). Cells possessing cell walls have more resistance to the movement of water. This resistance is referred to as Turgor Pressure.

When solutions are separated through a semi-permeable membrane, the terms *hypertonic, hypotonic,* and *isotonic* are used. Hypotonic solution has a lower solute concentration and a higher water potential than its environment. Water will move with the gradient across the membrane. Hypertonic solutions have higher solute concentration, and lower water potential when compared to its neighboring solution. This will cause water to flow into the hypertonic solution through a membrane. Isotonic reveals no net change in solutions due to equal water potentials on either side of the membrane.

The cell's ability to maintain homeostasis is a reoccurring theme throughout Biology. In order for cells to maintain internal environments, they must also control solute movement. This concept will

be presented through models and living cells. This topic will be expanded upon when students investigate plant structure and function.

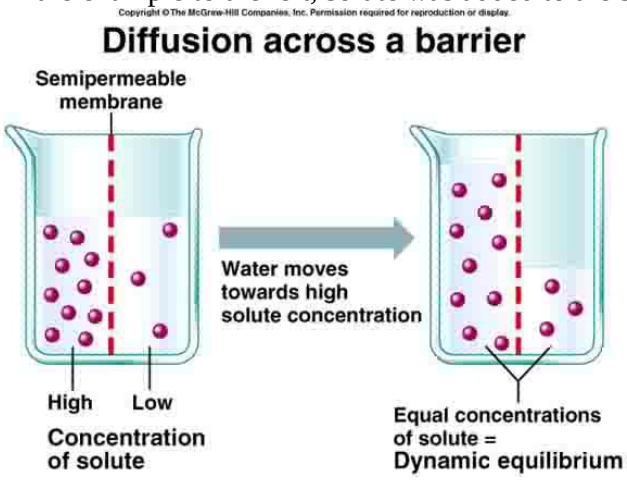
This lesson will be divided into three separate operations. Students will first use artificial cells to investigate the relationship between surface area and volume. Next, students will create cells models to demonstrate osmosis and diffusion. Finally, students will observe osmosis in living cells. Students will be asked to design and construct their own experiments for these inquiries.

Water Potential

Water potential (Ψ) is a measure of water's potential to do work. In order to do work, an object must be able to apply enough force to another object to cause displacement. In order for water to displace another object, water must be moving. The largest water potential any volume of water can have, if only standard atmospheric pressure is being applied to that volume of water, is defined as 0. This is the water potential for distilled water. Distilled water has the greatest potential to move, and thus displace another object.

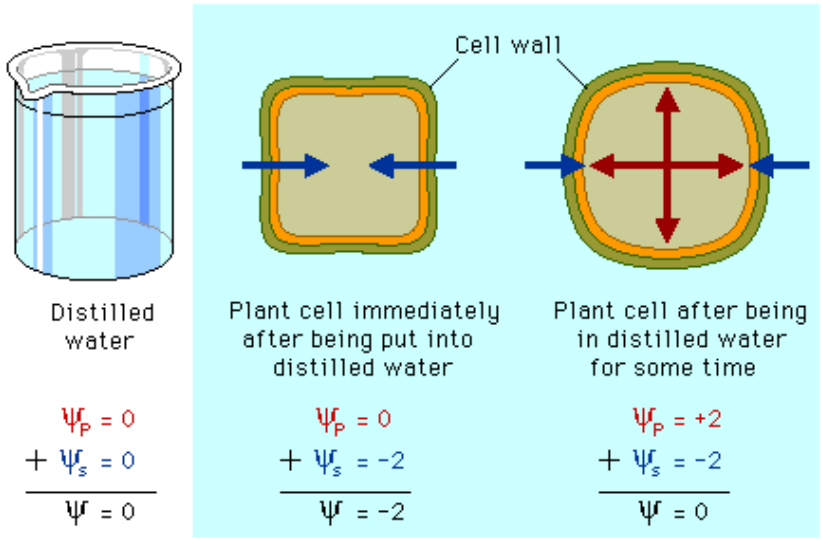
As solute is added to distilled water with no outside pressure being applied to it, the water potential of that solution drops. But what does it mean to say that the water potential of a solution drops? It means that the water in that solution is less likely to do work - in other words, it is less likely to move! Why is that? Well, as solute is added, the chances become less and less that a concentration gradient can be set up between that solution and a second solution that will favor the movement of water out of the initial solution.

In the example to the left, solute was added to the solution on the left side of the membrane. This decreased the chances that water would move out of the solution to the left of the membrane and into a solution to the right of the membrane. This means that the water on the left side of the membrane has less potential to do work than the water on the right side. What does this mean in terms of water potential? It means that the solution to the left of the membrane has a more negative water potential than the solution to the right of the membrane. Therefore, water will flow from the right side of the membrane to the left. Water always moves towards a more negative water potential.



Let's take a look at another example. The solute potential of a 0.1 M solution of distilled water and sucrose at 20º C at standard atmospheric pressure is -0.23. If we continue adding sucrose to the solution until it reaches a concentration of 0.75 M at 20º C at standard atmospheric pressure, the solute potential continues to drop to a value of -1.87. Which solution contains water that is less likely to do work? The one that has a higher concentration of solute and a lower concentration of water! Think about it - if we separated a 0.1M solution of sucrose and a 0.75M solution of sucrose with a selectively permeable membrane, which direction would the water move? Of course it would move from the 0.1M solution into the 0.75M solution. In the process, it would be doing work! Remember, water always moves from an area of higher water potential to an area of lower water potential.

Now that you think you've got water potential figured out, let's complicate matters a little bit! Water potential (Ψ) is actually determined by taking into account two factors - osmotic (or solute) potential (Ψ_S) and pressure potential (Ψ_P). The formula for calculating water potential is $\Psi = \Psi_S + \Psi_P$. Osmotic potential is directly proportional to the solute concentration. If the solute concentration of a solution increases, the potential for the water in that solution to undergo osmosis decreases. Therefore, the more solute that is added to a solution, the more negative its osmotic (solute) potential gets. If no physical pressure is applied to a solution, then the solute potential is equal to the water potential. However, if physical pressure is applied to a solution, then it's water potential (the potential for the water to move and do work) will be affected. How it is affected depends upon the direction of the pressure.



How could pressure be applied to a solution? Let's look at another example! If a plant cell is placed into distilled water, obviously water will move into the cell because distilled water has a higher water potential than the plant cell itself. However, when the plant cell's central vacuole fills with water, then it will push back out on the water surrounding the cell. The plant cell doesn't burst due to this pressure because it has a cell wall. An animal cell in the same situation would burst. When the pressure exerted outward on the water surrounding the plant cell is equal to the osmotic potential of the solution in the cell, the water potential of the cell will be equal to zero. The water potential of the plant cell will also be equal to the water surrounding it, and there will be no net movement of water molecules.

CLASSROOM ACTIVITY DESCRIPTION (LABORATORY/EXERCISES/PROBLEMS) including detailed procedures:

Surface Area and Cell Size:

Procedure A:

1. Add phenolphthalein to two test tubes. (Exact measurements are not necessary)
2. Add 0.1 M HCl to test tube 1 and swirl the solution.
3. Add 0.1M NaOH to test tube 2 and swirl the solution.
   a. Identify each solution as an acid or base.

Procedure B:

1. Create three mock cells using your cutting device, cut three pieces of agar into different sizes.
2. Calculate the Surface Area of each "cell"
3. Calculate the volume of each "cell"
4. Design a way for you to observe rates of diffusion on the different size blocks using the materials listed above. Review your experiment with me before performing it.

Diffusion and Osmosis:

Procedure A

1. Obtain a 30 -cm piece of 2.5-cm dialysis tubing that has been soaking in water. Tie off one end of the tubing to form a bag. To open the other end of the bag, rub the end between your fingers until the edges separate.
2. Place 15 mL of the 15% glucose/ 1% starch solution in the bag. Tie off the other end of the bag, leaving sufficient space for the expansion of the bag's contents. Record the color of the solution in **Table 1.1**.
3. Test the 15% glucose / 1% starch solution in the bag for the presence of glucose. Your teacher may have you do a Benedict's test. Record the results in **Table1.1.**
4. Fill a 250 mL beaker or cup 2/3 full with distilled water. Add approximately 4 mL of Lugol's solution to the distilled water and record the color in **Table 1.1**. Test the solution for glucose and record the results in **Table 1.1.**
5. Immerse the bag in the beaker of solution.
6. Allow your set up to stand for approximately 30 minutes or you see a distinct color change in the bag or the beaker. Record the final color of the solution in the bag, and of the solution in the beaker, in **Table 1.1.**
7. Test the liquid in the beaker and in the bag for the presence of glucose. Record the results in **Table 1.1**.

Procedure B:

1. Obtain 6 strips of presoaked dialysis tubing.
2. Tie a knot in one end of each piece of tubing to form 6 bags. Add about 15-25mL of each of the following solutions to each of your tubes.
    a. Distilled Water
    b. 0.2 M sucrose
    c. 0.4 M sucrose
    d. 0.6 M sucrose
    e. 0.8 M sucrose
    f. 1.0 M sucrose
3. Rinse and record weight of each bag.
4. Place each bag into a beaker to find the molarity of the solution in the dialysis bags.
5. Now fill each beaker with 2/3 of water or enough to completely submerge the bag.
6. After 30 minutes, remove bags from water and determine their mass.

Procedure C:

1. Obtain 100mL of your assigned solution.
2. Slice a potato into 4 discs without skin, and use a cork borer to do so.
3. Measure and record the mass of the 4 discs.
4. Put all 4 discs into the designated solution and let sit overnight.
5. The next day, remove discs. Measure and record their total mass.
6. Calculate percentage change from initial to final and graph data. Calculate the percent change in the weights. (final – initial)/initial X 100

Calculate Water Potential based upon percent mass change.

Procedure:

1. Students will use the data collected throughout the last experiment to calculate water potential of their samples.

Design An Experiment:

Procedure: TBD

Student Assessment (Demonstration of Acquired Skills & Knowledge):

Students are able to:
Compare kinetic and potential energy.
How does the environment affect kinetic energy and diffusion?
What affect does the concentration gradient have on diffusion and osmosis?
What is osmosis?
Why do hospitals use saline solution to hydrate patients?
Why is it important for cells to be small?
What is water potential?

REFERENCES:

All of the laboratory procedures were obtained/adapted from:
undefined. "Collegeboard." AP Central. undefined. College Board . 10 August 2012. <http://media.collegeboard.com/digitalServices/pdf/ap/bio-manual/CB_Bio_BigIdea_02_WEB_1_24_12.pdf>.

http://www.phschool.com/science/biology_place/labbench/lab1/watpot.html

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