Structure and Function of Cell Membranes

Strand Life at the Molecular and Cellular Level

Topic Investigating the structure and function of cell membranes

Primary SOL BIO.3 The student will investigate and understand relationships between cell structure and function. Key concepts include

d) the cell membrane model.

Related SOL BIO.4 The student will investigate and understand life functions of Archaea, Bacteria, and Eukarya. Key concepts include

b) maintenance of homeostasis.

Background Information

The cell is highly organized with many functional units or organelles. Most of these units are limited by one or more membranes. Each membrane is specialized in that it contains specific proteins and lipid components that enable it to perform its unique role(s) for that cell or organelle. Membranes are essential for the integrity and function of the cell.

This lesson may take several class periods to (1) create a cell membrane model, (2) design a model of semi-permeability, and (3) perform an osmosis lab.

Materials

- Sugar
- Water
- Assortment of small notions, such as wire, tubes, straws, string, pipe cleaners, beads, pieces of Styrofoam, magnets, small ball bearings, rubber bands, toothpicks
- Strainer or net
- 500mL beakers
- Tincture of iodine
- Stirrers
- Low quality plastic sandwich bags with ties (the lower the quality, the better)
- Cornstarch
- Copies of the three attached handouts
- 50mL graduated cylinders
- Permanent markers
- Triple beam balances
- Paper towels
- Potatoes or apples

Vocabulary

active transport, diffusion, facilitated diffusion, homeostasis, hypertonic, hypotonic, isotonic, molarity, osmoregulation, osmosis, passive transport, semi-permeable

Student/Teacher Actions (what students and teachers should be doing to facilitate learning)
Before undertaking this lesson, create six different solutions of sugar water of decreasing concentrations: 1.0M, 0.8M, 0.6M, 0.4M, 0.2M, and 0.0M.

(As an alternative to having students do the experiments presented on the handouts, Socratic questioning could be used to *guide* students in designing solid experiments themselves, similar to the given ones.)

1. Direct students to use an assortment of small notions and their prior learning to construct a model of a cell membrane such that it can be broken down and its pieces reused. The model must illustrate or demonstrate
   - phospholipid bilayer molecules
   - glycoprotein markers
   - channel proteins
   - cholesterol
   - receptor proteins.
2. Introduce the concept of semipermeability, using a strainer or a net. Discuss the practical applications of a semipermeable membrane.
3. Provide students with 500mL beakers, water, iodine solution, stirrers, sandwich bags, and cornstarch. Have them conduct the following experiment to illustrate that the sandwich bag is semipermeable to iodine but not to cornstarch. (Alternatively, to save time, run the experiment prior to class, and have students discuss why they know the sandwich bag must be semipermeable.)
   Procedure:
   a. Fill a 500mL beaker half full of water.
   b. Add tincture of iodine *(CAUTION!)* until the water is noticeably colored. Mix well, using a stirrer.
   c. In a separate space away from possible contamination, put 100–200mL of water in a plastic sandwich bag.
   d. Add a small amount of cornstarch to the water in the bag, and squeeze gently to mix.
   e. Tie off the bag to seal it, and rinse the outside of the bag well.
   f. Place the bag in the beaker of iodine solution.
   g. Set up a bag without cornstarch as a control.
4. Discuss with students the concepts of osmoregulation. Begin by asking what happens when they soak a while in a hot bath. (Shriveled-looking fingers) Tell them that in a bath, water diffuses into their slightly saline cells, which magnifies wrinkles, making them *appear* to be shriveled. Then, ask why humans often get dehydrated when they swim in the ocean. Incorporate the terms *hypertonic, hypotonic,* and *isotonic* into the discussion. Segue into the next experiment.
5. Group students into three tiers, based on ability levels. Distribute copies of the attached Osmoregulation Experiment handouts to the appropriate groups. The experiments are progressively more difficult: Tier 1 is the least challenging, and Tier 3 the most challenging. Give groups the basic instruction needed to complete their experiments.
6. Upon completion of the experiments, have groups present their findings to the class, beginning with the Tier 1 group and ending with the Tier 3 group.

Assessment

- **Questions**
  - What evidence supports the theory that the sandwich bags are semipermeable?
  - Predict what would happen if a bag with 0.0M solution were placed in a 0.4M solution overnight.
- **Journal/Writing Prompts**
  - What is the importance of your body's regulation of the amount of water in your cells?
  - How could the cell membranes of some cells be modified to be more efficient? Consider what the pros/cons of greater movement would be.
  - Design an experiment to determine which has more sugar in it: green grapes or red grapes; apples or potatoes.
- **Other**
  - Provide students with analogies of cell membrane parts, and have them apply metaphorical analyses to identify the parts, which map onto the analogy.
  - Have students create formal presentations to the class to share their results and conclusions for the tiered osmoregulation experiments.

Extensions and Connections (for all students)

- **Compare the structure/function of soap molecules with the structure/function of** membrane phospholipids.
- Most of the models will be static. An optional extension is to have students create models with at least one functional part to model a dynamic process. When presented with this challenge, students have been known to be rather creative in producing functioning analogs.
- Have students demonstrate osmosis, facilitated diffusion, ion channels, and active transport, using their models. Provide "substances" to move, such as sequins or cotton balls, that they can use to show how the type of transport depends on size, charge, and concentration.
- Engage students in a discussion of the practical value of an understanding of osmosis and diffusion (separation science, dialysis, bactericidal effects). Have students look at homeostasis life processes that depend on transport mechanisms, such as waste removal, prevention of freezing in some winter survival mechanisms, or gas exchange.
- Have students research the structure and function of the mammalian kidney.
- Have students research the osmoregulation adaptations of freshwater and saltwater fish.
- Have students research the concept of cotransport.

Strategies for Differentiation

- Provide differentiated sets of materials for students to use to create their cell membrane models.
- Ask students to paint a model of the cell membrane in the style of a famous artist while still including the required components.
- Have students share findings and explanations in various formats.

Tier 1 Osmoregulation Experiment

Hypothesis

If the molarity (concentration) of a sugar solution in a water-submerged plastic bag increases from 0.0M, then the bag will gain an increasing amount of mass.

Materials

- Six *labeled* sugar solutions of different concentrations: 1.0M, 0.8M, 0.6M, 0.4M, 0.2M, 0.0M
- 50mL graduated cylinder
- Six low quality sandwich bags with ties
- Permanent marker
- Triple beam balance
- Six 500mL beakers
- Water
- Paper towels

Procedure

1. Add 50mL of the 1.0M sugar solution to a sandwich bag. Tie off the bag to seal it, making sure there is some room for more water inside the bag. Label it with its concentration.
2. Repeat step 1 with the other five sugar solutions.
3. Find the *initial* mass of each bag, and record it in the data table.
4. Fill six 500mL beakers three-fourths full of water. Place one of the six bags into each beaker.
5. Let sit for 24 hours.
6. After 24 hours, remove the bags, and dry their surfaces.
7. Find the *final* mass of each bag, and record it in the data table.
8. Calculate the change in mass of each bag, and record it in the data table.

Conclusion

1. Analyze the data in the table.
2. Create a graph to illustrate the relationship between sugar concentration and change in mass over time.
3. Draw conclusions, including evaluation of your hypothesis.

Data Table

Solution Concentration	Initial Mass	Final Mass	Change in Mass
1.0M			
0.8M			
0.6M			
0.4M			
0.2M			
0.0M			

Tier 2 Osmoregulation Experiment

Hypothesis

If the molarity (concentration) of a sugar solution covering potato or apple slices increases from 0.0M to 1.0M, then the slices will gain a decreasing amount of mass at each increment until the molarity of the slices is reached; the solution in which there is no change in mass of the slices will have the same molarity as the slices.

Materials

- Six *labeled* sugar solutions of different concentrations: 1.0M, 0.8M, 0.6M, 0.4M, 0.2M, 0.0M
- 50mL graduated cylinder
- Six 500mL beakers
- Marker
- 12 identical size slices of potatoes or apples
- Triple beam balance
- Paper towels

Procedure

1. Add 50mL of the 1.0M sugar solution a 500mL beaker, and label it with its concentration.
2. Repeat step 1 with the other five sugar solutions.
3. Find the *initial* mass of a pair of potato or apple slices, and record it in the data table.
4. Add the pair of slices to the 1.0M solution.
5. Repeat steps 3 and 4 for the other 10 slices and the other five solutions.
6. Let sit for 24 hours.
7. After 24 hours, remove the slices, and dry their surfaces.
8. Find the *final* mass of each pair of slices, and record it in the data table.
9. Calculate the change in mass of each pair of slices, and record it in the data table.

Conclusion

1. Analyze the data in the table.
2. Create a graph to illustrate the relationship between sugar concentration and change in mass over time.
3. Draw conclusions, including evaluation of your hypothesis.

Data Table

Solution Concentration	Initial Mass	Final Mass	Change in Mass
1.0M			
0.8M			
0.6M			
0.4M			
0.2M			
0.0M			

Tier 3 Osmoregulation Experiment

Hypothesis

If the molarity (concentration) of a sugar solution covering potato or apple slices increases from 0.0M to 1.0M, then the slices in the solution of the lowest molarity will gain the most mass, and those in the solution of the highest molarity will lose the most mass; the others will fall on a sliding scale in between.

Materials

- Six *unlabeled* sugar solutions of different concentrations: 1.0M, 0.8M, 0.6M, 0.4M, 0.2M, 0.0M
- 50mL graduated cylinder
- Six 500mL beakers
- Marker
- 12 identical size slices of potatoes or apples
- Triple beam balance
- Paper towels

Procedure

1. Add 50mL of the 1.0M sugar solution a 500mL beaker, and label it #1.
2. Repeat step 1 with the other five sugar solutions.
3. Find the *initial* mass of a pair of potato or apple slices, and record it in the data table.
4. Add the pair of slices to the #1 solution.
5. Repeat steps 3 and 4 for the other 10 slices and the other five solutions.
6. Let sit for 24 hours.
7. After 24 hours, remove the slices, and dry their surfaces.
8. Find the *final* mass of each pair of slices, and record it in the data table.
9. Calculate the change in mass of each pair of slices, and record it in the data table.

Conclusion

1. Analyze the data in the table. Infer the concentrations of the solutions by determining which potato or apple slices gained mass, lost mass, or stayed the same.
2. Draw conclusions, including evaluation of your hypothesis.

Data Table

Solution No.	Initial Mass	Final Mass	Change in Mass	Solution Concentration
1				
2				
3				
4				
5				
6				