PEER-LED TEAM LEARNING
INTRODUCTORY BIOLOGY

MODULE 4: CELL MEMBRANES & TRANSPORT

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I. Introduction

The chemical environment inside living cells differs markedly from the environment outside the cell. **Cell membranes** regulate the ongoing exchange between the intracellular and extra-cellular environments, making it possible for cells to get vital raw materials (examples: oxygen, sugars, amino acids), rid themselves of wastes (examples: carbon dioxide, urea), and maintain a healthy electrical balance (membrane potential). It is the objective of this module to gain a deeper understanding of cell membrane structure and the processes of **transport** that systematically move molecules in and out of cells. Especially we will focus here on **diffusion** and **osmosis**, two passive means of exchange.

Prepare for your workshop by reading in your textbook (ex., Audesirk, et al. 6th edition, Chapter 4; Campbell, 4th edition, Chapter 8) and completing the Pre-Workshop Activities below. Show your work in these pages.

II. Pre-Workshop Activities

1. **Activity 1. Matching**

The following is a list of terms and concepts you will use in the workshop. Match the word with the definition by entering the letter of the definition next to the word. Make note cards if this technique helps you master the definitions.

___active transport
___amphipathic molecule
___cholesterol
___cotransport
___diffusion
___electrochemical gradient
___electrogenic pump
___endocytosis
___exocytosis
___facilitated diffusion
___fluid mosaic model
___gated channels
___hypertonic solution
___hypotonic solution
___integral membrane protein
___isotonic solution
___ligand
___osmosis
___passive transport
___peripheral membrane protein
___phagocytosis
___phospholipid
___pinocytosis
___ hydrocarbon tail

A. Secretion of molecules from a cell by fusion of vesicles
B. Solutions of equal solute concentration
C. An important steroid molecule in animal cell membranes
D. Molecules with both hydrophilic & hydrophobic regions
E. A molecule that binds to a receptor in a cell membrane
F. A type of endocytosis in which cell ingests fluid & solutes
G. A solution with a greater solution concentration than another
H. Passive movement of molecules down their concentration gradient
I. Coupling of downhill diffusion of one substance to uphill transport of another
J. Main molecule that makes up the cell membrane bilayer
K. Proteins that span the interior of a cell membrane
L. A process by which cells ingest large particles from outside the membrane
M. Diffusion of water across a selectively permeable membrane
N. Modern representation of membrane structure
O. hydrophobic part of phospholipid molecules

P. Passage across a membrane bound to a specific carrier, down the concentration gradient
Q. Movement across a cell membrane without using energy
R. Transport mechanism using ATP to move charged ions up their concentration gradient
S. A channel formed by membrane proteins that opens and closes in response to a chemical or electrical stimulus
T. Movement of substances across a membrane against the concentration gradient using energy and special proteins
U. The hydrophobic part of a phospholipid
V. Membrane proteins attaching to only one surface
W. An ion transport protein that generates voltage across a membrane.

Activity 2. Organization of Cell Membrane

Follow the instructions below to develop you own diagram of the cell membrane. Add components as described. If more information is needed refer to your text book.

1. In Figure 4.1 draw from memory, if possible, the following elements and label them.
   a. a phospholipid molecule: Label the hydrophilic and hydrophobic ends. Add a water molecule in the correct position.
   b. a "patch" of a phospholipid bilayer with the molecules in correct orientation. Leave one gap in your patch to insert other elements.
   c. an integral protein in the gap in your drawing. Show it with a carbohydrate attached forming a glycoprotein. Label the parts.
   d. the inside and outside areas of the drawing.
   e. two organelles which belong between the cell membrane and the cytoplasm.
   f. the pathway of O_2, CO_2, and H_2O across the membrane as indicated by arrows

Figure 4.1 Elements of the cell membrane

Activity 3. Gradients Use Fig. 4.2 to answer questions about gradients.

1. How many concentration gradients can you identify in Fig 4.2? Identify them specifically from high end to low end.
2. Explain using the figure as an example what a concentration gradient is.

3. Describe what we mean by a semi-permeable membrane.
4. If the cell membrane in Fig 4.2 were semi-permeable, how might the different solutes behave with respect to crossing it? Give specific examples that you make up to illustrate the concept.
5. What process(es) among the ones listed in activity 1 would be involved in moving solute molecules across the membrane?
6. Use the word hypertonic, hypotonic or isotonic to describe the relationship between the outside compartment B and the cytoplasm of cell A.

Practice Figure

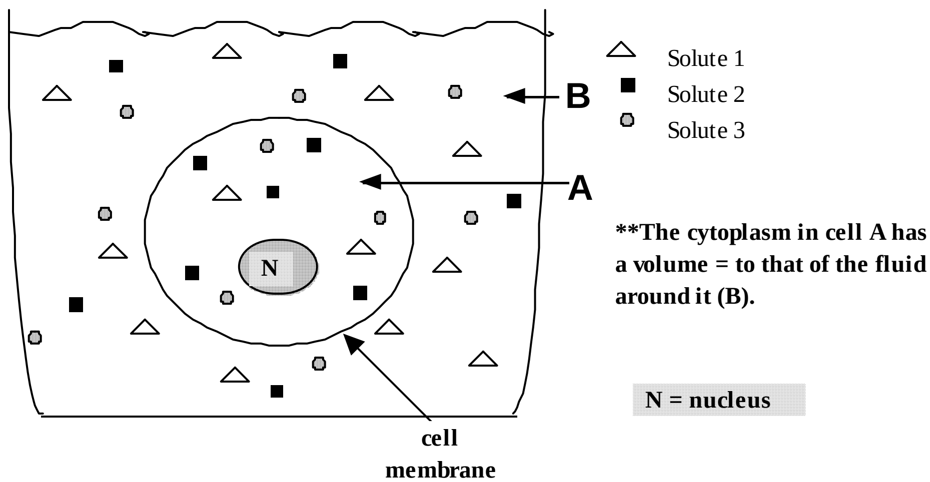


Figure 4.2. Cell in a watery solution: gradients

III. Workshop Activities

Activity 1. Draw a membrane: round robin.
In turn, each member of the group should add an element to the drawing as described. The student, with the help of others in the group should answer questions associated with the drawing. Each student should make his/her own drawing in Fig. 4.3 below.

1. (2 students) Draw a long section of phospholipid bilayer with 4 gaps to allow others to insert elements. Label a hydrophobic and hydrophilic area of the membrane and the specific molecular parts. Identify the cytoplasm and extracellular fluid on either side of the membrane.

2. In one gap insert a transport type protein that is a gated channel. Explain what it does. Suggest one molecule or ion that might cross it.

3. In a second gap insert a receptor protein and show the position of a ligand that could bind with the receptor. Explain the process that goes on here.

4. In a third gap insert a recognition protein—a glycoprotein. Explain what it does.

5. In the fourth gap insert an integral protein that spans the entire membrane. This protein is an electrogenic pump. Explain what it does and give an example.

6. Place some cholesterol molecules in the membrane? Try to get the general shape. What do the molecules do for the membrane?

7. Extend the membrane with an additional gap and add a section of membrane above it, also with a gap. This represents the membrane of an adjacent cell. Now create a gap junction between the membranes. How does this junction function for the two cells?

Figure 4.3 Cell membrane project

8. Redraw the gate on the gated channel so it is open. Place a cluster of 8 Na^+ (sodium) ions outside the cell, and 2 Na+ ions inside. If the channel conducts Na+ ions, what will happen when the gate opens? What process is involved?

9. Extend the original membrane drawing and add one more gap. Insert a potassium (K+) channel in the gap. The channel is an integral protein that spans the entire membrane. Place a cluster of 8 K+ (potassium) ions in the cytoplasm near the gated channel, and 2 ions outside. What will happen when the gate is open? Explain.

10. For the last question, why were you asked to draw another channel protein rather than using the one we had worked with for Na+ transport? Explain.

11. Discuss the type of energy used in getting the Na+ and K+ ions across the membranes in questions 8 and 9.

12. Insert some cytoskeletal elements into your drawings. Be sure the attachments in the membrane are correct. Explain what they do in organizing membrane structure.

<u>Activity 2: Pair problem solving: Representing transport processes</u>

Each pair of students takes one or two of the following problems. Spend 5-10 minutes working on them. When the group is reassembled, the pair should present their solutions to the rest of the group and answer questions and make corrections if needed.

1. A one-celled organism called an *Amoeba* encounters a particle of food in moving through its watery environment. The particle is too large to pass through its cell membrane. The Amoeba is able to ingest it anyway.

a. Suggest how the particle is taken in. Explain your suggestion
b. Draw a simple diagram of the process using several sketches to show the stages.
c. Describe where in the cell the particle is located after being ingested. Be specific.
d. Suggest what might happen to the particle next so the Amoeba can use it for food.

2. Small molecules are passing from inside the cell across the membrane to the extracellular fluid. The cell expends no energy, nor are there any special channels involved. The rate of movement is rapid for a while and then slows to a steady rate.

a. Suggest the type of transport moving the molecules. Explain your suggestion.
b. Draw a simple diagram of the process using several sketches to show the stages.
c. Propose the conditions (energy, gradients, metabolic activity) that must exist for the rapid and slow steady phases of molecular movement.
d. Think of a cell in which this transport might occur in the rapid and steady phases.

3. A large protein is secreted by a cell. It was manufactured in the ER.

a. Suggest a type of transport for getting the large protein out of the cell.
b. Draw a simple diagram of the process using several sketches to show the stages.
c. Discuss the role of membranes in this transport process.
d. Give an example of a substance that is transported in this manner.

4. A cell has too many Na^+ ions in its cytoplasm and must use energy to lower the internal concentration back to normal levels since the Na^+ concentration is higher outside the cell than in.

a. Suggest a type of transport for getting the Na^+ out of the cell. Explain your suggestion.
b. Draw a simple diagram of the process using several sketches to show the stages.
c. Explain how this type of transport differs from simple diffusion.
d. Give an example of this type of transport in cells.
e. Suggest the electrical consequences of moving Na^+ out of the cell.

5. A plant cell manufactures lots of sugar molecules using light (photosynthesis) and stores them in its central vacuole. The cell begins to swell and push hard against the surrounding cell walls.

a. Suggest what type of transport is causing the swelling.
b. Explain what conditions cause this transport to occur in the cell.
c. Draw a series of labeled diagrams which show the transport process.
d. Suggest how the plant cell might restore its central vacuole to its original size.

6. A cell has many more potassium ions (K^+) in its cytoplasm than in the extracellular fluid. The cell membrane has low permeability to potassium normally and very little leaves. Suddenly a large number of K^+ ions rush out of the cell, and then the transport stops again.

a. Suggest what type of transport is responsible for the outward rush of K^+ ions.
b. Draw a simple diagram of the process using several sketches to show the stages.
c. Identify the conditions (energy, gradients, stimuli, etc.) must be present in the cell for this type of transport to occur.
d. Propose a way that the K^+ ions might get back in the cell.

7. Figure 4.3 shown at the right is based upon the model of sucrose uptake by cells. Assume that cells have a lower concentration of hydronium ions (H^+) inside as compared to outside the cell.

a. What effect would increasing the extra-cellular sucrose concentration have on the rate of sucrose transport into the cell?
b. What effect would lowering the extracellular pH have on the rate of transport of sucrose into the cell? Be careful!! What happens with lowering pH?

c. What effect would adding an inhibitor of ATP generation have on the rate of transport of sucrose into the cell?

d. Name this type of transport mechanism.

8. You have just completed an experiment in which you measured the rate of uptake of amino acids by cells in the presence and absence of an inhibitor of ATP production. You found that amino acids enter cells at about the same rate, regardless of the presence or absence of the inhibitor.

a. Suggest a mechanism of amino acid transport that is consistent with the results above and explain your thinking.

b. Draw a simple diagram of the process using several sketches to show the stages.

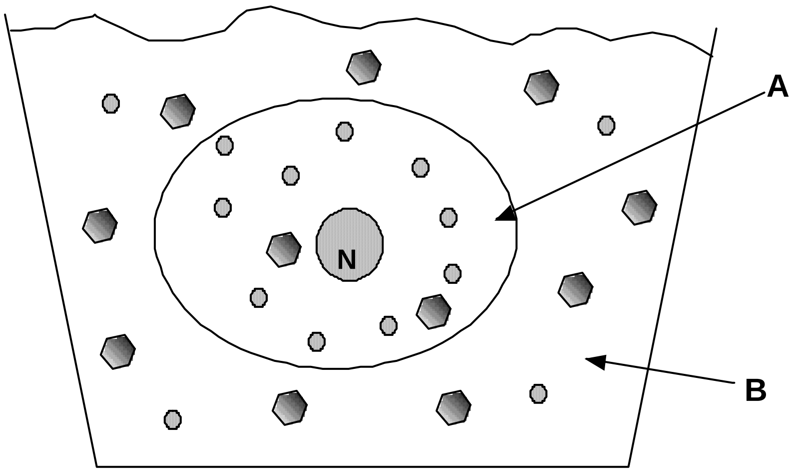
c. Under what conditions (gradients, energy, membrane structure and permeability) can this transport mechanism work?

Figure 4.4 Diagrams of transport mechanisms

Activity 3. Osmosis and Diffusion Problems

Pairs of students should do the following exercises, preferably on a large sheet of paper or on the blackboard. Each pair should do at least two exercises with each member taking the lead for one of the problems. Depending on time, more exercises could be done by each pair. Afterward each group should demonstrate to the others the solution for the problem, step-by-step. Another group that has done the same problem should comment on the solution: corrections, different approach, etc. Alternately these problems can be done as a round robin.

1. Answer the items below using Fig. 4.5. **N = nucleus**. Be sure to read the legends below the figure.



membrane is impermeable to this ion

membrane is permeable to this ion

Volume of the cell A is equal to the volume of the container B

N = Nucleus

Figure 4.5. Cell in a solution for problem 1.

a. Which is the intracellular compartment and which the extracellular compartment?
b. What will be in each compartment, beyond the solutes shown, in a live cell?
c. Determine the solute and solvent gradients that exist as it is drawn.
d. How does the osmotic pressure of the two compartments compare as it is drawn.
e. In a second drawing show what the distribution of solutes would be like after a few hours.
f. Compare the osmotic pressure in the two compartments if only solutes, but not solvents moved between the compartments.
g. Now indicate any solvent movements that might occur and how the shape of the cell might change.

2. Answer the following questions using Fig. 4.6. Each solute symbol stands for 0.01M of that solute. **N = nucleus**. Be sure to read the legends on the right.

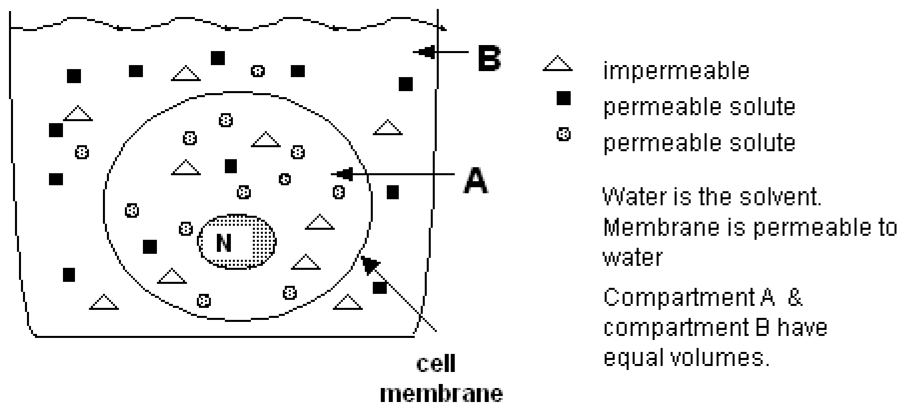


Figure 4.6. Cell in a solution for problem 2.

a. Which is the intracellular compartment and which the extracellular compartment? What will be in each beyond the solutes shown for a live cell?

b. Determine the concentrations of each solute in the two compartments.

c. Determine the solute and solvent gradients that exist as it is drawn.

d. How does the osmotic pressure of the two compartments compare as it is drawn.

e. In a second drawing show what the distribution of solutes would be like after a few hours.

f. Compare the osmotic pressure in the two compartments once equilibrium is reached

g. Indicate what changes occur in the shape and size of the cell at equilibrium.

h. After equilibrium is reached what movements of solutes across the membrane will occur?

3. Answer the following questions using Fig 4.7 below. Each solute symbol stands for 0.01M of that solute. **N = nucleus**. Be sure to read the legends on the right.

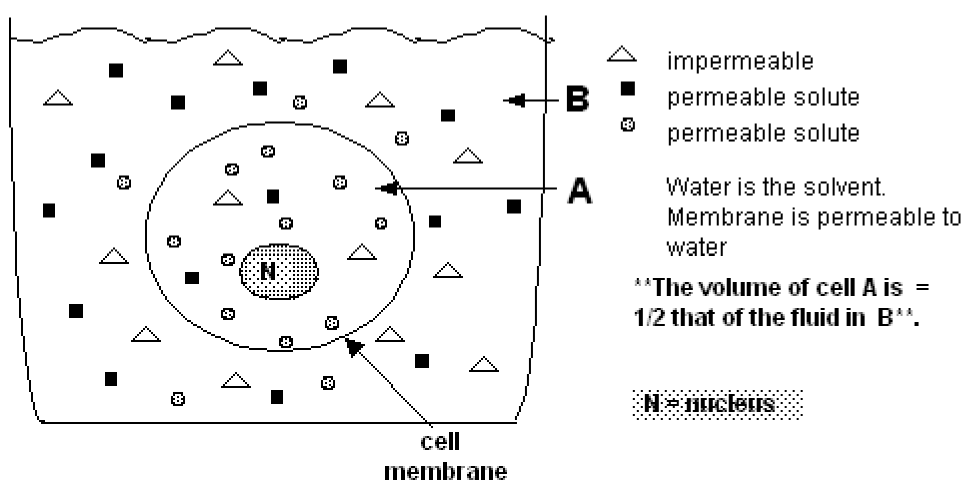


Fig 4.7. Cell in a solution for problem 3.

a. Determine the concentrations of each solute in the two compartments.

b. Determine the solute and solvent gradients that exist as it is drawn.

c. How does the osmotic pressure of the two compartments compare as it is drawn.

d. In a second drawing show what the distribution of solutes would be like after a few hours if only solutes moved across the membrane.

e. In this situation determine if osmosis would occur and in which direction.

f. Indicate what changes, if any, occur in the shape and size of the cell

g. Suggest a scenario in which the cell could reach equilibrium.

4. A round, artificial animal cell has a selectively permeable membrane and an internal concentration of three sugars as follows: glucose = 0.04M; fructose = 0.03M; sucrose = 0.02M. Recall that glucose and fructose are monosaccharides and sucrose is a disaccharide. The membrane is completely permeable to water and monosaccharides, but impermeable to larger sugars. You immerse the cell in an aqueous solution with glucose = 0.01M; fructose = 0.06M; and sucrose = 0.06M. After 24 hr you return and observe the cell.

a. Make a drawing of the arrangement at the beginning of the experiment, representing different types of molecules with different shapes (squares, circles, triangles, etc.). Make one symbol represent each 0.01M of solute concentration.

b. Make a similar drawing with the distribution of solutes in and outside the cell after 24 hours.

c. Which solute(s) have diffused across the membrane into the cell? Which out of the cell?

d. How will the cell appear in size and shape after 24 hr?

e. Describe the relationship between the inside of the cell and the extracellular environment using the terms hypertonic, hypotonic, or isotonic.

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