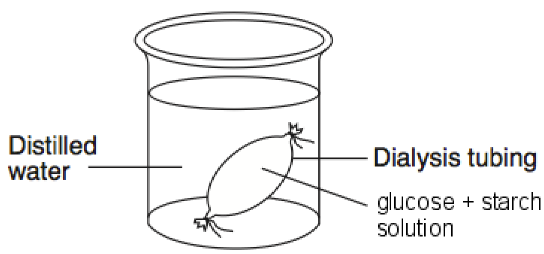
Cell Transport

Part A: Diffusion

A living cell interacts constantly with the environmental medium that surrounds it. The plasma membrane surrounding a cell is a living, selectively permeable structure. It helps to regulate which materials enter and leave the cell. **Diffusion** is the random movement of molecules from an area of higher concentration of those molecules to an area of lower concentration. For example, if you were to open a bag of delicious popcorn in one corner of a room, it would not be long before someone in the opposite corner would detect the smell of popcorn. The bag contains a higher concentration of popcorn smell molecules than the room does and, therefore, those molecules diffuse from the area of higher concentration to the area of lower concentration. Eventually a dynamic equilibrium will be reached; the concentration of popcorn smell molecules will be approximately equal throughout the room and no *net* movement of those molecules will occur from one area to the other, even though the random molecular motion of those molecules continues.

Small solute molecules and water molecules can move freely through a selectively permeable membrane, but larger molecules will pass through more slowly or not at all. In medicine, the movement of a solute through a selectively permeable membrane is called **dialysis.** The size of the minute pores in dialysis tubing determines which substances can pass through the membrane. By detecting the presence of particular molecules on each side of a piece of dialysis tubing, we can determine which molecules passed through the tubing and which did not.

Figure 1



Imagine that a solution of glucose and starch is placed inside a bag made of dialysis tubing (See Figure 1). Distilled water is placed in a beaker, outside the dialysis bag. Iodine is added to the water in the beaker until it is a faint yellow color. The solutions in the bag and beaker were subjected to the Lugol and Clinitest tests (Initial Color) and then again after 20 minutes (Final Color). The results are given in Table 1.

1. [SP 6] Make a prediction about the movement of glucose and starch.

2. [SP 3] Describe a method of detecting the presence of glucose and starch in the water.

Table 1 Initial and final results of Lugol and Clinitest tests on contents of bag and beaker

Initial Contents		Lugol test		Clinitest	
		Initial Color	Final Color	Initial Color	Final Color
Bag	15% glucose/1% starch	purple	purple	orange	orange
Beaker	H_2O + IKI	yellow	yellow	blue	green

Note: Initial means before the 20 minutes; final means after the 20 minutes.

3. [SP 1] Describe a positive result for both the Lugol test for starch and the use of Clinitest tablets for detecting glucose.

4. [SP 6] Make a statement about the movement of glucose and starch in the experiment. Justify your answer.

5. [SP 6] State whether the membrane is selectively permeable. Justify your response.

6. [SP 6] Suppose that a second dialysis bag filled with a 5% starch solution is placed in a beaker filled with a 10% starch solution. Describe the direction of movement of starch and water.

7. [SP 6] A single starch molecule may have thousands of atoms, a glucose molecule has 24, and the ions of dissolved salt are the size of single atoms. Each of these is placed in a separate dialysis bag suspended in water. State what would happen to each and predict the rate of diffusion in each case.

8. [SP 1] Starch is a source of glucose molecules which cells can use for energy. Explain why the chemical digestion of starch is necessary for cells to be able to use it.

9. [SP 1] Describe what this investigation shows about the movement of starch molecules across the membrane of a living cell.

Part B: Osmosis

Both the cytoplasm of a cell and its external environmental medium consist mainly of water. The plasma membrane is permeable to water. Water will diffuse through membranes in a process called **osmosis**. Osmosis is the diffusion of water through a selectively permeable membrane (a membrane that allows for diffusion of certain solutes and water) from a region of higher water potential (*i.e.*, low [solute]) to a region of lower water potential (*i.e.,* high [solute]). Water potential is the measure of free energy of water in a solution.

When two solutions have the same concentration of solutes, they are said to be **isotonic** to each other. If the two solutions are separated by a selectively permeable membrane, water will move between the two solutions, but there will be no **net** change in the amount of water in either solution. If two solutions differ in the concentration of solutes that each has, the one with more solute (less water) is **hypertonic** to the one with less solute. The solution that has less solute is **hypotonic** to the one with more solute. These words can only be used to compare solutions. Remember that the two solutions could be the cytosol and the extracellular fluid.

Now consider two solutions separated by a selectively permeable membrane. The solution that is hypertonic to the other must have more solute and therefore less water. The water potential of the hypertonic solution is less than the water potential of the hypotonic solution, so the **net** movement of water will be from the hypotonic solution into the hypertonic solution.

Imagine that six dialysis tubing bags are prepared and filled with: distilled water, 0.2 M sucrose, 0.4 M sucrose, 0.6 M sucrose, 0.8 M sucrose, and 1.0 M sucrose. The initial mass of each bag is recorded in Table 2. The bags are placed in six separate beakers of distilled H_2O and left for 30 minutes. Afterward, the final mass of each bag is determined and recorded in Table 2.

Table 2 Initial and final mass of dialysis bags.

Contents of Dialysis Bag	Mass (Initial)	Mass (Final)	ΔMass	Percent Change in Mass*

a) distilled water	28.0	28.0		
b) 0.2 M	26.9	28.5		
c) 0.4 M	27.0	29.4		
d) 0.6 M	28.4	32.6		
e) 0.8 M	28.2	32.0		
f) 1.0 M	29.9	34.8		

*To calculate: Percent Change in Mass = [Final Mass - Initial Mass x 100]/ Initial Mass

10. [SP 4] Graph the percent change in mass versus sucrose concentration.

11. [SP 1, SP 4] Explain the relationship between the change in mass and the molarity of sucrose within the dialysis bag.

12. [SP 4, SP 5] Pieces of zucchini were placed in sucrose solutions at 22^{o}C for 24 hours and the % change in mass was recorded. The results are shown below:

Table 3: Change in mass of zucchini slices place in sucrose.

Sucrose concentration (M)	% change in mass
0 (distilled water)	20
0.2	10
0.4	-3
0.6	-17
0.8	-25
1.0	-30

Graph the results. Use the graph to determine the molar concentration of solutes within the zucchini cells.

A series of three microscope slides is prepared as shown in Table 4. A drop of blood is added to each and the red blood cells are observed.

Table 4: Red blood cells and saline solutions

	Solution	Appearance of Red blood cells
Tube 1	3% NaCl	Shrivelled
Tube 2	0.9% NaCl	Biconcave disks
Tube 3	Distilled water	Swollen

13. [SP 1, SP 4] Identify the solution in each tube as hypertonic, hypotonic, or isotonic. Justify your answers.

14. a) [SP 1] Explain the importance of the homeostatic nature of blood plasma osmolarity.
    b) [SP 4, SP 6] Predict the normal concentration of NaCl in blood plasma.

15. You have been given three glucose solutions of unknown concentrations and some slices of potato.
    a) [SP 3] Design a protocol to enable you to rank the solutions in order from least concentrated to most concentrated. In your protocol you must identify
    - a hypothesis

- the independent variable
- the dependent variable
- two variables you will control
- an appropriate control group
- expected results

b) [SP 6] Describe the results that would enable you to determine the relative concentration of each solution.

Imagine a carrot is 60% water and 40% solutes. Carrot A is placed in distilled water while carrot B is placed in a solution of 50% solutes.

16. [SP 1, SP 6] Predict the effects on each carrot.

17. [SP 1, SP 6] a) Using particular reference to individual cells, describe what would happen to a marine jellyfish placed in a freshwater lake.
b) [SP 1, SP 6] A marine algae (seaweed) is placed in a freshwater lake and the cells are then examined under a microscope. Contrary to the jellyfish, no cells have lysed. Suggest an explanation.
c) [SP 1, SP 6] You planned on bringing some grapes to a friend's house for a study party, however the grapes were bought a little early and you noticed they are now slightly wrinkled instead of plump. Describe a method of restoring the grapes and explain why the method would be effective.

Part C: Active Transport

Many unicellular and simple multicellular organisms lack special excretory mechanisms. Harmful metabolic by-products simply diffuse directly across their cell membranes into the surrounding water environment. A number of protists have a specialized excretory device called a contractile vacuole. Protists with contractile vacuoles usually live in water that is hypotonic to their cytoplasm. While contractile vacuoles may excrete some metabolic by-products such as nitrogenous wastes, their primary function is to rid the organism of excess water.

One such protest is the paramecium, which has two contractile vacuoles. The vacuoles gradually enlarge as water enters and they eventually contract, ejecting their contents into the extracellular environment. This process requires energy.

18. a) [SP 1] Describe why contractile vacuoles are necessary.
b) [SP 1, SP 6] Very low concentrations of cyanide cause a rapid decrease in the rate of contraction in contractile vacuoles. Explain the effect of exposure of a paramecium to cyanide.
c) [SP 6] Some protists living in salt water also have contractile vacuoles but the rate of contraction of their vacuoles is very slow (maybe 3 times per hour). Predict the effect on the rate of contraction by completing Table 5 below.

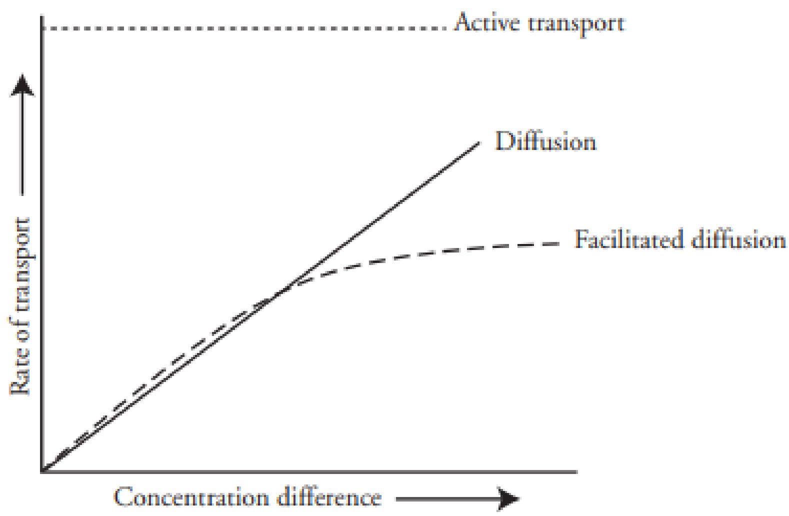
Table 5: Rate of contraction of vacuole with increasing osmolarity of surrounding fluid.

Osmolarity of solution	Relative rate of contraction of vacuole
1000 (sea water)	
200 (a freshwater lake)	
0 (distilled water)	

Some molecules must be moved into or out of cells from a low concentration to a high concentration. This requires active transport, which uses the energy in ATP to transport molecules across a membrane against a concentration gradient. In an experiment, students expose both living yeasts cells and cells killed by boiling to a dye called congo red. They notice that the boiled cells quickly become red inside while living cells never become red.

19. [SP 1] Suggest an explanation for their observation.

Figure 2



20. a) [SP 1] Identify the best type of transport to move substances into or out of the cell quickly. Justify your choice.
b) [SP 1] Identify the best type of transport to use if the cell needed to respond to a sudden concentration gradient difference. Justify your choice.
c) [SP 1, SP 4] Explain why the line representing facilitated diffusion levels off as the concentration increases higher while the line representing diffusion continues to increase steadily.
d) [SP 1, SP 4] Explain the continuous, relatively high rate of active transport.