



Osmosis Simulation Activity Model

INVESTIGATION

#30-1125

OBJECTIVES

- *Demonstrate* and observe the process of osmosis between hypotonic and hypertonic solutions separated by a semipermeable membrane.
- *Study* the effects of solute concentration, temperature, and pH on osmosis.
- *Predict* the characteristics of substances that allow them to pass through a semipermeable membrane.
- *Explain* the causes and effects of water movement in living cells.

Science Concepts

- Osmosis
- Diffusion
- Cell membrane
- Solute
- Solvent
- Osmoregulation
- Plasmolysis

Time Requirements

30-45 minutes

Safety & Disposal

Have your students always wear safety goggles, gloves and a lab apron to protect their eyes and clothing when working with any chemicals. Be sure that they wash their hands before leaving the laboratory.

Use extreme caution when inserting the glass capillary tubing into the rubber stopper. Lubricate the stopper and the glass tubing. Use heavy leather gloves to protect your hands from shattering glass. To prevent puncture wounds, be sure your hand is clear of the hole. Do not push the capillary tubing all the way through the hole of the rubber stopper.

Pre-Lab Preparation

Cut the semipermeable membrane into 3" long pieces. Soak the semipermeable membrane in a beaker of water for several minutes. Using scissors cut each along its length to create square pieces.

Prepare a colored 1 M sucrose solution by dissolving the sucrose provided in 500 mL of water.

As an option, you may want students to repeat the experiment, using 0.5 M sucrose solution, acidic sucrose solution, basic sucrose solution or solutions of different temperatures or other solutions of your choice including starch and salt.

To prepare a 0.5 M sucrose solution, dilute the 1M solution with equal amounts of water.

Acidic or basic sucrose solutions can be made by adding either dilute hydrochloric acid or sodium hydroxide. Be sure to use proper safety precautions when handling any chemicals.

Kit Materials List

Osmosis Simulation Apparatus

- 2 L-Shaped clear tubing
- Capillary tube
- One-hole rubber stopper
- Stand
- 1 Food coloring solution, 30 mL
- 1 Rubber band
- 1 Ruler
- 10 Semipermeable membrane sheets
- 171g Sucrose

Materials Needed But not Provided

- 1 Beaker or cup
- 1 Tap grease or Vaseline
- Distilled water
- Timer

ACTIVITY

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Observing and quantifying osmosis

What you need

Osmosis Simulation Activity Model

Hypertonic solutions

Colored sucrose solution, 1M

Colored sucrose solution, 0.5M *

Colored acidic sucrose solution, 1M *

Colored basic sucrose solution, 1M *

Distilled water

Rubber band

1 Ruler

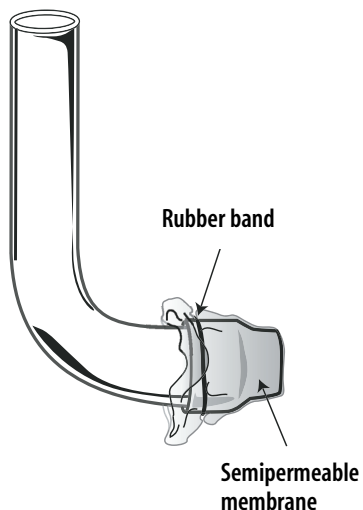
1 Semipermeable membrane sheet

* optional

What to do...

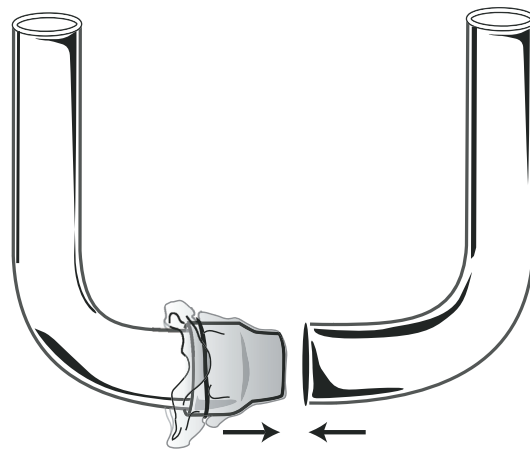
Step 1

Place a wet piece of semipermeable membrane over the L-shaped tube and hold it in place by wrapping a rubber band around it.



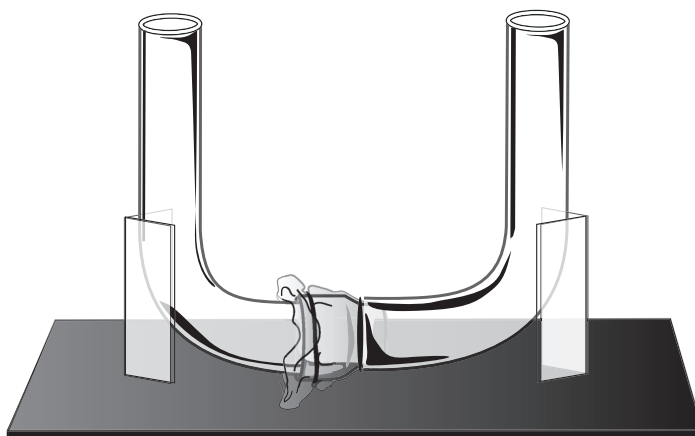
Step 2

Fit the L-shaped tube with the semipermeable membrane attached, into the other L-shaped tube. As an option, you may want to lightly grease the connector to ensure that the unit is watertight.



Step 3

Place the assembled apparatus on the stand as shown in the illustration below.



Step 4

Pour the prepared colored sucrose solution into one side of the apparatus and fill it to the top with a slight overflow.

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Step 5

Caution: For safety reasons, you may opt to perform this step for your students. Use extreme caution when inserting the glass capillary tube into the rubber stopper. Lubricate the stopper and the glass tubing. Use heavy leather gloves to protect your hands from shattering glass. To prevent puncture wounds, be sure your hand is clear of the hole. Do not push the capillary tube all the way through the hole of the rubber stopper. Carefully insert the glass capillary tube half way into the one-hole rubber tubing.

Carefully, insert the capillary tube into the rubber stopper. You may apply a thin layer of petroleum jelly around the rubber stopper hole to make it watertight.



Step 6

Insert the rubber stopper with the capillary tube attached to it, into the top orifice of the filled side. Twist it half a turn to ensure that it is securely placed into the orifice and that the solution is seen near the bottom end of the capillary measuring tube.

IMPORTANT. Make sure that the hypertonic solution is touching the rubber stopper and that there are no air bubbles or air gaps between the solution surface and the bottom of the rubber stopper. Add additional solution if necessary.

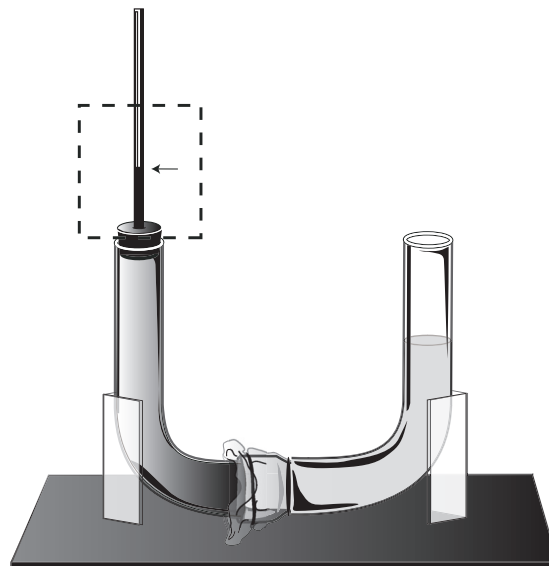


Step 7

Fill the other side of the osmosis apparatus 1/2 full with distilled or tap water.

Step 8

Note the starting level of the solution in the capillary tube and record it in Table 1. Start your timer.



Step 9

Over time, the level of the hypertonic sucrose colored solution should rise in the vertical capillary tube. Record the position of the colored solution every 2 minutes for up to 30 minutes and record your results in Table 1.

Step 10

As an option, you may want students to repeat the experiment, using 0.5 M sucrose solution, acidic sucrose solution, basic sucrose solution or solutions of different temperatures or other solutions of your choice including starch and salt.

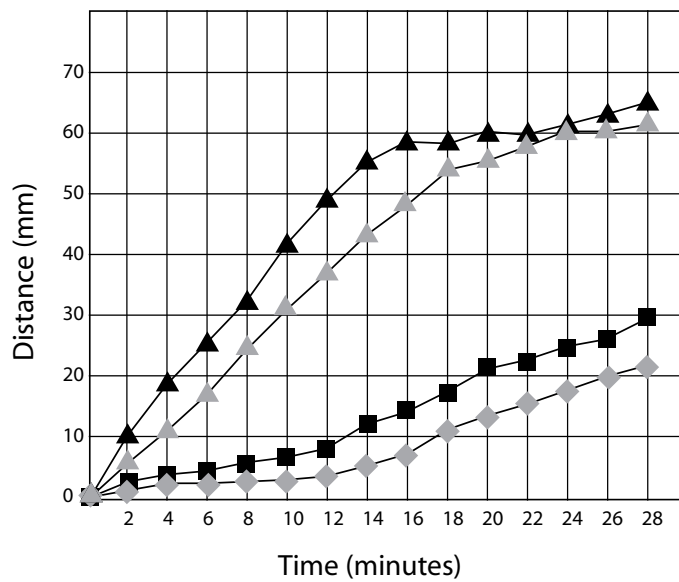
Step 11

Direct your students to wash their hands and clean up their area.

Table 1
Sample Results

Movement in mm				
Time	Sucrose, 1M	Sucrose, 0.5 M	Sucrose, 1 M plus HCl	Sucrose, 1 M plus NaOH
0	0	0	0	0
2	2	1	1	5
4	3	2	2	11
6	4	2	2	17
8	6	3	3	25
10	8	3	3	31
12	9	4	4	37
14	12	6	6	44
16	14	8	8	49
18	17	11	11	55
20	21	14	14	56
22	22	16	16	58
24	24	18	18	60
26	26	20	20	60
28	30	22	22	62

Graph 1
Rate of Osmosis



■ Sucrose, 1M ▲ Sucrose, 1M + HCl
 ◆ Sucrose, 0.5M ▲ Sucrose, 1M + NaOH

Analysis

1. Did osmosis occur through the semipermeable membrane? What observation led you to this conclusion?

Yes, osmosis occurred. The water level in the capillary tubing increased during the experiment. The water increased because the water (hypotonic solution) in the side tube water moved into the osmotic vessel containing a hypertonic solution (i.e. down its concentration gradient) by osmosis.

2. What is osmosis, and how does it differ from simple diffusion?

Osmosis is a special case of diffusion. It is the diffusion of water across a semipermeable membrane. It also requires no energy. It occurs when solutes cannot pass through the membrane, but water can.

3. What are two characteristics of substances that do not allow them to pass through the semipermeable membrane of living cells?

Molecules that are very large (proteins) or particles that have an electrical charge (ions), do not pass easily - if at all - through the cell membrane.

4. What types of substances pass easily through living cell membranes?

Small, uncharged particles, such as water molecules, oxygen and carbon dioxide, pass through the cell membrane easily.

Assessment

Assign a short research and writing project dealing with how osmosis effects human cells. You can introduce the topics of hypertonic, hypotonic, and isotonic solutions. Let the students decide what would happen to body cells placed in each type of solution.

Have your students research the topic of osmotic pressure. Why doesn't osmosis continue across a membrane until the concentration of solutes on either side is equal? In other words, ask them why, at some point, does osmosis have to stop?

Our body cells need a constant supply of oxygen and nutrients in order to grow and sustain life. They are also continuously producing carbon dioxide and metabolic wastes that need to be removed. Using the knowledge gathered in this investigation, explain how these materials get into and out of a cell.

Explain how water passes from the roots of a plant all the way to its highest point.

How does the water that we drink get into our cells from the gastrointestinal tract?

Cross Curricular Integration

Chemistry Skills

Assign the students an illustration project. Have them look up the chemical formula for glucose, and draw it as a dashed-line molecular model. Have them compare this to the average molecular weight for starch. They can draw several repeating sugar units in a starch molecule to give them an appreciation for how large it can be.

Human Biology/Health

Relate to students how blood dialysis machines work and how the process is similar to this investigation.

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Osmosis Simulation Activity Model

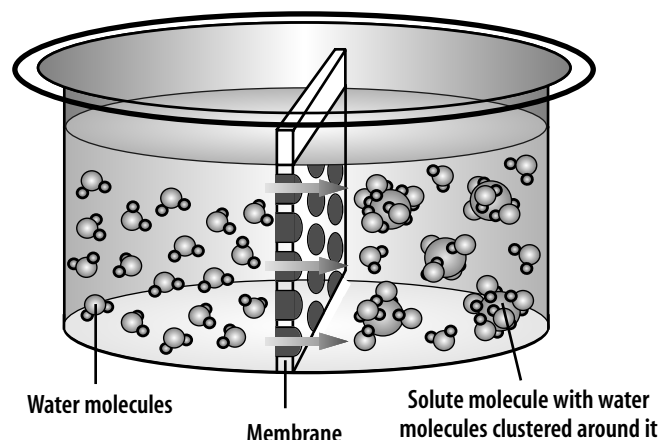
Objectives

- **Demonstrate** and observe the process of osmosis between hypotonic and hypertonic solutions separated by a semipermeable membrane.
- **Study** the effects of solute concentration, temperature, and pH on osmosis.
- **Predict** the characteristics of substances which allow them to pass through a semipermeable membrane.
- **Explain** the causes and effects of water movement in living cells.

Background

The plasma membrane is made up of a variety of different organic molecules. "Phospholipids" are the most common component. Phospholipid molecules have a dual nature. One end of the molecule is polar (the phosphate head) and the other is non-polar (the lipid tail). The phospholipid molecules in a cell membrane line up in two adjacent layers, much like two pieces of bread in a sandwich. The polar phosphate groups arrange themselves on the outside of the sandwich, while the non-polar lipid tails are found in the center of the sandwich. Since water is a polar molecule, it has a slight negative charge at one end and a slight positive charge at the other end, and is attracted to these polar phosphate groups. The lipid tails, which do not mix well with water - much like salad oil in water - are hidden on the inside of the membrane and do not have to interact with the polar water molecules. This arrangement allows the cell membrane to mix well with the fluids, which are mostly

water, both outside and inside the cell. The fluid outside the cell is called "extracellular," and the fluid inside the cell is called "intracellular" or "cytosol."



The addition of a solute (sucrose) to one side of a semipermeable membrane reduces the number of water molecules that can move freely on that side. It is because the water molecules bind to the solute molecule increasing its physical size, thus making it more difficult to move around. Water then moves by osmosis from the area where water molecules are more concentrated to an area that is less concentrated.

The cell membrane has several components besides phospholipids, including proteins which act as channels through the membrane, cholesterol molecules, enzymes, and carbohydrates. The cell membrane is said to be "selectively permeable." That is, it lets some substances pass freely into and out of the cell, but excludes others altogether. Molecules which are large - such as proteins and starch - and charged particles - such as ions, are usually not able to get through the cell membrane unless the appropriate "protein gate" is present. Molecules which cannot pass from one side of the membrane to the other can become concentrated on one side of the membrane.

Remember that a solution is a mixture of different types of molecules in a liquid. One of the molecule types acts as the solvent - the substance in which the other substance is dissolved. The molecule which is dissolved in the solvent is called the "solute." In living cells, the solvent is water. This is true for both the extracellular fluid and the cytosol. Many substances are dissolved in these aqueous solutions, including ions, proteins, waste products such as urea, and nutrient molecules such as glucose.

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New ideas for teaching science

Recall, also, that diffusion occurs whenever a concentration gradient exists between two areas and nothing blocks the diffusing substance from spreading out through that area. The cell membrane, however, acts as a barrier to certain types of molecules. If a solution becomes more concentrated on one side of a semipermeable membrane than on the other, osmosis will occur. Osmosis is the passive (i.e. no energy) diffusion of water molecules down their concentration gradient (i.e. from high concentration to low) across a semipermeable membrane. In other words, if the extracellular fluid solutes become more concentrated than the solutes in the cytosol, water will leave the cell by osmosis. Water is moving down its own concentration gradient. The solution outside the cell in this case is said to be "hypertonic" to the cytosol, meaning that it has a greater concentration of solutes than does the cytosol. In animal cells, this process is called "crenation," and can lead to the shrinkage and death of the cell. In plants, this process is called "plasmolysis," and can also lead to the death of the plant cell.

The opposite process, also involving osmosis, can occur if the intracellular fluid (i.e. cytosol) becomes more concentrated than the extracellular fluid. In this case, the concentration of water is greater outside the cell, so water moves across the membrane down its concentration gradient. The extracellular fluid in this case is said to be "hypotonic" to the intracellular fluid. The movement of water into the cell can lead to the rupture of the cell membrane in animal cells, a process called "lysis." In plant cells, this pressure within the cell pushes the plant cell membrane tightly against the cell wall, firming the cell. This pressure is called "turgor pressure," and the plant cell is said to be "turgid".

The ideal situation for animal cells is to have the intracellular and extracellular fluid in osmotic balance with one another. In such a case, the solutions would be isotonic (i.e. having the same solute concentrations). Here, water diffuses passively across the membrane at the same rate in both directions so there is no net gain or loss of water from the cell. This process of keeping solutes and water

balanced is called "osmoregulation." Most organisms have some method of regulating their water balance, from the cellular level to specialized organs (i.e. like your kidneys) which help do this job for the entire organism.

The hydrostatic (osmotic) pressure created between a hypotonic and a hypertonic solution separated by semipermeable membrane can be expressed by the following formula:

$$P \text{ (osmotic pressure)} = K \times T \times \frac{C}{M}$$

Where:

K is a factor for the solvent. For water $K=1.86^{\circ}\text{C}$. This value corresponds to the lowering of the freezing point for one mole of solute in a liter of water.

C is the concentration of the solute in the hypertonic solution (solution in osmometer vessel)

T is the temperature in $^{\circ}\text{K}$. An increase in temperature increases the speed of the molecules and therefore their diffusion.

M is the molecular weight of the solute.

Time Requirements

30-45 minutes

Safety & Disposal

You should always wear safety goggles, gloves and a lab apron to protect your eyes and clothing when working with any chemicals. Be sure that you wash your hands before leaving the laboratory.

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ACTIVITY

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What you need

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Hypertonic solutions

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Colored sucrose solution, 0.5M *

Colored acidic sucrose solution, 1M *

Colored basic sucrose solution, 1M *

Distilled water

Rubber band

1 Ruler

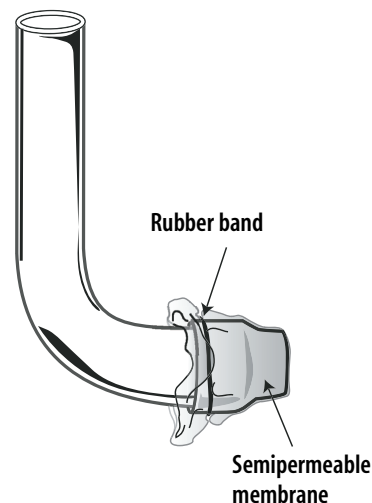
1 Semipermeable membrane sheet

** optional*

What to do...

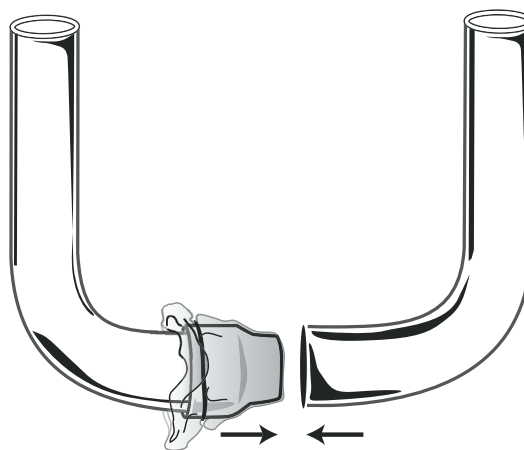
Step 1

Place a wet piece of semipermeable membrane over the L-shaped tube and hold it in place by wrapping a rubber band around it.



Step 2

Fit the L-shaped tube with the semipermeable membrane attached, into the other L-shaped tube. As an option, you may want to lightly grease the connector to ensure that the unit is watertight.



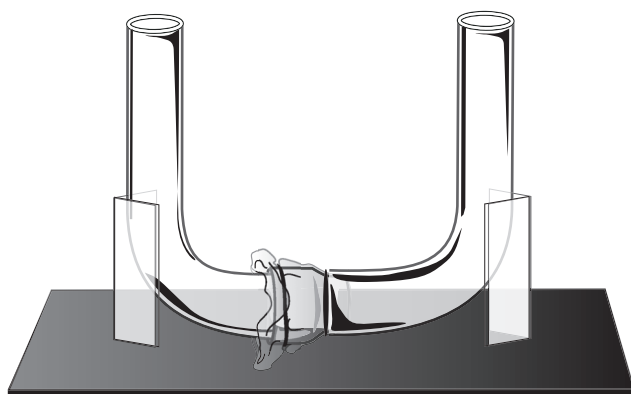
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Step 3

Place the assembled apparatus on the stand as shown in the illustration below.



Step 4

Pour the prepared, colored sucrose solution (1M) into one side of the apparatus and fill it to the top with a slight overflow.

Step 5

Caution: Use extreme caution when inserting the glass capillary tube into the rubber stopper. Lubricate the stopper and the glass tubing. Use heavy leather gloves to protect your hands from shattering glass. To prevent puncture wounds, be sure your hand is clear of the hole. Do not push the capillary tube all the way through the hole of the rubber stopper. For safety reasons, your teacher may opt to perform this step for you. Carefully insert the glass capillary tube half way into the one-hole rubber tubing.

Carefully insert the capillary tube into the rubber stopper. You may apply a thin layer of petroleum jelly around the rubber stopper hole to make it watertight.

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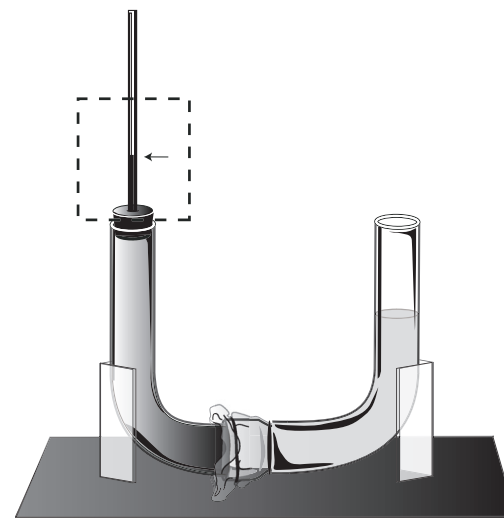


Step 7

Fill the other side of the osmosis apparatus 1/2 full with distilled or tap water.

Step 8

Note the starting level of the solution in the capillary tube and record it in Table 1. Start your timer.



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Step 9

Over time, the level of the hypertonic colored solution should rise in the vertical capillary tube. Record the position of the colored solution every 2 minutes for up to 30 minutes and record your results in Table 1.

Step 10

As an option, your teacher may ask you to repeat the experiment, using 0.5 M sucrose solution, acidic sucrose solution, basic sucrose solution or solutions of different temperatures or other solutions of your choice including starch and salt.

Step 11

Wash your hands and clean up your area as your teacher directs you.

Table 1
Sample Results

Movement in mm				
Time	Sucrose, 1M	Sucrose, 0.5 M	Sucrose, 1 M plus HCl	Sucrose, 1 M plus NaOH
0				
2				
4				
6				
8				
10				
12				
14				
16				
18				
20				
22				
24				
26				
28				
30				

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New ideas for teaching science

Questions

1. Did osmosis occur through the semipermeable membrane? What observation led you to this conclusion?

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2. What is osmosis, and how does it differ from simple diffusion?

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3. What are two characteristics of substances that do not allow them to pass through the semipermeable membrane of living cells?

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4. What types of substances pass easily through living cell membranes?

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Going Further

Using the formula provided in the "Background" section, calculate the osmotic pressures of various solutes of varying concentration and temperatures.

Design experiments to test the permeability of various types of membranes, both synthetic and natural such as animal bladder, etc.

Design experiments to test the osmotic pressure of other solutes such as caffeine, nicotine, etc. under varying environmental conditions.

You can observe osmosis in living plant cells. Use a red onion from the grocery store for this experiment. Peel off the thin skin from the inside of one of the onion's leaves. Place this tissue into a drop or two of distilled water on a microscope slide and cover it with a coverslip. Observe the cells under the compound light microscope. Now, add several drops of 5% saline solution on one side of the coverslip and wick it under the coverslip using a paper towel. Watch what happens to the onion cells. Since the salt in the extracellular fluid is not allowed through the cell membrane, water from the cells moves out (i.e. down its concentration gradient). This process in plant cells is called "plasmolysis." Re-flood the slide with distilled water. What happens? Why?

Predict the effect of exposing model cells to hypertonic, hypotonic, and isotonic solutions. Determine the water potential (i.e. movement of water in and out of a cell) of potato cells. Use a cork borer to cut a potato into cylinders. Place them in various sucrose solutions and calculate the change in mass over time. Determine what will happen if the potato cylinders are placed in a hypertonic, hypotonic, and isotonic solutions.

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New ideas for teaching science

Learn and Read More About It

Benjamin, Clinton; Garman, Gregory; and Funston, James.
Human Biology. McGraw-Hill. 1997.

Allan J. Tobin and Richard E. Morel. *Asking About Cells*.
HBJ School Div. 1997

Andres Llamas Ruiz and Luis Rizo. *The Life of a Cell (Cycles
of Life)*. Sterling Publications. 1997

Neat Websites

Information on biology-related topics in easy-to-under-
stand format for students

<http://www.chem4kids.com/biology4kids/cell/lys.html>

[http://www.chem4kids.com/biology4kids/chem/
prot.html](http://www.chem4kids.com/biology4kids/chem/prot.html)

[http://esg-www.mit.edu:8001/esgbio/cb/membranes/
transport.html](http://esg-www.mit.edu:8001/esgbio/cb/membranes/transport.html)

Provides a thorough overview of cell structure and
function

<http://www.kapili.com/biology4kids/cell/index.html>

Provides background information and suggested
activities to learn more about cells

[http://raven.umnh.utah.edu/secondlevel/teen/teen.
html](http://raven.umnh.utah.edu/secondlevel/teen/teen.html)

Provides a wide selection on various types of cells and
related information

<http://www.cellsalive.com/>