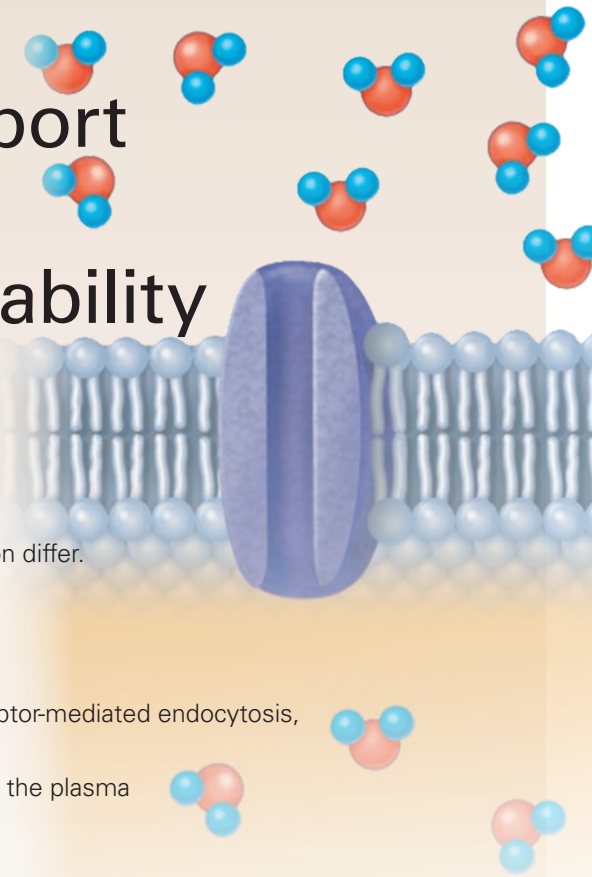
EXERCISE

5

The Cell: Transport Mechanisms and Cell Permeability



Objectives

- ☐ Define *selective permeability,* and explain the difference between active and passive transport processes.
- ☐ Define *diffusion,* and explain how simple diffusion and facilitated diffusion differ.
- ☐ Define *osmosis,* and explain the difference between isotonic, hypotonic, and hypertonic solutions.
- ☐ Define *filtration,* and discuss where it occurs in the body.
- ☐ Define *vesicular transport,* and describe phagocytosis, pinocytosis, receptor-mediated endocytosis, and exocytosis.
- ☐ List the processes that account for the movement of substances across the plasma membrane, and indicate the driving force for each.
- ☐ Name one substance that uses each membrane transport process.
- ☐ Determine which way substances will move passively through a selectively permeable membrane when given appropriate information about their concentration gradients.

Materials

Passive Processes

Diffusion of Dye Through Agar Gel

- Petri dish containing 12 ml of 1.5% agar-agar
- Millimeter-ruled graph paper
- Wax marking pencil
- 3.5% methylene blue solution (approximately 0.1 *M*) in dropper bottles
- 1.6% potassium permanganate solution (approximately 0.1 *M*) in dropper bottles
- Medicine dropper

Text continues on next page. →

Pre-Lab Quiz

1. Circle the correct underlined term. A passive process, diffusion / osmosis is the movement of solute molecules from an area of greater concentration to an area of lesser concentration.
2. A solution surrounding a cell is *hypertonic* if:
   a. it contains fewer nonpenetrating solute particles than the interior of the cell
   b. it contains more nonpenetrating solute particles than the interior of the cell
   c. it contains the same amount of nonpenetrating solute particles as the interior of the cell
3. Which of the following would require an input of energy?
   a. diffusion
   b. filtration
   c. osmosis
   d. vesicular transport
4. Circle the correct underlined term. In pinocytosis / phagocytosis, parts of the plasma membrane and cytoplasm extend and engulf a relatively large or solid material.
5. Circle the correct underlined term. In active / passive processes, the cell provides energy in the form of ATP to power the transport process.

5

(Materials list continued.)

Diffusion and Osmosis Through Nonliving Membranes

- Four dialysis sacs
- Small funnel
- 25-ml graduated cylinder
- Wax marking pencil
- Fine twine or dialysis tubing clamps
- 250-ml beakers
- Distilled water
- 40% glucose solution
- 10% sodium chloride (NaCl) solution
- 40% sucrose solution colored with Congo red dye
- Laboratory balance
- Paper towels
- Hot plate and large beaker for hot water bath
- Benedict's solution in dropper bottle
- Silver nitrate ($AgNO_3$) in dropper bottle
- Test tubes in rack, test tube holder

Experiment 1

- Deshelled eggs
- 400-ml beakers
- Wax marking pencil
- Distilled water
- 30% sucrose solution
- Laboratory balance
- Paper towels
- Graph paper
- Weigh boat

Experiment 2

- Clean microscope slides and coverslips
- Medicine dropper
- Compound microscope
- Vials of mammalian blood obtained from a biological supply house or veterinarian—at option of instructor
- Freshly prepared physiological (mammalian) saline solution in dropper bottle
- 5% sodium chloride solution in dropper bottle
- Distilled water
- Filter paper
- Disposable gloves
- Basin and wash bottles containing 10% household bleach solution
- Disposable autoclave bag
- Paper towels

Diffusion Demonstrations

1. Diffusion of a dye through water

Prepared the morning of the laboratory session with setup time noted. Potassium permanganate crystals are placed in a 1000-ml graduated cylinder, and distilled water is added slowly and with as little turbulence as possible to fill to the 1000-ml mark.

2. Osmometer

Just before the laboratory begins, the broad end of a thistle tube is closed with a selectively permeable dialysis membrane, and the tube is secured to a ring stand. Molasses is added to approximately 5 cm above the thistle tube bulb, and the bulb is immersed in a beaker of distilled water. At the beginning of the lab session, the level of the molasses in the tube is marked with a wax pencil.

Filtration

- Ring stand, ring, clamp
- Filter paper, funnel
- Solution containing a mixture of uncooked starch, powdered charcoal, and copper sulfate ($CuSO_4$)
- 10-ml graduated cylinder
- 100-ml beaker
- Lugol's iodine in a dropper bottle

Active Processes

- Video showing phagocytosis (if available)
- Video viewing system

Note to the Instructor: See directions for handling wet mount preparations and disposable supplies (p. 34, Exercise 3).

PEx PhysioEx™ 9.1 Computer Simulation Ex.1 on p. PEx-3.

Because of its molecular composition, the plasma membrane is selective about what passes through it. It allows nutrients to enter the cell but keeps out undesirable substances. By the same token, valuable cell proteins and other substances are kept within the cell, and excreta or wastes pass to the exterior. This property is known as **selective, or differential, permeability.** Transport through the plasma membrane occurs in two basic ways. In **passive processes,** concentration or pressure differences drive the movement. In **active processes,** the cell provides energy (ATP) to power the transport process.

Passive Processes

The two important passive processes of membrane transport are *diffusion* and *filtration*. Diffusion is an important transport process for every cell in the body. By contrast, filtration usually occurs only across capillary walls.

Molecules possess **kinetic energy** and are in constant motion. As molecules move about randomly at high speeds, they collide and ricochet off one another, changing direction with each collision (**Figure 5.1**). The driving force for diffusion is kinetic energy of the molecules themselves, and the speed of diffusion depends on molecular size and temperature. Smaller molecules move faster, and molecules move faster as temperature increases.

Diffusion

When a **concentration gradient** (difference in concentration) exists, the net effect of this random molecular movement is that the molecules eventually become evenly distributed throughout the environment. **Diffusion** is the movement of molecules from a region of their higher concentration to a region of their lower concentration.

There are many examples of diffusion in nonliving systems. For example, if a bottle of ether was uncorked at the front of the laboratory, very shortly thereafter you would be nodding off as the molecules became distributed throughout the room. The ability to smell a friend's fragrance shortly after he or she has entered the room is another example.

In general, molecules diffuse passively through the plasma membrane if they can dissolve in the lipid portion of the membrane, as CO_2 and O_2 can. The unassisted diffusion of solutes (dissolved substances) through a selectively permeable membrane is called **simple diffusion.**

Certain molecules, glucose for example, are transported across the plasma membrane with the assistance of a protein carrier molecule. The substances move by a passive transport process called **facilitated diffusion.** As with simple diffusion, the substances move from an area of higher concentration to

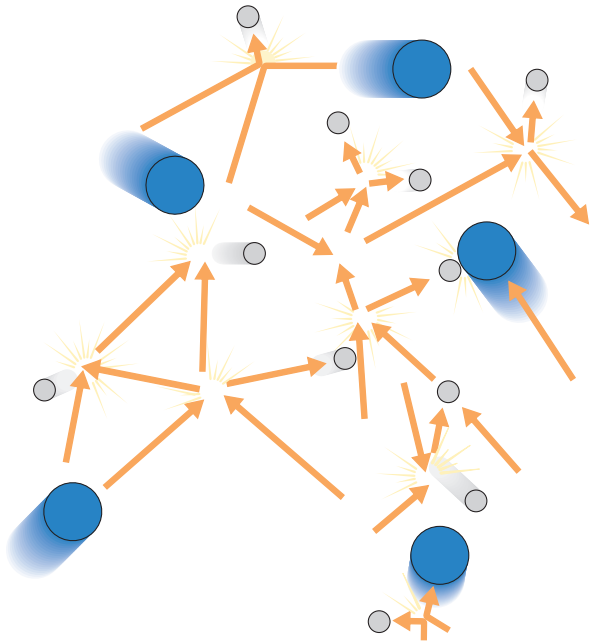


Figure 5.1 Random movement and numerous collisions cause molecules to become evenly distributed. The small spheres represent water molecules; the large spheres represent glucose molecules.

one of lower concentration, that is, down their concentration gradients.

Osmosis

The flow of water across a selectively permeable membrane is called **osmosis.** During osmosis, water moves down its concentration gradient. The concentration of water is inversely related to the concentration of solutes. If the solutes can diffuse across the membrane, both water and solutes will move down their concentration gradients through the membrane. If the particles in solution are nonpenetrating solutes (prevented from crossing the membrane), water alone will move by osmosis and in doing so will cause changes in the volume of the compartments on either side of the membrane.

Diffusion of Dye Through Agar Gel and Water

The relationship between molecular weight and the rate of diffusion can be examined easily by observing the diffusion of two different types of dye molecules through an agar gel. The dyes used in this experiment are methylene blue, which has a molecular weight of 320 and is deep blue in color, and potassium permanganate, a purple dye with a molecular weight of 158. Although the agar gel appears quite solid, it is primarily (98.5%) water and allows free movement of the dye molecules through it.

Activity 1

Observing Diffusion of Dye Through Agar Gel

1. Work with members of your group to formulate a hypothesis about the rates of diffusion of methylene blue and potassium permanganate through the agar gel. Justify your hypothesis.

2. Obtain a petri dish containing agar gel, a piece of millimeter-ruled graph paper, a wax marking pencil, dropper bottles of methylene blue and potassium permanganate, and a medicine dropper.

3. Using the wax marking pencil, draw a line on the bottom of the petri dish dividing it into two sections. Place the petri dish on the ruled graph paper.

4. Create a well in the center of each section using the medicine dropper. To do this, squeeze the bulb of the medicine dropper, and push it down into the agar. Release the bulb as you slowly pull the dropper vertically out of the agar. This should remove an agar plug, leaving a well in the agar. (See **Figure 5.2a**.)

5. Carefully fill one well with the methylene blue solution and the other well with the potassium permanganate solution (Figure 5.2b).

Record the time. _____

6. At 15-minute intervals, measure the distance the dye has diffused from each well by measuring the radius of the dye. Continue these observations for 1 hour, and record the results in the **Activity 1 chart** (p. 56).

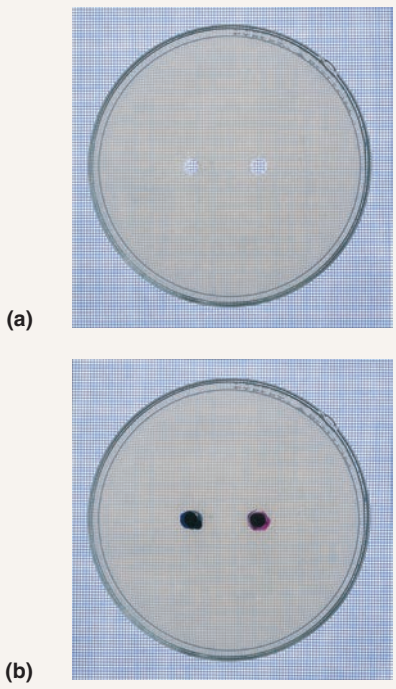


Figure 5.2 Comparing diffusion rates. Agar-plated petri dish as it appears after the placement of 0.1 *M* methylene blue in one well and 0.1 *M* potassium permanganate in another.

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Activity 1: Dye Diffusion Results		
Time (min)	Diffusion of methylene blue (mm)	Diffusion of potassium permanganate (mm)
15		
30		
45		
60		

Which dye diffused more rapidly? _____

What is the relationship between molecular weight and rate of molecular movement (diffusion)?

_____

Why did the dye molecules move? _____

_____

Compute the rate of diffusion of the potassium permanganate molecules in millimeters per minute (mm/min) and record.

_____ mm/min

Compute the rate of diffusion of the methylene blue molecules in mm/min and record.

_____ mm/min

7. Prepare a lab report for these experiments. (See Getting Started, on MasteringA&P.)

Make a mental note to yourself to go to the demonstration area at the end of the laboratory session to observe the extent of diffusion of the potassium permanganate dye through water. At that time, follow the next directions given.

Activity 2

Observing Diffusion of Dye Through Water

1. Go to the diffusion demonstration area, and observe the cylinder containing dye crystals and water set up at the beginning of the lab.

2. Measure the number of millimeters the dye has diffused from the bottom of the graduated cylinder, and record.

_____ mm

3. Record the time the demonstration was set up and the time of your observation. Then compute the rate of the dye's diffusion through water and record below.

Time of setup _____

Time of observation _____

Rate of diffusion _____ mm/min

4. Does the potassium permanganate dye diffuse more rapidly through water or agar gel? Explain your answer.

_____

_____

Prepare for lab: Watch the Pre-Lab Video
MasteringA&P®>Study Area>Pre-Lab Videos

Activity 3

Investigating Diffusion and Osmosis Through Nonliving Membranes

The following experiment provides information on the movement of water and solutes through selectively permeable membranes called dialysis sacs. Dialysis sacs have pores of a particular size. The selectivity of living membranes depends on more than just pore size, but using the dialysis sacs will allow you to examine selectivity due to this factor.

1. Read through the experiments in this activity, and develop a hypothesis for each part.

2. Obtain four dialysis sacs, a small funnel, a 25-ml graduated cylinder, a wax marking pencil, fine twine or dialysis tubing clamps, and four beakers (250 ml). Number the beakers 1 to 4 with the wax marking pencil, and half fill all of them with distilled water except beaker 2, to which you should add 125 ml of the 40% glucose solution.

3. Prepare the dialysis sacs one at a time. Using the funnel, half fill each with 20 ml of the specified liquid (see Activity 3 chart). Press out the air, fold over the open end of the sac, and tie it securely with fine twine or clamp it. Before proceeding to the next sac, rinse it under the tap, and quickly and carefully blot the sac dry by rolling it on a paper towel. Weigh it with a laboratory balance. Record the weight in the **Activity 3 chart**, and then drop the sac into the corresponding beaker. Be sure the sac is completely covered by the beaker solution, adding more solution if necessary.

- Sac 1: 40% glucose solution
- Sac 2: 40% glucose solution
- Sac 3: 10% NaCl solution
- Sac 4: Congo red dye in 40% sucrose solution

Activity 3: Experimental Data on Diffusion and Osmosis Through Nonliving Membranes						
Beaker	**Contents of sac**	**Initial weight**	**Final weight**	**Weight change**	**Tests—beaker fluid**	**Tests—sac fluid**
Beaker 1 ½ filled with distilled water	Sac 1, 20 ml of 40% glucose solution				Benedict's test:	Benedict's test:
Beaker 2 ½ filled with 40% glucose solution	Sac 2, 20 ml of 40% glucose solution					
Beaker 3 ½ filled with distilled water	Sac 3, 20 ml of 10% NaCl solution				$AgNO_3$ test:	
Beaker 4 ½ filled with distilled water	Sac 4, 20 ml of 40% sucrose solution containing Congo red dye				Benedict's test:	

Allow the sacs to remain undisturbed in the beakers for 1 hour. Use this time to continue with other experiments.

4. After an hour, boil a beaker of water on the hot plate. Obtain the supplies you will need to determine your experimental results: dropper bottles of Benedict's solution and silver nitrate solution, a test tube rack, four test tubes, and a test tube holder.

5. Quickly and gently blot sac 1 dry and weigh it. (**Note:** Do not squeeze the sac during the blotting process.) Record the weight in the data chart.

Was there any change in weight? _____

Conclusions: _____

_____

_____

Place 5 drops of Benedict's solution in each of two test tubes. Put 4 ml of the beaker fluid into one test tube and 4 ml of the sac fluid into the other. Mark the tubes for identification, and then place them in a beaker containing boiling water. Boil 2 minutes. Cool slowly. If a green, yellow, or rusty red precipitate forms, the test is positive, meaning that glucose is present. If the solution remains the original blue color, the test is negative. Record results in the data chart.

Was glucose still present in the sac? _____

Was glucose present in the beaker? _____

Conclusions: _____

_____

_____

6. Blot gently and weigh sac 2. Record the weight in the data chart.

Was there an *increase* or *decrease* in weight? _____

With 40% glucose in the sac and 40% glucose in the beaker, would you expect to see any net movement of water (osmosis) or of glucose molecules (simple diffusion)?

_____ Why or why not? _____

_____

7. Blot gently and weigh sac 3. Record the weight in the data chart.

Was there any change in weight? _____

Conclusions: _____

_____

Take a 5-ml sample of beaker 3 solution and put it in a clean test tube. Add a drop of silver nitrate ($AgNO_3$). The appearance of a white precipitate or cloudiness indicates the presence of silver chloride (AgCl), which is formed by the reaction of $AgNO_3$ with NaCl (sodium chloride). Record results in the data chart.

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Results: _____

Conclusions: _____

8. Blot gently and weigh sac 4. Record the weight in the data chart.

Was there any change in weight?_____

Did the beaker water turn pink?_____

Conclusions: _____

_____

Take a 1-ml sample of beaker 4 solution and put the test tube in boiling water in a hot water bath. Add 5 drops of Benedict's solution to the tube and boil for 5 minutes. The presence of glucose (one of the hydrolysis products of sucrose) in the test tube is indicated by the presence of a green, yellow, or rusty colored precipitate.

Did sucrose diffuse from the sac into the water in the small beaker? _____

Conclusions: _____

_____

9. In which of the test situations did net osmosis occur?

_____

In which of the test situations did net simple diffusion occur?

_____

What conclusions can you make about the relative size of glucose, sucrose, Congo red dye, NaCl, and water molecules?

_____

_____

_____

With what cell structure can the dialysis sac be compared?

_____

10. Prepare a lab report for the experiment. (See Getting Started, on MasteringA&P.) Be sure to include in your discussion the answers to the questions proposed in this activity.

Activity 4

Observing Osmometer Results

Before leaving the laboratory, observe the *osmometer demonstration* set up before the laboratory session to follow the movement of water through a membrane (osmosis). Measure the distance the water column has moved during the laboratory period, and record below. (The position of the meniscus [the surface of the water column] in the thistle tube at the beginning of the laboratory period is marked with wax pencil.)

Distance the meniscus has moved: _____ mm

Did net osmosis occur? Why or why not?

_____

_____

_____

Activity 5

Investigating Diffusion and Osmosis Through Living Membranes

To examine permeability properties of plasma membranes, conduct the following experiments. As you read through the experiments in this activity, develop a hypothesis for each part.

Experiment 1

1. Obtain two deshelled eggs and two 400-ml beakers. Note that the relative concentration of solutes in deshelled eggs is about 14%. Number the beakers 1 and 2 with the wax marking pencil. Half fill beaker 1 with distilled water and half fill beaker 2 with 30% sucrose.

2. Carefully blot each egg by rolling it gently on a paper towel. Place a weigh boat on a laboratory balance and tare the balance (that is, make sure the scale reads 0.0 with the weigh boat on the scale). Weigh egg 1 in the weigh boat, record the initial weight in the **Activity 5 chart**, and gently place it into beaker 1. Repeat for egg 2, placing it in beaker 2.

3. After 20 minutes, remove egg 1 and gently blot it and weigh it. Record the weight, and replace it into beaker 1. Repeat for egg 2, placing it into beaker 2. Repeat this procedure at 40 minutes and 60 minutes.

4. Calculate the change in weight of each egg at each time period, and enter that number in the data chart. Also calculate the percent change in weight for each time period and enter that number in the data chart.

Activity 5: Experiment 1 Data from Diffusion and Osmosis Through Living Membranes						
Time	**Egg 1 (in distilled H_2O)**	**Weight change**	**% Change**	**Egg 2 (in 30% sucrose)**	**Weight change**	**% Change**
Initial weight (g)		—	—		—	—
20 min.						
40 min.						
60 min.						

How has the weight of each egg changed?

Egg 1 _____

Egg 2 _____

Make a graph of your data by plotting the percent change in weight for each egg versus time.

How has the appearance of each egg changed?

Egg 1 _____

Egg 2 _____

A solution surrounding a cell is **hypertonic** if it contains more nonpenetrating solute particles than the interior of the cell. Water moves from the interior of the cell into a surrounding hypertonic solution by osmosis. A solution surrounding a cell is **hypotonic** if it contains fewer nonpenetrating solute particles than the interior of the cell. Water moves from a hypotonic solution into the cell by osmosis. In both cases, water moved down its concentration gradient. Indicate in your conclusions whether distilled water was a hypotonic or hypertonic solution and whether 30% sucrose was hypotonic or hypertonic.

Conclusions: _____

_____

_____

Experiment 2

Now you will conduct a microscopic study of red blood cells suspended in solutions of varying tonicities. The objective is to determine whether these solutions have any effect on cell shape by promoting net osmosis.

1. The following supplies should be available at your laboratory bench to conduct this experimental series: two clean slides and coverslips, a vial of mammalian blood, a medicine dropper, physiological saline, 5% sodium chloride solution, distilled water, filter paper, and disposable gloves.

Wear disposable gloves at all times when handling blood (steps 2–5).

2. Place a very small drop of physiological saline on a slide. Using the medicine dropper, add a small drop of the blood to the saline on the slide. Tilt the slide to mix, cover with a coverslip, and immediately examine the preparation under the high-power lens. Notice that the red blood cells retain their normal smooth disclike shape (**Figure 5.3a**, p. 60). This is because the physiological saline is **isotonic** to the cells. That is, it contains a concentration of nonpenetrating solutes (e.g., proteins and some ions) equal to that in the cells (same solute/water concentration). Consequently, the cells neither gain nor lose water by osmosis. Set this slide aside.

3. Prepare another wet mount of the blood, but this time use 5% sodium chloride (saline) solution as the suspending medium. Carefully observe the red blood cells under high power. What is happening to the normally smooth disc shape of the red blood cells?

_____

_____

_____

This crinkling-up process, called **crenation,** is due to the fact that the 5% sodium chloride solution is hypertonic to the cytosol of the red blood cell. Under these circumstances, water leaves the cells by osmosis. Compare your observations to the figure above (Figure 5.3b).

4. Add a drop of distilled water to the edge of the coverslip. Fold a piece of filter paper in half and place its folded edge at the opposite edge of the coverslip; it will absorb the saline solution and draw the distilled water across the cells. Watch the red blood cells as they float across the field. Describe the change in their appearance.

_____

_____

Distilled water contains *no* solutes (it is 100% water). Distilled water and *very* dilute solutions (that is, those containing less than 0.9% nonpenetrating solutes) are hypotonic to the cell. In a hypotonic solution, the red

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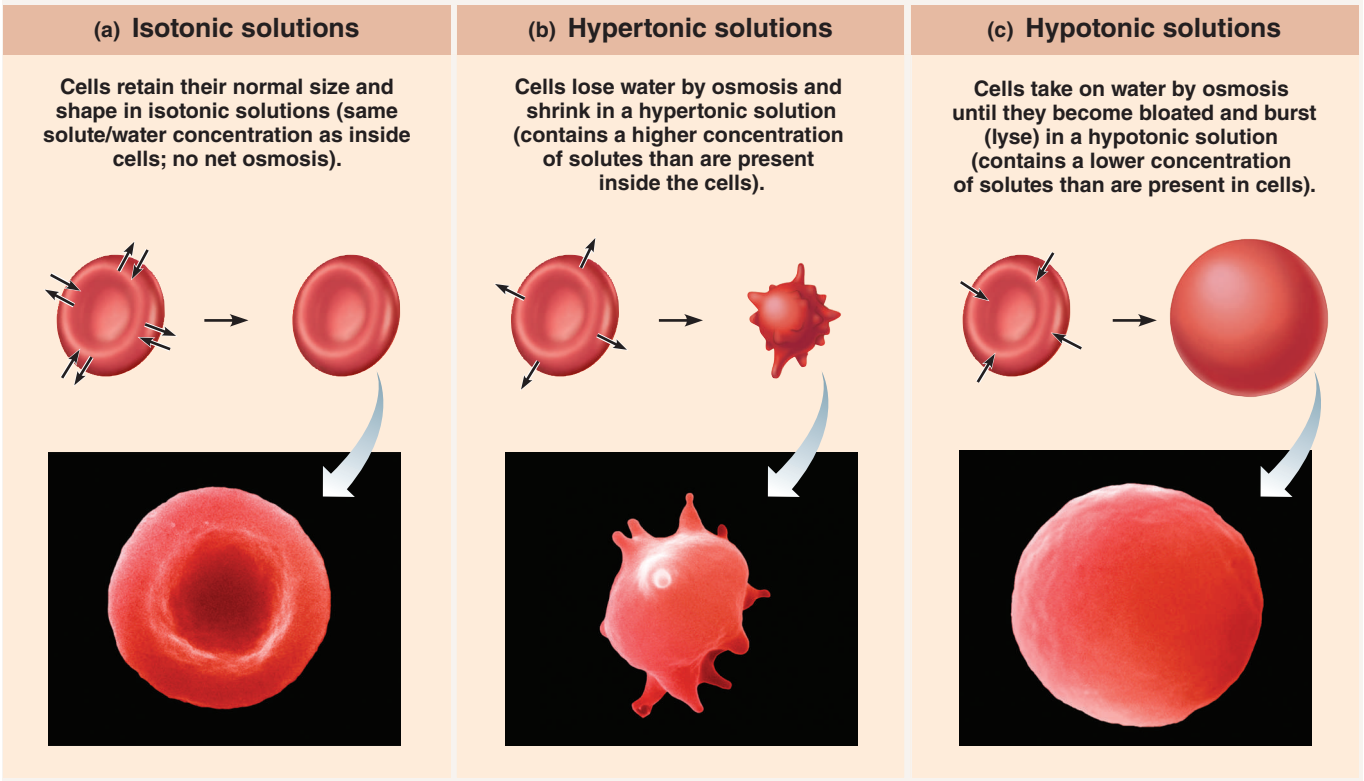


Figure 5.3 **Influence of isotonic, hypertonic, and hypotonic solutions on red blood cells.**

blood cells first "plump up" (Figure 5.3c), but then they suddenly start to disappear. The red blood cells burst as the water floods into them, leaving "ghosts" in their wake—a phenomenon called **hemolysis.**

5. Place the blood-soiled slides and test tube in the bleach-containing basin. Put the coverslips you used into the disposable autoclave bag. Obtain a wash (squirt) bottle containing 10% bleach solution, and squirt the bleach liberally over the bench area where blood was handled. Wipe the bench down with a paper towel wet with the bleach solution, and allow it to dry before continuing. Remove gloves, and discard in the autoclave bag.

6. Prepare a lab report for experiments 1 and 2. (See Getting Started, on MasteringA&P.) Be sure to include in the discussion answers to the questions proposed in this activity.

WHY THIS MATTERS | **Isotonic Sports Drinks**

You have just completed your daily run or fitness class. Do you need to drink a specialized post-workout beverage? A body fluid loss of as little as 2% of your body weight can affect physiological function, so this is an important question. For an exercise session lasting 90 minutes or less, water should suffice. Exercise sessions lasting longer than 90 minutes, however, can result in a significant loss of fluid and electrolytes. After exercising that long, you should drink an isotonic sports drink. Isotonic sports drinks are formulated to contain the same concentration of nonpenetrating solutes as our cells, hence the name *isotonic*. They are designed to restore hydration, replace electrolytes, and replenish carbohydrates. ■

Filtration

Filtration is a passive process in which water and solutes are forced through a membrane by hydrostatic (fluid) pressure. For example, fluids and solutes filter out of the capillaries in the kidneys and into the kidney tubules because the blood pressure in the capillaries is greater than the fluid pressure in the tubules. Filtration is not selective. The amount of filtrate (fluids and solutes) formed depends almost entirely on the pressure gradient (difference in pressure on the two sides of the membrane) and on the size of the membrane pores.

Activity 6

Observing the Process of Filtration

1. Obtain the following equipment: a ring stand, ring, and ring clamp; a funnel; a piece of filter paper; a beaker; a 10-ml graduated cylinder; a solution containing uncooked starch, powdered charcoal, and copper sulfate; and a dropper bottle of Lugol's iodine. Attach the ring to the ring stand with the clamp.

2. Fold the filter paper in half twice, open it into a cone, and place it in a funnel. Place the funnel in the ring of the ring stand and place a beaker under the funnel. Shake the starch solution, and fill the funnel with it to just below the top of the filter paper. When the steady stream of filtrate changes to countable filtrate drops, count the number of drops formed in 10 seconds and record.

_____ drops

When the funnel is half empty, again count the number of drops formed in 10 seconds, and record the count.

_____ drops

3. After all the fluid has passed through the filter, check the filtrate and paper to see which materials were retained by the paper. If the filtrate is blue, the copper sulfate passed. Check both the paper and filtrate for black particles to see whether the charcoal passed. Finally, using a 10-ml graduated cylinder, put a 2-ml filtrate sample into a test tube. Add several drops of Lugol's iodine. If the sample turns blue/black when iodine is added, starch is present in the filtrate.

Passed: _____

Retained: _____

What does the filter paper represent? _____

During which counting interval was the filtration rate greatest? _____

Explain: _____

_____

_____

What characteristic of the three solutes determined whether or not they passed through the filter paper?

_____

Active Processes

Whenever a cell uses the bond energy of ATP to move substances across its boundaries, the process is an *active process*. Substances moved by active means are generally unable to pass by diffusion. They may not be lipid soluble; they may be too large to pass through the membrane channels; or they may have to move against rather than with a concentration gradient. There are two types of active processes: *active transport* and *vesicular transport.*

Active Transport

Like carrier-mediated facilitated diffusion, **active transport** requires carrier proteins that combine specifically with the transported substance. Active transport may be primary, driven directly by hydrolysis of ATP, or secondary, driven indirectly by energy stored in ionic gradients. In most cases, the substances move against concentration or electrochemical gradients or both. These substances are insoluble in lipid and too large to pass through membrane channels but are necessary for cell life.

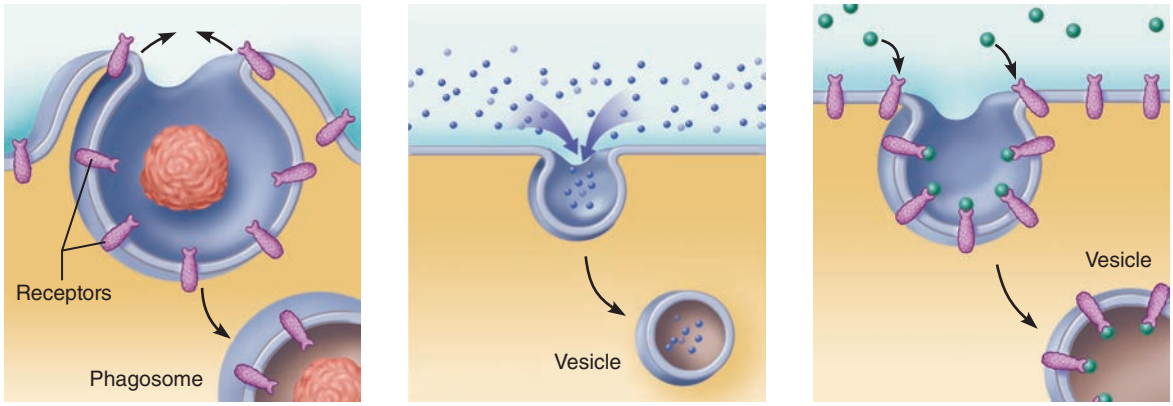
Vesicular Transport

In **vesicular transport,** fluids containing large particles and macromolecules are transported across cellular membranes inside membranous sacs called *vesicles*. Like active transport, vesicular transport moves substances into the cell **(endocytosis)** and out of the cell **(exocytosis)**. Vesicular transport requires energy, usually in the form of ATP, and all forms of vesicular transport involve protein-coated vesicles to some extent.

There are three types of endocytosis: phagocytosis, pinocytosis, and receptor-mediated endocytosis. In **phagocytosis** ("cell eating"), the cell engulfs some relatively large or solid material such as a clump of bacteria, cell debris, or inanimate particles (**Figure 5.4a**, p. 62). When a particle binds to receptors on the cell's surface, cytoplasmic extensions called pseudopods form and flow around the particle. This produces a vesicle called a *phagosome*. In most cases, the phagosome then fuses with a lysosome and its contents are digested. Indigestible contents are ejected from the cell by exocytosis. In the human body, only macrophages and certain other white blood cells perform phagocytosis. These cells help protect the body from disease-causing microorganisms and cancer cells.

In **pinocytosis** ("cell drinking"), also called **fluid-phase endocytosis,** the cell "gulps" a drop of extracellular fluid containing dissolved molecules (Figure 5.4b). Since no receptors are involved, the process is nonspecific. Unlike phagocytosis, pinocytosis is a routine activity of most cells, allowing them a way of sampling the extracellular fluid. It is particularly important in cells that absorb nutrients, such as cells that line the intestines.

The main mechanism for *specific* endocytosis of most macromolecules is **receptor-mediated endocytosis** (Figure 5.4c). The receptors for this process are plasma membrane proteins that bind only certain substances. This exquisitely selective mechanism allows cells to concentrate material that is present only in small amounts in the extracellular fluid. The ingested vesicle may fuse with a lysosome that either digests or releases its contents, or it may be transported across the cell to release its contents by exocytosis. The latter case is common in endothelial cells lining blood vessels because it provides a quick means to get substances from blood to extracellular fluid. Substances taken up by receptor-mediated endocytosis include enzymes, insulin and some other hormones, cholesterol (attached to a transport protein), and iron.



(a) Phagocytosis (b) Pinocytosis (c) Receptor-mediated endocytosis

Figure 5.4 Three types of endocytosis. (a) In phagocytosis, cellular extensions flow around the external particle and enclose it within a phagosome. **(b)** In pinocytosis, fluid and dissolved solutes enter the cell in a tiny vesicle. **(c)** In receptor-mediated endocytosis, specific substances attach to cell-surface receptors and enter the cell in protein-coated vesicles.

Exocytosis is a vesicular transport process that ejects substances from the cell into the extracellular fluid. The substance to be removed from the cell is first enclosed in a protein-coated vesicle called a **secretory vesicle.** In most cases the vesicle migrates to the plasma membrane, fuses with it, and then ruptures, spilling its contents out of the cell. Exocytosis is used for hormone secretion, neurotransmitter release, mucus secretion, and ejection of wastes.

Activity 7

Observing Phagocytosis

Go to the video viewing area and watch the video demonstration of phagocytosis (if available).

Note: *If you have not already done so, complete Activity 2 (Observing Diffusion of Dye Through Water, p. 56), and Activity 4 (Observing Osmometer Results, p. 58).*

Group Challenge

Comparing and Contrasting Membrane Transport Processes

Work in groups of three to discuss the characteristics of each membrane transport process listed in the Group Challenge chart below. On a separate piece of paper, one student will record the characteristics of each transport process. The group will then consider each pair of processes listed in the chart, discuss their similarities and differences, and complete the chart based on consensus answers.

Group Challenge: Membrane Transport Comparison

Membrane transport processes	Similarities	Differences
Simple diffusion Osmosis		
Simple diffusion Facilitated diffusion		
Active transport Facilitated diffusion		
Filtration Osmosis		
Pinocytosis Receptor-mediated endocytosis		

EXERCISE 5

REVIEW SHEET

The Cell: Transport Mechanisms and Permeability

Name _____ Lab Time/Date _____

Choose all answers that apply to questions 1 and 2, and place their letters on the response blanks to the right.

1. Molecular motion _____
   a. reflects the kinetic energy of molecules
   b. reflects the potential energy of molecules
   c. is ordered and predictable
   d. is random and erratic

2. Speed of molecular movement _____.
   a. is higher in larger molecules
   b. is lower in larger molecules
   c. increases with increasing temperature
   d. decreases with increasing temperature
   e. reflects kinetic energy

3. Summarize below the results of Activity 3, Investigating Diffusion and Osmosis Through Nonliving Membranes. List and explain your observations relative to tests used to identify diffusing substances, and the changes in sac weight you observed.

   Sac 1 containing 40% glucose, suspended in distilled water

   _____

   _____

   Sac 2 containing 40% glucose, suspended in 40% glucose

   _____

   _____

   Sac 3 containing 10% NaCl, suspended in distilled water

   _____

   _____

   Sac 4 containing 40% sucrose and Congo red dye, suspended in distilled water

   _____

   _____

4. What single characteristic of the selectively permeable membranes *used in the laboratory* determines the substances that can pass through them? _____

   In addition to this characteristic, what other factors influence the passage of substances through living membranes?

_____

_____

5. A semipermeable sac filled with a solution containing 4% NaCl, 9% glucose, and 10% albumin is suspended in a solution with the following composition: 10% NaCl, 10% glucose, and 40% albumin. Assume that the sac is permeable to all substances except albumin. State whether each of the following will (a) move into the sac, (b) move out of the sac, or (c) not move.

glucose: _____ albumin: _____

water: _____ NaCl: _____

6. Summarize below the results of Activity 5, Experiment 1 (Investigating Diffusion and Osmosis Through Living Membranes—the egg). List and explain your observations.

Egg 1 in distilled water: _____

_____

_____

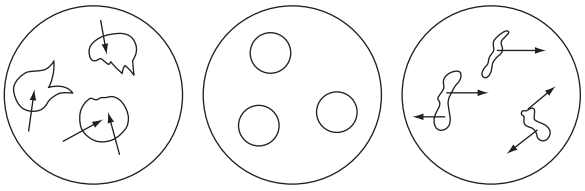
Egg 2 in 30% sucrose: _____

_____

_____

7. The diagrams below represent three microscope fields containing red blood cells. Arrows show the direction of net osmosis. Which field contains a hypertonic solution? _____ The cells in this field are said to be _____. Which field contains an isotonic bathing solution? _____ Which field contains a hypotonic solution? _____ What is happening to the cells in this field? _____

_____



(a) (b) (c)

WHY THIS MATTERS

8. Many classroom protocols for extracting DNA from cheek cells instruct students to swish a sports drink in their mouths as they gently scrape the inside of the cheek with the teeth. Why would it be better to use a sports drink than plain water? (*Hint*: You want DNA from the cheek cells to end up in the test tube, not in your mouth.)

_____

_____

9. Drinking too much plain water in a short period of time can result in water intoxication. As a result, blood plasma will become hypotonic. What effect do you think this would have on cells, and why?

_____

_____

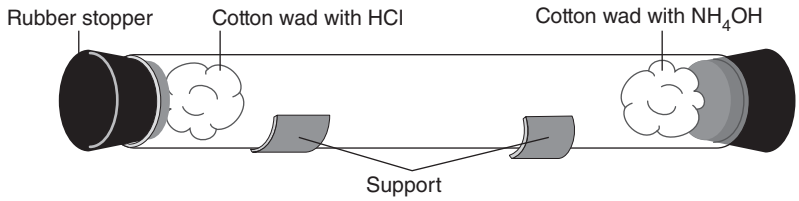
10. Assume you are conducting the experiment illustrated in the next figure. Both hydrochloric acid (HCl), with a molecular weight of about 36.5, and ammonium hydroxide (NH_4OH), with a molecular weight of 35, are volatile and easily enter the gaseous state. When they meet, the following reaction will occur:

$$HCl + NH_4OH \rightarrow H_2O + NH_4Cl$$

Ammonium chloride (NH_4Cl) will be deposited on the glass tubing as a smoky precipitate where the two gases meet. Predict which gas will diffuse more quickly, and indicate to which end of the tube the smoky precipitate will be closer.

a. The faster-diffusing gas is _____.

b. The precipitate forms closer to the _____ end.



11. What determines whether a transport process is active or passive?

_____

12. Characterize membrane transport as fully as possible by choosing all the phrases that apply and inserting their letters on the answer blanks.

Passive processes: _____ Active processes: _____

a. account for the movement of fats and respiratory gases through the plasma membrane
b. explain phagocytosis and pinocytosis
c. include osmosis, simple diffusion, and filtration
d. may occur against concentration and/or electrical gradients
e. use hydrostatic pressure or molecular energy as the driving force
f. move ions, amino acids, and some sugars across the plasma membrane

13. For the osmometer demonstration (Activity 4), explain why the level of the water column rose during the laboratory session.

_____

_____

14. Define the following terms.

selective permeability: _____

_____

diffusion: _____

_____

simple diffusion: _____

_____

facilitated diffusion: _____

_____

osmosis: _____

_____

filtration: _____

_____

vesicular transport: _____

_____

endocytosis: _____

_____

exocytosis: _____

_____