The Working Cell

5

You can read these words because enzymes and membranes enable your cells to use energy. The light energy that bounces off the page enters your eyes and stimulates pigments held in special cell membranes. Enzymes make these pigments and convert them to a form that can absorb light. The eye cells can transmit signals through nerve cells to the brain because the membranes of these cells can selectively absorb and pump out charged particles. The energy for moving these particles comes from processes that make ATP. These processes take place through the action of enzymes on and between cell membranes. Every biological activity—not just reading, but walking, laughing, and thinking—depends on energy produced by processes that involve enzymes and membranes. Energy, enzymes, and membranes are the subjects discussed in this chapter.

Organizing Your Knowledge

Exercise 1 (Modules 5.1 – 5.5)

Web/CD Activity 5A *Energy Transformations*
Web/CD Activity 5B *Chemical Reactions and ATP*
Web/CD Activity 5C *The Structure of ATP*

After reading Modules 5.1–5.5, review energy, chemical reactions, and the function of enzymes by filling in the blanks in the following story.

If you were to stop eating, you would probably starve to death in weeks or months. If you were unable to breathe, you would die in minutes. Organisms need the energy that is released when food and oxygen combine. This energy is used not only to move the body but also to keep it from falling apart.

Energy is the ability to perform 1 ________________. The sun is the source of the energy that sustains living things. Sunlight is pure 2 ________________ energy, energy of movement that is actually doing work. In the process of photosynthesis, plants are able to use the energy of sunlight to produce food molecules. This process obeys the laws of 3 ________________, the principles that govern energy transformations. Plants do not make the energy in food. According to the 4 ________________ law of thermodynamics, energy can be 5 ________________ or transferred, but it cannot be created or destroyed. In photosynthesis, no energy is created. Rather, the plant transforms the energy of sunlight into stored energy, called 6 ________________ energy, stored in molecules of glucose.

No energy change is 100% efficient, and the changes that occur in photosynthesis are no exception to this rule. Some of the energy of sunlight is not stored in glucose, but rather is converted to 7 ________________, which is random molecular motion. The

[8]_____________ law of thermodynamics says that energy changes are always accompanied by an increase in [9]_________________, a measure of disorder. One of the reasons living things need a constant supply of energy is to counter this natural tendency toward disorder.

The products of photosynthesis contain [10]________________ potential energy than the reactants. This means that, overall, photosynthesis is an [11]________________ reaction. Such a reaction consumes energy, which in photosynthesis is supplied by the sun.

Photosynthesis produces food molecules, such as glucose, which store energy. An animal might obtain this food by eating a plant or an animal that has eaten a plant. The food molecules enter the animal's cells, where their potential energy is released in the process of cellular respiration. The products of this chemical reaction (actually a series of reactions) contain less potential energy than the reactants. Therefore, cellular respiration is an [12]_______________ process; it [13]_______________ energy. In fact, this is the same overall change that occurs when glucose in a piece of wood or paper burns in air. When paper burns, the energy escapes as the heat and light of the flames. In a cell, the reaction occurs in a more controlled way, and some of the energy is captured for use by the cell.

Energy released by the exergonic "burning" of glucose in cellular respiration is used to make a substance called [14]_________________. A molecule of [15]_____________ and a [16]_________________ group are joined to form each molecule of ATP. This is an endergonic reaction, because it takes energy to assemble ATP. The covalent bond connecting the phosphate group to the rest of the ATP molecule is unstable and easily broken. This arrangement of atoms stores [17]_________________ energy. The [18]_________________ of ATP is an exergonic reaction. When ATP undergoes hydrolysis, a [19]_________________ is removed, ATP becomes [20]_________________, and energy is released. Thus, ATP is a kind of energy "currency" that can be used to perform cellular [21]_________________. Most cellular activities depend on ATP energizing other molecules by transferring its phosphate group to them—a process called [22]_________________. It should be noted that energy is not destroyed when ATP is used to do work. When an ATP molecule is hydrolyzed to make muscles move, some of its energy moves the body, and some ends up as random molecular motion, or [23]_________________.

A less obvious but important function of ATP is supplying the energy for fighting the natural tendency for a system to become disordered. A cell constantly needs to manufacture molecules to replace ones that are used up or damaged. Building a large molecule from smaller parts is an [24]_________________ reaction. Energy released by the exergonic hydrolysis of ATP is used to drive essential endergonic reactions. The linking of exergonic and endergonic processes is called energy [25]_________________, and ATP is the critical connection between the processes that release energy and those that consume it.

What prevents a molecule of ATP from breaking down until its energy is needed? Molecules can break down spontaneously; that is why ATP energy is needed to repair them. Fortunately for living things, it takes some additional energy, called energy of [26]__________, to get a chemical reaction started. This creates an energy [27]_________________ that prevents molecules from breaking down spontaneously. Energy barriers exist for both exergonic and endergonic reactions. Most of the time, most molecules in a cell lack the extra energy needed to clear the barrier, so chemical reactions occur slowly, if at all.

So what enables the vital reactions of metabolism to occur when and where they are needed, at a rate sufficient to sustain life? This is where enzymes come in. An enzyme is a special [28]_______________ molecule that acts as a biological [29]_______________. It [30]_______________ the rate of a chemical reaction without being [31]_______________ by it. An enzyme holds reactants in such a way as to [32]_______________ the energy barrier that prevents them from reacting. Even though reactants would not normally possess the activation energy needed to start the reaction, the enzyme creates conditions that make the reaction possible. Enzymes enable the cell to carry out vital chemical changes when and where they are needed, enabling it to control the many chemical reactions that make up cellular [33]_______________.

Exercise 2 (Modules 5.1 – 5.5)

Web/CD Activity 5A *Energy Transformations*
Web/CD Activity 5B *Chemical Reactions and ATP*
Web/CD Activity 5C *The Structure of ATP*

Briefly summarize the differences between the words or phrases in each of the following pairs.

1. Kinetic energy and potential energy

2. Exergonic reactions and endergonic reactions

3. Reactants and products

4. ATP and ADP

5. A reaction without an enzyme and a reaction with an enzyme

6. Photosynthesis and cellular respiration

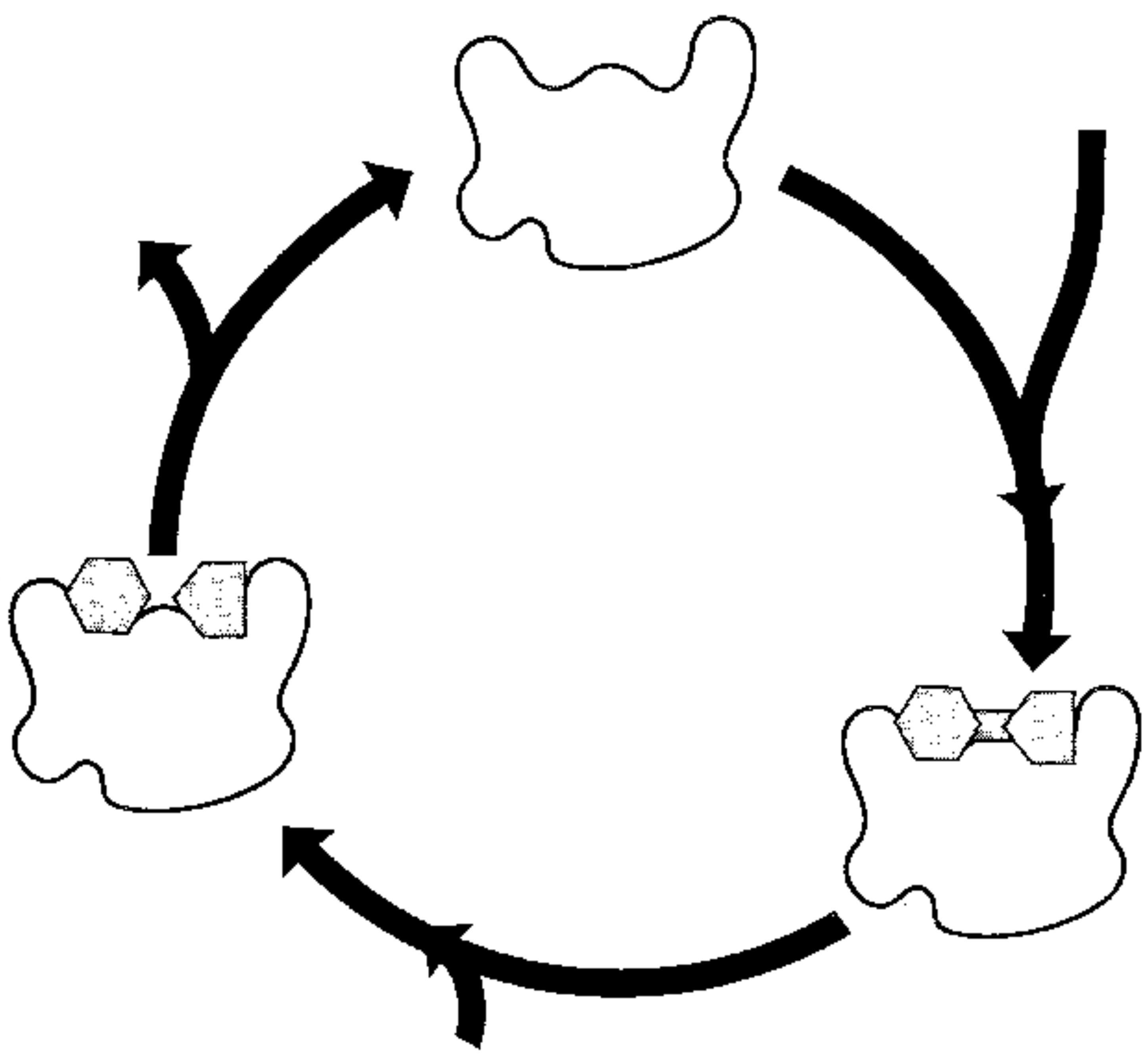
7. First and second laws of thermodynamics

Exercise 3 (Modules 5.6 – 5.9)

Web/CD Activity 5D *How Enzymes Work*

Review enzyme action by completing the activities below.

1. Complete the diagram below so that it shows the cycle of enzyme activity. Imagine that the reaction carried out by this enzyme is splitting a substrate molecule into two parts. Color the diagram as suggested, and label the items in **boldface** type. Color the **enzyme** purple. Sketch the **substrate** as a dark pink shape. Sketch the **products,** and color them light pink. Also label the **active site.**



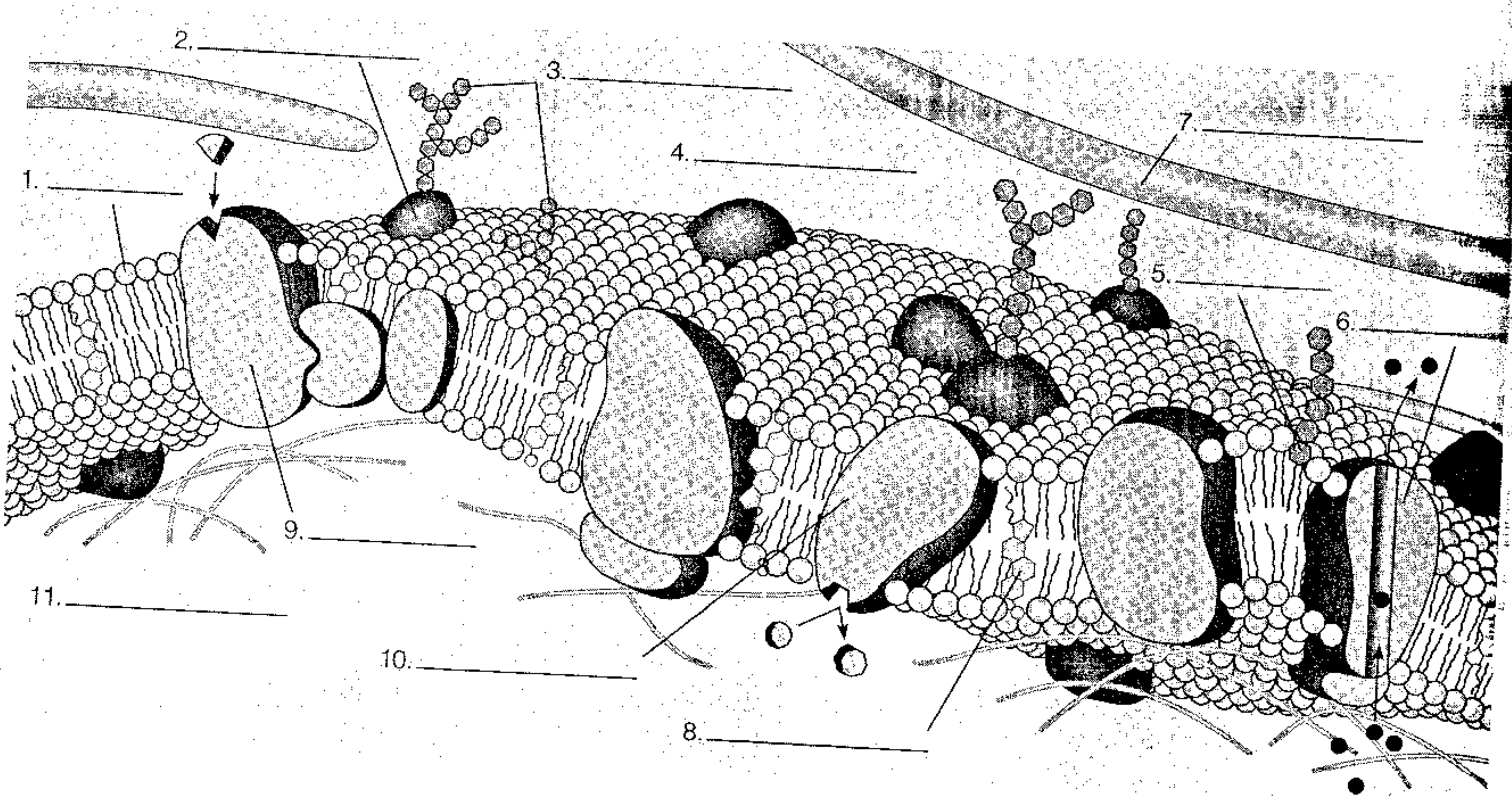
2. Make a sketch showing how heat or change in pH might change the above enzyme and alter its ability to catalyze its chemical reaction. Color and label the **enzyme,** its **active site,** and its **substrate,** as above.

3. On the left side of the space below, make a sketch showing how a competitive inhibitor might interfere with activity of the enzyme. Label the **competitive inhibitor,** and color it orange. On the right side, make a sketch showing how a noncompetitive inhibitor might interfere with activity of the enzyme. Label the **noncompetitive inhibitor,** and color it red.

Exercise 4 (Modules 5.10 – 5.13)

Web/CD Activity 5E *Membrane Structure*
Web/CD Activity 5F *Signal Transduction*
Web/CD Activity 5G *Selective Permeability of Membranes*

Review fluid mosaic membrane structure by coloring and labeling this diagram. It is a composite based on the figures in Modules 5.12 and 5.13. Label the items in **boldface** type: Start with the **cytoplasm, extracellular fluid,** and a **fiber of the extra cellular matrix.** In the membrane, color **phospholipids** gray, protein molecules purple, **carbohydrate I.D. tags** on **glycoprotein** and **glycolipid** molecules green, and **cholesterol** molecules yellow. Also show the functions of certain proteins by labeling them **enzyme, receptor protein,** and **transport protein.**



Exercise 5 (Modules 5.14 – 5.20)

Web/CD Activity 5H *Diffusion*
Web/CD Activity 5I *Osmosis and Water Balance in Cells*
Web/CD Activity 5J *Facilitated Diffusion*
Web/CD Activity 5K *Active Transport*
Web/CD Activity 5L *Exocytosis and Endocytosis*

Review diffusion and the function of cell membranes by matching each of the phrases on the right with the appropriate mechanisms from the list on the left. Two questions require more than one answer.

A. Diffusion
B. Active transport
C. Osmosis
D. Phagocytosis
E. Passive transport
F. Facilitated diffusion
G. Pinocytosis
H. Receptor-mediated endocytosis
I. Exocytosis

_______ 1. Diffusion across a biological membrane
_______ 2. Moves solutes against concentration gradient
_______ 3. Any spread of molecules from area of higher concentration to area of lower concentration
_______ 4. Diffusion with help of transport protein
_______ 5. Three types of endocytosis
_______ 6. Engulfing of fluid in membrane vesicles
_______ 7. Diffusion of water across selectively permeable membrane, from hypotonic to hypertonic solution
_______ 8. Transport molecules need ATP to function
_______ 9. Enables cell to engulf bulk quantities of specific large molecules
_______10. How oxygen and carbon dioxide enter and leave cells
_______11. Two types of passive transport
_______12. Engulfing of particle in membrane vesicle
_______13. Fusion of membrane-bound vesicle with membrane, and dumping of contents outside cell
_______14. How a cell might capture a bacterium

Exercise 6 (Modules 5.15 – 5.16)

Web/CD Activity 5I *Osmosis and Water Balance in Cells*

Osmosis is an important process that has many effects on living things. Test your understanding of osmosis by predicting in each of the following cases whether water will enter the cell (*In*) or leave the cell (*Out*), or whether there will be no net movement of water (*None*). Assume that the plasma membrane is permeable to water but not solutes.

_______ 1. Cell is exposed to hypertonic solution.
_______ 2. Cell is placed in salt solution whose concentration is greater than cell contents.
_______ 3. Due to disease, solute concentration of body fluid outside cell is less than solute concentration of cells.
_______ 4. Cell is in isotonic solution.
_______ 5. Single-celled organism is placed in drop of pure water for examination under microscope.
_______ 6. Cell is immersed in solution of sucrose and glucose whose individual concentrations are less than concentration of solutes in cytoplasm, but whose combined concentration is greater than concentration of solutes in cytoplasm.
_______ 7. Solute concentration of cell is greater than solute concentration of surrounding fluid.
_______ 8. Cell is exposed to hypotonic solution.
_______ 9. Concentration of solutes in cytoplasm is equal to solute concentration of extracellular fluid.
_______10. Cytoplasm more dilute than surrounding solution.

Exercise 7 (Modules 5.10 – 5.20)

Web/CD Activity 5E *Membrane Structure*
Web/CD Activity 5F *Signal Transduction*
Web/CD Activity 5G *Selective Permeability of Membranes*
Web/CD Activity 5H *Diffusion*
Web/CD Activity 5I *Osmosis and Water Balance in Cells*
Web/CD Activity 5J *Facilitated Diffusion*
Web/CD Activity 5K *Active Transport*
Web/CD Activity 5L *Exocytosis and Endocytosis*

Try to picture membranes and their functions close up by completing the following story.

Your first mission as a Bionaut requires you to enter a blood vessel and observe the structure and functions of cell membranes. You step into the water-filled chamber of the Microtron, which quickly shrinks you to a size much smaller than a red blood cell.

You tumble through the tunnel-like needle and into a blood vessel in the arm of a volunteer. Huge, rubbery red blood cells slowly glide past. Floating in the clear, yellowish blood plasma, you switch on your headlamp and examine the epithelial cells of the vessel wall. Their plasma membranes seem made of millions of small balloons. These are the polar "heads" of the 1 ________________ molecules that make up most of the membrane surface. Through the transparent surface, you can see their flexible, 2 ________________ tails projecting inward toward the interior of the membrane, and beyond them an inner layer of 3 ________________ molecules with their tails pointing toward you. Here and there there are globular 4 ________________ molecules embedded in the membrane; some rest lightly on the surface, but most project all the way into the interior of the cell. The membrane is indeed a 5 ________________ mosaic; the proteins are embedded like the pieces of a picture, but you can see that they are free to move around. You push on one of the proteins, and it bobs like an iceberg. Some of the phospholipids and proteins have chains of sugar molecules attached to them, forming 6 ________________ and 7 ________________. These are the molecules that act as cell 8 ________________ tags. You notice that one of the proteins has a dimple in its surface. Just then a small, round molecule floating in the plasma nestles in the dimple. The molecule is a hormone, a chemical signal, and the dimpled protein is the 9 ________________ that enables the cell to respond to it.

In your light beam, you can see the sparkle and shimmer of many molecules, large and small, in the blood and passing through the cell membrane. Oxygen is moving from the plasma, where it is more concentrated, to the cell interior, where it is less concentrated. This movement is 10 ________________; when it occurs through a biological membrane, it is called 11 ________________ transport. Similarly, carbon dioxide is flowing out of the cell, down its 12 ________________ gradient, from the cell interior, where it is 13 ________________ concentrated, to the blood, where it is 14 ________________ concentrated.

You note that water molecules are passing through the membrane equally in both directions. The total concentration of solutes in the cell and in the blood must be equal; the solutions must be [15]________________. You signal the control team to inject a small amount of concentrated salt solution into the blood, making the blood slightly [16]________________ relative to the cell contents. This causes water to flow [17]________________ the cell, until the two solutions are again in equilibrium. This diffusion of water through a [18]________________ permeable membrane is called [19]________________.

Some sugar molecules floating in the blood are simply too large to pass easily through gaps in the membrane like the much smaller water molecules can. The sugar molecules simply bounce off, unless they happen to pass through pores in special [20]________________ proteins. This is a type of passive transport, because the molecules move down a concentration gradient without the expenditure of [21]________________. Because transport proteins help out, it is called [22]________________ diffusion.

Your chemscanner detects a high concentration of potassium ions inside the cell. Transport proteins here and there in the membrane are able to move potassium into the cell against the concentration gradient. This must be [23]________________ transport; the cell expends [24]________________ to provide energy to "pump" the potassium into the cell.

Suddenly there is a tug at your foot. You look down to see your flipper engulfed by a rippling membrane. A white blood cell the size of a building quickly pins you against the vessel wall. The phospholipids of its membrane are pressed against your face mask. The cell is engulfing you, protecting the body from a foreign invader! Taking in a substance in this way is called [25]________________, more specifically [26]____________, if the substance is a solid particle. Suddenly the pressure diminishes, and you are inside the white blood cell, floating free in a membrane-enclosed bag, or [27]________________. Another sac is approaching; it is a [28]________________, full of digestive enzymes. You manage to get your legs outside of the vacuole and move it back toward the inner surface of the cell membrane. As the vacuole fuses with the membrane, you tear your feet free and swim away from the voracious cell, realizing that [29]________________ expelled you almost as fast as endocytosis trapped you!

You swim to the exit point, and the control team removes you by syringe. This is quite enough adventure for one day.