Chapter 3

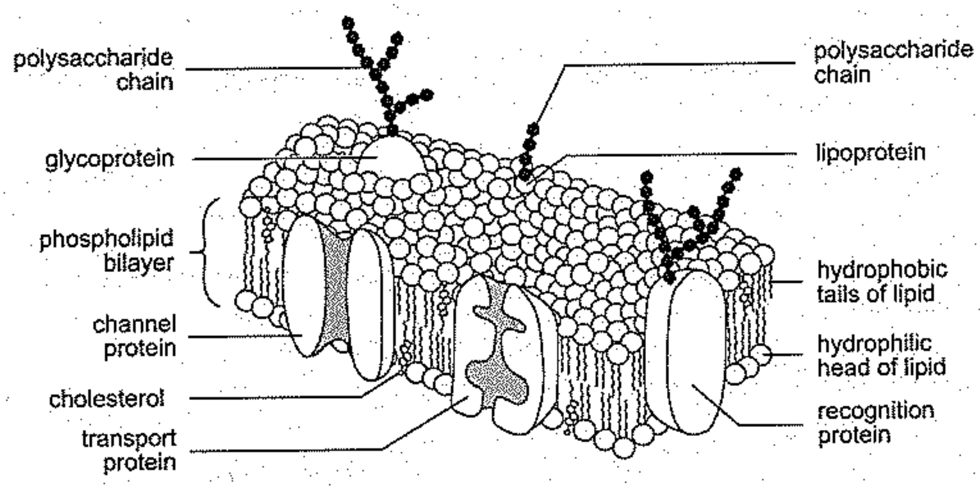
Cell Structure and Function

Review

Structure and Function of the Cell

The **cell** is the basic functional unit of all living things. The **plasma membrane (cell membrane)** bounds the cell and encloses the **nucleus** and **cytoplasm**. The **cytoplasm** consists of specialized bodies called **organelles** suspended in a fluid matrix, the **cytosol**, which consists of water and dissolved substances such as proteins and nutrients.

The **plasma membrane** separates internal metabolic events from the external environment and controls the movement of materials into and out of the cell. The plasma membrane is a **double phospholipid membrane** (phospholipid **bilayer**) with the polar hydrophilic heads forming the two outer faces and the nonpolar hydrophobic tails pointing toward the inside of the membrane (Figure 3-1).



The Plasma Membrane

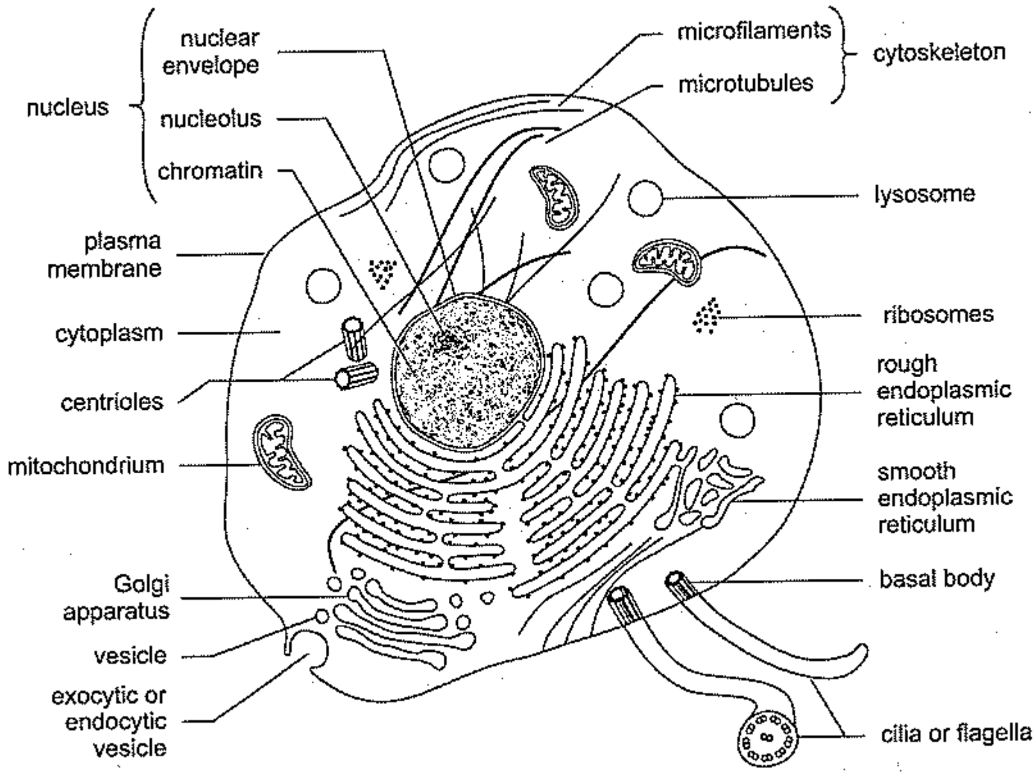
Figure 3-1

Proteins are scattered throughout the flexible phospholipid membrane. Proteins may attach loosely to the inner or outer surface of the membrane, or they may extend into the membrane. Similar to how phospholipids are oriented, proteins may span across the membrane with their hydrophobic regions embedded in the membrane and their hydrophilic regions exposed to the aqueous solutions bordering the membrane. The molecules that comprise the membrane are not fixed in a permanent pattern but move within the membrane. This mosaic nature of scattered proteins within a flexible matrix of phospholipid molecules describes the **fluid mosaic model** of the cell membrane. Variations in the fatty acid makeup of the phospholipids influence the fluidity of the membrane. Phospholipids with saturated fatty acids pack more tightly, leading to a more rigid membrane. In contrast, unsaturated fatty acids, which bend at their double-covalent bonds, limit packing and result in a more flexible membrane. Additional features of the plasma membrane follow:

1. The **phospholipid** membrane is selectively permeable. Only small, uncharged, polar molecules (such as H_2O) and hydrophobic molecules (nonpolar molecules like O_2, CO_2, and lipid-soluble molecules such as hydrocarbons) freely pass across the membrane. In contrast, large polar molecules (such as glucose) and all ions are impermeable.
   - **Glycolipids** are lipids to which a short polysaccharide chain is attached. The polysaccharide chain extends away from the outer surface of the membrane into the external environment. Glycolipids help establish cell identity—they help identify the cell as a *self* cell rather than a foreign cell or a virus-infected cell. There is no phosphate group in a glycolipid.
2. **Proteins** in the plasma membrane provide a wide range of functions and include the following:
   - **Channel proteins** provide open passageways through the membrane for certain hydrophilic (water-soluble) substances such as polar and charged molecules. **Aquaporins** are channel proteins of certain cells (such as those found in kidneys and plant roots) that dramatically increase the passage rate of H_2O molecules.
   - **Ion channels** allow the passage of ions across the membrane. In nerve and muscle cells, ion channels called **gated channels** open and close in response to specific chemical or electrical stimuli to allow the passage of specific ions (such as Na^+ and K^+).
   - **Carrier proteins** bind to specific molecules, which are then transferred across the membrane after the carrier protein undergoes a change of shape. The passage of glucose into a cell is by a carrier protein.
   - **Transport proteins** use energy (in the form of ATP, adenosine triphosphate) to transport materials across the membrane. When energy is used for this purpose, the materials are said to be actively transported, and the process is called **active transport.** The **sodium-potassium pump,** for example, uses ATP to maintain higher concentrations of Na^+ and K^+ on opposite sides of the plasma membrane.
   - **Recognition proteins,** like glycolipids, give each cell type a unique identification. This identification provides for a distinction between cell types, between *self* cells and foreign cells, and between normal cells and cells infected with viruses. Recognition proteins are actually **glycoproteins,** proteins with short polysaccharide chains that extend away from the outer surface of the membrane. The differences between blood types, for example, are the result of recognition proteins on the surface of red blood cells.
   - **Receptor proteins** provide binding sites for hormones or other trigger molecules. In response to the hormone or trigger molecule, a specific cell response is activated.
   - **Adhesion proteins** attach cells to neighboring cells or provide anchors for the internal filaments and tubules that give stability to the cell.
3. **Cholesterol** molecules distributed throughout the phospholipid bilayer provide some stability to the plasma membranes of *animal cells.* At higher temperatures, cholesterol helps maintain firmness, but at lower temperatures, it helps keep the membrane flexible.

Organelles are bodies within the cytoplasm that serve to physically separate the various metabolic reactions that occur within eukaryotic cells. Within these bodies, chemical reactions are isolated and can take place without interference or competition with other reactions that might be occurring nearby. Many of these bodies also provide large surface areas to maximize the space over which these chemical reactions can take place. Also, cells can be specialized for specific functions depending on the kinds and number of organelles in that cell. Descriptions of the important organelles, as well as other structures in the cell, follow (Figure 3-2):

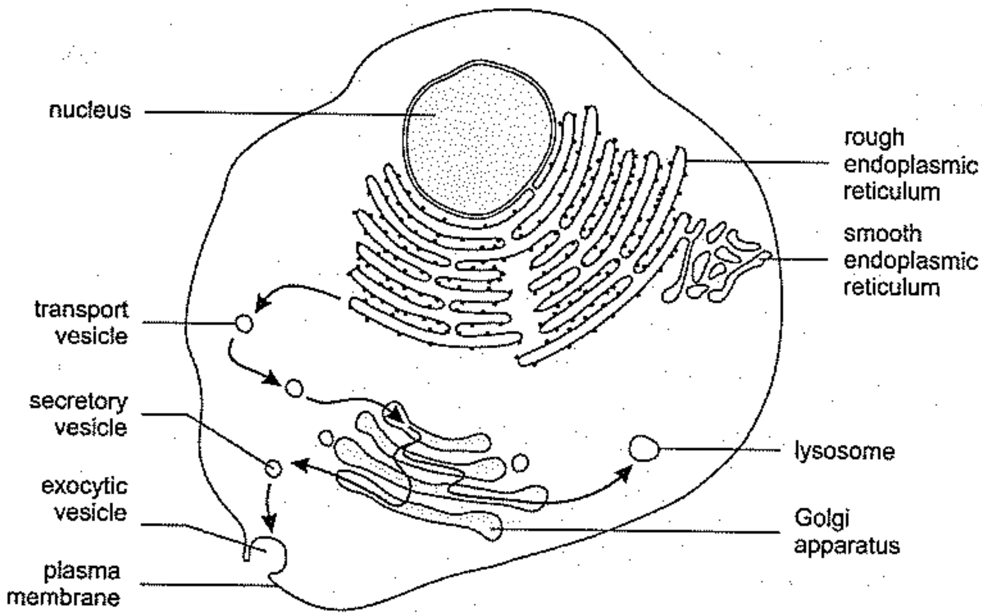
1. The **nucleus** is bounded by the **nuclear envelope** consisting of *two* phospholipid bilayers, each similar to the plasma membrane. The nucleus contains DNA (deoxyribonucleic acid), the hereditary information of the cell. Normally, the DNA is spread out within the nucleus as a thread-like matrix called **chromatin.** When the cell begins to divide, the chromatin condenses into rod-shaped bodies called **chromosomes,** each of which, before dividing, is made up of two long DNA molecules and various histone (protein) molecules. The histones serve to organize the lengthy DNA, coiling it into bundles called **nucleosomes.** Also visible within the nucleus are one or more **nucleoli,** concentrations of DNA in the process of manufacturing the components of **ribosomes.** The nucleus also serves as the site for the separation of chromosomes during cell division. On the surface of the nuclear envelope are **nuclear pores,** which serve as passageways for proteins and RNA molecules.



An Animal Cell

Figure 3-2

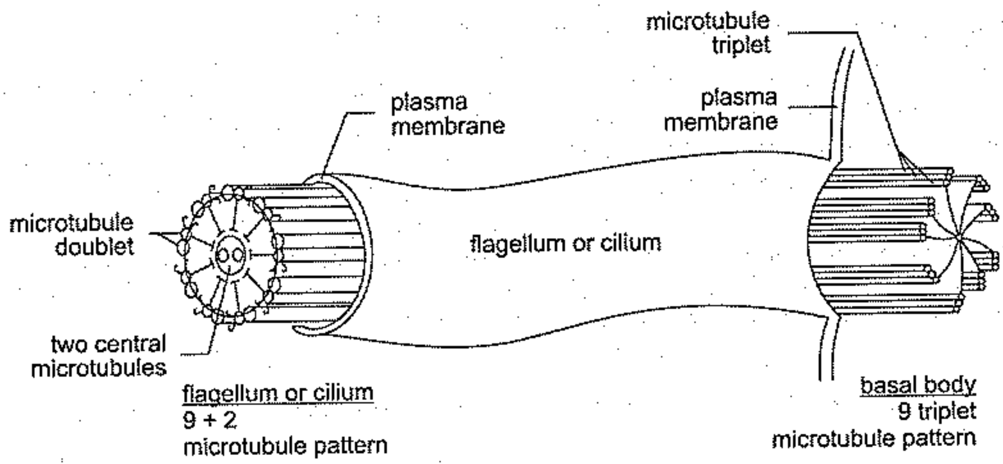
2. **Ribosome** subunits are manufactured in the nucleus and consist of RNA molecules and proteins. The two subunits, labeled 60S and 40S, move across the nuclear envelope through nuclear pores and into the cytoplasm, where they are assembled into a single 80S ribosome. (An S value expresses how readily a product forms sediment in a centrifuge, with larger values representing larger and heavier products.) In the cytoplasm, ribosomes assist in the assembly of amino acids into proteins.
3. The **endoplasmic reticulum,** or **ER,** consists of stacks of flattened sacs that begin as an extension of the outer bilayer of the nuclear envelope. In cross section, the ER appears as a series of maze-like channels, closely associated with the nucleus. When ribosomes are present, the ER (called **rough ER**) creates **glycoproteins** by attaching polysaccharide groups to polypeptides as they are assembled by the ribosomes. **Smooth ER,** without ribosomes, is responsible for various activities, including the synthesis of lipids and steroid hormones, especially in cells that produce these substances for export from the cell. In liver cells, smooth ER is involved in the breakdown of toxins, drugs, and toxic by-products from cellular reactions.
4. A **Golgi apparatus (Golgi body, Golgi complex)** is a group of flattened sacs **(cisternae)** arranged like a stack of bowls. They collect and modify proteins and lipids made in other areas of the cell and package them into **vesicles,** small, spherically shaped sacs that bud from the outside surface of the Golgi apparatus. For example, a glycoprotein made and packaged into a vesicle by the ER may be transported to the Golgi apparatus, where it is modified as it passes through its chambers (Figure 3-3). At the outer side of the Golgi apparatus, the modified protein can be packaged into a secretory vesicle, which migrates to and merges with the plasma membrane, releasing its contents to the outside of the cell. Other packaged substances may be retained within the cell for other purposes.



Transport and Modification of Cellular Substances

Figure 3-3

5. **Lysosomes** are vesicles from a Golgi apparatus that contain hydrolytic enzymes (enzymes that break down molecules by hydrolysis) (Figure 3-3). They break down food, cellular debris, and foreign invaders (such as bacteria) and generally contribute to a recycling of cellular nutrients. A low pH (acidic), favorable to the activity of the enzymes, is maintained inside the lysosome. As a result, any enzyme that might escape from the lysosome remains inactive in the neutral pH of the cytosol.
6. **Mitochondria** carry out aerobic respiration, a process in which energy (in the form of ATP) is obtained from carbohydrates, fats, and occasionally proteins. Mitochondria have two bilayer membranes, allowing the separation of metabolic processes that occur inside the inner membrane from those occurring in the intermembrane space.
7. **Chloroplasts** carry out **photosynthesis,** the plant process of incorporating energy from sunlight into carbohydrates. Chloroplasts, like mitochondria, also have two membranes.
8. **Microtubules, intermediate filaments,** and **microfilaments** are three protein fibers of decreasing diameter, respectively. All are involved in establishing the shape of or in coordinating movements of the **cytoskeleton,** the internal structure of the cytoplasm.
   - **Microtubules** are made of the protein **tubulin** and provide support and motility for cellular activities. They are found in the **spindle apparatus,** which guides the movement of chromosomes during cell division, and in flagella and cilia (described in item 10), structures that project from the plasma membrane to provide motility to the cell.
   - **Intermediate filaments** provide support for maintaining the shape of the cell.
   - **Microfilaments (actin filaments)** are made of the protein **actin** and are involved in cell motility. They are found in muscle cells and in cells that move by changing shape, such as phagocytes (white blood cells that wander throughout the body, attacking bacteria and other foreign invaders). In plants, microfilaments promote the movement of cytoplasmic materials around the cell **(cytoplasmic streaming).**
9. **Flagella** and **cilia** are structures that protrude from the cell membrane and make wave-like movements. Flagella and cilia are classified by their lengths, by their numbers per cell, and by their movement: Flagella are long, few, and move in a snake-like motion; cilia are short, many, and move with a back-and-forth, serpentine movement. A single flagellum propels sperm, while the numerous cilia that line the respiratory tract sweep away debris. Structurally, both flagella and cilia consist of microtubules arranged in a "9 + 2" array—nine pairs (doublets) of microtubules arranged in a circle surrounding a pair of microtubules (Figure 3-4).



Flagella, Cilia, and Basal Bodies

Figure 3-4

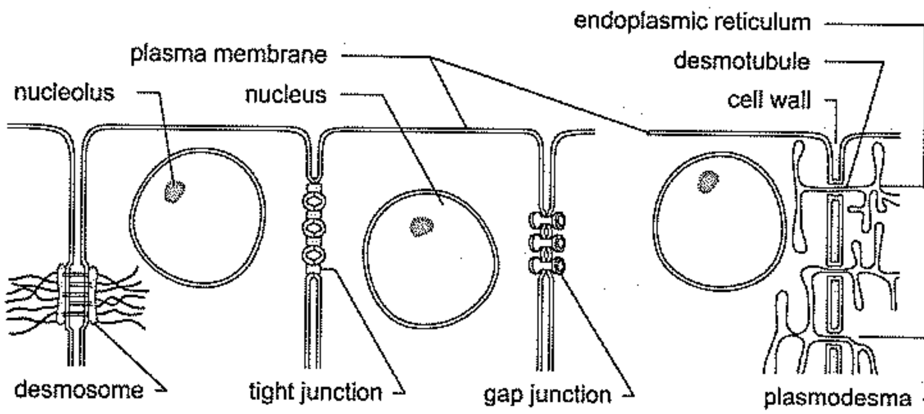
10. **Centrioles** and **basal bodies** act as **microtubule organizing centers (MTOCs).** A pair of centrioles (enclosed in a **centrosome**) located outside the nuclear envelope gives rise to the microtubules that make up the spindle apparatus used during cell division. Basal bodies organize the development of flagella and cilia and anchor them to the cell surface. Both centrioles and basal bodies are made up of nine triplets of microtubules arranged in a circle (Figure 3-4). Plant cells lack centrioles and only *lower* plants (such as mosses and ferns) with motile sperm have flagella and basal bodies.

11. **Vacuoles** and **vesicles** are fluid-filled, membrane-bound bodies.
    - **Transport vesicles** move materials between organelles.
    - **Secretory vesicles** move materials from the Golgi apparatus to the plasma membrane.
    - **Food vacuoles** are temporary receptacles of nutrients. Food vacuoles often merge with lysosomes, whose digestive enzymes break down the food.
    - **Contractile vacuoles** are specialized organelles in single-celled organisms that collect and pump excess water out of the cell.
    - **Central vacuoles** are large bodies occupying most of the interior of many plant cells. When fully filled, they exert **turgor,** or pressure, on the cell walls, thus maintaining rigidity in the cell. The central vacuole provides other functions as well, some of which specialize the cell for specific functions. These include the following:
        - It may store starch, nutrients, pigments, cellular waste, or toxins (nicotine, for example).
        - It may carry out functions such as digestion that are otherwise assumed by lysosomes in animal cells.
        - It provides cell "growth" by simply absorbing water to allow expansion of the cell. In contrast, animal cells require nutrients to build macromolecules to generate growth.
        - It renders a large surface area-to-volume ratio of cytoplasm as it interfaces with the plasma membrane and the outside environment. This occurs because the central vacuole occupies so much of the cell that the organelles and cytoplasm are flattened into a narrow area between the central vacuole and the plasma membrane.

The **extracellular** region is the area outside the plasma membrane. The following may occur in this region:

- **Cell walls** are found in plants, fungi, and many protists (**protists** are mostly single-celled organisms). Cell walls develop outside the plasma membrane and provide support for the cell. In plants, the cell wall consists mainly of **cellulose,** a polysaccharide made from β-glucose. The cell walls of fungi are usually made of chitin. **Chitin** is a modified polysaccharide, differing from cellulose in that one of the hydroxyl groups is replaced by a group containing nitrogen.
- The **extracellular matrix** is found in animals, in the area between adjacent cells. The area is occupied by fibrous structural proteins, adhesion proteins, glycoproteins, and glycolipids secreted by the cells. The matrix provides mechanical support and helps bind adjacent cells together. The most common substance in this region is the protein collagen.

Cell junctions serve to *anchor* cells to one another or to provide a passageway for cellular *exchange.* They include the following (Figure 3-5):



Cell Junctions
Figure 3-5

- **Anchoring junctions** are protein attachments between adjacent *animal* cells. One such junction, the **desmosome,** consists of proteins that bind adjacent cells together, providing mechanical stability to tissues. Desmosomes are also associated with intermediate filaments that extend into the interior of the cell and serve to hold cellular structures together.
- **Tight junctions** are tightly stitched seams between *animal* cells. The junction completely encircles each cell, producing a seal that prevents the passage of materials between the cells. Tight junctions are characteristic of cells lining the digestive tract, where materials are required to pass through cells (rather than intercellular spaces) to enter the bloodstream.
- **Communicating junctions** are passageways between cells that allow the transfer of chemical or electrical signals. Two kinds of communicating junctions occur, as follows:
  - **Gap junctions** are narrow tunnels between *animal* cells. The proteins that make up these junctions prevent cytoplasmic proteins and nucleic acids of each cell from mixing, but allow the passage of ions and small molecules. In this manner, gap junctions allow communication between cells through the exchange of materials or through the transmission of electrical impulses. Gap junctions are essentially channel proteins of two adjacent cells that are closely aligned. Because the proteins of each cell extend beyond the plasma membranes before they meet, a small *gap* occurs between the two plasma membranes.
  - **Plasmodesmata** (singular, **plasmodesma**) are narrow channels between *plant* cells. A narrow tube of endoplasmic reticulum, surrounded by cytoplasm and the plasma membrane, passes through the channel.

Note that plant cells can *generally* be distinguished from animal cells by the following:

1. The *presence* of cell walls, chloroplasts, and central vacuoles in *plant cells* and their absence in *animal* cells
2. The *presence* of centrioles and cholesterol in *animal cells* and their absence in *plant* cells

Prokaryotes and Eukaryotes

The cells described so far are those of **eukaryotic** organisms. Eukaryotes include all organisms except for bacteria and archaea. Bacteria and archaea are **prokaryotes** and lack most of the structures described above. They generally consist of only a plasma membrane, a DNA molecule, ribosomes, cytoplasm, and often a cell wall. In addition, they differ from eukaryotes in the following respects:

1. Prokaryotes do not have a nucleus.
2. The hereditary material in prokaryotes exists as a single "naked" DNA molecule without the proteins that are associated with the DNA in eukaryotic chromosomes.
3. Prokaryotic ribosomes are smaller than those of eukaryotes.
4. The cell walls of bacteria, when present, are constructed from peptidoglycans, a polysaccharide-protein molecule. The cell walls of archaea are chemically diverse and may contain proteins, glycoproteins, and/or polysaccharides, but *not* peptidoglycans, cellulose (as in plants), or chitin (as in fungi).
5. Flagella, when present in prokaryotes, are not constructed of microtubules and are not enclosed by the plasma membrane. The flagella deliver motion by twisting like a screw.

Movement of Substances

Various terms are used to describe the movement of substances between cells and into and out of a cell. These terms differ in the following respects:

1. The movement of substances may occur across a **selectively permeable membrane** (such as the plasma membrane). A selectively permeable membrane allows only specific substances to pass.
2. The substance whose movement is being described may be *water* (the *solvent*) or it may be the substance dissolved in the water (the *solute*).
3. Movement of substances may occur from higher to lower concentrations (*down* or *with* the concentration gradient) or the reverse (*up* or *against* the gradient).
4. Solute concentrations between two areas may be compared. A solute may be **hypertonic** (a higher concentration of *solutes*), **hypotonic** (a lower concentration of *solutes*), or **isotonic** (an equal concentration of *solutes*) relative to another region.
5. The movement of substances may be *passive* or *active*. Active movement requires the expenditure of energy and usually occurs up a gradient.

Bulk flow is the collective movement of substances (solvent and solutes) in the same direction in response to a force or pressure. Blood moving through a blood vessel is an example of bulk flow.

Passive transport processes describe the movement of substances from regions of higher concentrations to regions of lower concentrations (*down* a concentration gradient) and do not require expenditure of energy. Rates of passive transport increase with higher concentration gradients, higher temperatures, and smaller particle size. The different passive transport processes are as follows:

1. **Simple diffusion, or diffusion,** is the *net* movement of substances from an area of higher concentration to an area of lower concentration. This movement occurs as a result of the random and constant motion characteristic of all molecules (or atoms or ions), motion that is independent from the motion of other molecules. Since, at any one time, some molecules may be moving up the gradient and some molecules may be moving down the gradient (remember, the motion is random), the word "net" is used to indicate the overall, eventual result of the movement. Ultimately, a state of equilibrium is attained, where molecules are uniformly distributed but continue to move randomly.

2. **Osmosis** is the diffusion of *water* molecules across a selectively permeable membrane. When water moves into a body by osmosis, hydrostatic pressure (osmotic pressure) may build up inside the body. **Turgor pressure** is the hydrostatic pressure that develops when water enters the cells of plants and microorganisms.
3. **Plasmolysis** is the movement of water out of a *cell* (by osmosis) that results in the collapse of the cell (especially plant cells with central vacuoles). In contrast, when water moves into a cell (by osmosis), the cell volume increases and the cell expands. **Cell lysis** occurs when swelling causes the cell to burst (especially animal cells and other cells that lack a cell wall).
4. **Facilitated diffusion** is the diffusion of *solutes* or *water* through channel proteins or carrier proteins in the plasma membrane. Some *channel* proteins facilitate the movement of ions such as Na^+, K^+, Ca^{2+}, or Cl^- across the plasma membrane, while other channel proteins, the aquaporins, facilitate the movement of water across the plasma membrane. *Carrier* proteins can facilitate the movement of ions, as well as some larger organic molecules such as amino acids or glucose.
5. **Countercurrent exchange** describes the diffusion of substances between two regions in which substances are moving by bulk flow in opposite directions. For example, the direction of water flow through the gills of a fish is opposite to the flow of blood in the blood vessels. Diffusion of oxygen from water to blood is maximized because the relative motion of the molecules between the two regions is increased and because the concentration gradients between the two regions remain constant along their area of contact.

Active transport is the movement of *solutes against* a gradient and requires the expenditure of *energy* (usually in the form of ATP). Transport proteins in the plasma membrane transfer solutes such as small ions (Na^+, K^+, Cl^-, H^+), amino acids, and monosaccharides across the membrane. Active transport differs from facilitated diffusion in several ways. First, active transport does not result from random movements of molecules (as does any kind of diffusion). Rather, active transport moves *specific* solutes across a membrane from *lower to higher* concentrations (opposite direction of diffusion). The term "active" in active transport implies the use of energy, whereas the various processes of diffusion are passive.

Vesicular transport uses vesicles or other bodies in the cytoplasm to move macromolecules or large particles across the plasma membrane. Types of vesicular transport are described here:

- **Exocytosis** describes the process of vesicles fusing with the plasma membrane and releasing their contents to the outside of the cell. This is common when a cell produces substances for export.
- **Endocytosis** describes the capture of a substance outside the cell when the plasma membrane merges to engulf it. The substance subsequently enters the cytoplasm enclosed in a vesicle. There are three kinds of endocytosis.
  - **Phagocytosis** ("cellular eating") occurs when *undissolved* material enters the cell. The plasma membrane wraps around the solid material and engulfs it, forming a phagocytic vesicle. Phagocytic cells (such as certain white blood cells) attack and engulf bacteria in this manner.
  - **Pinocytosis** ("cellular drinking") occurs when *dissolved* substances enter the cell. The plasma membrane folds inward to form a channel, allowing the liquid to enter. Subsequently, the plasma membrane closes off the channel, encircling the liquid inside a vesicle.
  - **Receptor-mediated** endocytosis, a form of pinocytosis, occurs when *specific molecules* in the fluid surrounding the cell bind to specialized receptors that concentrate in coated pits in the plasma membrane. The membrane pits, the receptors, and their specific molecules (called **ligands**) fold inward, and the formation of a vesicle follows. Proteins that transport cholesterol in blood (low-density lipoproteins, or LDLs) and certain hormones target specific cells by receptor-mediated endocytosis.

Review Questions

Multiple-Choice Questions

The questions that follow provide a review of the material presented in this chapter. Use them to evaluate how well you understand the terms, concepts, and processes presented. Actual AP multiple-choice questions are often more general, covering a broad range of concepts, and often more lengthy. For multiple-choice questions typical of the exam, take the two practice exams in this book.

Directions: Each of the following questions or statements is followed by four possible answers or sentence completions. Choose the one best answer or sentence completion.

1. The cellular structure that is involved in producing ATP during aerobic respiration is the

- **A.** nucleus
- **B.** nucleolus
- **C.** chloroplast
- **D.** mitochondrion

2. Which of the following cellular structures are common to both prokaryotes and eukaryotes?

- **A.** ribosomes
- **B.** nucleoli
- **C.** mitochondria
- **D.** Golgi bodies

3. The plasma membrane consists principally of

- **A.** proteins embedded in a carbohydrate bilayer
- **B.** phospholipids embedded in a protein bilayer
- **C.** proteins embedded in a phospholipid bilayer
- **D.** proteins embedded in a nucleic acid bilayer

4. When the concentration of solutes differs on the two sides of a membrane permeable only to water,

- **A.** water will move across the membrane by osmosis
- **B.** water will move across the membrane by active transport
- **C.** water will move across the membrane by plasmolysis
- **D.** solutes will move across the membrane from the region of higher concentration to the region of lower concentration

5. All of the following characterize microtubules EXCEPT:

- **A.** They are made of protein.
- **B.** They are involved in providing motility.
- **C.** They develop from the plasma membrane.
- **D.** They make up the spindle apparatus observed during cell division.

6. Lysosomes are

- **A.** involved in the production of fats
- **B.** involved in the production of proteins
- **C.** often found near areas requiring a great deal of energy (in the form of ATP)
- **D.** involved in the degradation of cellular substances

7. Mitochondria

A. are found only in animal cells
B. produce energy (in the form of ATP) with the aid of sunlight
C. are often more numerous near areas of major cellular activity
D. are microtubule organizing centers

Questions 8–11 refer to the following key. Each answer in the key may be used once, more than once, or not at all.

A. active transport
B. bulk flow
C. osmosis
D. facilitated diffusion

8. Movement of solutes across a plasma membrane from a region of higher solute concentration to a region of lower solute concentration with the aid of proteins

9. Movement of water across a membrane from a region of higher concentration of water to a region of lower concentration of water without the aid of proteins

10. Movement of urine through the urinary tract

11. Movement of solutes across a plasma membrane requiring the addition of energy

12. The movement of water out of a cell resulting in the collapse of the plasma membrane is called

A. endocytosis
B. bulk flow
C. cell lysis
D. plasmolysis

13. The movement of molecules during diffusion can be described by all of the following EXCEPT:

A. Molecular movements are random.
B. Net movement of solute molecules is from a region of higher concentration to a region of lower concentration.
C. Each molecule moves independently of other molecules.
D. Solute molecules always move down the concentration gradient.

14. Plant and animal cells differ mostly in that

A. only animal cells have mitochondria
B. only plant cells have plasma membranes with cholesterol
C. only plant cells have cell walls
D. only plant cells have ribosomes attached to the endoplasmic reticulum

15. A smooth endoplasmic reticulum exhibits all of the following activities EXCEPT:

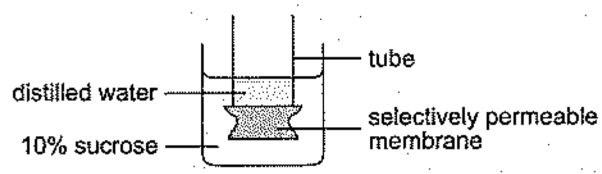
A. assembling amino acids to make proteins
B. manufacturing lipids
C. manufacturing hormones
D. breaking down toxins

16. All of the following are known to be components of cell walls EXCEPT:

- **A.** phospholipids
- **B.** chitin
- **C.** polysaccharides
- **D.** peptidoglycans

17. A saturated suspension of starch is enclosed in a bag formed from dialysis tubing, a material through which water can pass, but starch cannot. The bag with the starch is placed into a beaker of distilled water. All of the following are expected to occur EXCEPT:

- **A.** There will be a net movement of water from a hypotonic region to a hypertonic region.
- **B.** There will be a net movement of solute from a hypertonic region to a hypotonic region.
- **C.** The dialysis bag with its contents will gain weight.
- **D.** No starch will be detected outside the dialysis bag.



18. As shown above, a tube covered on one end by a membrane impermeable to sucrose is inverted and half filled with distilled water. It is then placed into a beaker of 10% sucrose to a depth equal to the midpoint of the tube. Which of the following statements is true?

- **A.** The water level in the tube will rise to a level above the water in the beaker.
- **B.** The water level in the tube will drop to a level below the water in the beaker.
- **C.** There will be no change in the water level of the tube, and the water in the tube will remain pure.
- **D.** The concentration of sucrose in the beaker will increase.

Free-Response Questions

The AP exam has long and short free-response questions. The long questions have considerable descriptive information that may include tables, graphs, or figures. The short questions are brief but may also include figures. Both kinds of questions have four parts and generally require that you bring together concepts from multiple areas of biology.

The questions that follow are designed to further your understanding of the concepts presented in this chapter. Unlike the free-response questions on the exam, they are narrowly focused on the material in this chapter. For free-response questions typical of the exam, take the two practice exams in this book.

Directions: The best way to prepare for the AP exam is to write out your answers as if you were taking the exam. Use complete sentences and do *not* use outline form or bullets. You may use diagrams to supplement your answers, but be sure to describe the importance or relevance of your diagrams.

1. The membranes of the rough endoplasmic reticulum have a very large surface area. Describe how a large surface area aids the activities of the structure.

2. The plasma membrane provides a flexible boundary to the cell. Describe the differences you would expect to find in the makeup of the plasma membrane for a plant cell in a leaf growing with full exposure to the sun compared to one growing in the shade.

3. Glycoproteins produced in the rough endoplasmic reticulum may ultimately be exported from the cell. Describe the pathway of the glycoprotein from the ER to the outside of the cell.

4. Describe each of the following:
   a. the structure of the plasma membrane
   b. the various ways in which the plasma membrane permits interactions with the outside environment

5. Compare and contrast the cellular characteristics of prokaryotes and eukaryotes.

6. Describe the various activities that occur within cells and the methods that cells use to separate these activities from one another.

Answers and Explanations

Multiple-Choice Questions

1. **D.** Aerobic respiration takes place in the mitochondrion. ATP is also produced in the chloroplast, but that is from photosynthesis.

2. **A.** Prokaryotes lack nucleoli, mitochondria, and Golgi bodies.

3. **C.** The plasma membrane consists principally of proteins embedded in a phospholipid bilayer. The phospholipid bilayer establishes a hydrophobic boundary across which solutes and solvents cannot penetrate. Many of the proteins in the membrane serve to facilitate the movement of these materials across the membrane, either by passive diffusion (channel proteins, ion channels, carrier proteins) or by active transport.

4. **A.** When there is a concentration gradient, water will move across a membrane unassisted by ATP or channel proteins. In contrast, solutes (the dissolved substances) cannot cross the membrane unassisted.

5. **C.** Microtubules originate from basal bodies or centrioles (microtubule organizing centers, or MTOCs), not from the plasma membrane.

6. **D.** Fats usually originate from smooth ER; proteins originate from ribosomes or rough ER; answer choice C would be appropriate for mitochondria.

7. **C.** Since mitochondria produce ATP (but not with the aid of sunlight, as stated in answer choice B), they are often found near areas of major cellular activity, areas that require large amounts of energy.

8. **D.** Note that this question asks about solutes moving down a concentration gradient across a plasma membrane and without ATP.

9. **C.** Note that this question asks about water moving down a gradient.

10. **B.** The movement of urine through the urinary tract is by bulk flow, a collective movement of substances moving in the same general direction. This is in contrast to diffusion, osmosis, and other molecular motions, in which the motion of particular molecules with respect to other molecules is being described.

11. **A.** The energy requirement indicates active transport.

12. **D.** If the solute concentration is higher outside than inside the cell, water moves out of the cell (by osmosis). This causes the cell volume to decrease, resulting in plasmolysis, the collapse of the cell. In contrast, cell lysis occurs when water *enters* the cell, causing the cell volume to increase to the point where the cell bursts.

13. **D.** Since the motion of the molecules is random, at any particular moment there are sure to be some molecules moving against the concentration gradient. It is only the *net* movement of molecules that moves down the gradient.

14. **C.** Animal cells, not plant cells, have plasma membranes that contain cholesterol. Both animals and plants have cells with mitochondria and have ribosomes attached to the ER.

15. A. Ribosomes assemble amino acids into proteins. Such activity would be associated with *rough* endoplasmic reticulum.

16. A. Phospholipids are the main constituent of plasma membranes and are not found in cell walls. Chitin is found in the cell walls of fungi; polysaccharides are found in the cell walls of plants and archaea; peptidoglycans are found in the cell walls of bacteria.

17. B. The solute, starch, cannot pass through the dialysis tubing. The dialysis bag will gain weight because water will diffuse into it. Note that answer choice A refers to the movement of water and answer choice B refers to the movement of the solute and that both describe the gradient relative to the solute. Also note that the distilled water in the beaker is hypotonic and the solution in the dialysis bag is hypertonic when their solute concentrations are compared.

18. B. Since sucrose cannot pass through the membrane, no sucrose will enter the tube. However, since there is a concentration gradient, water will diffuse down the gradient. The beginning concentrations of water in the tube and in the beaker are 100% and 90%, respectively. Therefore, water will move from the tube and into the beaker. The water level in the tube will drop (and the beaker level will rise), and the concentration of sucrose in the beaker will decrease.

Free-Response Questions

1. The large surface area of the rough endoplasmic reticulum provides abundant space for the embedded ribosomes and the production and modification of proteins.

2. The flexibility of the plasma membrane is influenced by the relative numbers of saturated and unsaturated fatty acids in the phospholipids. More phospholipids with unsaturated fatty acids would be found in shade leaves because the bend caused by the double bonds in the unsaturated fatty acids increases the separation of the phospholipids, which increases the membrane's flexibility in response to cooler temperatures.

3. After the protein is produced by a ribosome on the membrane surface of the ER, the ER attaches a carbohydrate to the protein and packages the glycoprotein within a vesicle. The vesicle then transports the glycoprotein to a Golgi apparatus, where it may undergo additional modification. The modified glycoprotein is again packaged into a vesicle that transports the glycoprotein from the Golgi apparatus to the plasma membrane, where it is exported by exocytosis.

4. a. The plasma membrane is composed of a phospholipid bilayer. A molecule of phospholipid consists of two fatty acids and a phosphate group attached to a glycerol component. The fatty acid tails represent a hydrophobic region of the molecule, while the glycerol-phosphate head is hydrophilic. The phospholipids are arranged into a bilayer formation with the hydrophilic heads pointing to the outside and the hydrophobic tails pointing toward the inside. As a result, the plasma membrane is a barrier to most molecules. In plants, fungi, and bacteria, the membrane deposits cellulose or other polysaccharides on the outside of the membrane to create a cell wall. The cell wall provides support to the cell.

   Embedded in the phospholipid bilayer are various proteins and, in animal cells, cholesterol molecules. This mixture of molecules accounts for the fluid mosaic model of the plasma membrane, that is, a highly flexible lipid boundary impregnated with various other molecules.

   b. The plasma membrane is a selectively permeable membrane. Small molecules, like O_2 and CO_2, readily diffuse through the membrane. The movement of larger molecules is regulated by proteins in the plasma membrane. There are several kinds of these proteins. Channel proteins provide passage for certain dissolved substances. Transport proteins actively transport substances against a concentration gradient. The extracellular matrix in animal cells, consisting of the polysaccharides of glycolipids, recognition proteins, and other glycoproteins, provides adhesion or participates in cell-to-cell interactions. Receptor proteins recognize hormones and transmit their signals to the interior of the cell.

c. Various substances can be exported into the external environment by exocytosis. In exocytosis, substances are packaged in vesicles that merge with the plasma membrane. Once they merge with the membrane, their contents are released to the outside. In an opposite kind of procedure, food and other substances can be imported by endocytosis. In endocytosis, the plasma membrane encircles the substance and encloses it in a vesicle.

Note: When a question has two or more parts, separate your answers and identify each part with the corresponding letter.

5. *For this question, be sure to separate your answer into two parts. The first part should compare prokaryotes and eukaryotes, that is, describe characteristics they have in common. For example, they both have a plasma membrane, ribosomes, and DNA. Also, many prokaryotes have a cell wall, a structure they have in common with the eukaryotic cells of plants and fungi.*

In the second part of your answer, contrast prokaryotes and eukaryotes, that is, describe how they are different. Indicate that the DNA is packaged differently (naked DNA molecules in prokaryotes compared to DNA associated with proteins in eukaryotes), that prokaryotic ribosomes are smaller than those of eukaryotes, that the prokaryotic flagella do not contain microtubules, and that prokaryotic cells lack a nuclear membrane and the various eukaryotic organelles. Also, the cell walls of bacteria contain peptidoglycans, and those of archaea contain other polysaccharides, but not the cellulose and chitin found in the cell walls of plants and fungi.

6. *For this question, be sure to separate your answer into two parts. In the first part, describe each cell organelle and its function. In the second part, explain that partitioning metabolic functions into organelles serves primarily to separate the biochemical activities. In addition, describe how the channels among layers of endoplasmic reticulum serve to create compartments as well. Last, describe the packaging relationship between the ER and Golgi bodies.*