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UNIT II

Molecules, Cells, and Organs

Foundational Concept: Highly organized assemblies of molecules, cells, and organs interact to carry out the functions of living organisms.

CHAPTER 5 Assemblies of Molecules, Cells, and Groups of Cells Within Multicellular Organisms

CHAPTER 6 Structure, Growth, Physiology, and Genetics of Prokaryotes and Viruses

CHAPTER 7 Processes of Cell Division, Differentiation, and Specialization

Unit II MINITEST

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CHAPTER 5

Assemblies of Molecules, Cells, and Groups of Cells Within Multicellular Organisms

Read This Chapter to Learn About

- The Plasma Membrane
- Movement of Solutes Across Membranes
- Eukaryotic Cell Structure and Function
- Cellular Adhesion
- Tissues
- Membranes

THE PLASMA MEMBRANE

The outer boundary of the cell is the **plasma membrane** (cell membrane). It forms a selectively permeable barrier between the cell and its external environment. The structure of the membrane itself allows for the selective passage of materials into and out of the cell through various mechanisms.

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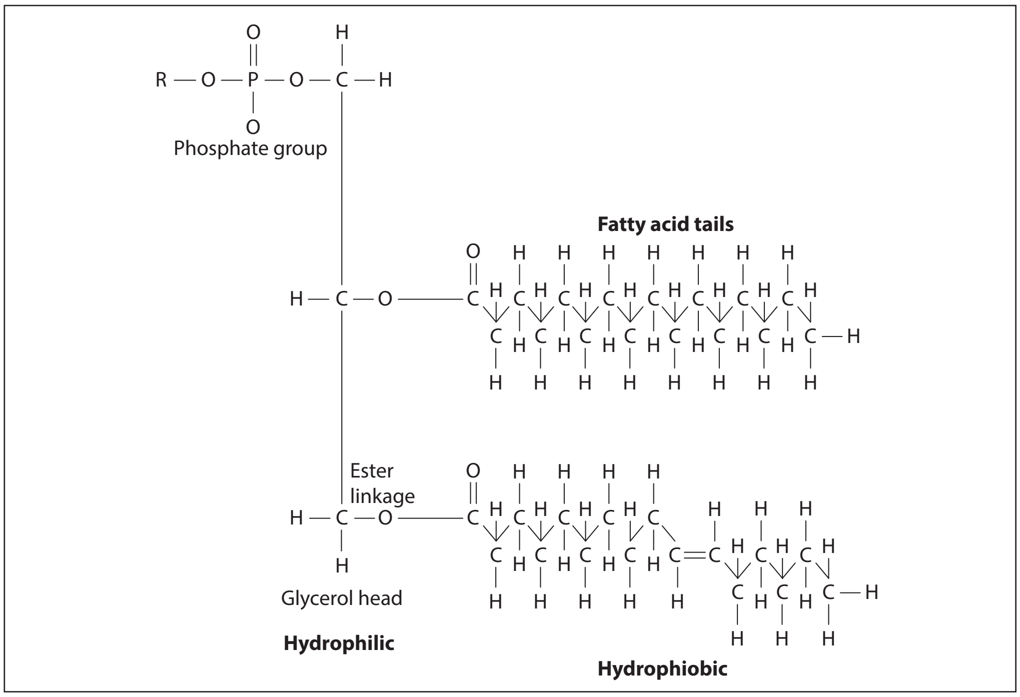

FIGURE 5-1 Phospholipid structure.

The plasma membrane is composed of a bilayer of phospholipids and proteins scattered within the bilayer. **Phospholipids** are unique molecules because they have polar (charged) and nonpolar (uncharged) regions. Figure 5-1 shows that the head of a phospholipid is composed of a glycerol and phosphate group (PO_4) that carries a charge and is **hydrophilic**. The tails of the phospholipid are fatty acids that are not charged and are **hydrophobic**. These fatty acids can be characterized as saturated or unsaturated depending on their structure. This is discussed in more detail in Chapter 4.

Phospholipids spontaneously arrange themselves in a bilayer in which the heads align themselves toward the inside and outside of the cell where water is located, and the fatty acid tails are sandwiched between the layers. Nonpolar molecules have an easier time crossing the bilayer than other types of molecules.

The Fluid Mosaic Model

In addition to the phospholipid bilayer, there are some other substances present in the plasma membrane. The **fluid mosaic model** seen in Figure 5-2 shows the basic membrane structure. **Cholesterol**, a steroid molecule, is found embedded within the interior of the membrane and its primary purpose is to regulate the fluidity of the membrane. Proteins are scattered within the bilayer, and they may serve multiple purposes such as membrane transport, enzymatic activity, cell adhesion, communication, as well as to serve as receptors for specific substances that may need to cross the membrane. Some proteins and lipids within the cell membrane contain carbohydrates on

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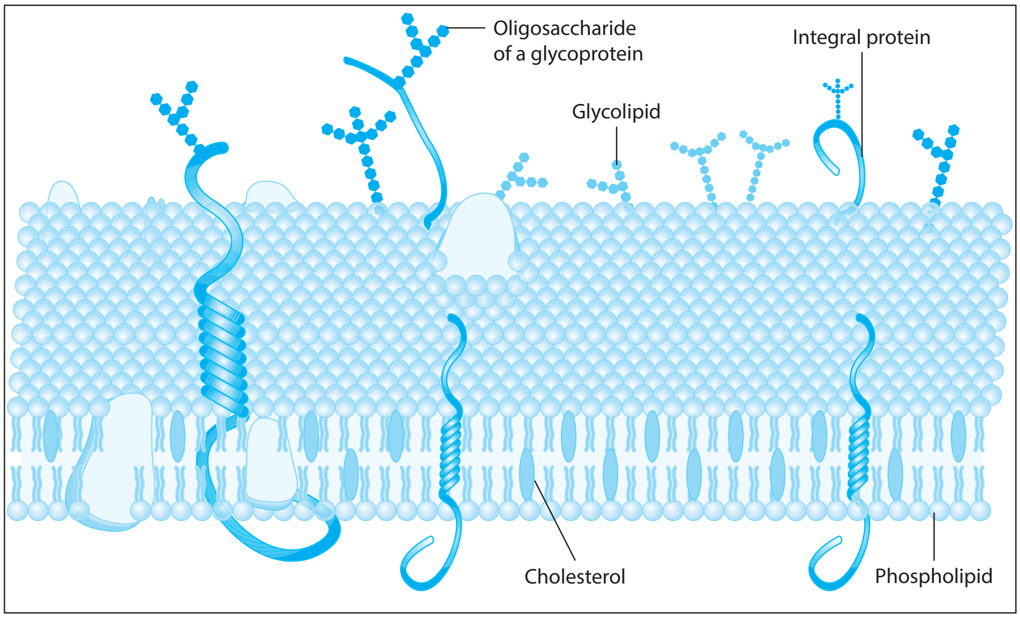

FIGURE 5-2 The fluid mosaic model.

the exterior surface. These glycoproteins and glycolipids often serve as identifying markers, or antigens, for the cell.

Membrane Dynamics

Within the plasma membrane, phospholipids display dynamic movement. This movement can be uncatalyzed or catalyzed. **Uncatalyzed forms** of movement include transbilayer diffusion where a phospholipid moves from one layer to another and lateral diffusion where the phospholipids move from side to side but stay on the same layer of the membrane. **Catalyzed forms** of diffusion use a protein catalyst to facilitate movement. Phospholipids can move from inner to outer or outer to inner layers using protein catalysts and ATP. There can also be coupled movement where one phospholipid moves from one layer to the other and another phospholipid moves in an opposite direction. This form of catalyzed movement requires a protein catalyst but does not require ATP.

MOVEMENT OF SOLUTES ACROSS MEMBRANES

There are a variety of ways that substances can cross the plasma membrane. The three main membrane transport methods are passive transport, active transport, and bulk transport. Passive transport occurs spontaneously without energy, active transport requires energy in the form of ATP, and bulk transport involves the transport of large items or large quantities of an item using specific mechanisms.

Concentration gradients are a key consideration with movement across the plasma membrane. The **concentration gradient** refers to a relative comparison of solutes and overall concentrations of fluids inside and outside the cell. Without the influence of outside forces, substances tend to move down their concentration gradient (from high concentration to low concentration) toward equilibrium. Items can move against their concentration gradient only with an energy input.

The direction in which transport of a substance occurs is regulated by the Gibbs free energy change. In passive transport, no additional input of energy is required ($\Delta G' = 0$) and all movement will be with the concentration gradient (moving from high to low concentration). In active transport mechanisms, movement against the concentration gradient (from low to high) may occur using the $\Delta G'$, which is not available in passive transport situations.

Passive Transport

Passive transport mechanisms include diffusion and osmosis, both of which move a substance from an area of high concentration to an area of low concentration. Diffusion and osmosis are spontaneous processes and do not require ATP.

DIFFUSION

Diffusion is defined as the movement of small solutes down their concentration gradients. In other words, dissolved particles move from whichever side of the membrane that has more of them to the side of the membrane that has less. Diffusion is a slow process by nature, but its rate can be influenced by temperature, the size of the molecule attempting to diffuse (large items are incapable of diffusion), and how large the concentration gradient is. Diffusion continues until equilibrium is met. Some small solutes move across the membrane through a carrier protein. When this occurs, the process is termed **facilitated diffusion**. All of the same normal rules of diffusion apply.

OSMOSIS

Osmosis is a very specific type of diffusion where the substance moving down its concentration gradient is water. As the concentration of solutes increases, the concentration of water decreases. Osmosis displays colligative properties in that the osmotic pressure depends on the concentration of solute present but not on the identity of the solute. In an attempt to have equally concentrated solutions both inside and outside the cell, osmosis occurs if the solute itself is unable to cross the cell membrane because its size is too large. Simply put, osmosis moves water from the side of the membrane that has more water (and less solute) to the side of the membrane that has less water (and more solute).

When the concentrations of solutes inside and outside the cell are equal, the solutions are termed **isotonic** and there is no net movement of water into or out of the cell.

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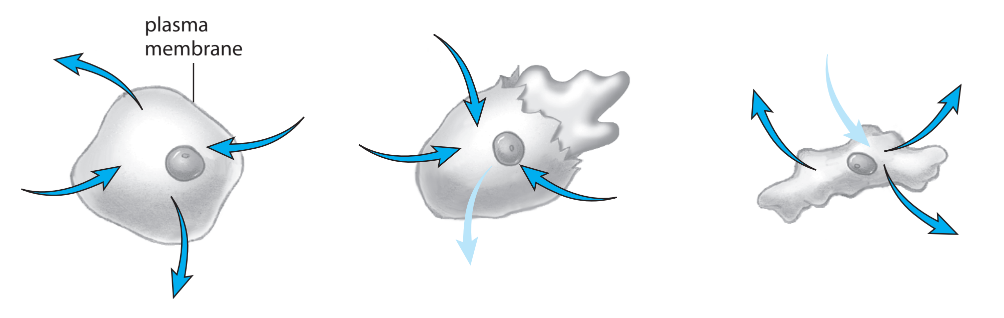

FIGURE 5-3 Osmotic effects on animal cells. The arrows indicate the movement of water. In an isotonic solution, a cell neither gains nor loses water; in a hypertonic solution, the cell loses water; in a hypotonic solution, the cell gains water. *Source:* From Sylvia S. Mader, *Biology*, 8th ed., McGraw-Hill, 2004; reproduced with permission of The McGraw-Hill Companies.

In most situations, isotonic solutions are the goal for cells. A solution that has more water and less solute relative to what it is being compared to is termed **hypotonic**, while a solution that has less water and more solute relative to what it is being compared to is termed **hypertonic**. When cells are placed in hypertonic solutions, water leaves the cell via osmosis, which can cause cells to shrivel. Cells placed in hypotonic solutions gain water via osmosis and potentially swell and burst. The osmotic effects of each type of solution can be seen in Figure 5-3.

Active Transport

In contrast to passive transport, **active transport** is used to move solutes against their concentration gradient from the side of the membrane that has less solute to the side that has more. The solutes move via transport proteins in the membrane that act as pumps. Because this is in contrast to the spontaneous nature of passive transport, energy in the form of ATP must be invested to pump solutes against their concentration gradients. Individual items can be actively transported through protein pumps such as the proton pumps used during cellular respiration. There are also co-transporters that move more than one item at a time by active transport. Active transport mechanisms are essential to maintaining membrane potentials (charged states) within a variety of specialized cells within the body.

THE SODIUM-POTASSIUM PUMP AND MEMBRANE CHANNELS

The **sodium-potassium pump** is an example of a co-transporter used in neurons and will be discussed more extensively in Chapter 8. When neurons are not transmitting messages, their membranes are in resting potential. During **resting potential**, sodium-potassium (Na^+/K^+) pumps within the membrane are used to actively

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transport ions into and out of the axon. The Na^+/K^+ pumps bring 2 K^+ ions into the axon while sending out 3 Na^+ ions. This results in a high concentration of Na^+ outside the membrane and a high concentration of K^+ inside the membrane. There are also many negatively-charged molecules such as proteins within the neuron so that ultimately the inside of the neuron is more negative than the outside of the neuron.

To transmit a message, the resting potential of the neuron must be disrupted and depolarized such that the inside of the cell becomes slightly less negative. Once the **action potential** has initiated, voltage-gated channels in the membrane of the axon will open. Specifically, Na^+ channels open, allowing Na^+ to flow passively across the membrane into the axon in a local area. As soon as the Na^+ channels open and depolarize a small area of the axon, K^+ channels open, allowing K^+ to leak passively out of the axon. This restores the more negative charge within the axon, temporarily preventing the initiation of another action potential during a refractory period. The Na^+/K^+ pump can then be used to completely restore the resting potential by repolarization.

Bulk Transport

The methods for membrane transport described thus far are limited by the size of molecules and do not consider the movement of large items (or large quantities of an item) across the membrane. Endocytosis and exocytosis are used to move large items across the cell membrane and can be seen in Figure 5-4.

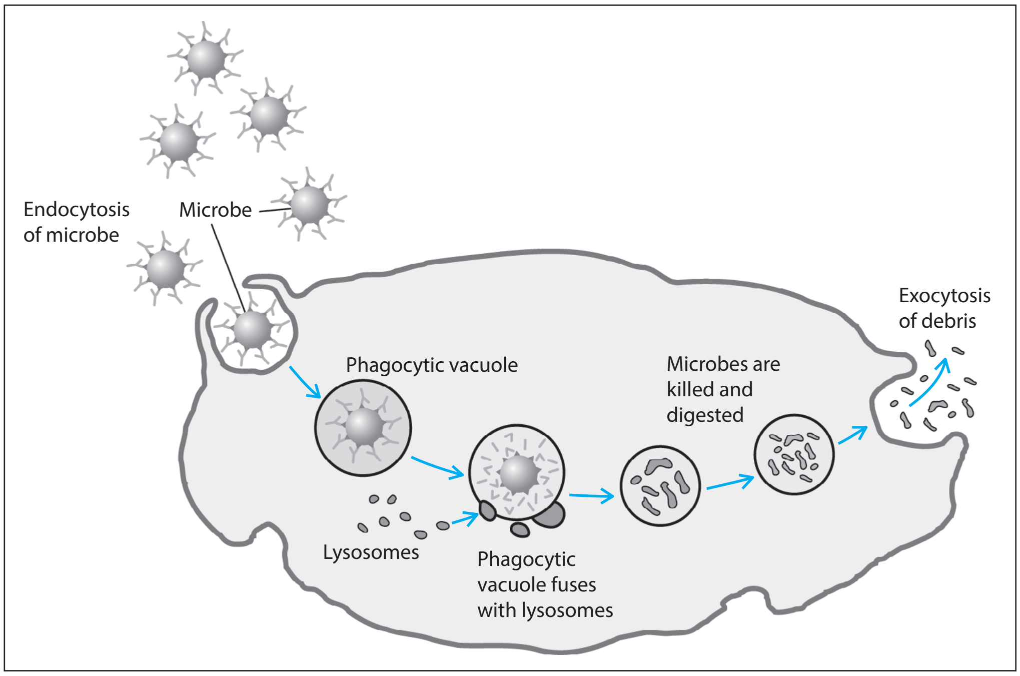

FIGURE 5-4 Endocytosis and exocytosis. Cells engulf large substances such as microbes via endocytosis and excrete large substances via exocytosis. *Source:* From Eldon D. Enger, Frederick C. Ross, and David B. Bailey, *Concepts in Biology*, 11th ed., McGraw-Hill, 2005; reproduced with permission of The McGraw-Hill Companies.

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ENDOCYTOSIS

Endocytosis is used to bring items into the cell. The membrane surrounds the item to form a vesicle that pinches off and moves into the cell. When liquids are moved into the cell this way, the process is termed **pinocytosis**. When large items, such as other cells, are brought into the cell, the process is termed **phagocytosis**. White blood cells are notorious for performing phagocytosis on items such as bacterial cells. Finally, there is receptor-mediated endocytosis, where the molecule to be moved into the cell must first bind to a cell membrane receptor before it can be transported.

EXOCYTOSIS

Exocytosis is used to transport molecules out of the cell. In this case, vesicles containing the substance to be transported move toward the cell membrane and fuse with the membrane. This releases the substance to the outside of the cell.

EUKARYOTIC CELL STRUCTURE AND FUNCTION

The **cell** is the basic unit of life. As a general rule, all cells are small in size in order to maintain a large surface area to volume ratio. Having a large surface area relative to a small volume allows cells to perform vital functions at a reasonably fast rate, which is necessary for survival. Cells that are too large have small surface area to volume ratios and have difficulties getting the nutrients that they need and expelling wastes in a timely manner.

There are two major categories of cells: **prokaryotic** and **eukaryotic**. Both prokaryotic and eukaryotic cells contain a variety of structures that are used to perform specific functions within the cell. There are some similarities between the two cell types, but there are also some significant differences. In this chapter, the focus will remain on eukaryotic cells, but prokaryotic cells will be revisited in Chapter 6. The following table depicts the major structural differences between prokaryotic and eukaryotic cells.

TABLE 5-1 A Summary of Differences Between Eukaryotic and Prokaryotic Cells

Characteristic	Eukaryotic Cells	Prokaryotic Cells
Cell size	Relatively larger	Relatively smaller
Presence of membrane-bound organelles	Present	Absent
Organization of genetic material	Linear pieces of DNA organized as chromosomes housed within the nucleus	A single loop of DNA floating in the cytoplasm
Oxygen requirements	Generally need oxygen to produce energy during cellular respiration	May not require oxygen to produce energy during cellular respiration

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One primary factor that differentiates eukaryotic cells from prokaryotic cells is the presence of organelles. **Organelles** are membrane-bound compartments within the cell that have specialized functions. They help with cellular organization and ensure that specific reactions occurring in one organelle do not interfere with those occurring in another organelle.

There are many different structures and organelles that are found in eukaryotic cells, each with a specialized function to be discussed shortly. The structure of a typical eukaryotic cell can be seen in Figure 5-5. An overview of all major cellular components found in eukaryotic cells can be found in following table.

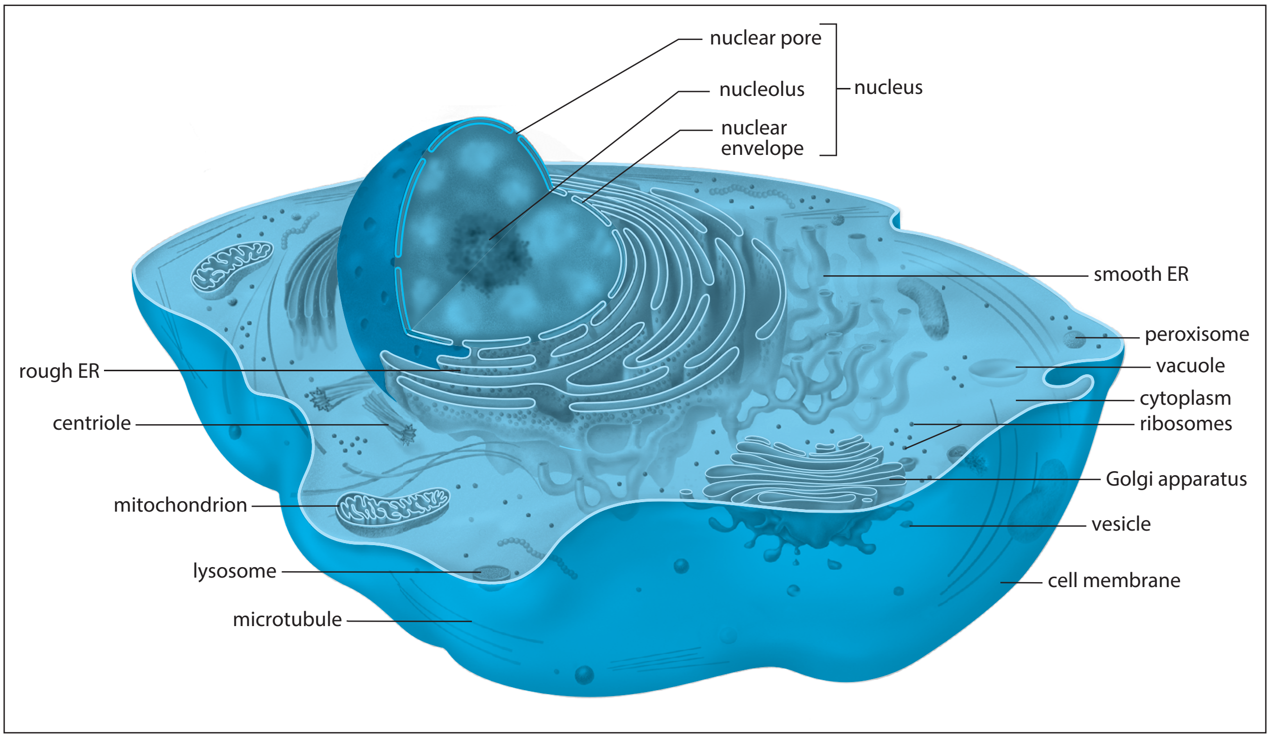

FIGURE 5-5 Animal cell structure. A typical animal cell contains a variety of structures and membrane-bound organelles. *Source:* From Sylvia S. Mader, *Biology*, 8th ed., McGraw-Hill, 2004; reproduced with permission of The McGraw-Hill Companies.

The Cytoplasm

The liquid portion of the cell is the **cytoplasm**, which consists of water, nutrients, ions, and wastes and can be the site of a variety of chemical reactions within the cell. The organelles and other structures of the cell are suspended within the cytoplasm.

The Nucleus

All eukaryotic cells contain a membrane-bound nucleus. The **nucleus** houses the genetic material of the cell in the form of **chromosomes**, which consist of **deoxyribonucleic acid** (DNA) associated with specialized proteins. The outer boundary of the

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TABLE 5-2 Major Cell Structures and Their Functions

Organelle or Structure	Function
Cytoplasm	Liquid portion of the cell in which organelles are suspended
Nucleus	Stores DNA of the cell
Nucleolus	Housed within the nucleus; makes rRNA used to produce ribosomes
Ribosomes	Involved in protein synthesis
Smooth endoplasmic reticulum	Produces lipids for the cell and is also involved in detoxification in liver cells
Rough endoplasmic reticulum	Produces and chemically modifies proteins
Golgi complex	Sorts contents from the endoplasmic reticulum and routes them to appropriate locations in the cell or marks them for secretion from the cell
Lysosomes	Vacuoles containing enzymes needed for cellular digestion and recycling
Peroxisomes	Vacuoles that digest fatty acids and amino acids; also breaks down the metabolic waste product hydrogen peroxide to water and oxygen
Mitochondria	Perform aerobic cellular respiration to produce ATP (energy) for the cell during aerobic cellular respiration
Cytoskeleton	*Hollow microtubules* are used for structural support, organelle movement, and for cell division. *Microfilaments* are used for cell movement. *Intermediate filaments* assist in structural support for the cell.
Cell wall	A rigid structure composed of cellulose on the outer surface of plant cells; provides structural support and prevents desiccation
Chloroplasts	Used for the process of photosynthesis in plants
Central vacuole	Used to store water, nutrients, and wastes in plants

nucleus is referred to as the **nuclear membrane** (also termed the **nuclear envelope**). It keeps the contents of the nucleus separate from the rest of the cell. The nuclear membrane has nuclear pores that allow certain substances to enter and exit the nucleus. Within the nucleus, there is a **nucleolus**. The job of the nucleolus is to make the **ribosomal ribonucleic acid** (rRNA) needed to produce ribosomes.

Ribosomes

Ribosomes can be found loose in the liquid cytoplasm of the cell (free ribosomes) or attached to the endoplasmic reticulum of the cell (bound ribosomes). Made from rRNA

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produced in the nucleolus and proteins, a ribosome consists of one large subunit and one small subunit that are assembled when protein synthesis is needed.

The Endomembrane System

The **endomembrane system** consists of several organelles that work together as a unit to synthesize and transport molecules within the cell. This endomembrane system consists of the smooth endoplasmic reticulum, rough endoplasmic reticulum, Golgi complex, lysosomes, peroxisomes, and vesicles that transport materials within the system.

ENDOPLASMIC RETICULUM

The **endoplasmic reticulum** (ER) is a folded network of double membrane-bound space that has the appearance of a maze. Some areas of the ER, known as the **rough ER**, contain bound ribosomes, whereas other areas, known as the smooth ER, do not. These two structures are connected, but their functions are distinct from each other.

In the **smooth ER**, the primary function is lipid synthesis. In certain types of eukaryotic cells (such as the liver), the smooth ER also plays a critical role in the production of detoxifying enzymes. The primary function of the rough ER, which has bound ribosomes, is related to protein synthesis. The ribosomes produce proteins that enter the rough ER where they are chemically modified and moved to the smooth ER.

The combined contents of the smooth ER and the rough ER are shipped by vesicles to the Golgi complex for sorting. **Vesicles** are tiny pieces of membrane that will break off and carry the contents of the ER throughout the endomembrane system.

GOLGI COMPLEX

Vesicles from the ER arrive at the **Golgi complex** (also called the Golgi apparatus) and deliver their contents, which include proteins and lipids. These molecules are further modified, repackaged, and tagged for their eventual destination. The contents of the Golgi complex leave via vesicles, with many of them moved to the plasma membrane for secretion out of the cell.

LYSOSOMES

Lysosomes are membrane-bound vacuoles (large sacs) that contain hydrolytic (digestive) enzymes used to break down any substances that enter the lysosomes. Cellular structures that are old, damaged, or unnecessary can be degraded in the lysosomes, as can substances taken into the cell by endocytosis. To function properly, the pH of the lysosomes must be acidic. If lysosomes rupture, the cell itself is destroyed. In some cases, cells purposefully rupture their lysosomes in an attempt to destroy themselves in a process known as **apoptosis**.

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PEROXISOMES

Peroxisomes are another type of vacuole found within the endomembrane system. They are capable of digesting fatty acids and amino acids. Enzymes within the peroxisomes degrade toxic hydrogen peroxide, a metabolic waste product, to water and oxygen gas. Peroxisomes also assist with the degradation of alcohol in the liver and kidney cells.

Mitochondria

Mitochondria are the organelles responsible for the production of energy in the cell. They perform aerobic cellular respiration that ultimately creates ATP, which is the preferred source of energy for cells. Because all cells require energy to survive, the process of cellular respiration is a vital one for the cell.

Mitochondria have some interesting and unusual features. They are bound by an inner and outer membrane, they contain their own DNA distinct from the nuclear DNA, and they can self-replicate. These unique features have led to the development of the **endosymbiotic theory**, which suggests that mitochondria are the evolutionary remnants of bacteria that were engulfed by other cells long ago in evolutionary time.

The Cytoskeleton

The **cytoskeleton** is composed of three types of fibers that exist within the cytoplasm of the cell. These fibers have a variety of functions, including structural support, maintenance of cell shape, and cell division.

Microtubules are responsible for structural support and provide tracks that allow for the movement of organelles within the cell. They are hollow fibers, made of the protein tubulin. A specialized grouping of microtubule is the **centriole**. A pair of centrioles is used within animal cells to assist with cell division. **Microfilaments** are made of the protein actin, which assists with cellular movement. **Intermediate filaments** provide structural support for the cell. These fibers vary in composition, depending on the cell type.

STRUCTURES THAT ALLOW FOR MOVEMENT

Certain types of animal cells contain additional structures, such as cilia and flagella, that allow for movement. **Cilia** are hairlike structures that move in synchronized motion on the surface of some cells. For example, cilia on the surface of cells lining the respiratory tract constantly move in an attempt to catch and remove bacteria and particles that may enter the respiratory tract. Some animal cells, such as sperm, contain a **flagellum**, which essentially acts as tails to allow for movement. Both cilia and flagella are composed of nine pairs of microtubules arranged circularly around a pair of microtubules. This is referred to as a $9 + 2$ arrangement. The sliding of microfilaments powered by ATP is what allows for the movement of these structures.

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Cell Structures Not Found in Animal Cells

Plant cells generally have all of the structures and organelles described to this point. However, there are a few additional structures that are unique to plant cells. These include a cell wall, chloroplasts, and a central vacuole.

The **cell wall** is composed of cellulose (fiber) and serves to protect the cell from its environment and desiccation. The chloroplasts within a plant cell contain the green pigment chlorophyll, which is used in the process of photosynthesis. **Chloroplasts** are similar to mitochondria in that they have their own DNA and replicate independently. Endosymbiotic theory is used to explain their existence in plants. Finally, plant cells contain a large central vacuole that serves as reserve storage for water, nutrients, and waste products. The **central vacuole** typically takes up the majority of space within a plant cell. Figure 5-6 illustrates the typical structure of a plant cell.

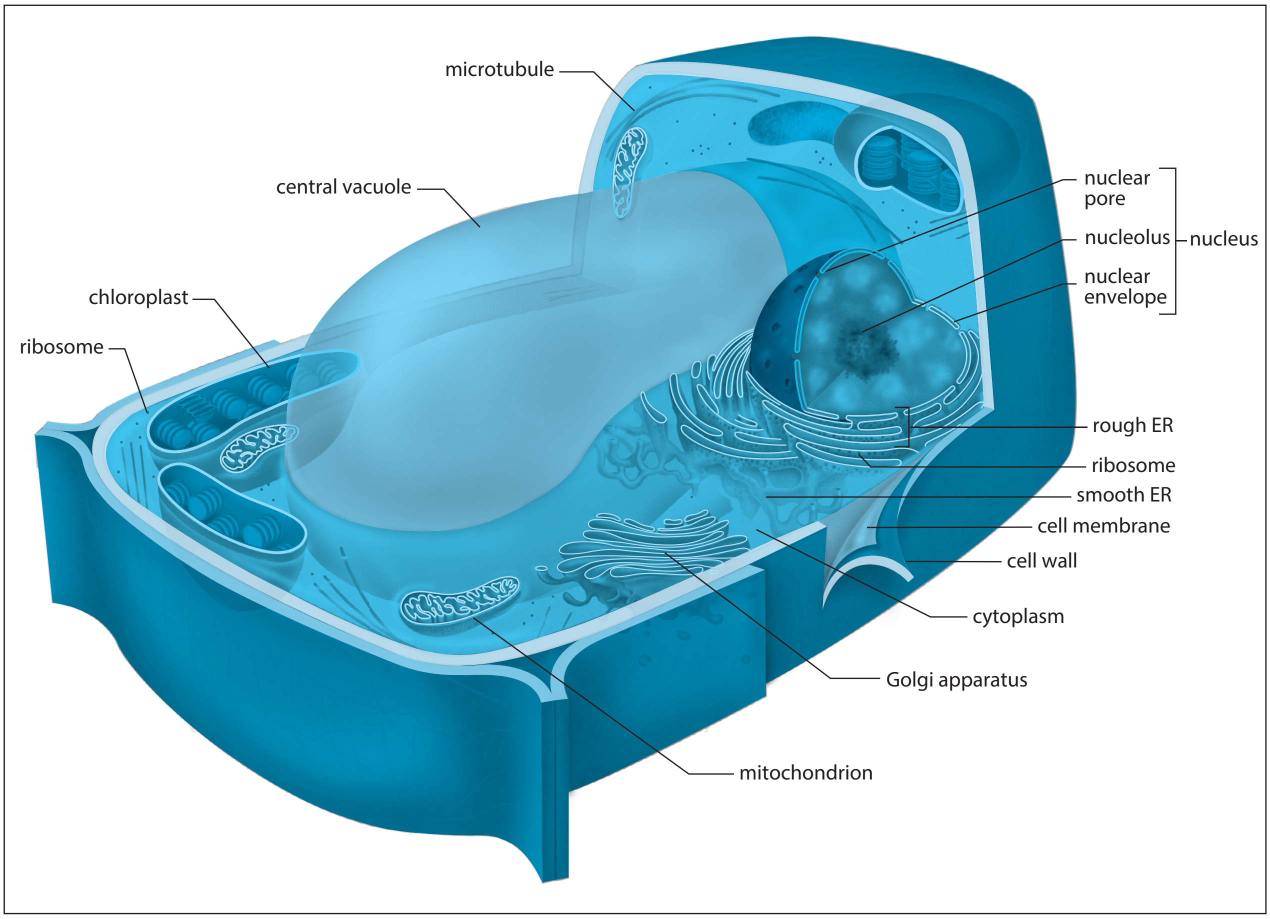

FIGURE 5-6 Plant cell structure. A typical plant cell contains structures and organelles similar to animal cells with the addition of chloroplasts, a cell wall, and a central vacuole. *Source:* From Sylvia S. Mader, *Biology*, 8th ed., McGraw-Hill, 2004; reproduced with permission of The McGraw-Hill Companies.

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CELLULAR ADHESION

Even though a cell is bound by its plasma membrane, it must be able to interact with the outside environment and other cells. **Cellular junctions** are connections between the membranes of cells that allow them to adhere to one another and to communicate with one another. These junctions occur in multiple forms: gap junctions, tight junctions, adherens junctions, and desmosomes.

In **gap junctions**, the cytoplasm of two or more cells connects directly. These connections serve as channels to allow for the rapid movement of substances between cells. One location where gap junctions are prominent is within the cells of cardiac muscle. **Tight junctions** are used to attach cells together, producing a leak-proof seal. This is critical in areas of the body where it would not be desirable to leak fluids. Tight junctions are common and are found in places such as the stomach lining, internal body cavities, and the outer surfaces of the body. **Adherens junctions** are used to attach cells in areas that need to stretch, such as the skin and bladder. **Desmosomes** are localized patches used to hold cells together within tissues. The major functions of cell junctions can be seen in the following table.

TABLE 5-3 Cell Junctions

Type	Function
Gap junctions	Used for rapid communication between cells via cytoplasmic connections
Tight junctions	Used to form tight, waterproof seals between cells
Adherens junctions	Used to form strong connections between cells that need to stretch
Desmosomes	Used to hold cells together in tissues such as the epithelia

TISSUES

A **tissue** is a group of similar type cells that perform specialized functions. Two or more tissue types associate with each other to form organs. There are four major tissue types found in animals: epithelial, connective, muscular, and nervous.

Epithelial Tissue

Epithelial tissues are generally found on surfaces of any part of the body in contact with the environment. The cells that form epithelial tissue occur in sheets or layers where one cell is directly connected to the next. A basement membrane of sticky polysaccharides and proteins made by the cells attaches the tissue to other underlying tissues.

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Epithelial tissues are named according to the shape of their cells as well as the number of layers that compose the tissue. The cells that compose epithelial tissues come in the following shapes seen in Figure 5-7:

- **Squamous.** Flat cells
- **Cuboidal.** Cube-shaped cells
- **Columnar.** Oblong-shaped cells

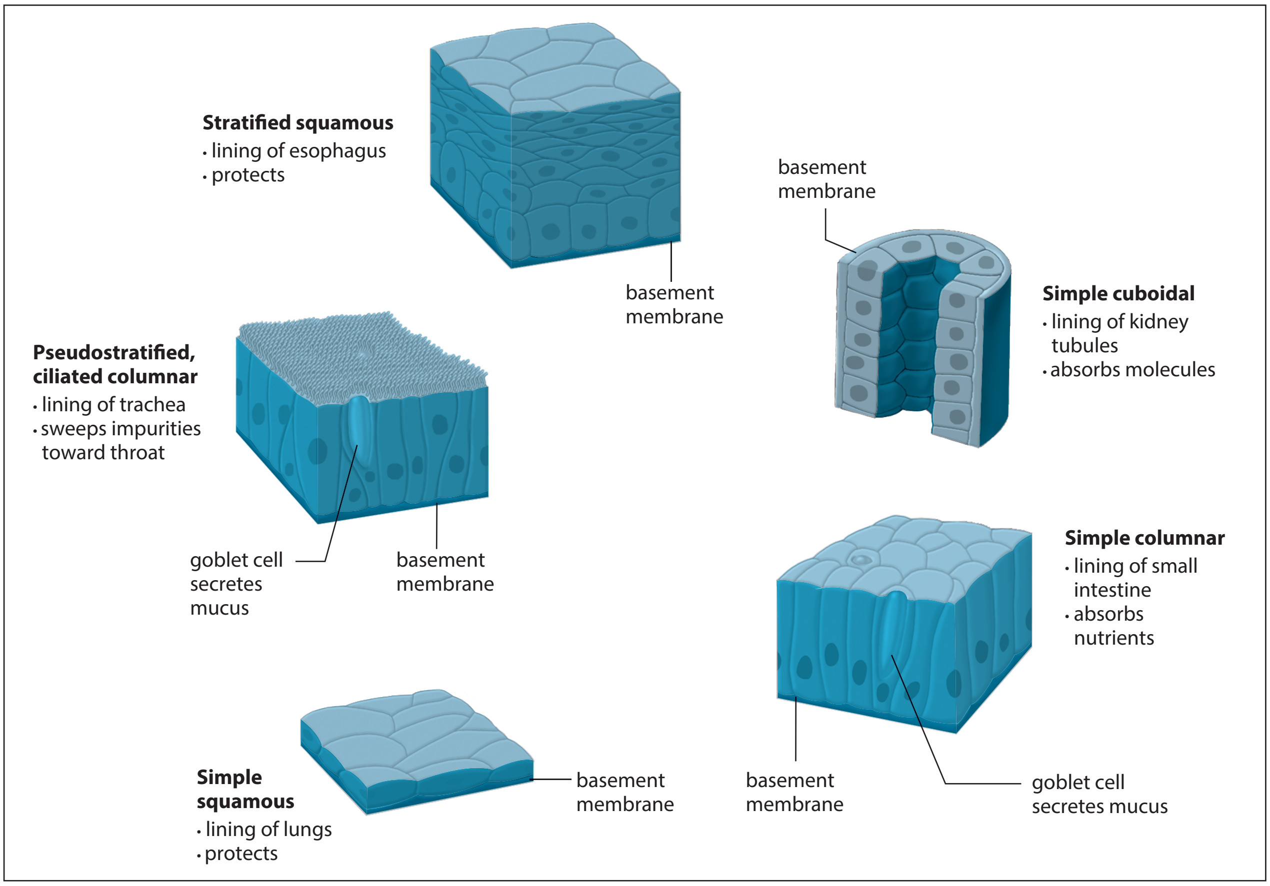

FIGURE 5-7 Epithelial tissues are classified based on the shape of the cells that compose the tissue and the number of layers found within the tissue. *Source:* From Sylvia S. Mader, *Biology*, 8th ed., McGraw-Hill, 2004; reproduced with permission of The McGraw-Hill Companies.

If there is a single layer of cells, the tissue is termed **simple**. If multiple layers of cells are present, the tissue is termed **stratified**. Epithelial tissue always has two names—one to indicate the cell shape and one to indicate the number of layers present.

There are multiple types of epithelial tissues that all have specific functions. Generally, cuboidal and columnar tissues are well-suited to secreting products such as mucus or digestive enzymes and are usually found in simple form. They are also used for absorption in areas such as the digestive tract. Simple squamous epithelium is well-suited to diffusion in places such as the alveoli (air sacs) of the lungs because it

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is so thin. Stratified squamous is used for structures such as skin, where entire layers of the tissue might be lost on a regular basis. Simple forms of epithelial cells that line closed spaces in the body, including body cavities, blood vessels, and lymphatic vessels, are termed **endothelium**. Most epithelial cells are replaced as often as they are shed.

Connective Tissue

Connective tissue comes in multiple varieties with very diverse functions. The common characteristic shared between all types of connective tissues is that they contain cells scattered within a **nonliving matrix** separated from surrounding tissues. The type of matrix varies from one type of connective tissue to the next, but generally it contains fibers such as collagen, elastic, and reticular fibers seen in Figure 5-8.

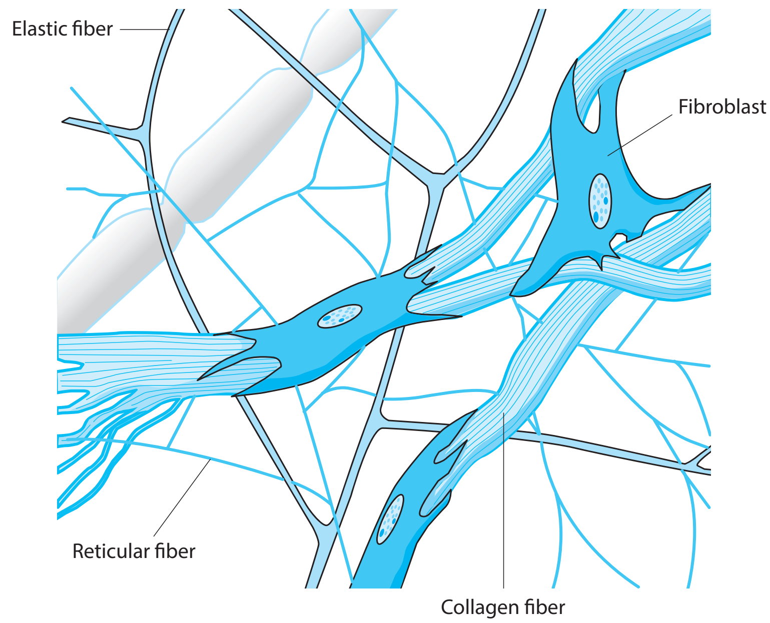

FIGURE 5-8 Connective tissues are composed of cells scattered within a nonliving matrix.

Fibroblasts are the primary cell type that produces matrix fibers. **Collagen fibers** have great strength, whereas **elastic fibers** have stretchability. **Reticular fibers** help attach one type of connective tissue to another type.

There are several types of connective tissue, including loose, dense, cartilage, bone, blood, and lymph. Each type of connective tissue is characterized by the specific cell types as well as the properties of the matrix. The characteristics of the major types of connective tissues can be seen in the following table.

TABLE 5-4 Major Connective Tissue Types

Tissue Type	Characteristics	Functions
Loose	Collagen and elastic fibers are abundant in the matrix to form a fairly loose consistency. Fibroblasts are the main cell types. Adipose tissue is a specialized form that stores fat for energy reserves and insulating properties.	Fills space in body cavities, attaches skin to underlying tissues, stores fat
Dense	Collagen fibers are abundant and tightly packed to provide tensile strength. Fibroblasts are the main cell type.	Tendons (attach muscles to bones) and ligaments (attach bone to bone)
Cartilage	Collagen fibers are embedded in a gel-like matrix. Chondrocytes are the major cell type.	Supports body structures such as ears, nose, trachea, and vertebrae
Bone	Collagen fibers are abundant within a rigid calcium phosphate matrix. Osteocytes, osteoblasts, and osteoclasts are the major cell types.	Provides structural support for the body, protection of internal organs, storage of calcium
Blood	Liquid matrix termed **plasma** Major cell types are red blood cells, white blood cells, and platelets.	Transports substances within the body, including oxygen and carbon dioxide, fights infection, blood clotting
Lymph	Liquid matrix Major cell type is white blood cells.	Fights infection, transports substances within the body, regulates fluid levels in other tissues

Muscular Tissue

There are three types of muscle found within the body: smooth, cardiac, and skeletal. All are composed of bundles of muscle cells, which all have the ability to contract. Each contains many mitochondria that produce the ATP required for contraction. The appearance of the muscle as well as its interaction with the nervous system determines the tissue type. The three muscle types seen in Figure 5-9 are as follows:

- **Skeletal muscle** is under voluntary or conscious control. It has a striated appearance. Skeletal muscles are usually connected to bones and are used for movement.
- **Cardiac muscle** is found only in the heart and is also under involuntary control. It has a striated (striped) appearance when viewed microscopically. Any damage to the cardiac muscle, such as a heart attack, can have major, if not fatal, consequences.
- **Smooth muscle** is under involuntary control by the nervous system. This means that it contracts with no conscious effort. Its appearance looks smooth, hence the name. Smooth muscle is found throughout the digestive tract, urinary tract, and

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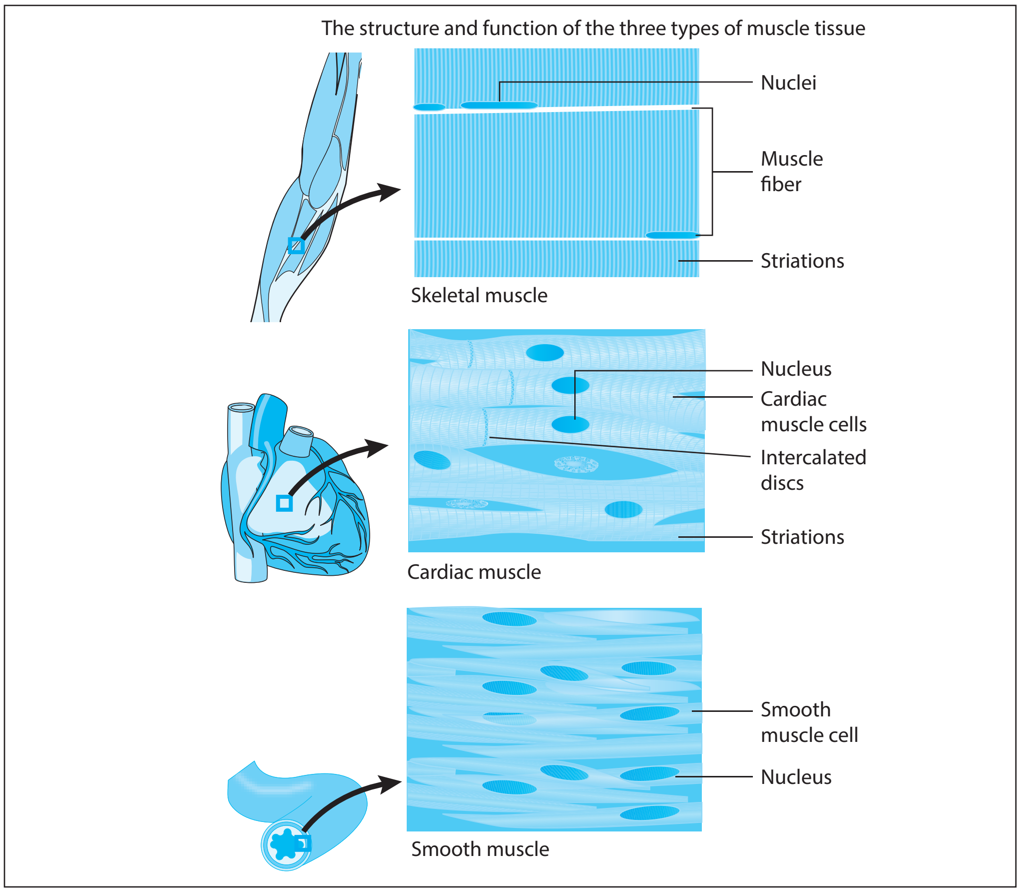

FIGURE 5-9 The three types of muscle.

reproductive system. It is also found in veins, where it helps blood move toward the heart.

Nervous Tissue

Nervous tissue is composed of two primary cell types: neurons and glial cells. **Neurons** have the ability to communicate with each other as well as with other cells in the body, while **glial cells** provide supporting functions to neurons. Mature neurons are unable to perform mitosis to replace themselves, which is one reason that neurological injuries and illnesses are so serious.

All neurons have a **cell body** that contains the nucleus and most of the cell's organelles. Projections reaching out from the cell body are dendrites and axons. **Dendrites** pick up messages and send them to the cell body. The cell body then processes the message and sends electrical impulses out through a long projection called the **axon**. In some cases, axons may be more than a meter in length. The axon terminates in synaptic knobs, which are extensions of the axon. The **synaptic knobs** can send messages to the dendrites of other neurons via neurotransmitters. The space between a synaptic knob of one neuron and the dendrite of another composes the synapse. The structure of a generalized neuron can be seen in Figure 5-10.

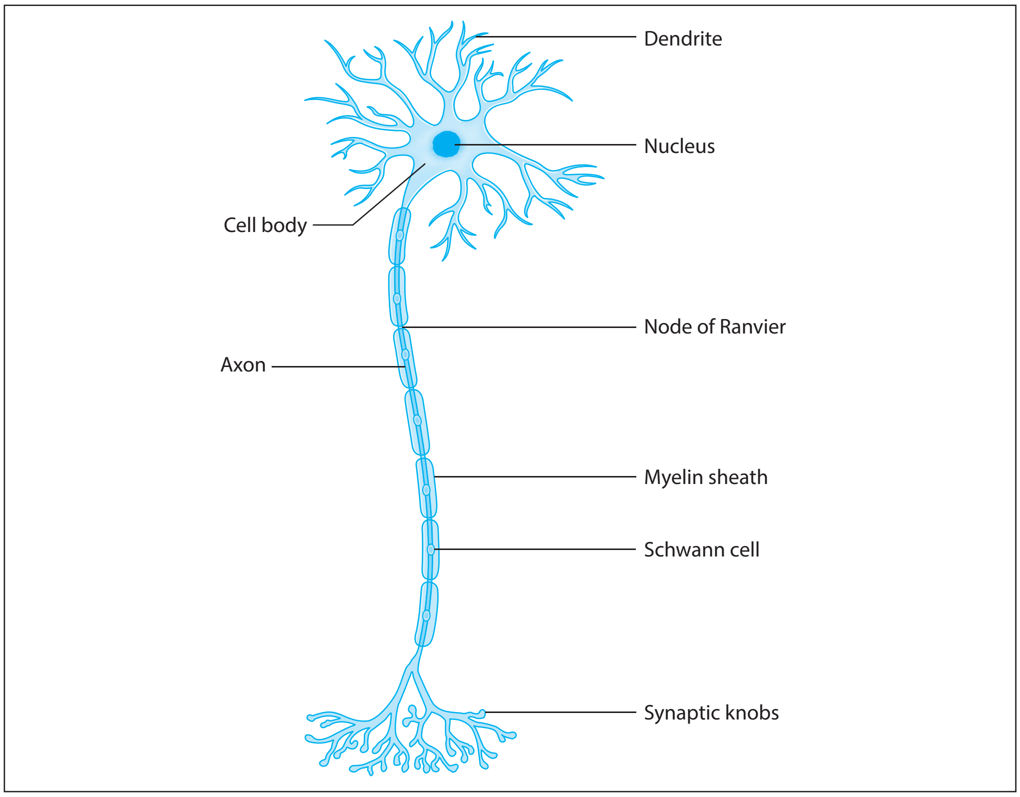

FIGURE 5-10 Neuron structure.

Many neurons have **Schwann cells** wrapped around their axons. These cells produce a hydrophobic lipoprotein called **myelin** that forms a **sheath** to insulate the axon and help impulses propagate at the fastest possible rate. The myelin sheath contains **nodes of Ranvier** that are gaps in the sheath. As impulses are sent down the length of the axon, they jump from node to node.

MEMBRANES

Membranes within the body are composed of an association of two tissue types. There are three major types of membranes: serous, mucous, and cutaneous.

- **Serous membranes** are made of epithelial and connective tissues and line internal body cavities and cover organs.
- **Mucous membranes** are also composed of epithelial and connective tissues. Their job is to secrete mucus onto surfaces of the body that are in contact with the outside environment such as the mouth, nose, trachea, and digestive tract.
- The **cutaneous membrane** covers the outer surface of the body and is also known as **the skin**. The upper layers of the skin are composed of epithelial and connective tissues.