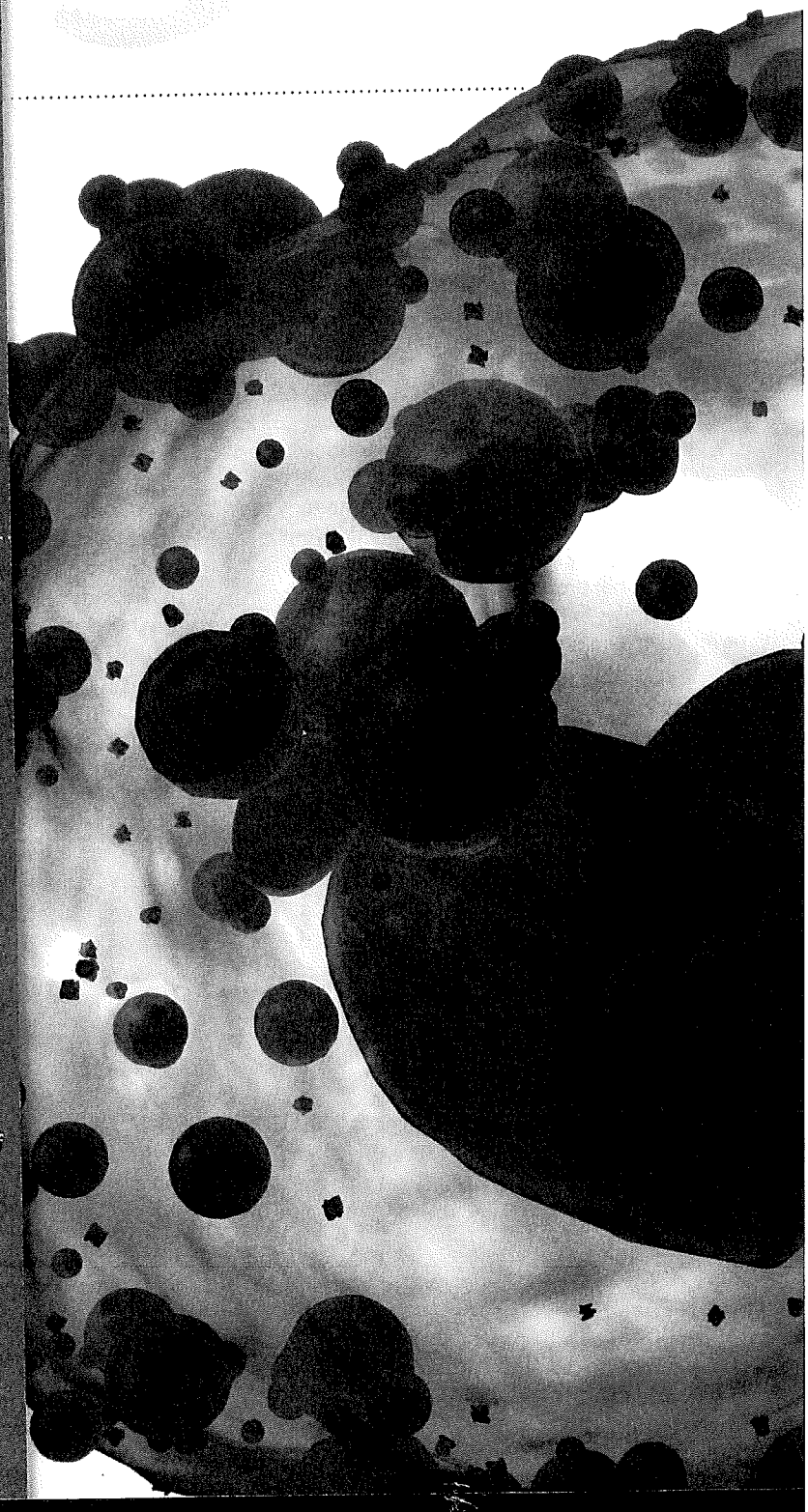
Cells and Tissues

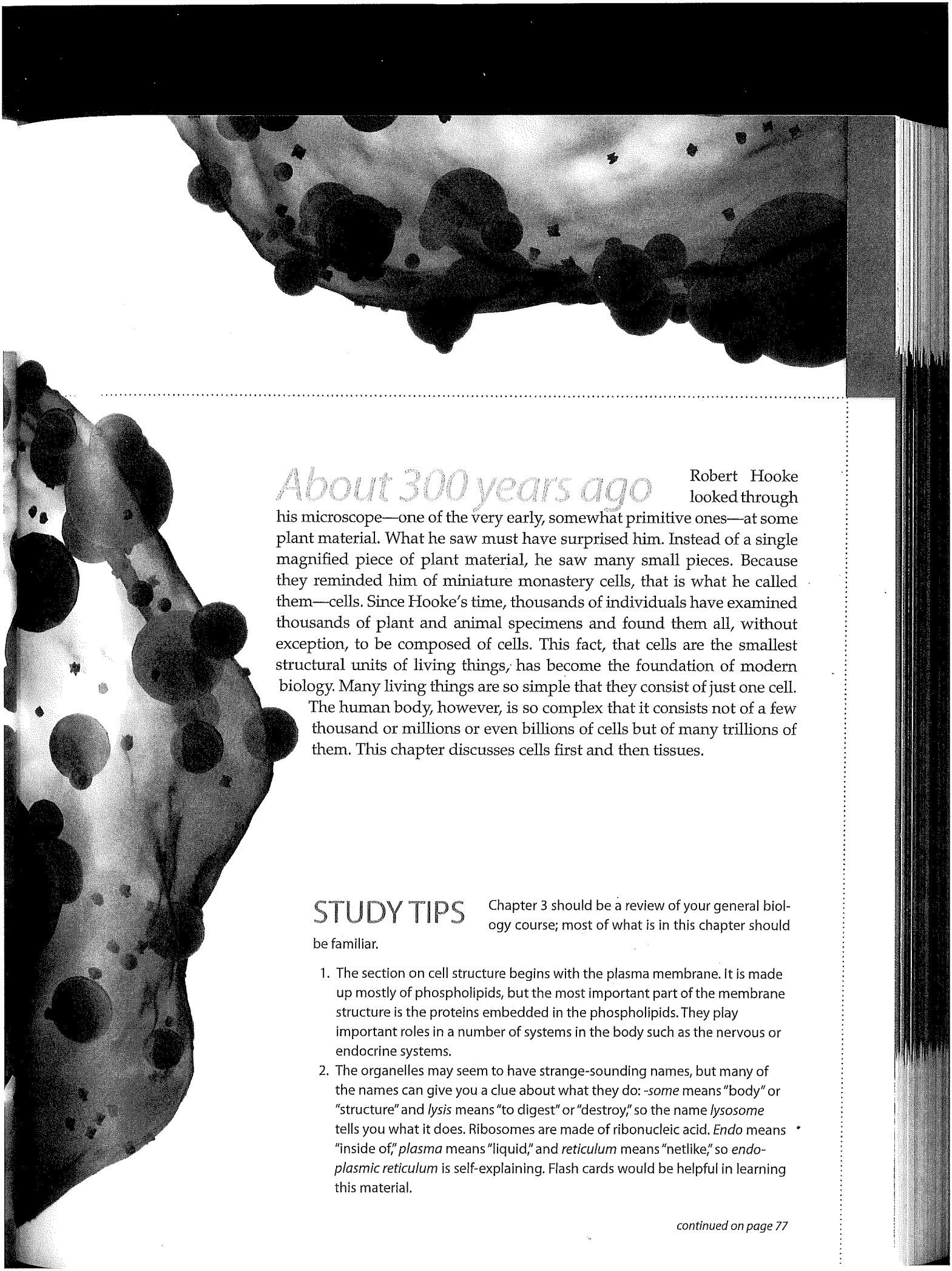
Outline

Objectives

After you have completed this chapter, you should be able to:

1. Identify and discuss the basic structure and function of the three major components of a cell.
2. List and briefly discuss the functions of the primary cellular organelles.
3. Compare the major passive and active transport processes that act to move substances through cell membranes.
4. Compare and discuss DNA and RNA and their function in protein synthesis.
5. Discuss the stages of mitosis and explain the importance of cellular reproduction.
6. Explain how epithelial tissue is grouped according to shape and arrangement of cells.
7. List and briefly discuss the major types of connective and muscle tissue.
8. List the three structural components of a neuron.





About 300 years ago Robert Hooke looked through his microscope—one of the very early, somewhat primitive ones—at some plant material. What he saw must have surprised him. Instead of a single magnified piece of plant material, he saw many small pieces. Because they reminded him of miniature monastery cells, that is what he called them—cells. Since Hooke's time, thousands of individuals have examined thousands of plant and animal specimens and found them all, without exception, to be composed of cells. This fact, that cells are the smallest structural units of living things, has become the foundation of modern biology. Many living things are so simple that they consist of just one cell. The human body, however, is so complex that it consists not of a few thousand or millions or even billions of cells but of many trillions of them. This chapter discusses cells first and then tissues.

STUDY TIPS

Chapter 3 should be a review of your general biology course; most of what is in this chapter should be familiar.

1. The section on cell structure begins with the plasma membrane. It is made up mostly of phospholipids, but the most important part of the membrane structure is the proteins embedded in the phospholipids. They play important roles in a number of systems in the body such as the nervous or endocrine systems.
2. The organelles may seem to have strange-sounding names, but many of the names can give you a clue about what they do: *-some* means "body" or "structure" and *lysis* means "to digest" or "destroy," so the name *lysosome* tells you what it does. Ribosomes are made of ribonucleic acid. *Endo* means "inside of," *plasma* means "liquid," and *reticulum* means "netlike," so *endoplasmic reticulum* is self-explaining. Flash cards would be helpful in learning this material.

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Cells

Size and Shape

Human cells are microscopic in size; that is, they can be seen only when magnified by a microscope. However, the different types of human cells vary considerably in size. An ovum (female sex cell), for example, has a diameter of about 150 micrometers, whereas red blood cells have a diameter of only 7.5 micrometers. Cells differ even more notably in shape than in size. Some are flat, some are brick shaped, some are thread-like, and some have irregular shapes.

Composition

Cells contain **cytoplasm** (SYE-toh-plaz-em), or "living matter," a substance that exists only in cells. The term *cyto-* is a Greek combining form and denotes a relationship to a cell. Each cell in the body is surrounded by a thin membrane, the **plasma membrane.** This membrane separates the cell contents from the dilute saltwater solution called **interstitial** (in-ter-STISH-all) **fluid,** or simply **tissue fluid,** that bathes every cell in the body. Numerous specialized structures called **organelles** (or-gah-NELLZ), which will be described in subsequent sections, are contained within the cytoplasm of each cell. A small, circular body called the **nucleus** (NOO-klee-us) is also inside the cell.

Important information related to body composition is included in Chapter 2. You are encouraged to review this material, which includes a discussion of the chemical elements and compounds important to body structure and function.

Parts of the Cell

The three main parts of a cell are:

1. Plasma membrane
2. Cytoplasm
3. Nucleus

The plasma membrane surrounds the entire cell, forming its outer boundary. The cytoplasm is all the living material inside the cell (except the nucleus). The nucleus is a large, membrane-bound structure in most cells that contains the genetic code.

PLASMA MEMBRANE

As the name suggests, the **plasma membrane** is the membrane that encloses the cytoplasm and forms the outer boundary of the cell. It is an incredibly delicate structure—only about 7 nm (nanometers) or 3/10,000,000 of an inch thick! Yet it has a precise, or-

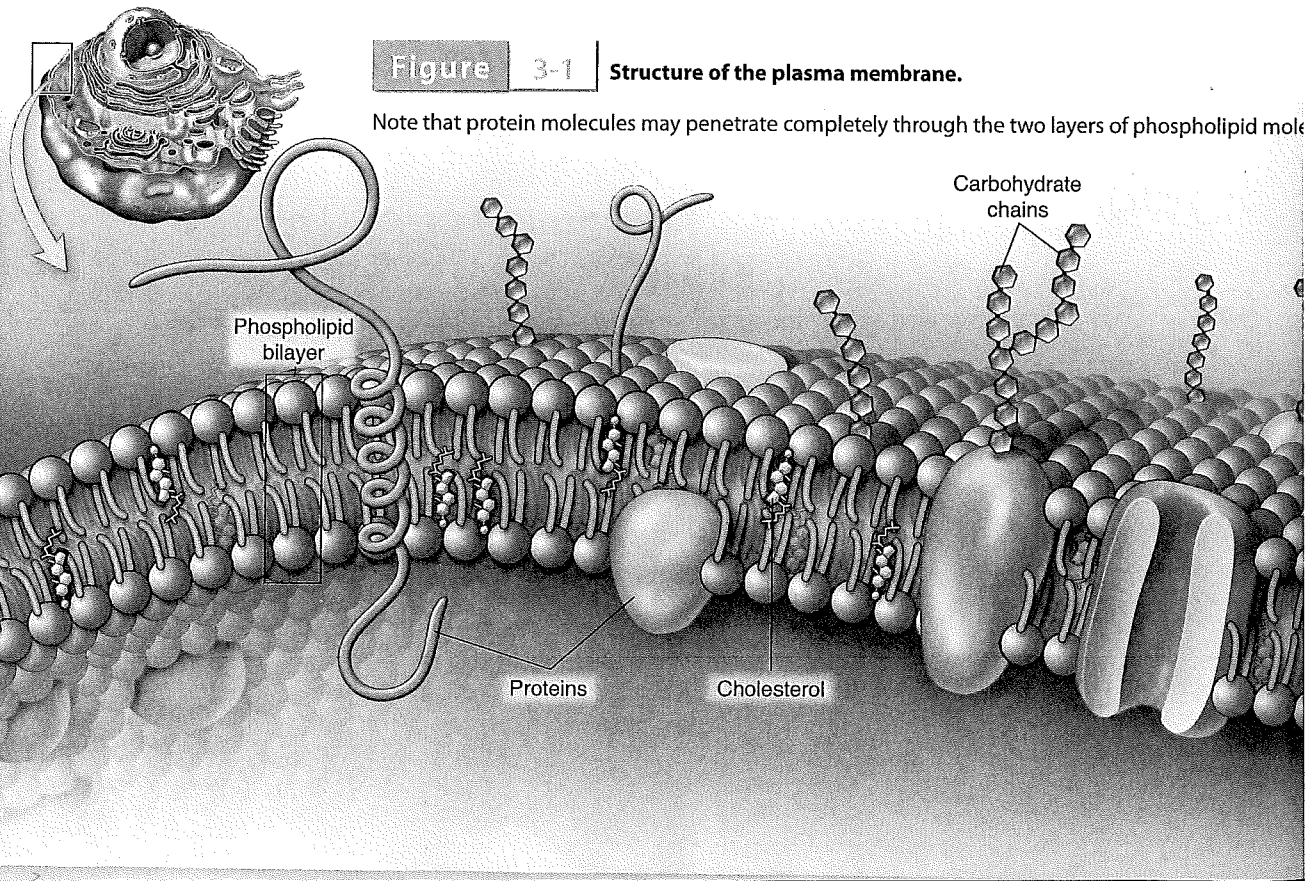


Figure 3-1 **Structure of the plasma membrane.**

Note that protein molecules may penetrate completely through the two layers of phospholipid mole

derly structure (Figure 3-1). Two layers of phosphate-containing fat molecules called **phospholipids** form a fluid framework for the plasma membrane. Another kind of fat molecule called *cholesterol* is also a component of the plasma membrane. Cholesterol helps stabilize the phospholipid molecules to prevent breakage of the plasma membrane. Note in Figure 3-1 that protein molecules dot the surfaces of the membrane and extend all the way through the phospholipid framework.

Despite its seeming fragility, the plasma membrane is strong enough to keep the cell whole and intact and also performs other life-preserving functions for the cell. It serves as a well-guarded gateway between the fluid inside the cell and the fluid around it. Certain substances can move through the membrane, but others are barred from entry. The plasma membrane even functions as a communication device. In what way, you may wonder? Some proteins on the membrane's outer surface serve as receptors for certain other molecules when these other molecules contact the proteins. In other words, certain molecules bind to certain receptor proteins. For example, some hormones (chemicals secreted into blood from ductless glands) bind to membrane receptors, and a change in cell functions follows. We might therefore think of such hormones as chemical messages that are communicated to cells by way of binding to their cytoplasmic membrane receptors.

The plasma membrane also identifies a cell as being part of one particular individual. Its surface proteins serve as positive identification tags because they occur only in the cells of that individual. A practical application of this fact is made in *tissue typing*, a procedure performed before an organ from one individual is transplanted into another. Carbohydrate chains attached to the surface of cells often play a role in the identification of cell types.

CYTOPLASM

Cytoplasm is the internal living material of cells. It fills the space between the plasma membrane and the nucleus, which can be seen in Figure 3-2 as a round or

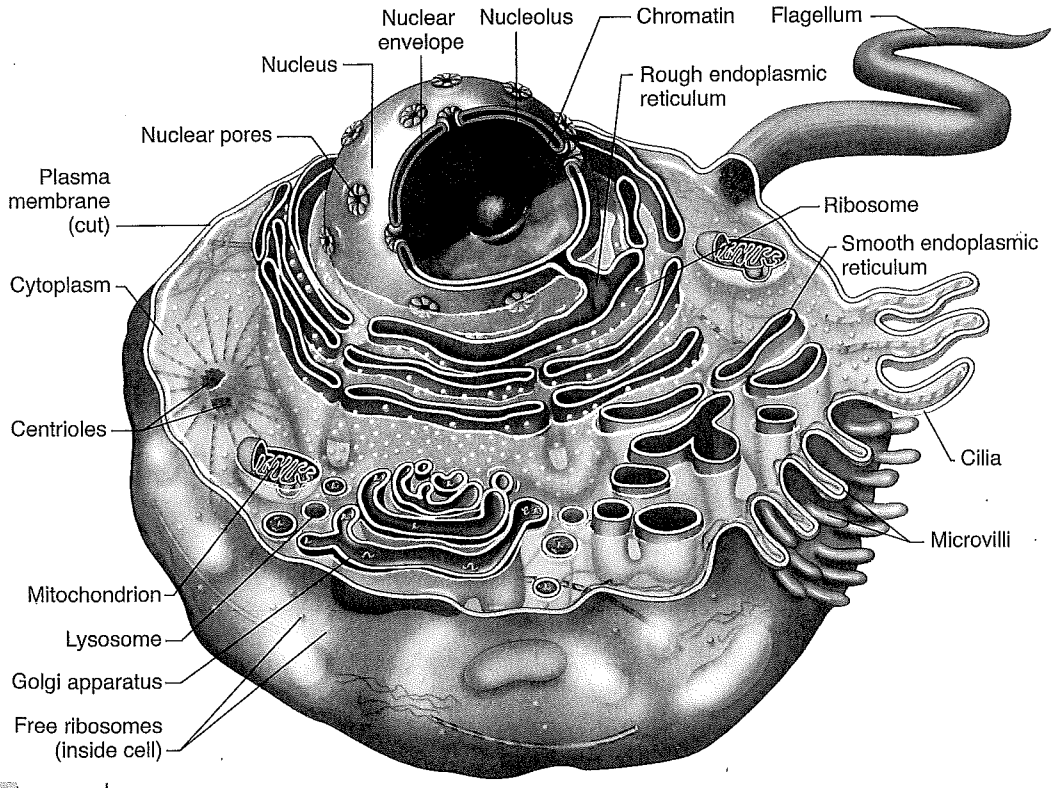


Figure 3-2 **General characteristics of the cell.**

Artist's interpretation of cell structure. Some of these structures, such as a flagellum or groups of cilia, are present only in certain types of cells.

spherical structure in the center of the cell. Numerous small structures are part of the cytoplasm, along with the fluid that serves as the interior environment of each cell. As a group, the small structures that make up much of the cytoplasm are called **organelles.** This name means "little organs," an appropriate name because they function for the cell like organs function for the body.

Look again at Figure 3-2. Notice how many different kinds of structures you can see in the cytoplasm of this cell. A little more than a generation ago, almost all of these organelles were unknown. They are so small that they are still invisible even when magnified 1000 times by a light microscope. The advent of electron microscopes finally brought them into view by magnifying them many thousands of times. Next we briefly discuss the following organelles, all of which are found in cytoplasm (Table 3-1):

1. Ribosomes
2. Endoplasmic reticulum
3. Golgi apparatus
4. Mitochondria
5. Lysosomes
6. Centrioles
7. Cilia
8. Flagella

Ribosomes

Organelles called **ribosomes** (RYE-boh-sohms), shown as dots in Figure 3-2, are very tiny particles found throughout the cell. They are each made up of two tiny subunits constructed mostly of a special kind of RNA called *ribosomal RNA (rRNA).* Some ribosomes are found temporarily attached to a network of membranous canals called *endoplasmic reticulum (ER).* Ribosomes also may be free-floating in the cytoplasm. Ribosomes perform a very complex function: they make enzymes and other protein compounds. Thus they are aptly nicknamed "protein factories."

Table 3-1 Structures and Function of Some Major Cell Parts

CELL PART	STRUCTURE	FUNCTION(S)
Plasma membrane	Phospholipid bilayer studded with proteins	Serves as the boundary of the cell; protein and carbohydrate molecules on outer surface of plasma membrane perform various functions; for example, they serve as markers that identify cells as being from a particular individual or as receptor molecules for certain hormones
Ribosomes	Tiny particles, each made up of rRNA subunits	Synthesize proteins; a cell's "protein factories"
Endoplasmic reticulum (ER)	Membranous network of interconnected canals and sacs, some with ribosomes attached (rough ER) and some without attachments (smooth ER)	Rough ER receives and transports synthesized proteins (from ribosomes); smooth ER synthesizes lipids and certain carbohydrates
Golgi apparatus	Stack of flattened, membranous sacs	Chemically processes, then packages substances from the ER
Mitochondria	Membranous capsule containing a large, folded membrane encrusted with enzymes; contains its own DNA molecule	Adenosine triphosphate (ATP) synthesis; a cell's "powerhouses"
Lysosomes	"Bubble" of enzymes encased by membrane	A cell's "digestive system"
Centrioles	Pair of hollow cylinders, each made up of tiny tubules	Function in cell reproduction
Cilia	Short, hairlike extensions on surface of some cells	Move substances along surface of the cell
Flagella	Single and much longer projection of some cells	The only example in humans is the "tail" of a sperm cell, propelling the sperm through fluids
Nucleus	Double-membraned, spherical envelope containing DNA strands	Dictates protein synthesis, thereby playing an essential role in other cell activities, namely active transport, metabolism, growth, and heredity
Nucleolus	Dense region of the nucleus	Plays an essential role in the formation of ribosomes

Endoplasmic Reticulum

An **endoplasmic reticulum** (en-doh-PLAZ-mik reh-TIK-yoo-lum) **(ER)** is a system of membranes forming a network of connecting sacs and canals that wind back and forth through a cell's cytoplasm, from the nucleus almost to the plasma membrane. The tubular passageways or canals in the ER carry proteins and other substances through the fluid cytoplasm of the cell from one area to another. There are two types of ER: *rough* and *smooth*. Rough ER is named such because many ribosomes are attached to its outer surface, giving it a rough texture similar to sandpaper. As ribosomes make their proteins, they may attach to the rough ER and drop the protein into the interior of the ER. The ER then begins folding the new proteins and transports them to areas in which chemical processing takes place. These areas of the ER are so full of molecules that ribosomes have no room into which they can pass their proteins and so they do not attach. The absence of attached ribosomes gives this type of ER a smooth texture. Fats, carbohydrates, and proteins that make up cellular membrane material are manufactured in smooth ER. Thus the smooth ER makes new membrane for the cell. To sum up: rough ER receives, folds, and transports newly made proteins and smooth ER manufactures new membrane.

Golgi Apparatus

The **Golgi** (GOL-jee) **apparatus** consists of tiny, flattened sacs stacked on one another near the nucleus. Little bubbles, or sacs, break off the smooth ER and carry new proteins and other compounds to the sacs of the Golgi apparatus. These little sacs, also called **vesicles,** fuse with the Golgi sacs and allow the contents of both to mingle. The Golgi apparatus chemically processes the molecules from the ER by continuing the folding of proteins begun in the ER and combining them with other molecules to form quaternary proteins or combinations such as glycoproteins (carbohydrate/protein combinations). The Golgi apparatus then packages the processed molecules into new little vesicles that break away from the Golgi apparatus and move slowly outward to the plasma membrane. Each vesicle fuses with the plasma membrane, opens to the outside of the cell, and releases its contents. An example of a Golgi apparatus product is the slippery substance called *mucus*. If we wanted to nickname the Golgi apparatus, we might call it the cell's "chemical processing and packaging center."

Mitochondria

Mitochondria (my-toh-KON-dree-ah) are another kind of organelle found in all cells. Mitochondria are so tiny that a lineup of 15,000 or more of them would fill a space only about 2.5 cm (1 inch) long. Two membranous sacs, one inside the other, compose a single mitochondrion. The inner membrane forms folds that look like miniature incomplete partitions. Within a mitochondrion's fragile walls, complex, energy-releasing chemical reactions occur continuously. Because these reactions supply most of the power for cellular work, mitochondria have been nicknamed the cell's "power plants." The survival of cells and therefore of the body depends on mitochondrial chemical reactions. Enzymes (molecules that promote specific chemical reactions), which are found in mitochondrial walls and the mitochondrial fluids, use oxygen to break down glucose and other nutrients to release energy required for cellular work. The process is called *aerobic* or *cellular respiration.* Each mitochondrion has its own DNA molecule, sometimes called a *mitochondrial chromosome,* that contains information for building and running the mitochondrion.

Lysosomes

The **lysosomes** (LYE-soh-sohms) are membranous-walled organelles that in their active stage look like small sacs, often with tiny particles in them (see Figure 3-2). Because lysosomes contain enzymes that can digest food compounds, they have the nickname "digestive bags." Lysosomal enzymes also can digest substances other than foods. For example, they can digest and thereby destroy microbes that invade the cell. Thus lysosomes can protect cells against destruction by microbes. Formerly, scientists thought lysosomes were involved in programmed cell death. Now, however, we know a different set of mechanisms is responsible for "cell suicide," or **apoptosis** (ap-op-TOH-sis), which makes space for newer cells.

Centrioles

The **centrioles** (SEN-tree-ohlz) are paired organelles. Two of these rod-shaped structures exist in every cell. They are arranged so that they lie at right angles to each other (see Figure 3-2). Each centriole is composed of fine tubules that play an important role during cell division.

Microvilli

Microvilli (my-kroh-VILL-eye) are small fingerlike projections of the plasma membrane of some cells

(Figure 3-3, *A*). These projections increase the surface area of the cell and thus increase its ability to absorb substances. For example, cells that line the small intestine are covered with microvilli that increase the absorption rate of nutrients into the blood.

Cilia

Cilia (SIL-ee-ah) are extremely fine, almost hairlike extensions on the exposed or free surfaces of some cells (Figure 3-3, *A*). Cilia are organelles capable of movement. One cell may have a hundred or more cilia capable of moving together in a wavelike fashion over the surface of a cell. They often have highly specialized functions. For example, by moving as a group in one direction, they propel mucus upward over the cells that line the respiratory tract. Single, nonmoving cilia have a sensory function and are present in some sensory cells of the eye, ear, nose, and other sensory organs.

Flagella

A **flagellum** (flah-JEL-um) is a single projection extending from the cell surface. Flagella are much larger than cilia. In the human, the only example of a flagellum is the "tail" of the male sperm cell. Propulsive movements of the flagellum make it possible for sperm to "swim" or move toward the ovum after they are deposited in the female reproductive tract (Figure 3-3, *B*).

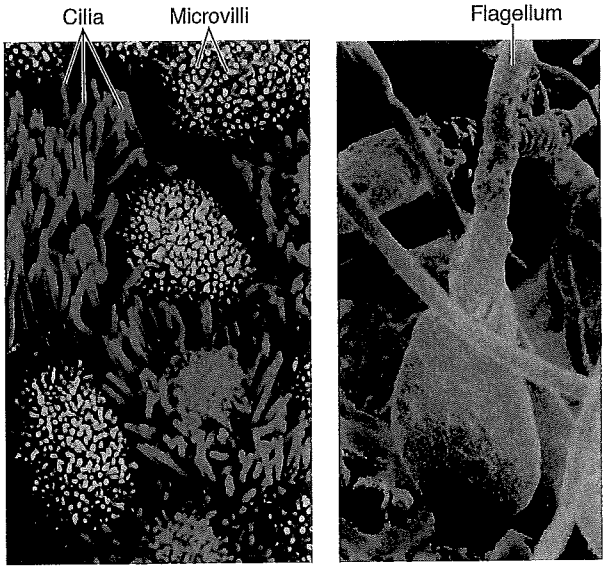


Figure 3-3 **Cell extensions.**

A, Microvilli *(light blue)* are small, fingerlike extensions of the plasma membrane that increase the surface area for absorption. Cilia *(darker blue)* are longer than microvilli and move back and forth, pushing fluids along the surface. **B,** The tail-like flagellum that propels each sperm cell is so long that it does not fit into the photograph at this magnification.

NUCLEUS

Viewed under a light microscope, the **nucleus** of a cell looks like a very simple structure—just a small sphere in the central portion of the cell. However, its simple appearance belies the complex and critical role it plays in cell function. The nucleus ultimately controls every organelle in the cytoplasm. It also controls the complex process of cell reproduction. In other words, the nucleus must function properly for a cell to accomplish its normal activities and be able to duplicate itself.

Note that the cell nucleus in Figure 3-2 is surrounded by a **nuclear envelope,** made up of two separate membranes. The nuclear envelope has many tiny openings called *nuclear pores* that permit large molecules to move into and out of the nucleus. The nuclear envelope encloses a special type of cell material within the nucleus called **nucleoplasm.** Nucleoplasm contains a number of specialized structures; two of the most important are shown in Figure 3-2. They are the **nucleolus** (noo-KLEE-oh-lus) and the **chromatin** (KROH-mah-tin) **granules.**

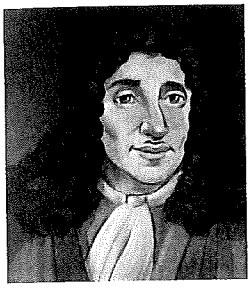
Nucleolus

The nucleolus is a dense region of the nuclear material that is critical in protein formation because it "programs" the formation of ribosomes in the nucleus. The ribosomes then migrate through the nuclear envelope into the cytoplasm of the cell and produce proteins.

Chromatin and Chromosomes

Chromatin granules in the nucleus are threadlike structures made of proteins and hereditary molecules called **DNA,** or **deoxyribonucleic** (dee-OK-see-rye-boh-noo-KLAY ik) **acid.** DNA is the genetic material often described as the chemical "cookbook" of the body. Because it contains the code for building both structural proteins and functional proteins, DNA determines everything from gender and metabolism rate to body build and hair color in every human being. During cell division, DNA molecules become tightly coiled. They then look like short, rodlike structures and are called **chromosomes.** Each cell of the body contains a total of 46 different DNA molecules in its nucleus and one copy of a 47th DNA molecule in each of its mitochondria. The importance and function of DNA are explained in greater detail in the section on cell reproduction later in this chapter.

SCIENCE APPLICATIONS

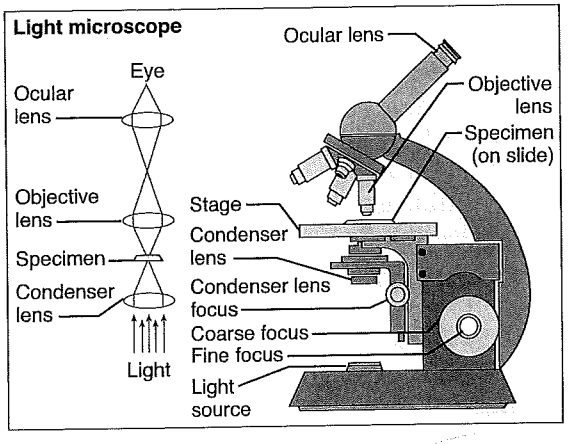


Antoni van Leeuwenhoek (1632–1723)

MICROSCOPY

Until the very hour of his death in 1723, the Dutch drapery merchant Antoni van Leeuwenhoek *(left)* spent most of his 91 years pursuing adventures with the hundreds of microscopes he had built or collected. Using what were, even then, very simple lenses or combinations of lenses, van Leeuwenhoek discovered a whole world of tiny structures he called "animalcules" in body fluids. Although scientists a century later would declare that all living organisms are made up of cells, van Leeuwenhoek was the first to see and describe human blood cells (see Figure 3-22), human sperm cells (see Figure 3-3, *B*), and many other cells and tissues of the body. He was also the first to observe many microscopic organisms that live on or in the human body—many of which are capable of producing disease.

Scientists today use light microscopes that are much more advanced than those of van Leeuwenhoek's time. Some of the most modern microscopes, called *electron microscopes,* use electron beams instead of light to produce images of very high magnification (see Figure 3-3). Both cell biologists and *histologists* (tissue biologists) use microscopes to research the fine structure and function of the human body. A wide variety of professions have found practical applications for microscopy. Most health professionals use microscopes, or the images produced with microscopes, to perform routine duties. For example, clinical laboratory technicians and pathologists use microscopes to assess the health of human cells and tissues. Outside of the health sciences, professionals such as law enforcement investigators, archaeologists, anthropologists, and paleontologists often use microscopes to further their study of human and animal tissues.



Modern compound light microscope

Relationship of Cell Structure and Function

Every human cell performs certain functions; some maintain the cell's survival, and others help maintain the body's survival. In many instances, the number and type of organelles within cells cause cells to differ dramatically in terms of their specialized functions. For example, cells that contain large numbers of mitochondria, such as heart muscle cells, are capable of sustained work. Why? Because the numerous mitochondria found in these cells supply the necessary energy required for rhythmic and ongoing contractions of the heart. Movement of the flagellum of a sperm cell is another example of the way a specialized organelle has a specialized function. The sperm's flagellum propels it through the reproductive tract of the female, thus increasing the chances of successful fertilization. This is how and why organizational structure at the cellular level is so important for function in living organisms. Examples in every chapter of the text illustrate how structure and function are intimately related at every level of body organization.

QUICK CHECK

1. What is the molecular structure of the *plasma membrane* of the cell?
2. What is *cytoplasm*? What does it contain?
3. List five major structures of the cell and briefly describe their function.
4. Which two kinds of cell structures contain DNA?

Movement of Substances Through Cell Membranes

The plasma membrane in every healthy cell separates the contents of the cell from the tissue fluid that surrounds it. At the same time the membrane

must permit certain substances to enter the cell and allow others to leave. Heavy traffic moves continuously in both directions through cell membranes. Molecules of water, foods, gases, wastes, and many other substances stream in and out of all cells in endless procession. A number of processes allow this mass movement of substances into and out of cells. These **transport processes** are classified under two general headings:

1. Passive transport processes
2. Active transport processes

As implied by their names, active transport processes require the expenditure of energy by the cell, and passive transport processes do not. The energy required for active transport processes is obtained from a very important chemical substance called **adenosine triphosphate** (ah-DEN-oh-seen try-FOS-fayt), or **ATP.** ATP is produced in the mitochondria using energy from nutrients and is capable of releasing that energy to do work in the cell. For active transport processes to occur, the breakdown of ATP and the use of the released energy are required.

The details of active and passive transport of substances across cell membranes are much easier to understand if you keep in mind the following two key facts: (1) in passive transport processes, no cellular energy is required to move substances from a high concentration to a low concentration; and (2) in active transport processes, cellular energy is required to move substances from a low concentration to a high concentration.

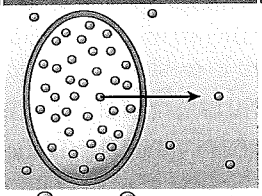
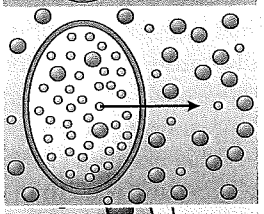
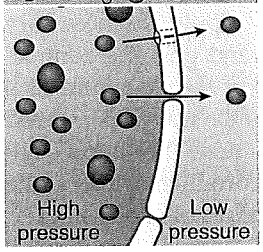
Passive Transport Processes

The primary **passive transport** processes that move substances through the cell membranes include the following:

1. Diffusion
   a. Osmosis
   b. Dialysis
2. Filtration

Scientists describe the movement of substances in passive systems as going "down a concentration gradient." This means that substances in passive systems move from a region of high concentration to a region of low concentration until they reach equal

Table 3-2 | Passive Transport Processes

PROCESS	DESCRIPTION		EXAMPLES
Diffusion	Movement of particles through a membrane from an area of high concentration to an area of low concentration—that is, down the concentration gradient		Movement of carbon dioxide out of all cells; movement of sodium ions into nerve cells as they conduct an impulse
Osmosis	Diffusion of water through a selectively permeable membrane in the presence of at least one impermeant solute		Diffusion of water molecules into and out of cells to correct imbalances in water concentration
Filtration	Movement of water and small solute particles, but not larger particles, through a filtration membrane; movement occurs from area of high pressure to area of low pressure		In the kidney, water and small solutes move from blood vessels but blood proteins and blood cells do not, thus beginning the formation of urine

proportions on both sides of the membrane. As you read the next few paragraphs, refer to Table 3-2, which summarizes important information about passive transport processes.

DIFFUSION

Diffusion, a good example of a passive transport process, is the process by which substances scatter themselves evenly throughout an available space. The system does not require additional energy for this movement. To demonstrate diffusion of particles throughout a fluid, perform this simple experiment the next time you pour yourself a cup of coffee or tea. Place a cube of sugar on a teaspoon and lower it gently to the bottom of the cup. Let it stand for 2 or 3 minutes, and then, holding the cup steady, take a sip off the top. It will taste sweet. Why? Because some of the sugar molecules will have diffused from the area of high concentration near the sugar cube at the bottom of the cup to the area of low concentration at the top of the cup.

The process of diffusion is shown in Figure 3-4. Note that both substances diffuse rapidly through the membrane in both directions. However, as indicated by the green arrows, more of the solute (dissolved substance) moves out of the 20% solution, where the concentration is higher, into the 10% solution, where the concentration is lower, than in the opposite direction. This is an example of movement down a concentration gradient. Simultaneously, more water moves from the 10% solution, where there are more water molecules, into the 20% solution, where there are fewer water molecules. This is also an example of movement down a concentration gradient. Water moves from high to low concentration. The result? Equilibration (balancing) of the concentrations of the two solutions after an interval of time. From then on, equal amounts of solute will diffuse in both directions, as will equal amounts of water.

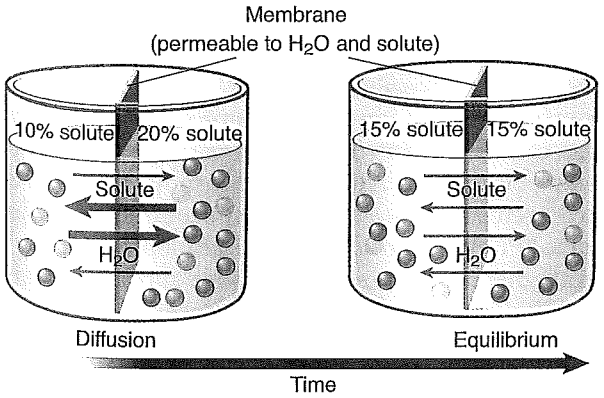


Figure 3-4 Diffusion.

Note that the membrane is permeable to solute and water and that it separates a 10% solution of solute particles from a 20% solution. The container on the left shows the two solutions separated by the membrane at the start of diffusion. The container on the right shows the result of diffusion after some time has passed.

Osmosis and Dialysis

Osmosis (os-MOH-sis) and **dialysis** (dye-AL-i-sis) are specialized examples of diffusion. In both cases, diffusion occurs across a selectively permeable membrane. The plasma membrane of a cell is said to be selectively permeable because it permits the passage of certain substances but not others; that is, this necessary property permits some substances, such as nutrients, to gain entrance to the cell while excluding others. Osmosis is the diffusion of water, but not **solutes** (substances dissolved in the water), across a selectively permeable membrane.

FILTRATION

Filtration is the movement of water and solutes through a membrane as a result of a pushing force that is greater on one side of the membrane than on the other side. The force is called *hydrostatic pressure,* which is simply the force or weight of a fluid pushing against some surface (an example is blood pressure, in which blood pushes against vessel walls). A principle concerning filtration that is of great physiological importance is that it always occurs *down* a hydrostatic pressure gradient. This means that when two fluids have unequal hydrostatic pressures and are separated by a membrane, water and diffusible solutes or particles (those to which the membrane is permeable) will filter out of the solution that has the higher hydrostatic pressure into the solution that has the lower hydrostatic pressure. Filtration is the process responsible for urine formation in the kidney; wastes are filtered out of the blood into the kidney tubules because of a difference in hydrostatic pressure.

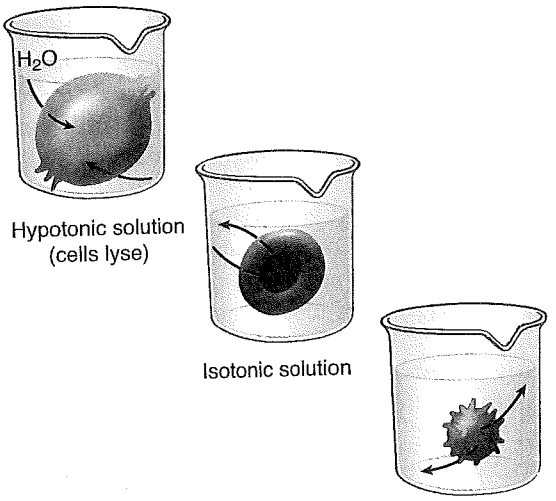
CLINICAL APPLICATION

TONICITY

A salt (NaCl) solution is said to be **isotonic** (*iso* = equal) if it contains the same concentration of salt normally found in a living red blood cell, which measures 0.9% NaCl. Salt particles (Na^+ and Cl^- ions) do not cross the plasma membrane easily, so salt solutions that differ in concentration from the cell's fluid will promote the osmosis of water one way or the other. A solution that contains a higher level of salt than the cell (above 0.9%) is said to be **hypertonic** (*hyper* = above) to the cell and one containing less (below 0.9%) is **hypotonic** (*hypo* = below) to the cell. With what you now know about filtration, diffusion, and osmosis, can you predict what would occur if red blood cells were placed in isotonic, hypotonic, and hypertonic solutions?

Examine the figures. Note that red blood cells placed in isotonic solution remain unchanged because there is no effective difference in salt or water concentrations. The movement of water into and out of the cells is about equal. This is not the case with red cells placed in hypertonic salt solution; they immediately lose water from their cytoplasm into the surrounding salty solution, and they shrink. This process is called **crenation.**

The opposite occurs if red cells are placed in a hypotonic solution; they swell as water enters the cell from the surrounding dilute solution. Eventually the cells break, or **lyse,** and the hemoglobin they contain is released into the surrounding solution.




To learn more about passive transport, go to **AnimationDirect** on your CD.

Active Transport Processes

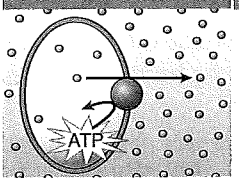
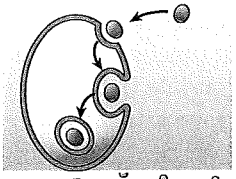
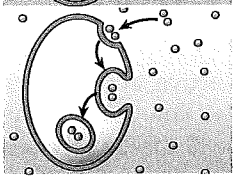
Active transport is the uphill movement of a substance through a living cell membrane. *Uphill* means "up a concentration gradient" (that is, from a lower to a higher concentration). The energy required for this movement is obtained from ATP. Because the formation and breakdown of ATP require complex cellular activity, active transport mechanisms can take place only through living membranes. Table 3-3 summarizes active transport processes.

ION PUMPS

A specialized cellular component called the *ion pump* makes possible a number of active transport mechanisms. An ion pump is a protein structure in the cell membrane called a *carrier.* The ion pump uses energy from ATP to actively move ions across cell membranes *against* their concentration gradients. "Pump" is an appropriate term because it suggests that active transport moves a substance in an uphill direction just as a water pump does, that is, moves water uphill.

An ion pump is specific to one particular ion; different ion pumps are required to move different types of ions. For example, sodium pumps move sodium ions only. Likewise, calcium pumps move calcium ions and potassium pumps move potassium ions.

Table 3-3 | Active Transport Processes

PROCESS	DESCRIPTION		EXAMPLES
Ion pump	Movement of solute particles from an area of low concentration to an area of high concentration (up the concentration gradient) by means of a carrier protein structure		In muscle cells, pumping of nearly all calcium ions to special compartments—or out of the cell
Phagocytosis	Movement of cells or other large particles into cell by trapping it in a section of plasma membrane that pinches off inside the cell		Trapping of bacterial cells by phagocytic white blood cells
Pinocytosis	Movement of fluid and dissolved molecules into a cell by trapping them in a section of plasma membrane that pinches off inside the cell		Trapping of large protein molecules by some body cells

Some ion pumps are "coupled" to one another so that two or more different substances may be moved through the cell membrane at one time. For example, the **sodium-potassium pump** shown in Figure 3-5 pumps sodium ions out of a cell while it pumps potassium ions into the cell. Because both ions are moved against their concentration gradients, this pump creates a high sodium concentration outside the cell and a high potassium concentration inside the cell. Such a pump is required to remove sodium from the inside of a nerve cell after it has rushed in as a result of the passage of a nerve impulse. Some ion pumps are coupled with other specific carriers that transport glucose, amino acids, and other substances. However, there are no transporter pumps for moving water—it can move only passively by osmosis.

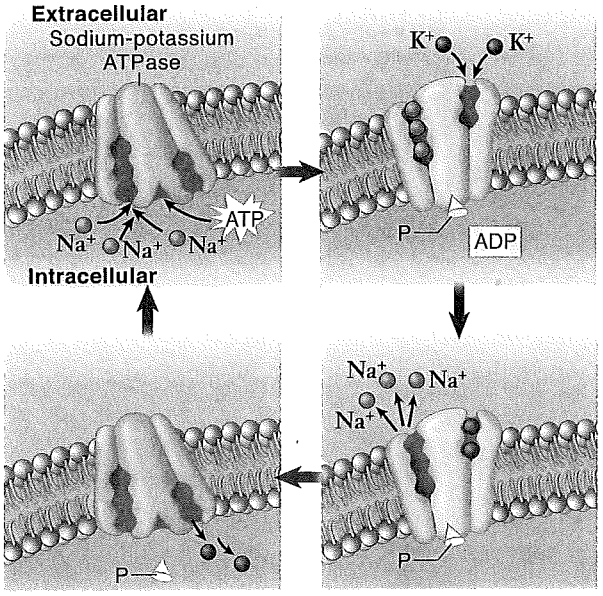


Figure 3-5 Sodium-potassium pump.

Three sodium ions (Na^+) are pumped out of the cell and two potassium ions (K^+) are pumped into the cell during one pumping cycle of this carrier molecule. ATP is broken down in the process so that the energy freed from ATP can be used to pump the ions.

PHAGOCYTOSIS AND PINOCYTOSIS

Phagocytosis (fag-oh-sye-TOH-sis) is another example of how a cell can actively move an object or substance through the plasma membrane and into the cytoplasm. The term *phagocytosis* comes from a Greek word meaning "to eat." The word is appropriate because this process permits a cell to engulf and literally

"eat" foreign material (Figure 3-6). Certain white blood cells destroy bacteria in the body by phagocytosis. During this process the cell membrane forms a pocket around the bacterium, by expenditure of energy from ATP; then it is moved to the interior of the cell. Once inside the cytoplasm, the bacterium fuses with a lysosome and is destroyed.

Pinocytosis (pin-oh-sye-TOH-sis) is an active transport mechanism used to incorporate fluids or dissolved substances into cells by trapping them in a pocket of plasma membrane that pinches off inside the cell. Again, the term is appropriate because the word part *pino-* comes from the Greek word meaning "drink."

Cell Transport and Disease

Considering the importance of active and passive transport processes to cell survival, you can imagine the problems that arise when one of these processes fails. Several very severe diseases result from damage to cell transport processes. **Cystic fibrosis (CF),** for example, is an inherited condition in which chloride ion (Cl^-) pumps in the plasma membrane are missing. Because chloride ion transport is altered, cells that rely heavily on chloride transporters may die and their remains then thicken the secretions of many exocrine glands. Such is the case when abnormally thick mucus in the lungs impairs normal breathing; frequently this leads to recurring lung infections. Figure 3-7 shows a child with CF next to a normal child of the same age. Because of the difficulty with breathing and digestion and other problems caused by the disease, the affected child has not developed normally. Digestion is compromised by thick pancreatic secretions that may plug the duct leading from the pancreas and thereby prevent important digestive juices from flowing into the intestines. Advances in treatment of CF, including gene therapy (see Chapter 23), have recently improved survivability and quality of life in many CF patients. There is real hope for even more improvements in the near future as our understanding of CF's cellular mechanisms increases.

Cholera (KAHL-er-ah) is a bacterial infection that causes cells lining the intestines to leak chlo-

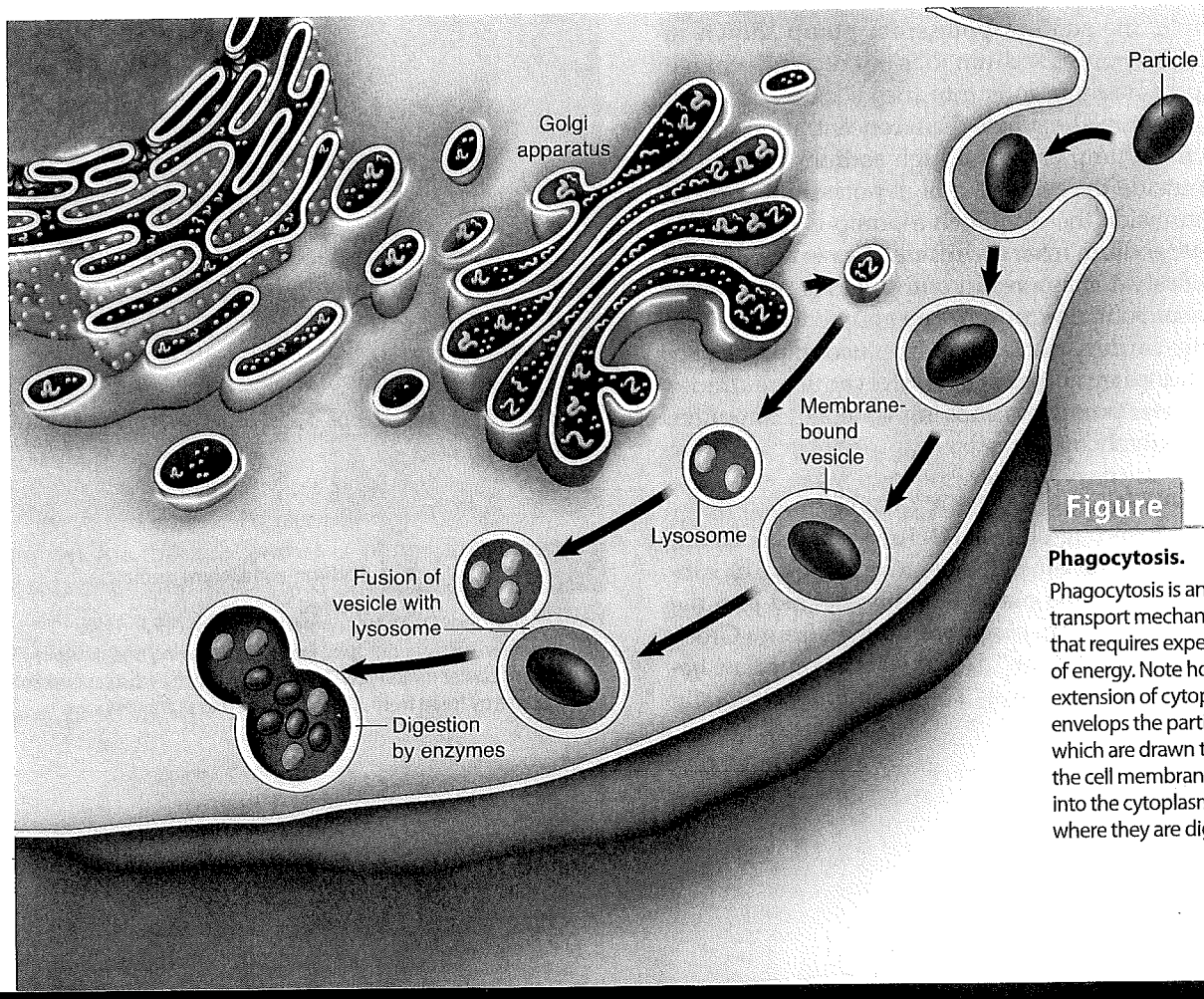


Figure 3-6

Phagocytosis.
Phagocytosis is an active transport mechanism that requires expenditure of energy. Note how an extension of cytoplasm envelops the particles, which are drawn through the cell membrane and into the cytoplasm, where they are digested.

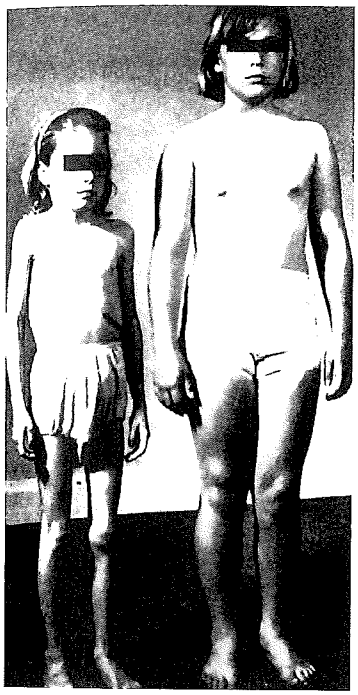


Figure 3-7

Cystic fibrosis.
Even though both children in the photo are the same age, the child with cystic fibrosis *(left)* is smaller and thinner than the normal child *(right)*. In cystic fibrosis, the absence of chloride ion pumps causes thickening of some glandular secretions. Because thickened secretions block airways and digestive ducts, children born with this disease become weakened, often dying before adulthood.

ride ions (Cl^-). Water follows Cl^- out of the cells by osmosis, causing severe diarrhea and the resulting loss of water by the body. Death can occur in a few hours if treatment is not received.

To learn more about active transport, go to **AnimationDirect** on your CD.

QUICK CHECK

1. What are the differences between *passive* and *active* transport processes?
2. What is *osmosis?*
3. How does an *ion pump* work? How do faulty ion pumps cause disease?
4. Describe the process of *phagocytosis.*

Cell Reproduction and Heredity

All human cells that reproduce do so by a process called **mitosis** (my-TOH-sis). During this process a cell divides to multiply; that is, one cell divides to form two cells. Cell reproduction and ultimately the transfer of heritable traits is closely tied to the production of proteins. Two *nucleic acids,* **ribonucleic acid,** or **RNA,** in the cytoplasm and **deoxyribonucleic acid,** or **DNA,** in the nucleus play crucial roles in protein synthesis.

DNA Molecule and Genetic Information

Chromosomes, which are composed largely of DNA, make heredity possible. The "genetic information" contained in segments of the DNA molecules that are called *genes* ultimately determines the transmission and expression of heritable traits such as skin color and blood group from each generation of parents to their children (Figure 3-8).

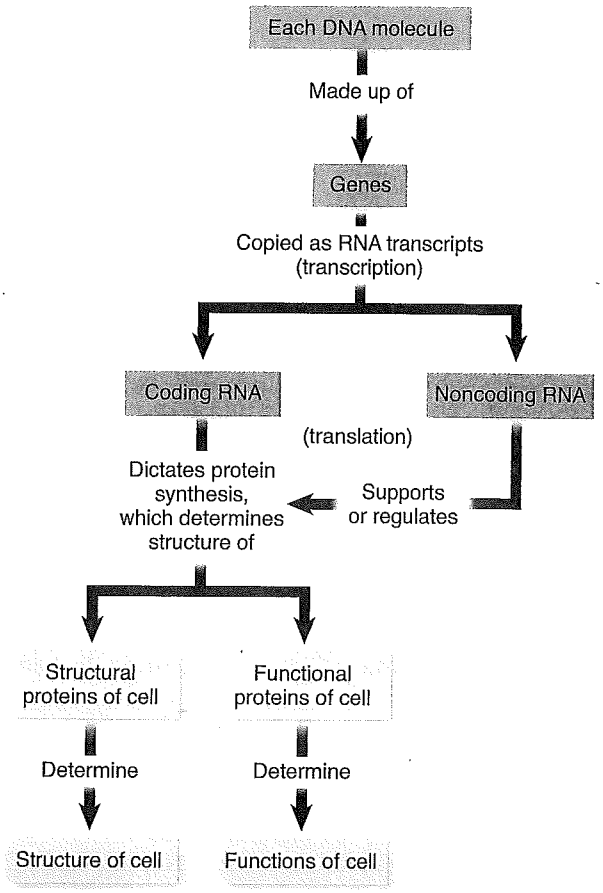


Figure 3-8 **Function of genes.**

Genes copied from DNA are copied to RNA in a process called *transcription.* The RNA transcripts are then used in a process called *translation,* in which a code that determines the sequence of amino acids is translated to form a protein. The structure of the resulting protein determines the role of the protein in body structure and function—and ultimately, the structure and function of the body.

Structurally, the DNA molecule resembles a long, narrow ladder made of a pliable material. It is twisted round and round its axis, taking on the shape of a double helix. Each DNA molecule is made of many smaller units, namely, a sugar, bases, and phosphate units (Table 3-4). The bases are adenine, thymine, guanine, and cytosine. These nitrogen-containing chemicals are called *bases* because by themselves they have a high pH and chemicals with a high pH are called "bases" (see pp. 28-30 for a discussion of acids and bases). As you can see in Figure 3-9 (also Figure 2-11, p. 34), each step in the DNA ladder consists of a pair of bases. Only two combinations of bases occur, and the same two bases invariably pair off with each other in a DNA molecule. Adenine always binds to thymine, and cytosine always binds to guanine. This characteristic of DNA structure is called **complementary base pairing.**

A **gene** is a specific segment of base pairs in a chromosome. Although the types of base pairs in all chromosomes are the same, the order or *sequence* of base pairs is not the same. This fact has tremendous functional importance because it is the sequence of base pairs in each gene of each chromosome that determines heredity. Each gene directs the synthesis of one kind of protein molecule that may function, for example, as an enzyme, a structural component of a cell, or a specific hormone. In humans, having 46 chromosomes in each body cell, the nuclear DNA has a content of genetic information totaling more than 3 *billion* base pairs in 80,000 or so genes. This means that each parent contributes about one and a half billion bits of genetic information in the 23 chromosomes each parent provides for the original cell of each offspring. Is it any wonder, then, with all of this genetic information packed into each of our cells, that no two of us inherit exactly the same traits?

Table 3-4 Components of Nucleotides

NUCLEOTIDE	DNA	RNA
Sugar	Deoxyribose	Ribose
Phosphate	Phosphate	Phosphate
Nitrogen base	Cytosine	Cytosine
	Guanine	Guanine
	Adenine	Adenine
	Thymine	Uracil

GENETIC CODE

How do genes bring about heredity? There is, of course, no short and easy answer to that question. We know that the genetic information contained in each gene is capable of "directing" the synthesis of a specific protein. The unique sequence of a thousand or so base pairs in a gene determines the sequence of specific building blocks required to form a particular protein. This store of information in each gene is called the *genetic code.* In summary, the coded information in genes controls protein and enzyme production, enzymes facilitate cellular chemical reactions, and cellular chemical reactions determine cell structure and function and therefore heredity.

RNA MOLECULES AND PROTEIN SYNTHESIS

DNA, with its genetic code that dictates directions for protein synthesis, is contained in the nucleus of the cell. The actual process of protein synthesis, however, occurs in ribosomes and on ER. Another specialized nucleic acid, ribonucleic acid (RNA), transfers this genetic information from the nucleus to the cytoplasm.

Both RNA and DNA are composed of four bases, a sugar, and phosphate. RNA, however, is a single rather than a double-stranded molecule, and it contains a different sugar and base component. The base uracil replaces thymine.

The process of transferring genetic information from the nucleus into the cytoplasm where proteins are actually produced requires completion of two specialized steps called *transcription* and *translation.*

Transcription

During **transcription** the double-stranded DNA molecule separates or unwinds, and a special type of RNA called **messenger RNA** or **mRNA** is formed (Figure 3-9, *step 1*). Each strand of mRNA is a duplicate or copy of a particular gene sequence along one of the newly separated DNA spirals. The messenger RNA is said to have been "transcribed" or copied from its DNA mold or template. The mRNA molecules pass from the nucleus to the cytoplasm to direct protein synthesis in the ribosomes and ER (Figure 3-9, *step 2*).

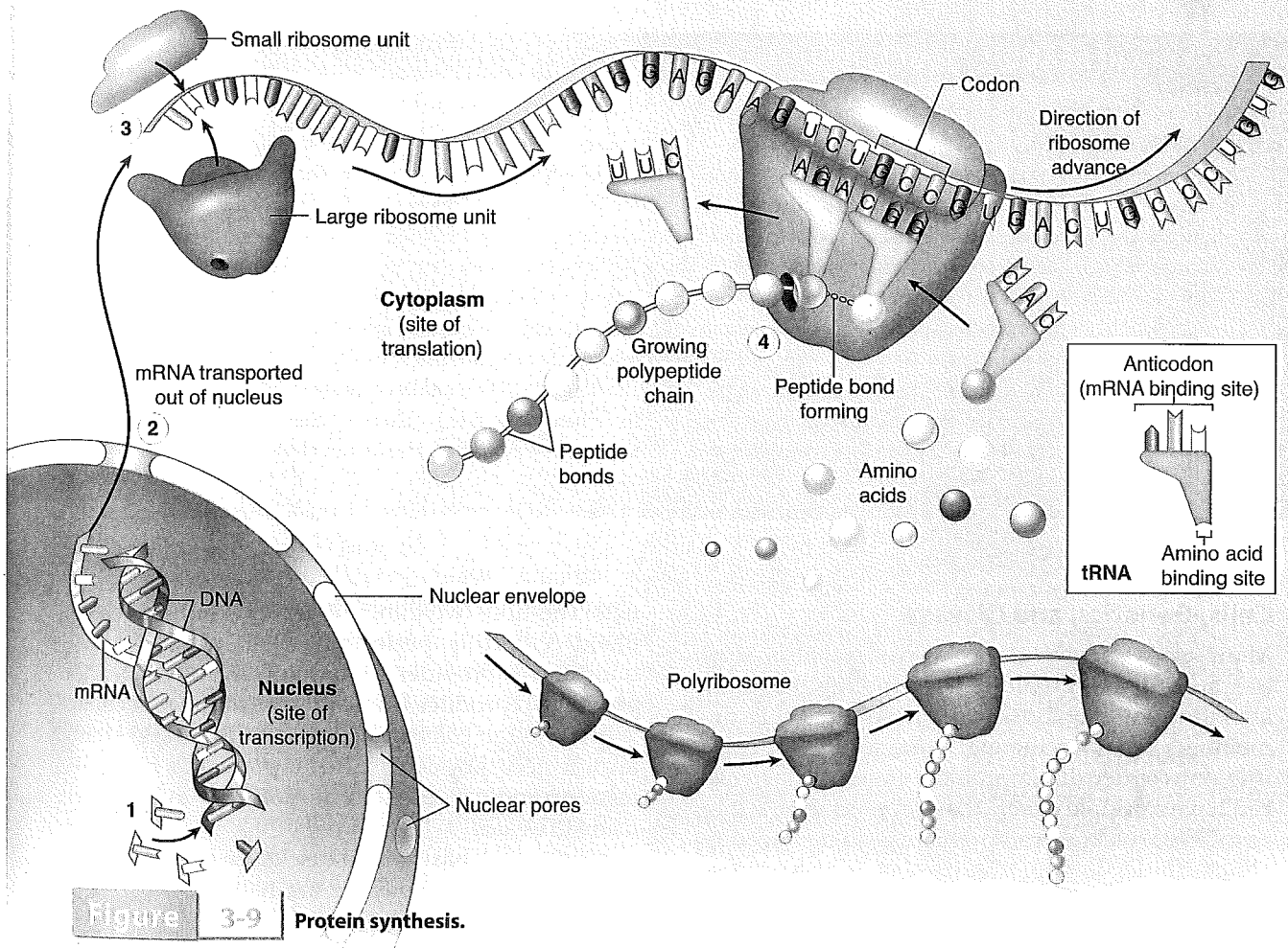
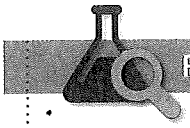


Figure 3-9 Protein synthesis.

1, Protein synthesis begins with transcription, a process in which an mRNA molecule forms along one gene sequence of a DNA molecule within the cell's nucleus. As it is formed, the mRNA molecule separates from the DNA molecule. *2,* The mRNA transcript then leaves the nucleus through the large nuclear pores. *3,* Outside the nucleus, ribosome subunits attach to the beginning of the mRNA molecule and begin the process of translation. *4,* In translation, transfer RNA (tRNA) molecules bring specific amino acids—encoded by each mRNA codon—into place at the ribosome site. As the amino acids are brought into the proper sequence, they are joined together by peptide bonds to form long strands called *polypeptides*. Several polypeptide chains may be needed to make a complete protein molecule.

TRANSLATION

Translation is the synthesis of a protein by ribosomes, which use the information contained in an mRNA molecule to direct the choice and sequencing of the appropriate chemical building blocks called *amino acids*. First, the two subunits of a ribosome attach at the beginning of the mRNA molecule (Figure 3-9, *step 3*). The ribosome then moves down the mRNA strand and amino acids are assembled into their proper sequence (Figure 3-9, *step 4*). **Transfer RNA (tRNA)** molecules assist the process by bringing specific amino acids in to "dock" at each **codon** along the mRNA strand. A codon is a series of three nucleotide bases that act as a code representing a specific amino acid. Each gene is made up of a series of codons that tell the cell the sequence of amino acids to string together to form a protein strand. This strand then folds on itself and perhaps even combines with another strand to form a complete protein molecule (see Figure 2-9, p. 33). The specific, complex shape of each type of protein molecule allows the molecule to perform specific functions in the cell. It is clear that because DNA directs the shape of each protein, DNA also directs the function of each protein in a cell.



RESEARCH, ISSUES, AND TRENDS

HUMAN GENOME

The sum total of all of the DNA in each cell of the body is called the **genome** (JEE-nohm). With intense, coordinated effort, a team of scientists recently mapped all of the gene locations in the human genome. Efforts at reading the different genetic codes possible at each location are still underway. Much of the work of mapping the human genome was done as part of the Human Genome Project (HGP), which was started in 1990. Besides producing a human genetic map and developing tools of genetic mapping, a new field called *genomics*, the HGP also addresses the ethical, legal, and social issues that may arise—a notable first for such a massive scientific research effort. The HGP is sponsored by the Department of Energy (DOE) and the National Institutes of Health (NIH), and its first director was James Watson, one of the scientists credited with originally discovering the structure of the DNA molecule in 1953. With the human genome already mapped, many scientists are working now to fill in the details concerning the many genes and gene variants found in the human genome. Many are also working in the emerging field of *proteomics*—the study of all the proteins encoded by each of the genes of the human genome.

Cells, Genetics, and Disease

Many diseases have a cellular basis; that is, they are basically cell problems even though they may affect the entire body. Because individual cells are members of an interacting "community" of cells, it is no wonder that a problem in just a few cells can have a "ripple effect" that influences the entire body. Most of these cell problems can be traced to abnormalities in the DNA itself or in the process by which DNA information is transcribed and translated into proteins.

In individuals with inherited diseases, abnormal DNA from one or both parents may cause production of dysfunctional proteins in certain cells or prevent a vital protein from being synthesized. For example, DNA may contain a mistake in its genetic code that prevents production of normal blood-clotting proteins. Deficiency of these essential proteins results in excessive, uncontrollable bleeding—a condition called *hemophilia* (see Chapters 12 and 24). Chemical or mechanical irritants, radiation, bacteria, viruses, and other factors can directly damage DNA molecules and thus disrupt a cell's normal function. For example, the virus that causes *acquired immunodeficiency syndrome (AIDS)* eventually inserts its own genetic codes into the DNA of certain cells. The viral codes trigger synthesis of viral molecules, detouring raw materials intended for use in building normal human products. This does two things: it prevents human white blood cells from performing their normal functions and it provides a mechanism by which the virus can reproduce itself and spread to other cells. When enough cells of the human immune system are affected, they can no longer protect us from infections and cancer—a condition that eventually leads to death.

The genetic basis for disease discussed briefly in Chapter 5 is fully explained in Chapter 24.

Table 3-5 Stages of Cell Division

STAGE	CHARACTERISTICS
Prophase	The chromatin condenses into visible chromosomes Chromatids become attached at the centromere Spindle fibers appear The nucleolus and nuclear envelope disappear
Metaphase	Spindle fibers attach to each chromatid Chromosomes align across the center of the cell
Anaphase	Centromeres break apart Chromosomes move away from the center of the cell The cleavage furrow appears
Telophase	The nuclear envelope and both nuclei appear The cytoplasm and organelles divide equally The process of cell division is completed

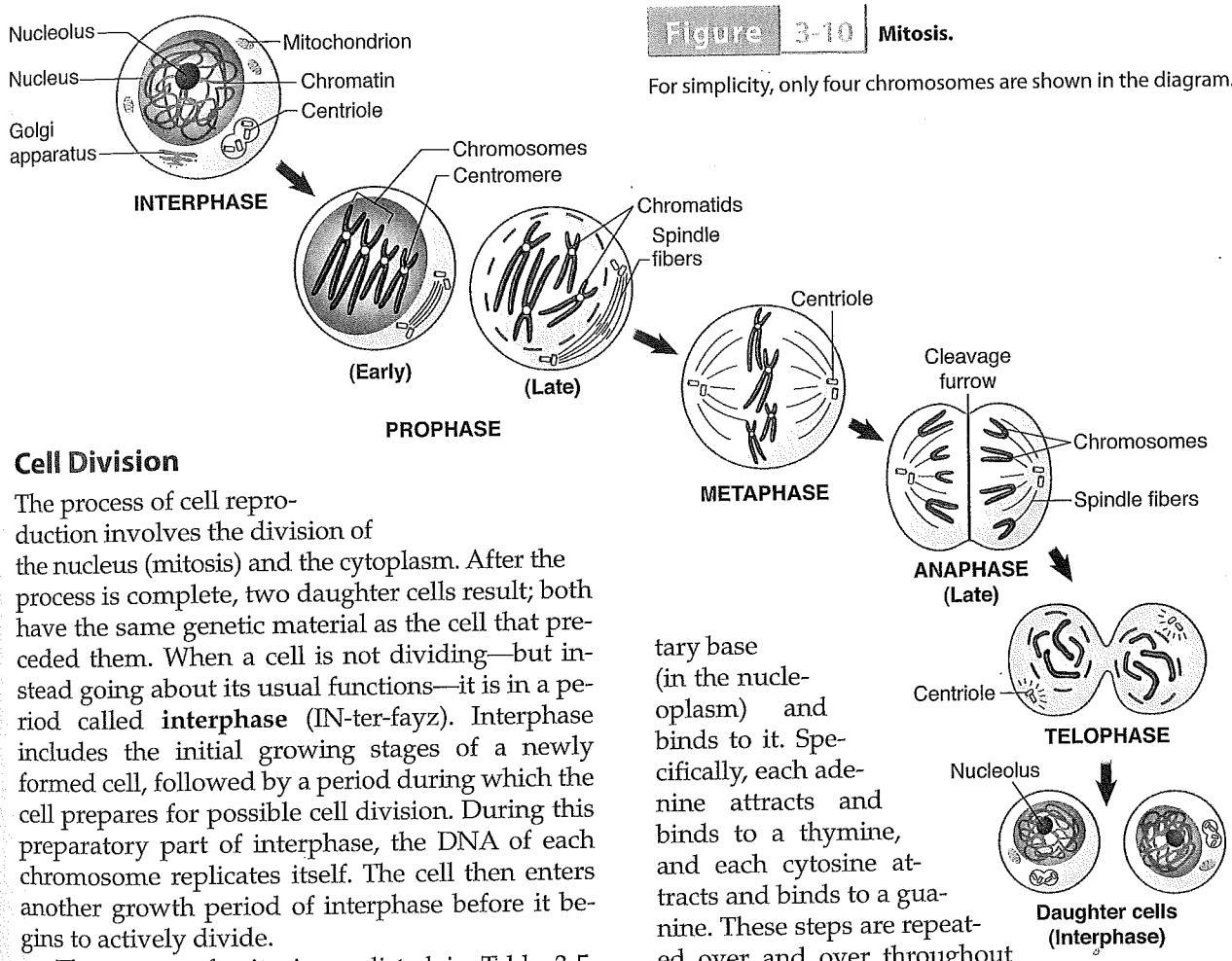


Figure 3-10 **Mitosis.**

For simplicity, only four chromosomes are shown in the diagram.

Cell Division

The process of cell reproduction involves the division of the nucleus (mitosis) and the cytoplasm. After the process is complete, two daughter cells result; both have the same genetic material as the cell that preceded them. When a cell is not dividing—but instead going about its usual functions—it is in a period called **interphase** (IN-ter-fayz). Interphase includes the initial growing stages of a newly formed cell, followed by a period during which the cell prepares for possible cell division. During this preparatory part of interphase, the DNA of each chromosome replicates itself. The cell then enters another growth period of interphase before it begins to actively divide.

The stages of mitosis are listed in Table 3-5, along with a brief description of the changes that occur during each stage.

DNA REPLICATION

DNA molecules possess a unique ability that no other molecules in the world have. They can make copies of themselves, a process called **DNA replication.** Before a cell divides to form two new cells, each DNA molecule in its nucleus forms another DNA molecule just like itself. When a DNA molecule is not replicating, it has the shape of a tightly coiled double helix. As it begins replication, short segments of the DNA molecule uncoil and the two strands of the molecule pull apart between their base pairs. The separated strands therefore contain unpaired bases. Each unpaired base in each of the two separated strands attracts its complementary base (in the nucleoplasm) and binds to it. Specifically, each adenine attracts and binds to a thymine, and each cytosine attracts and binds to a guanine. These steps are repeated over and over throughout the length of the DNA molecule. Thus each half of a DNA molecule becomes a whole DNA molecule identical to the original DNA molecule. After DNA replication is complete, the cell continues to grow until it is ready for the first phase of mitosis.

PROPHASE

Look at Figure 3-10 and note the changes that identify the first stage of mitosis, **prophase** (PRO-fayz). The chromatin becomes "organized." Chromosomes in the nucleus have formed two strands called **chromatids** (KROH-mah-tids). Note that the two chromatids are held together by a beadlike structure called the **centromere** (SEN-troh-meer). In the cytoplasm the centrioles are moving away from each other as a

network of tubules called **spindle fibers** forms between them. These spindle fibers serve as "guidewires" and assist the chromosomes to move toward opposite ends of the cell later in mitosis.

METAPHASE

By the time **metaphase** (MET-ah-fayz) begins, the nuclear envelope and nucleolus have disappeared. Note in Figure 3-10 that the chromosomes have aligned themselves across the center of the cell. Also, the centrioles have migrated to opposite ends of the cell, and spindle fibers are attached to each chromatid.

ANAPHASE

As **anaphase** (AN-ah-fayz) begins, the beadlike centromeres, which were holding the paired chromatids together, break apart. As a result, the individual chromatids, identified once again as chromosomes, move away from the center of the cell. Movement of chromosomes occurs along spindle fibers toward the centrioles. Note in Figure 3-10 that chromosomes are being pulled to opposite ends of the cell. A **cleavage furrow** that begins to divide the cell into two daughter cells can be seen for the first time at the end of anaphase.

TELOPHASE

During **telophase** (TEL-oh-fayz) cell division is completed. Two nuclei appear, and chromosomes become less distinct and appear to break up. As the nuclear envelope forms around the chromatin, the cleavage furrow completely divides the cell into two parts. Before division is complete, each nucleus is surrounded by cytoplasm in which organelles have been equally distributed. By the end of telophase, two separate daughter cells, each having identical genetic characteristics, are formed. Each cell is fully functional and will perhaps itself undergo mitosis in the future.

RESULTS OF CELL DIVISION

Mitosis results in the production of identical new cells. In the adult, mitosis replaces cells that have become less functional with age or have been damaged or destroyed by illness or injury. During periods of body growth, mitosis allows groups of similar cells to *differentiate*, or develop into different **tissues.**

Changes in Cell Growth and Reproduction

Cells have the ability to adapt to changing conditions. Cells may alter their size, reproductive rate, or other characteristics to adapt to changes in the internal environment. Such adaptations usually allow cells to work more efficiently. However, sometimes cells alter their characteristics abnormally—decreasing their efficiency and threatening the health of the body. Common types of changes in cell growth and reproduction are summarized below and in Table 3-6.

Cells may respond to changes in function, hormone signals, or availability of nutrients by increasing or decreasing in size. The term **hypertrophy** (hye-PER-troh-fee) refers to an increase in cell size, and the term **atrophy** (AT-roh-fee) refers to a decrease in cell size. Either type of adaptive change can occur easily in muscle tissue. When a person continually uses muscle cells to pull against heavy resistance, as in weight training, the cells respond by increasing

Table 3-6 Alterations in Cell Growth and Reproduction

TERM	DEFINITION	EXAMPLE
CHANGES IN GROWTH OF INDIVIDUAL CELLS		
Hypertrophy	Increase in size of individual cells	Strength training stimulates increase in size of skeletal muscle fibers
Atrophy	Decrease in size of individual cells	Immobility of limbs causes skeletal muscles that move limbs to decrease in size
CHANGES IN CELL REPRODUCTION		
Hyperplasia	Increase in cell reproduction	Skin tumor causes thickening of skin by overproduction of skin cells
Anaplasia	Production of abnormal, undifferentiated cells	Lung cancer causes production of abnormal cells that do not function properly

in size. Bodybuilders thus increase the size of their muscles by hypertrophy—increasing the size of muscle cells. Atrophy often occurs in underused muscle cells. For example, when a broken arm is immobilized in a cast for a long period, muscles that move the arm often atrophy. Because the muscles are temporarily out of use, muscle cells decrease in size. Atrophy also may occur in tissues whose nutrient or oxygen supply is diminished.

Sometimes cells respond to changes in the internal environment by increasing their rate of reproduction—a process called **hyperplasia** (hye-per-PLAY-zha). The word part *-plasia* comes from a Greek word that means "formation"—referring to formation of new cells. Because *hyper-* means "excessive," *hyperplasia* means excessive cell reproduction. Like hypertrophy, hyperplasia causes an increase in the size of a tissue or organ. However, hyperplasia is an increase in the *number of cells* rather than an increase in the size of each cell. A common example of hyperplasia occurs in the milk-producing glands of the female breast during pregnancy. In response to hormone signals, the glandular cells reproduce rapidly, preparing the breast for nursing.

If the body loses its ability to control mitosis, abnormal hyperplasia may occur. The new mass of cells thus formed is a tumor or **neoplasm** (NEE-oh-plaz-em). Many neoplasms also exhibit a characteristic called **anaplasia** (an-ah-PLAY-zha). Anaplasia is a condition in which cells change in orientation to each other and fail to mature normally; that is, they fail to differentiate into a specialized cell type. Neoplasms may be relatively harmless growths called *benign* (be-NYNE) tumors. If tumor cells can break away and travel through the blood or lymphatic vessels to other parts of the body (Figure 3-11), the neoplasm is a *malignant* (mah-LIG-nant) *tumor* or **cancer.** Neoplasms are discussed further in Chapter 4.

QUICK CHECK

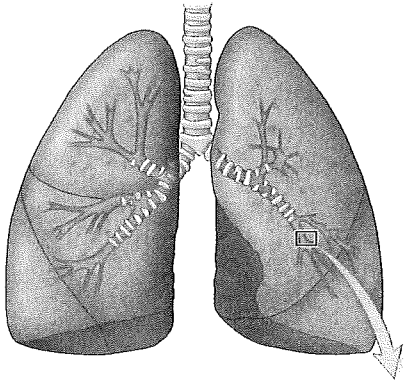
1. How do *genes* determine the structure and function of the body?
2. What are the main steps in making proteins in the cell?
3. What are the four phases of *mitotic cell division?*
4. What is the relationship between *cell division* and *cancer?*

Tissues

The four main kinds of tissues that compose the body's many organs include:

1. Epithelial tissue
2. Connective tissue
3. Muscle tissue
4. Nervous tissue

Tissues differ from each other in the size and shape of their cells, in the amount and kind of material between the cells, and in the special functions they



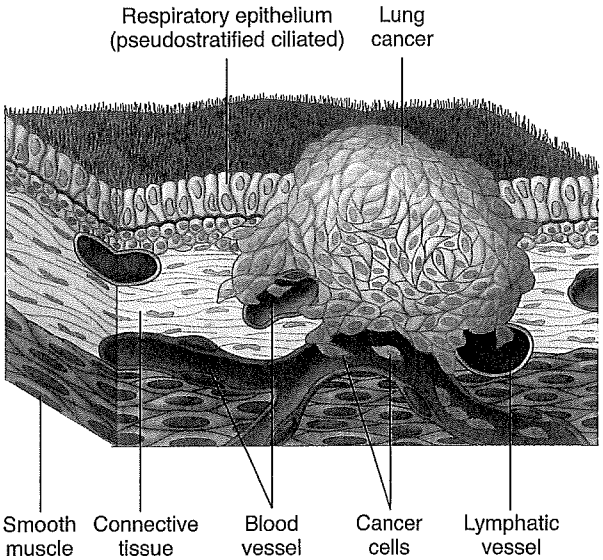


Figure 3-11 **Cancer.**

This depiction of an abnormal mass of proliferating cells in the lining of lung airways is a malignant tumor—lung cancer. Notice how some cancer cells are leaving the tumor and entering the blood and lymph vessels.

Review Questions

1. Describe the structure of the plasma membrane.
2. List three functions of the plasma membrane.
3. Give the function of each of the following organelles: ribosome, Golgi apparatus, mitochondria, lysosome, and centrioles.
4. Give the function of the nucleus and nucleolus.
5. Explain the difference between chromatin and chromosomes.
6. Describe the processes of diffusion and filtration.
7. Describe the functioning of the ion pump and explain the process of phagocytosis.
8. What cell transport mechanism failure results in the disease cystic fibrosis?
9. Describe the process of transcription.
10. Describe the process of translation.
11. List the four stages in active cell division (mitosis) and briefly describe what occurs in each stage.
12. What important event in mitosis occurs during interphase?
13. Name and describe three epithelial tissues.
14. Name and describe three connective tissues.
15. Name and describe two muscle tissues.
16. Name the two types of nervous tissue. Which is functional nerve tissue and which is support tissue?

Critical Thinking

17. Explain what is meant by tissue typing. Why has this become so important in recent years?
18. Explain what would happen if a cell containing 97% water were placed in a 10% salt solution.
19. If one side of a DNA molecule had the following base sequence: adenine-adenine-guanine cytosine-thymine-cytosine-thymine, what would the sequence of bases on the opposite side of the molecule be?
20. If a molecule of mRNA was made from the DNA base sequence in question 19, what would the sequence of bases be in the RNA?
21. Compare and contrast tissue repair in epithelial, connective, muscle, and nervous tissue.

Chapter Test

1. _____ and _____ are two fat-based molecules that make up part of the structure of the plasma membrane.
2. _____ is a term that refers to small structures inside the cell, it means "little organs."
3. _____ is the movement of substances across a cell membrane using cell energy, whereas _____ is the movement of substances across a cell membrane without using cell energy.
4. _____ refers to the movement of fluids or dissolved molecules into the cell by trapping them in the plasma membrane.
5. _____ is a disease caused by the inability of cells to transport Cl^- ions.
6. _____ is the process in protein synthesis that uses the information in mRNA to build a protein molecule.
7. _____ is the process in protein synthesis that forms the mRNA molecule.
8. _____ is a segment of base pairs in a chromosome.
9. _____ is the total genetic information packaged in a cell.
10. _____, _____, _____, and _____ are the four main tissues in the body.
11. Which of the following is not a form of diffusion?
    a. Filtration
    b. Dialysis
    c. Osmosis
    d. All of the above are examples of diffusion
12. The disease caused by the muscle cell's inability to control chloride ion movement is:
    a. cystic fibrosis
    b. hemophilia
    c. Duchenne muscular dystrophy
    d. AIDS
13. The disease caused by an inherited mistake in the genetic code that prevents production of normal blood clotting proteins is: