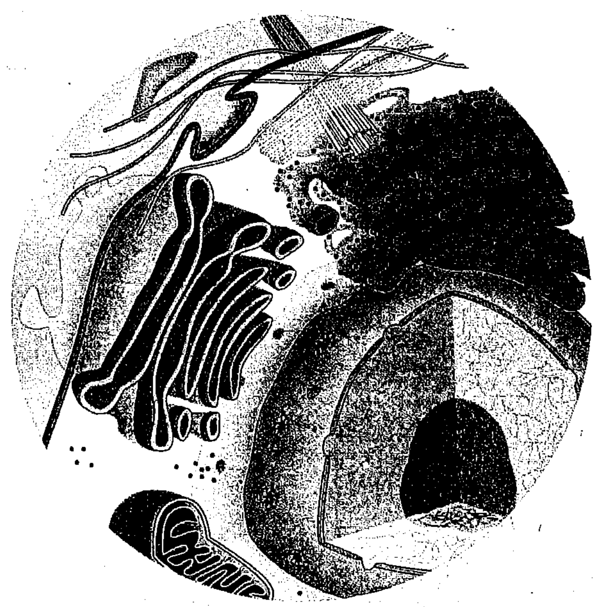
2

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.

A*bout 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 groups of similar cells, which are called tissues.

CELLS

Size and Shape

Human cells are microscopic in size; that is, they can be seen only when magnified by a microscope. However, they vary considerably in size. An ovum (female sex cell), for example, has a diameter of a little less than 1000 micrometers (about 1⁄25 of an inch), 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 threadlike, and some have irregular shapes.

Composition

Cells contain **cytoplasm** (SI-to-plazm), 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 salt water solution called **interstitial** (in-ter-STISH-al) **fluid,** or simply **tissue fluid,** that bathes every cell in the body. Numerous specialized structures called **organelles** (or-gan-ELZ), which will be described in subsequent sections, are contained within the cytoplasm of each cell. A small, circular body called the **nucleus** (NOO-kle-us) is also inside the cell.

Important information related to body composition is included in Appendix A. 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

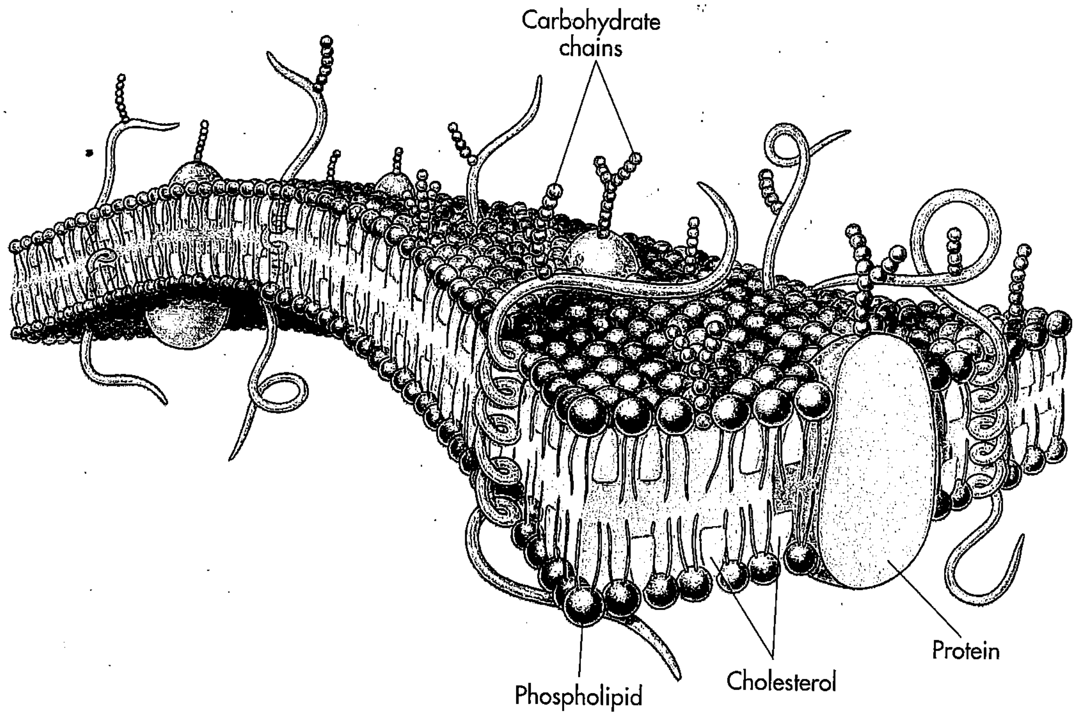
As the name suggests, the **plasma membrane** is the membrane that encloses the cytoplasm and forms the outer boundary of the cell. It is an incredibly delicate structure—only about 7 nm (nanometers) or 3/10,000,000 of an inch thick! Yet it has a precise, orderly structure (Figure 2-1). Two layers of 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 2-1 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. It 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 move through it, but it bars the passage of others. The plasma membrane even functions as a communication device. How? 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, communicated to cells by binding to their cytoplasmic membrane receptors.

The plasma membrane also identifies a cell as coming from 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

FIGURE 2-1

Structure of the plasma membrane. Note that protein molecules may penetrate completely through the two layers of phospholipid molecules.



surface of cells often play a role in the identification of cell types.

CYTOPLASM

Cytoplasm is the specialized living material of cells. It lies between the plasma membrane and the nucleus, which can be seen in Figure 2-2 as a round or 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 like organs function for the body.

Look again at Figure 2-2. 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 invisible even when magnified 1000 times by a light microscope. Electron microscopes brought them into view by magnifying them many thousands of times. We shall briefly discuss the following organelles, which are found in cytoplasm (see also Table 2-1):

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

Ribosomes. Organelles called **ribosomes** (RI-bo-sohms), shown as dots in Figure 2-2, are very tiny

FIGURE 2-2

General characteristics of the cell. Artist's interpretation of cell structure.

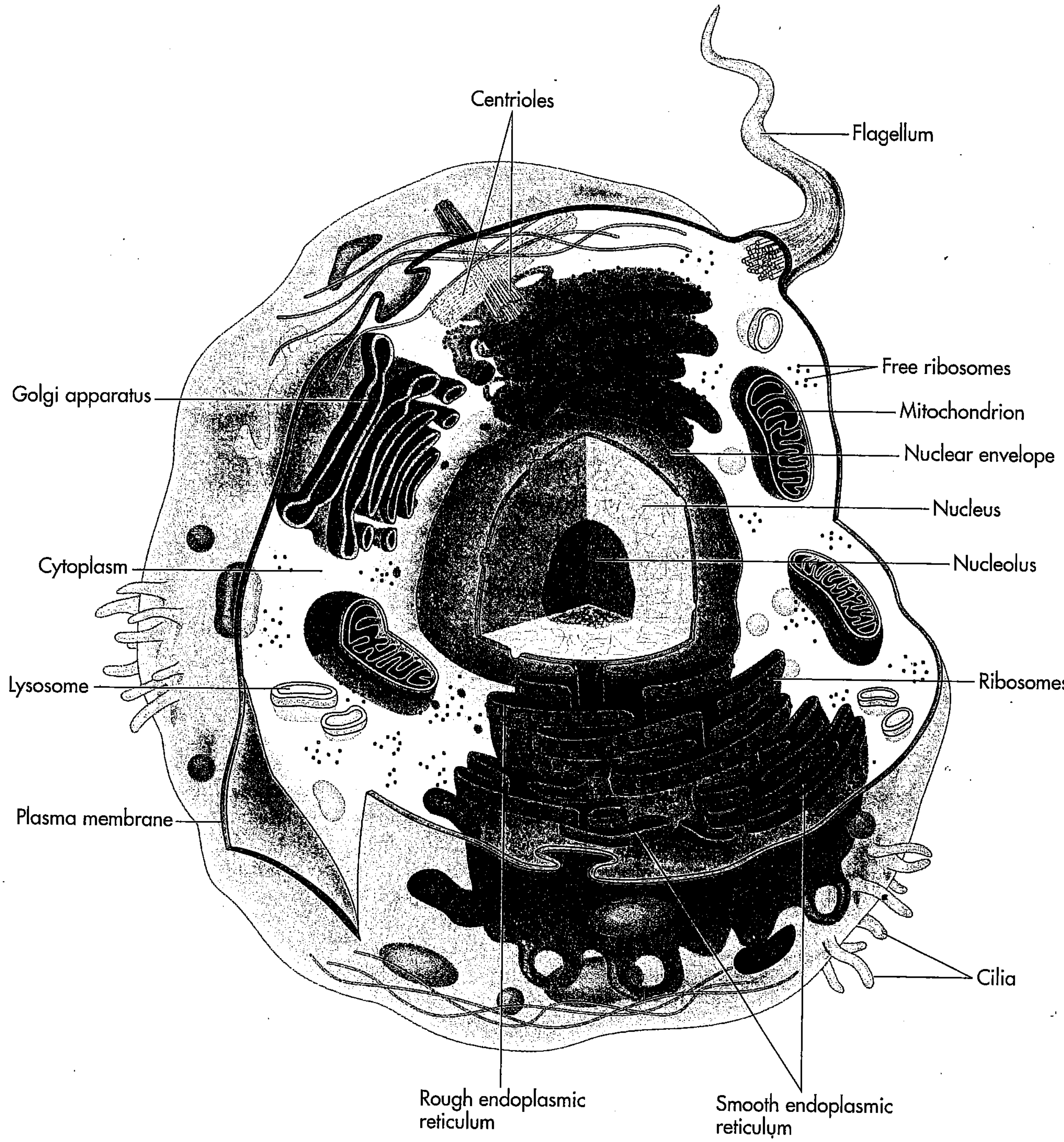


TABLE 2-1

Structure 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 markers that identify cells of each 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	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 a surface of some cells	Move substances long 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
Nucleoli	Dense region of the nucleus	Play an essential role in the formation of ribosomes

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)*—another type of organelle described in the next paragraph. Ribosomes may also be free in the cytoplasm. Ribosomes perform a very complex function; they make enzymes and other protein compounds. Their nickname, "protein factories," indicates this function.

Endoplasmic reticulum. An **endoplasmic reticulum** (en-doe-PLAZ-mik ree-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, all the way from the nucleus and almost to the plasma membrane. The tubular passageways or canals in the ER carry proteins and other substances through the cytoplasm of the cell from one area to another. There are two types of ER: *rough* and *smooth.* Rough ER gets its name from the fact that 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 transports the proteins to areas where chemical processing takes place. These areas of the ER are so full that ribosomes do not attach to pass their proteins, giving 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 and transports newly made proteins and smooth ER makes 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, then packages them into 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-toe-KON-dree-ah) are another kind of organelle 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 or 1 inch long. Two membranous sacs, one inside the other, compose a 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 inner substance, use oxygen to break down glucose and other nutrients to release energy required for cellular work. The process is called *aerobic* or *cellular respiration.*

Lysosomes. The **lysosomes** (LYE-so-sohms) are membranous-walled organelles that in their active stage look like small sacs, often with tiny particles in them (see Figure 2-2). Because lysosomes contain chemicals (enzymes) that can digest food compounds, one of their nicknames is "digestive bags." Lysosomal enzymes can also 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. Yet, paradoxically, lysosomes sometimes kill cells instead of protecting them. If their powerful enzymes escape from the lysosome sacs into the cytoplasm, they kill the cell by digesting it. This fact has earned lysosomes their other nickname, which is "suicide bags."

Centrioles. The **centrioles** (SEN-tree-olz) 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 2-2). Each centriole is composed of fine tubules that play an important role during cell division.

Cilia. **Cilia** (SIL-ee-ah) are extremely fine, almost hairlike extensions on the exposed or free surfaces of some cells. 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.

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 2-3).

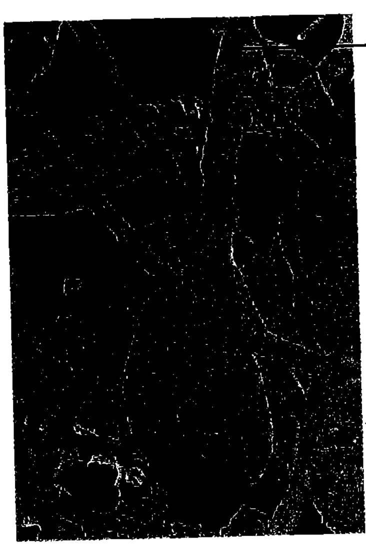
NUCLEUS

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 2-2 is surrounded by a **nuclear envelope.** The envelope, made up of two separate membranes, encloses a special type of cell material in the nucleus called **nucleoplasm.** Nucleoplasm contains a number of specialized structures; two of the most important are shown in Figure 2-2. They are the **nucleolus** (noo-KLEE-oh-lus) and the **chromatin** (KRO-mah-tin) **granules.**

FIGURE 2-3

Human sperm. Note the tail-like flagellum on each sperm cell. The flagella are so long that they do not fit into the photograph at this magnification.



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 material called **DNA** or **deoxyribonucleic** (dee-OK-see-rye-bo-noo-KLEE-ik) **acid.** DNA is the genetic material often described as the chemical "blueprint" of the body. It determines everything from gender 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.** The importance and function of DNA will be explained in greater detail in the section on cell reproduction later in this chapter. Information about DNA can also be found in *Appendix A, Chemistry of Life,* on p. 504.

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 allow 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. 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