CHAPTER PREVIEW

Main Ideas

In this chapter, you will learn about the cell theory and the scientists who discovered it. You will also read about the structure of a cell and its organelles, important cellular functions, and the basic organization of cells into a living organism.

Reading Strategy

Sequencing Events As you read this chapter, construct a time line that shows each year in which a discovery about cells was made. Indicate who made the discovery.

Journal Activity

Biology and Your World When did you first learn about cells? How did you feel when you found out that you were made of cells? (More than 100 trillion of them, in fact!) Describe your thoughts and feelings in your journal.

5–1 The Cell Theory

Guide For Reading

- How did van Leeuwenhoek, Hooke, Schleiden, Schwann, and Virchow contribute to the development of the cell theory?
- What are the parts of the cell theory?

Each of us, at one time or another, has tried to look closely at something. You may have picked up a coin and tried to read the initials of its designer, cut closely into the coin's surface. You may have tried to read the details on the face of a stamp or stared at a blade of grass until the tiniest detail was clear.

Such curiosity led early investigators to examine living things under lenses and microscopes in the hope of getting a better glimpse of their structure. Little by little, their findings led to the most fundamental of all discoveries about the nature of living things: All living things are made of cells. Cells are the basic units of structure and function in living things.

The first lenses were used in Europe hundreds of years ago by merchants who needed to determine the quality of cloth. They used their magnifying lenses to examine the quality of the thread and the precision of the weave in a bolt of cloth. From these simple glass lenses, combinations of lenses were put together. In Holland in the early 1600s, two useful instruments were constructed. One was the telescope, which enabled people to see objects at a distance. The telescope made the distant stars in the sky visible. The other instrument, the microscope, made the very small objects in nature visible.

The person who is given credit for developing the first microscope was Anton van Leeuwenhoek (LAY-vuhn-hook), a

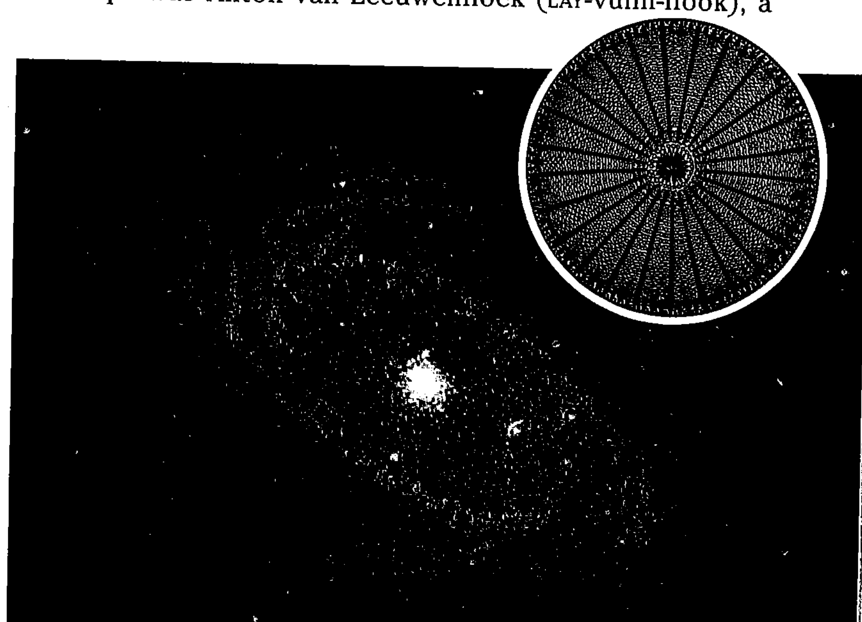
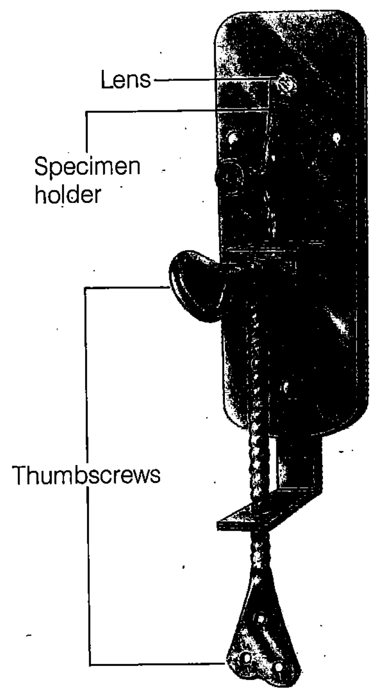


Figure 5–1 The invention of the telescope enabled astronomers to study distant objects such as this spiral galaxy. The microscope, on the other hand, opened up the world of the very small to biologists. Before the invention of the microscope, a microscopic alga, such as this diatom, could not have been observed.



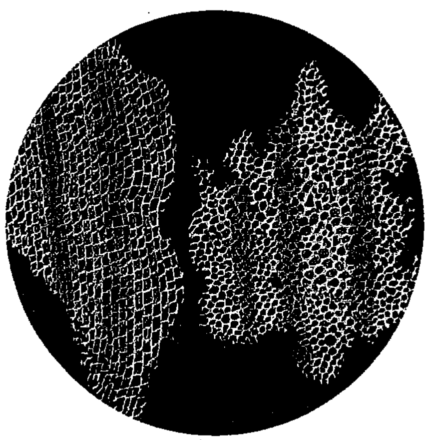


Figure 5–2 *Van Leeuwenhoek's simple microscope (top) could magnify objects a few hundred times. Robert Hooke made this drawing of cork cells (bottom) using a microscope that he built. Hooke, however, was not looking at living cells; what he saw were the cell walls that surround living cork cells.*

Dutch biologist. His invention enabled him to see things that no one had ever seen before. He could see tiny living organisms whose world consisted of a drop of water. Van Leeuwenhoek carefully observed the tiny living things in pond water and made detailed drawings of each kind of organism.

Van Leeuwenhoek's work interested other people in building microscopes. Before long, pioneers in several countries were experimenting with these new instruments. One such person was the Englishman Robert Hooke, who used one of his microscopes to look at thin slices of plant stems, wood, and pieces of cork. Looking at the cork, Hooke saw that it was composed of thousands of tiny chambers. He called these chambers cells because they reminded him of the small rooms called cells in a monastery.

Unfortunately, Hooke was not looking at living cells. He was looking at the nonliving outer walls of what had once been living plant cells. Nonetheless, Hooke's discovery was significant because it opened up the study of cells.

Gradually over the next 200 years, other scientists began to discover that cells were not only found in plants but in other living things too. In 1833, Robert Brown, a Scottish scientist, observed that many cells seemed to have a dark structure near the center of the cell. We now call this structure the nucleus. Five years later, German botanist Matthias Schleiden stated that all plants are made of cells. The next year, Theodor Schwann discovered that all animals are made of cells too. In 1855, Rudolf Virchow, a German physician, added one more element to the developing theory of cells. Based on research, he stated that all cells arise from the division of preexisting cells.

Today, the observations and conclusions of these scientists are summarized into the **cell theory**. The cell theory forms the basic framework in which biologists have tried to understand living things ever since. **The cell theory states:**

- **All living things are composed of cells.**
- **Cells are the basic units of structure and function in living things.**
- **All cells come from preexisting cells.**

5–1 SECTION REVIEW

1. What contributions did van Leeuwenhoek, Hooke, Schleiden, Schwann, and Virchow make to the development of the cell theory?
2. When Hooke first used the term cell, did he intend it to apply to living material? Explain your answer.
3. **Critical Thinking—Identifying Relationships** What role did the invention of the microscope play in the development of the cell theory?

5–2 Cell Structure

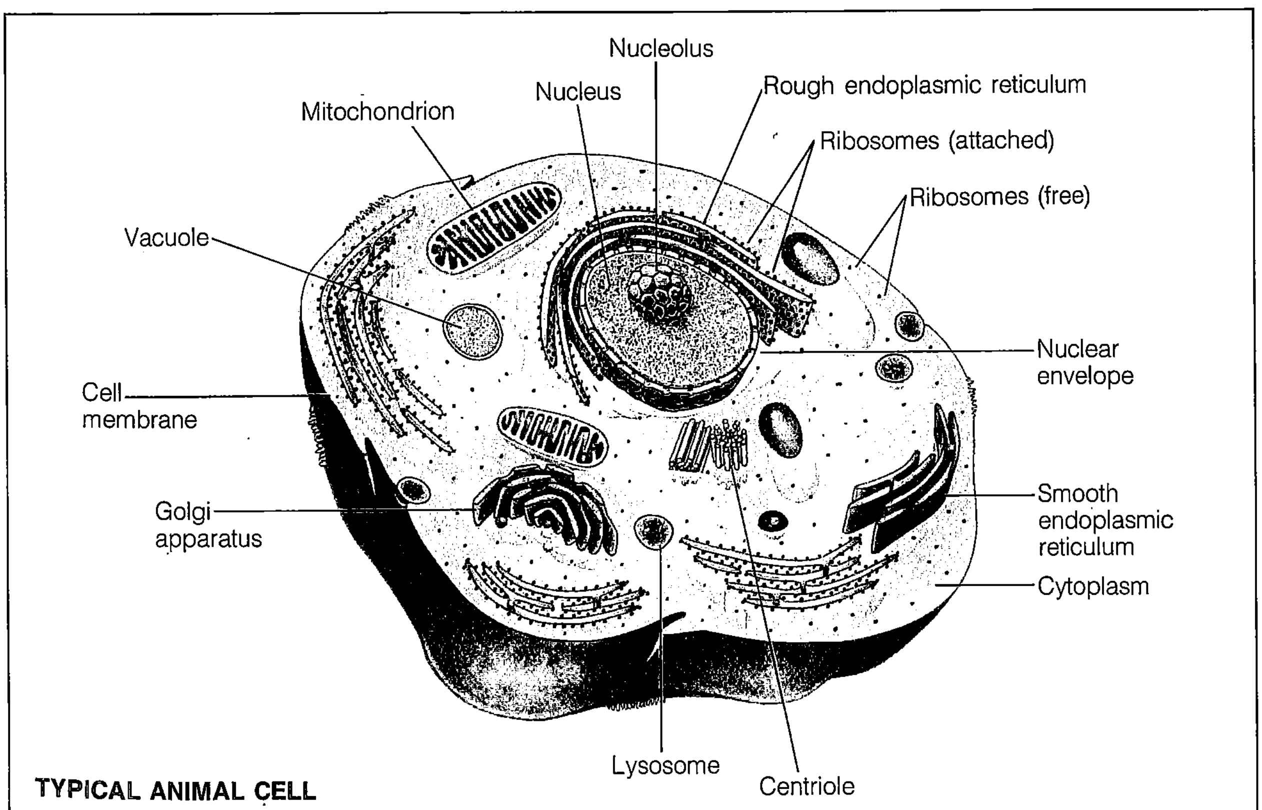
Guide For Reading

- What are the functions of the three basic structures of most cells?
- How do prokaryotes and eukaryotes differ?

There is enormous variety in the size and shape of different cells. The smallest cells, belonging to a group of organisms known as mycoplasmas (migh-koh-PLAZ-mahz), are only about 0.2 micrometers in diameter. A micrometer is equal to one millionth of a meter. Mycoplasmas are so small that they often are beyond the resolving power of light microscopes. Larger cells include the giant ameba *Chaos chaos,* which is about 1000 micrometers in diameter. Larger still are the yolks of bird eggs, which are actually single cells containing stored food for the developing bird. For the most part, cells are between 5 and 50 micrometers in diameter. Physical limits on the flow of information through the cell and on the flow of materials into and out of the cell prevent most cells from being much larger than this.

Despite differences in size and shape, there are certain structures that are common to most cells. **The cells of animals, plants, and related organisms have three basic structures: the cell membrane, or outer boundary of the cell; the nucleus, or control center; and the cytoplasm, or material between the cell membrane and the nucleus.** Let's examine a typical plant cell and an animal cell to learn about some of these basic structures.

Figure 5–3 *This diagram shows a typical animal cell. Note that the structures shown are not to scale. (This is true of almost all cell diagrams.) Most structures have been enlarged so that they can be clearly seen. In addition, some structures are more extensive or more numerous in an actual cell than they are in this diagram.*



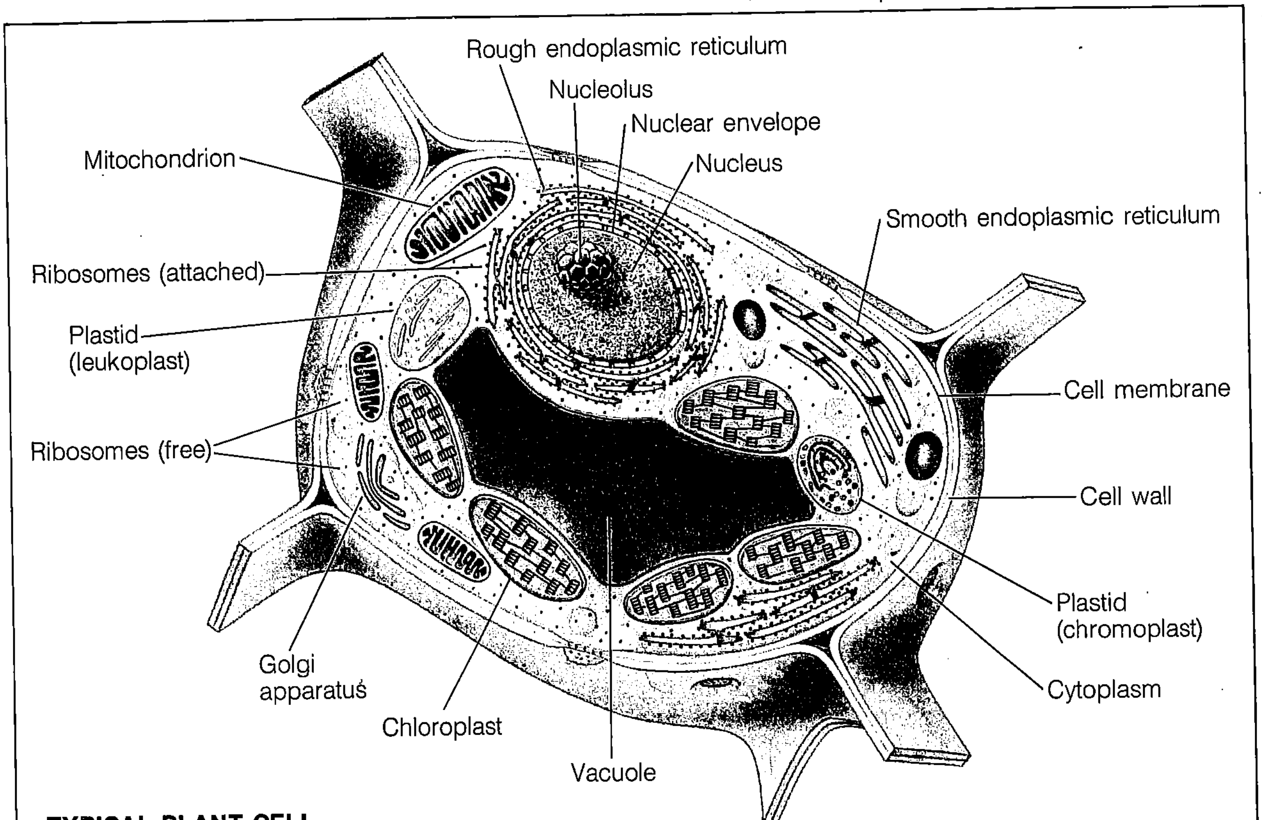


Figure 5–4 *A typical plant cell is shown in this diagram. What is the outer boundary of a plant cell called?*

Cell Membrane

All cells are separated from their surroundings by a **cell membrane**. The cell membrane regulates what enters and leaves the cell and also aids in the protection and support of the cell.

In a way, the cell membrane is similar to the walls that surround a house. As these walls help to protect the house from what is outside, so the cell membrane seals off the cell from its outside environment. But if you lived inside the house, you would still want to receive messages, fuel, and power from outside. So telephone, gas, and electric lines would have to be able to pass through the walls of the house. You would also want to bring in food and take out the trash. Thus doors would be needed. The needs of a cell are similar. It must communicate with other cells, take in food and water, and eliminate wastes. All of these processes take place through the cell membrane.

The cell membrane is composed of several kinds of molecules. The most important of these are the lipids. A double layer of lipid molecules, known as a bilayer, forms the basic unit from which cell membranes are constructed. You can see the structure of the cell membrane in Figure 5–5.

Proteins and carbohydrates are also associated with the cell membrane. Some proteins stick to the surface of the lipid

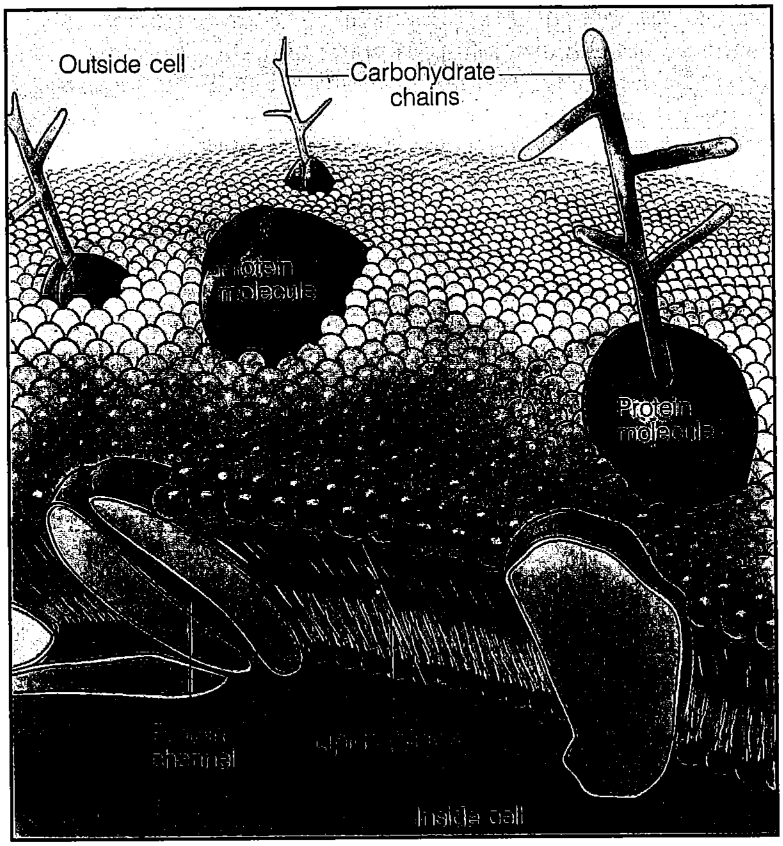


Figure 5–5 *According to a widely accepted model of membrane structure called the fluid-mosaic model, cell membranes are formed from double layers of lipids (bilayers) in which proteins are embedded. Some of the proteins form channels that allow certain molecules to pass into and out of the cell. Others resemble small pumps that push molecules from one side of the membrane to the other.*

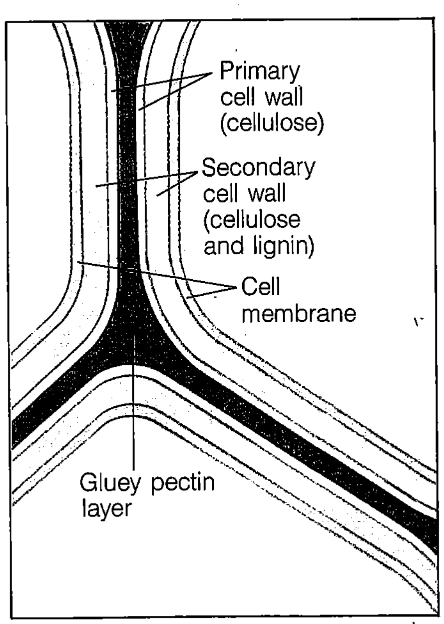
bilayer, whereas others are free to move around within the layer. Some of the free-moving proteins act as channels through which molecules can pass. Others act like small pumps, actively pushing molecules from one side of the membrane to the other. The carbohydrates are attached to proteins or lipids at the membrane surface. Many of these carbohydrates act like chemical identification cards, allowing cells to recognize and interact with each other.

Cell Wall

In organisms such as plants, algae, and some bacteria, the cell membrane is surrounded by a **cell wall.** In other words, the cell wall lies outside the cell membrane. The cell wall helps to protect and support the cell. Because the cell wall is very porous, water, oxygen, carbon dioxide, and other substances can pass through easily.

If we looked at an electron micrograph of a plant cell, we would discover that the cell wall is made up of two or more layers. These layers form in a series of steps. The first layer to form develops where two plant cells meet. See Figure 5–6. This layer contains a gluey substance, called pectin, that helps hold the cells together. Each of the cells then forms a primary cell

Figure 5–6 *The primary cell wall forms the outer boundary of plants, algae, and some bacteria. The secondary cell wall, however, generally forms only in woody stems.*



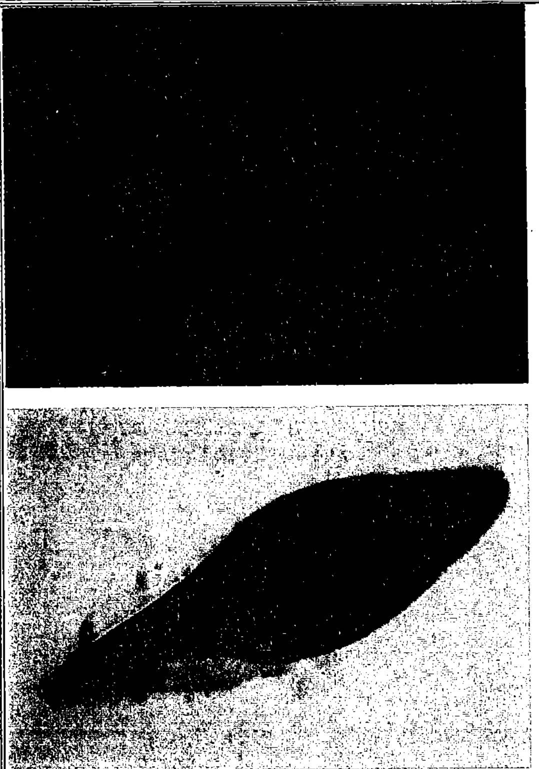


Figure 5–7 *One way of classifying living things is by the presence or absence of a nucleus. Prokaryotes, such as bacteria, do not have a nucleus (top). Eukaryotes, such as a blepharisma, contain a nucleus surrounded by a nuclear envelope (bottom).*

wall on its side of this gluey layer. The primary cell wall is made up of cellulose, a fibrous material. Cellulose fibers make the cell wall elastic, so that it can stretch as the cell grows.

In plants that have woody stems, another layer, called the secondary cell wall, develops. This wall is composed of cellulose and lignin (LIHG-nihn). Lignin makes cellulose more rigid. Wood consists mainly of secondary cell walls.

Nucleus

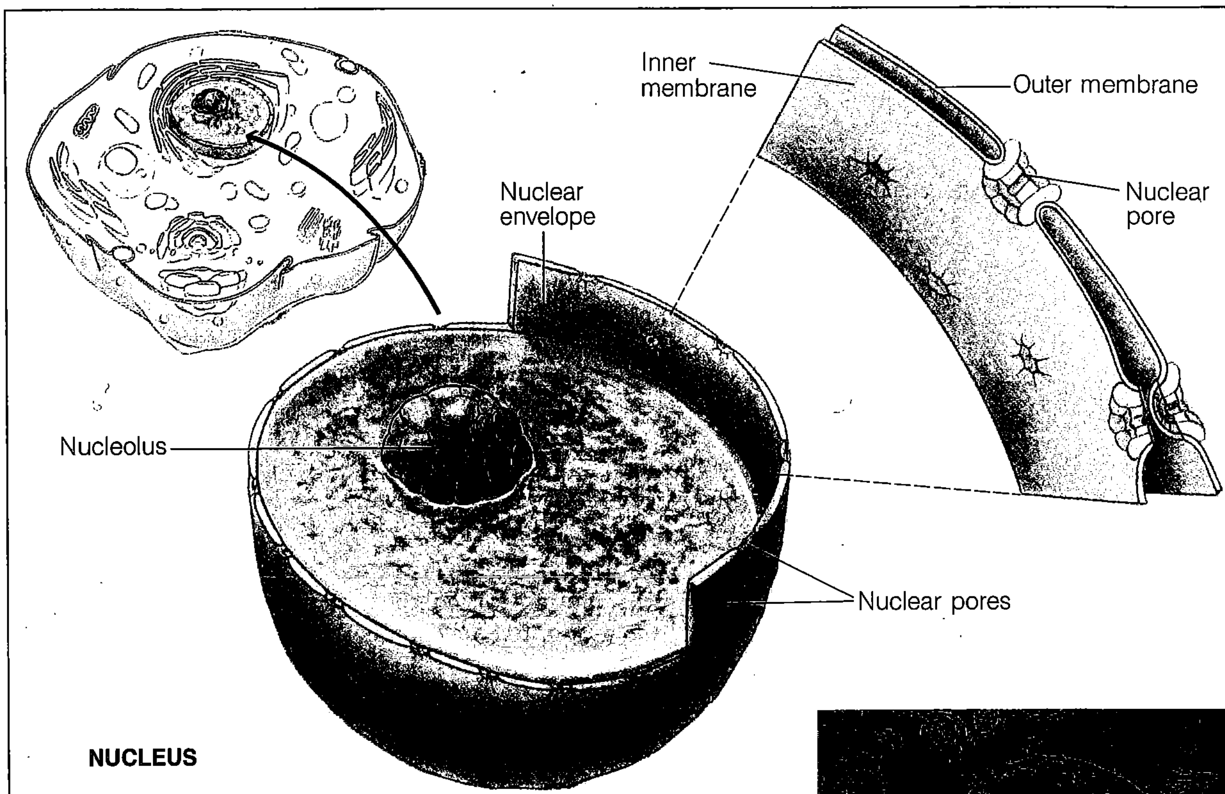
In many cells we can see a large dark structure, called the **nucleus,** which was first described by Robert Brown. Not all cells have nuclei. Small unicellular organisms known as bacteria, as well as several other kinds of organisms, do not have nuclei. The absence or presence of a nucleus can be used to divide organisms into two general categories. **Prokaryotes** (proh-KAIR-ee-ohts) are organisms whose cells lack nuclei. **Eukaryotes** (yoo-KAIR-ee-ohts) are organisms whose cells contain nuclei. *Karyon* means nucleus, *pro-* means before, and *eu-* means true. Can you see why the terms are appropriate?

Prokaryotic organisms, which include bacteria and their relatives, are usually small and unicellular. Eukaryotic organisms include both unicellular and multicellular forms. The distinction between prokaryotes and eukaryotes is a basic one, and we will return to it many times as we consider the diversity of living things. In fact, scientists consider this distinction far more important than the distinction between plant and animal cells!

Many of the scientists who first examined cells under a microscope suspected that the nucleus was doing something important. What could it be? The nucleus has been found to be the information center of the cell and contains DNA (deoxyribonucleic acid). The instructions for making thousands of different molecules are found in the nucleus. These instructions are decoded and executed by a process that we will discuss in Chapter 7. The nucleus also directs all the activities that occur in a living cell.

NUCLEAR ENVELOPE The nucleus of a eukaryotic cell is generally 2 to 5 micrometers in diameter. Surrounding the nucleus are two membranes that form the **nuclear envelope.** These two membranes form the boundary around the nucleus. In the nuclear envelope are thousands of nuclear pores, or small openings. The molecules that move in and out of the nucleus pass through the nuclear pores.

NUCLEOLUS Most nuclei contain a small region called the **nucleolus** (noo-KLEE-uh-luhs) that is made up of RNA (ribonucleic acid) and proteins. The nucleolus is the structure in which parts of ribosomes are made. Ribosomes, as you will soon learn, aid in the production of proteins within the cell.



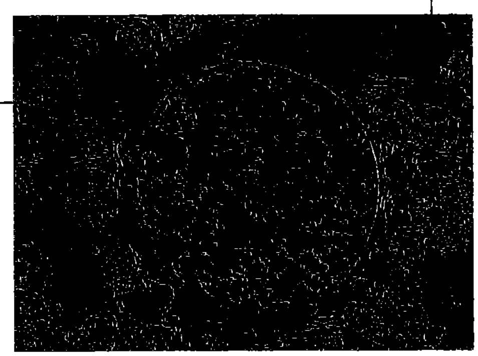


Figure 5–8 *The nucleus directs all the activities of a cell. Notice the various structures that make up the nucleus and the appearance of the nucleus in the micrograph.*

CHROMOSOMES The DNA in the nucleus of eukaryotic cells is attached to special proteins and forms large structures called **chromosomes.** Chromosomes contain the genetic information that must be passed to each new generation of cells.

Cytoplasm

Because the nucleus sits in the center of many eukaryotic cells, we can divide the space within a cell into two compartments: the nucleus and the **cytoplasm.** The cytoplasm is the area between the nucleus and the cell membrane. The cytoplasm contains many important structures that we shall discuss in the next section.

5–2 SECTION REVIEW

1. What are the three basic structures found in most cells?
2. What is the function of the cell membrane?
3. **Critical Thinking—Assessing Concepts** Distinguish between prokaryotes and eukaryotes. Why is this distinction important?