1.1 Studying the Structure of Cells

Before the invention of microscopes in the 1660s, people had only a limited understanding of the human body and no knowledge of the microscopic world. For example, people had not yet seen their own blood **cells**, as shown in **Figure 1.1**, and had never seen the micro-organisms (such as bacteria) that cause many diseases. Therefore, they did not know that they could help to prevent diseases by disposing of sewage properly, sterilizing surgical instruments between operations, and washing their hands regularly. Most importantly, they did not know the importance of clean drinking water.

Microscopes and Human Health

In the 1860s and 1870s, compound microscopes were put to good use. Scientists and physicians around the world did experiments that paved the way for one of the biggest discoveries in medicine—that "germs" (viruses, many bacteria, and some other microscopic organisms) cause diseases. This discovery made it possible to introduce simple methods (such as hand washing and drinking clean water) to prevent many diseases, and thus increase the human life span. Since then, discoveries in **microscopy** continue to advance medical diagnosis and the treatment of diseases caused by micro-organisms and other illnesses, such as diabetes and cancer. In **Figure 1.2**, on pages 8 and 9, you can see a range of the microscopes used today.

Key Terms

cell
microscopy
nucleus
organelle
micrograph
cytoplasm

cell the smallest unit that can perform the functions of life

microscopy the science of using microscopes to view samples or objects

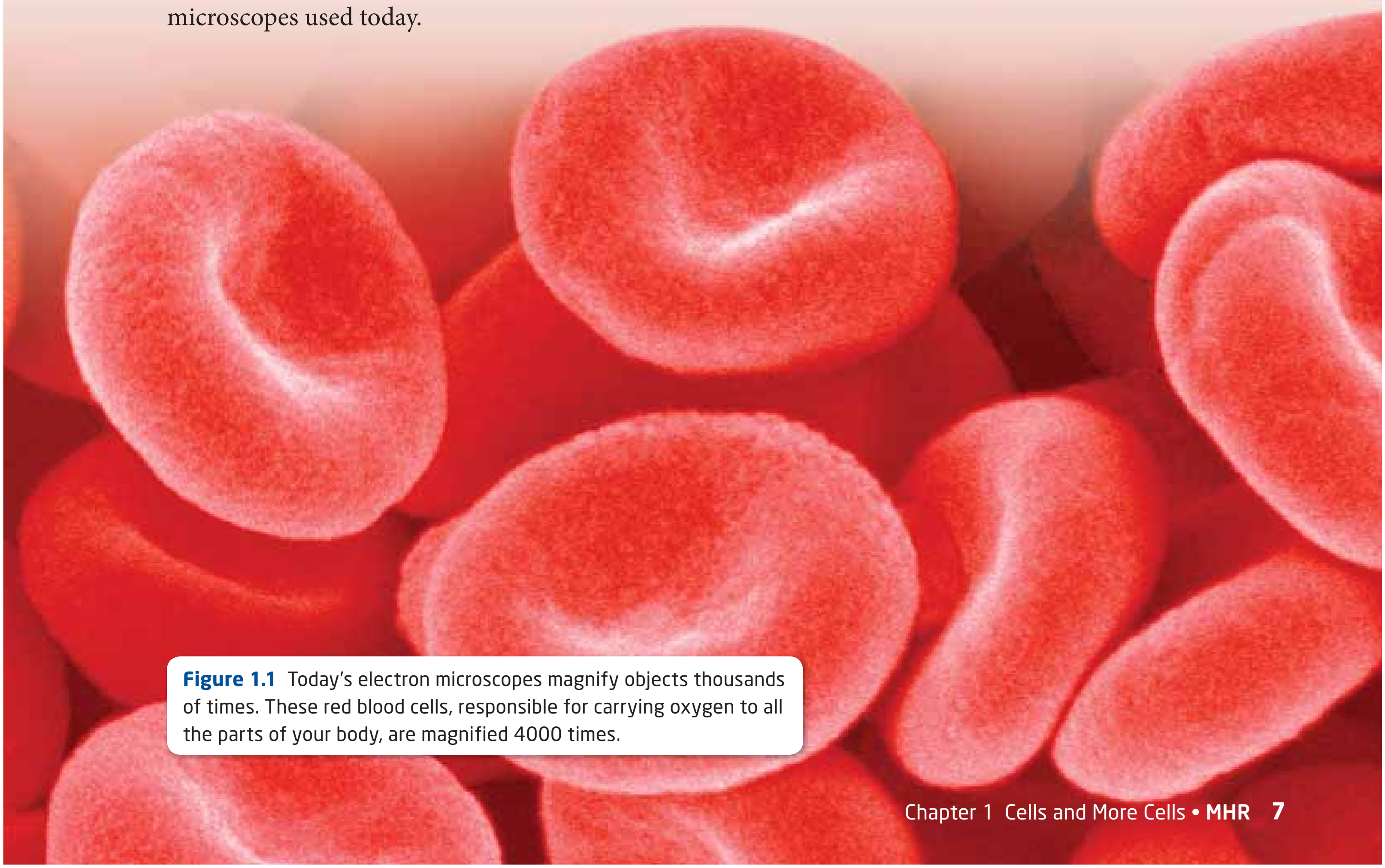


Figure 1.1 Today's electron microscopes magnify objects thousands of times. These red blood cells, responsible for carrying oxygen to all the parts of your body, are magnified 4000 times.

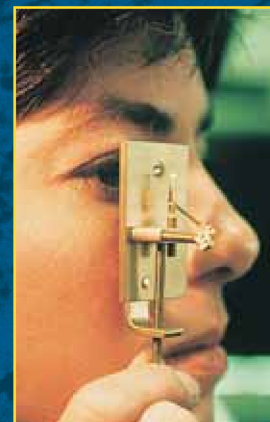
NATIONAL GEOGRAPHIC

VISUALIZING MICROSCOPES

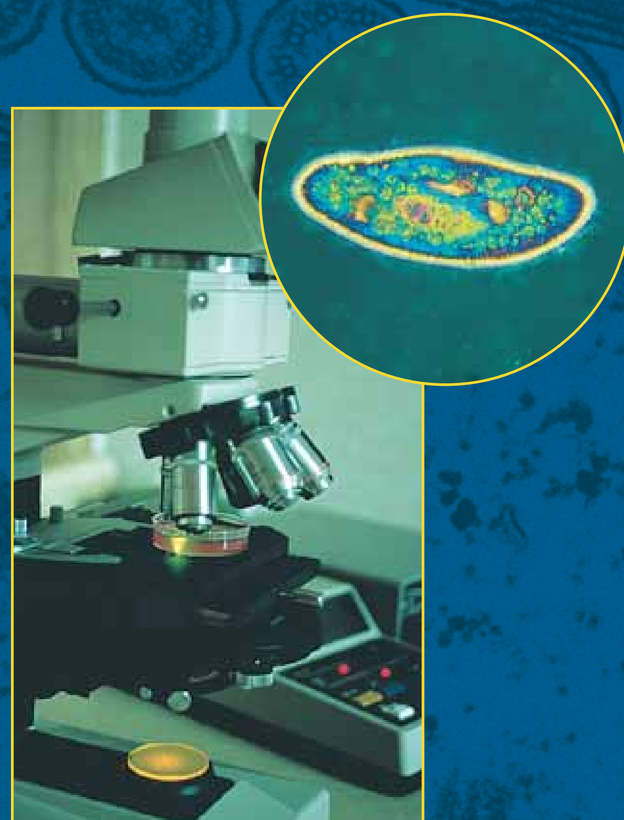
Figure 1.2

Microscopes give us a glimpse into a previously invisible world. Improvements have vastly increased their range of visibility, allowing researchers to study life at the molecular level. A selection of these powerful tools is shown here, along with their magnification powers.

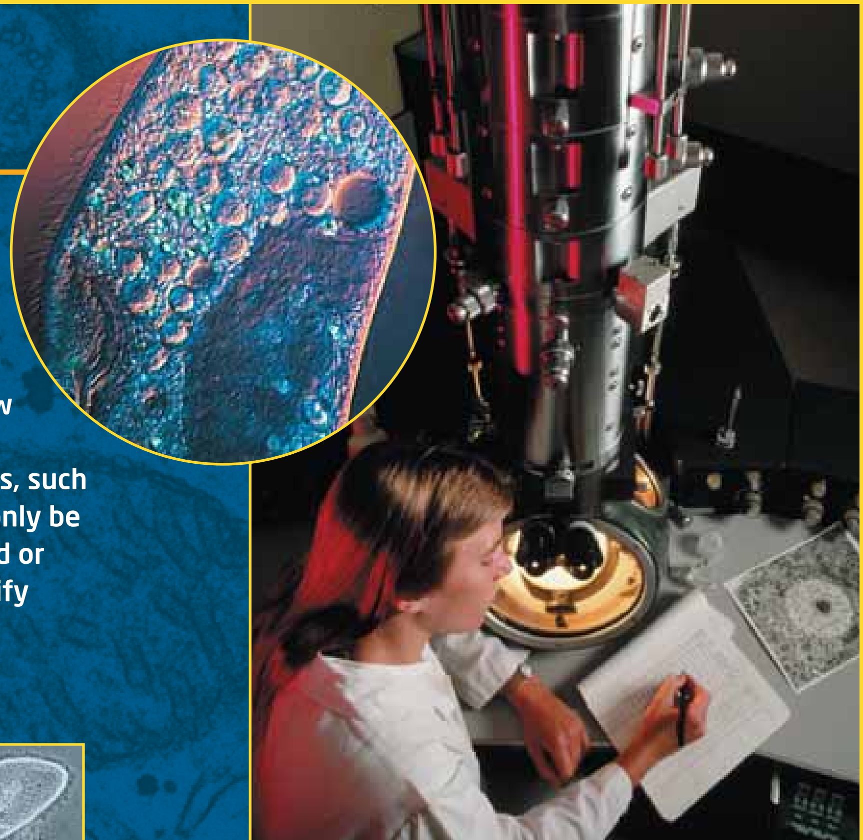
▶ **Up to 250×** **LEEUWENHOEK MICROSCOPE** Held by a modern researcher, this historic microscope allowed Leeuwenhoek to see clear images of tiny freshwater organisms that he called "beasties."



▼ **Up to 2000×** **BRIGHTFIELD / DARKFIELD MICROSCOPE** The light microscope is often called the brightfield microscope because the image is viewed against a bright background. A brightfield microscope is the tool most often used in laboratories to study cells. Placing a thin metal disc beneath the stage, between the light source and the objective lenses, converts a brightfield microscope to a darkfield microscope. The image seen using a darkfield microscope is bright against a dark background. This makes details more visible than with a brightfield microscope. Below are images of a paramecium, seen using both types of microscopes.



▲ **Up to 1500×** **FLUORESCENCE MICROSCOPE** This type of microscope requires that the specimen be treated with special fluorescent stains. When viewed through a fluorescence microscope, certain cell structures or types of substances glow, as seen in the image of a paramecium above.



Up to 1 000 000× TRANSMISSION ELECTRON MICROSCOPE A TEM aims a beam of electrons through a specimen. Denser portions of the specimen allow fewer electrons to pass through and appear darker in the image. Organisms, such as the paramecium on the right, can only be seen when the image is photographed or shown on a monitor. A TEM can magnify hundreds of thousands of times.

Up to 1500× PHASE-CONTRAST MICROSCOPE A phase-contrast microscope emphasizes slight differences in a specimen's capacity to bend light waves, thereby enhancing light and dark regions without the use of stains. This type of microscope is especially good for viewing living cells, like the paramecium above, on the left. The images from a phase-contrast microscope can only be seen when the specimen is photographed or shown on a monitor.

Up to 200 000× SCANNING ELECTRON MICROSCOPE An SEM sweeps a beam of electrons over a specimen's surface, causing other electrons to be emitted from the specimen. SEMs produce realistic three-dimensional images, like the image of the paramecium on the right. SEM images can only be viewed as photographs or on a computer monitor, however. Here a researcher compares an SEM image with an enhanced image on a computer monitor.

Cell Structure

Most of today's advances in the treatment of diseases would not be possible without an understanding of what happens inside cells. In turn, our understanding of cells would not be possible without advances in microscopy.

In 1665, English scientist Robert Hooke became the first person to study cells. Using a microscope he made himself, Hooke examined a piece of cork. There he saw a series of similar "pores" that he called cells because they reminded him of monks' living quarters in a monastery, which were called cells.

One of the first cell structures that scientists could see with early microscopes was the **nucleus**. The nucleus was usually the only cell **organelle** visible through light microscopes—it looked like a dark spot. Even cell membranes were not usually visible. Now, however, scientists know a great deal about the nucleus and cell membrane, what they are made of, and how they function. **Figure 1.3** shows a **micrograph** and diagram of a nucleus, while **Figure 1.4** allows you to compare the level of detail you can see in micrographs of cells as seen through a light microscope and through an electron microscope.

nucleus the organelle that controls the cell's activities

organelle a specialized structure in a cell

micrograph a photograph taken with a microscope

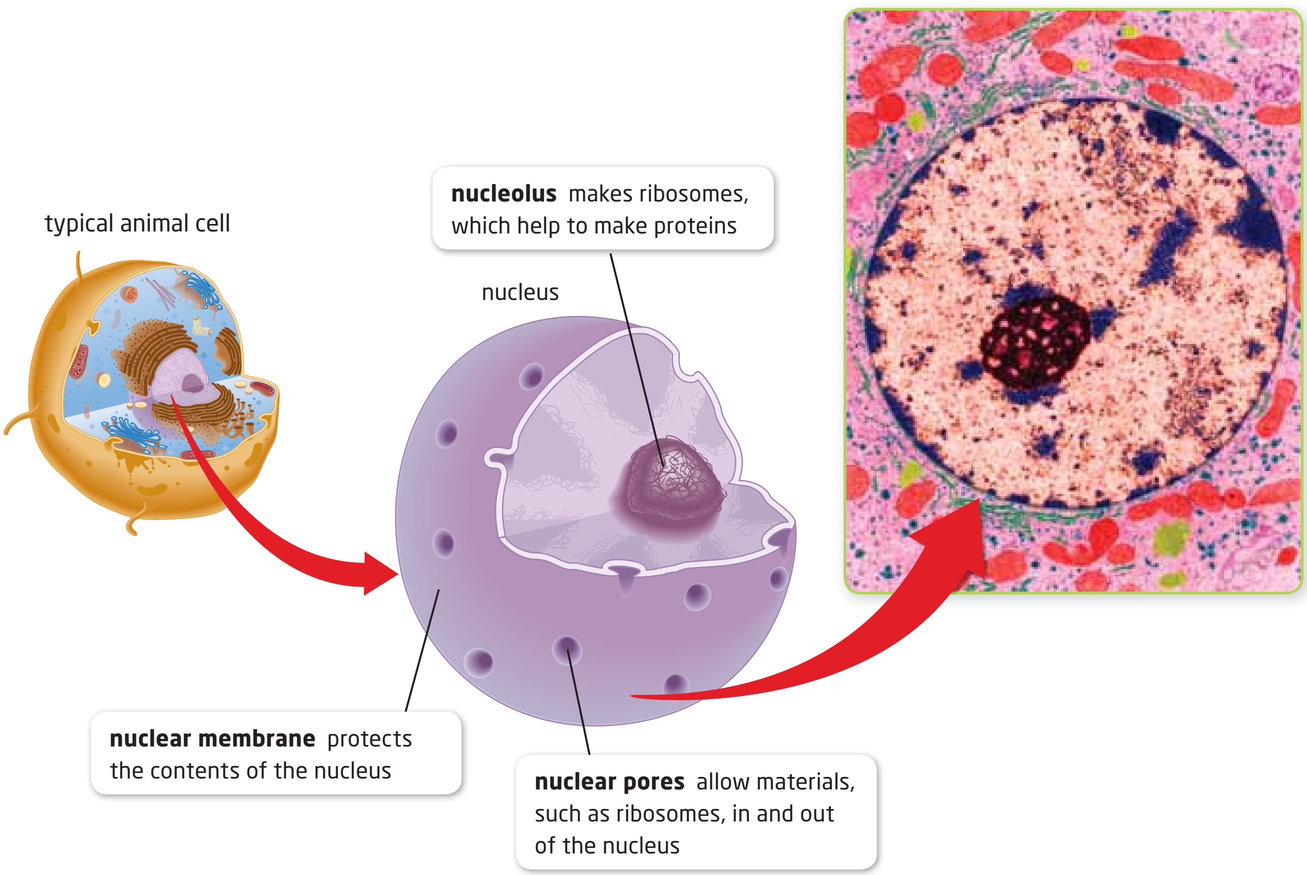


Figure 1.3 Here you can see a diagram of a nucleus, as well as an electron micrograph of the nucleus in a human liver cell, magnified 2730 times.

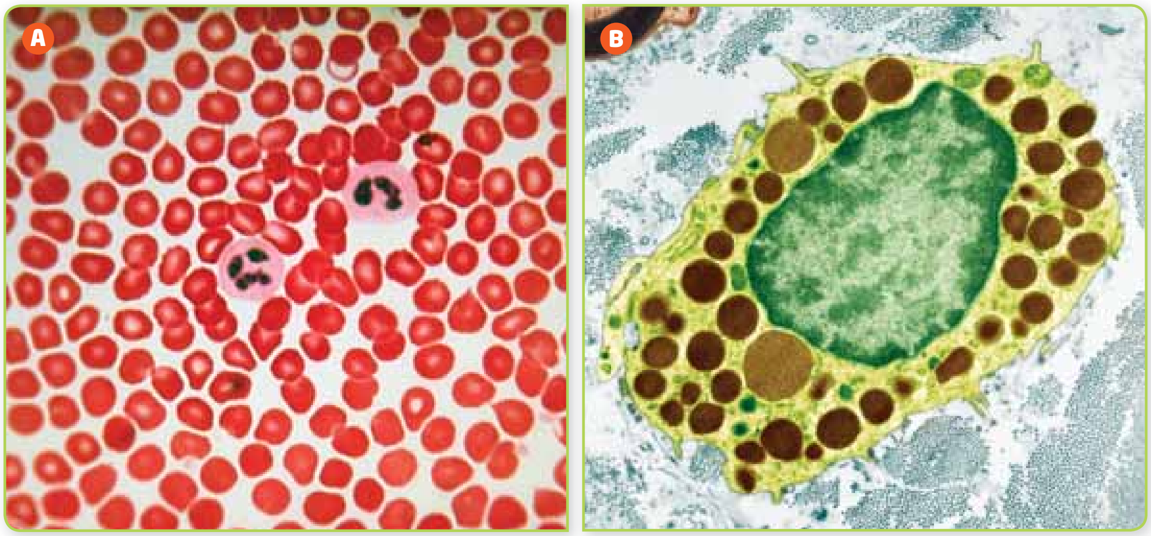


Figure 1.4 Micrograph **A** shows many red blood cells and two white blood cells, magnified 210 times by a light microscope. Micrograph **B** shows a single white blood cell, magnified 2500 times by an electron microscope. The nucleus of the cell is shown in green.

The Cell Theory

Largely based on what early microscopists observed, a theory of cells was developed in the mid-1800s. The cell theory is one of the most important developments in the study of biology. It has three main ideas:

1. All living organisms are made of one or more cells.
2. The cell is the basic organizational unit of life.
3. All cells come from pre-existing cells.

The first of these ideas is fairly easy to understand. The third idea refers to cell reproduction, which you will learn about in Section 1.3. The second idea means that to understand how living things function, you must know what is going on inside cells. In other words, all of an organism's body functions, such as eating, breathing, and eliminating waste, are designed to supply the needs of its cells. This section will help you understand the normal structure and function of cells. Later in this unit, you will learn more about how cells form the smallest unit of all living organisms. Some organisms, such as humans, are made of millions of cells, each with a specialized function.

Sense of scale

If 1000 human body cells were lined up, they would be less than 2 cm long–about the width of a thumbnail.

Contents of the Cytoplasm

The fluid material between the cell membrane and the nucleus—the *cytosol*—is filled with many specialized organelles. Together, the cytosol and the organelles it contains are called the **cytoplasm**.

cytoplasm the cytosol and organelles contained by the cell membrane

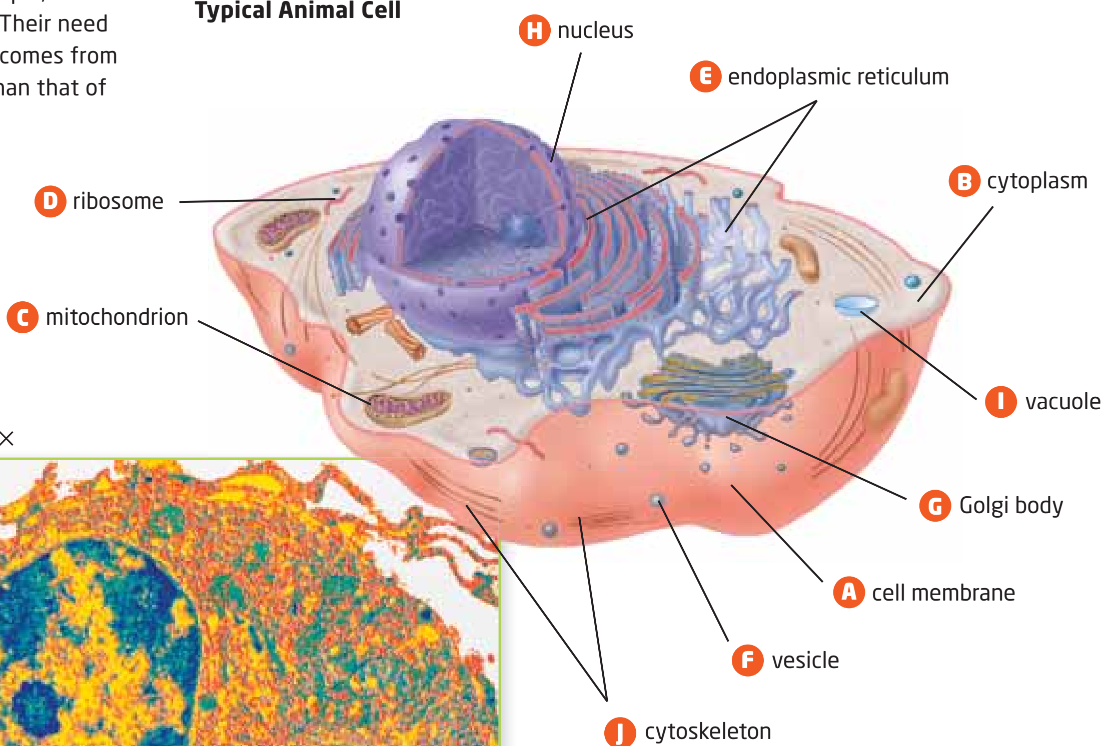
Animal and Plant Cell Organelles

The organelles of a cell are like the organs of a body—each plays a role in the proper functioning of the "body" that contains it. **Figures 1.5** and **1.6** illustrate typical animal and plant cells. Of course, not all plant and animal cells look exactly like those illustrated here. As you will see in this unit, there are many different kinds of cells, even within the same organism. Yet even cells with very different functions can have the same kinds of organelles.

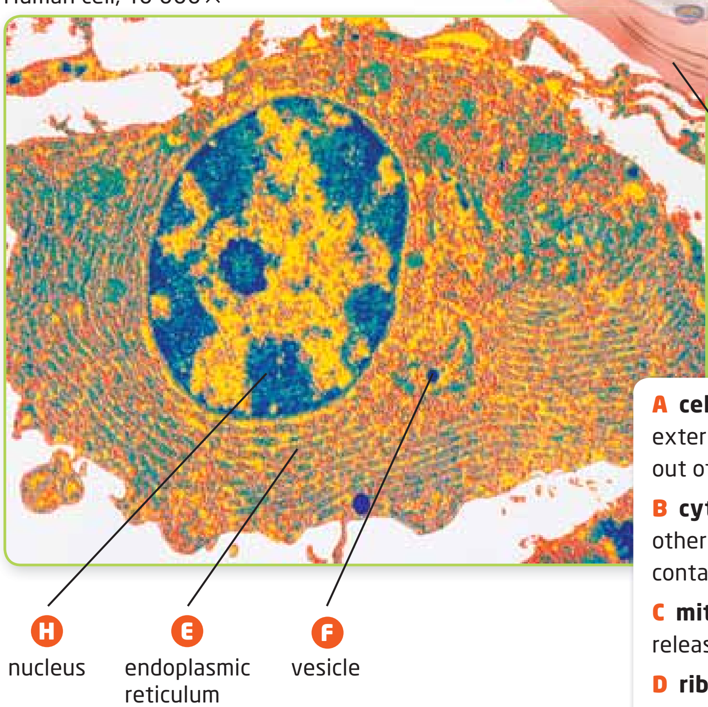
As you study these diagrams, you may notice that a number of the organelles are involved in the production, storage, or transport of *proteins*. All cells in your body depend on proteins, which allow the cells to carry out the life processes that keep you healthy. Proteins are essential nutrients for the growth and repair of body tissues. You will learn more about proteins in the sections that follow.

Figure 1.5 This diagram and the micrograph below it show a typical animal cell. Just as cells in your body vary in structure and function, so do the organelles they contain. Cells that help a body move, for example, contain more mitochondria. Their need for the energy that comes from glucose is greater than that of other kinds of cells.

Typical Animal Cell



Human cell, 10 000×



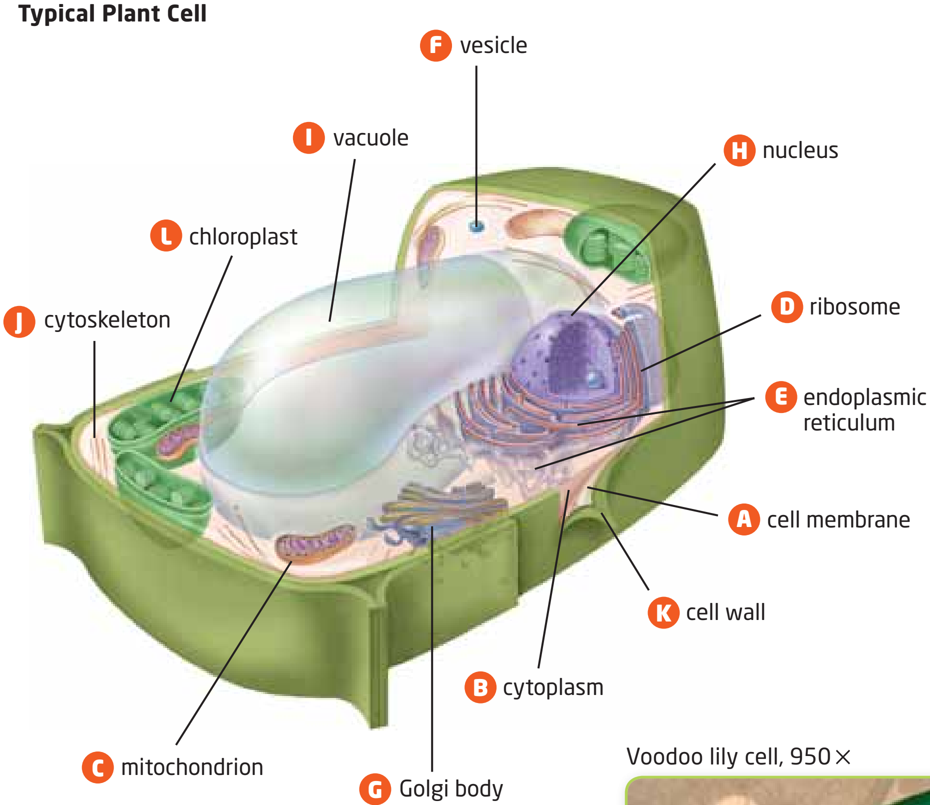
A cell membrane separates the inside of the cell from the external environment; controls the flow of materials into and out of the cell

B cytoplasm includes the cytosol, the organelles, and other life-supporting materials, such as sugar and water, all contained by the cell membrane

C mitochondria (singular: mitochondrion) where energy is released from glucose to fuel cell activities

D ribosomes help to produce proteins, which make up much of a cell's structure and are required for activities necessary for the cell's survival; some ribosomes float in the cytoplasm, and others are attached to the endoplasmic reticulum

Typical Plant Cell



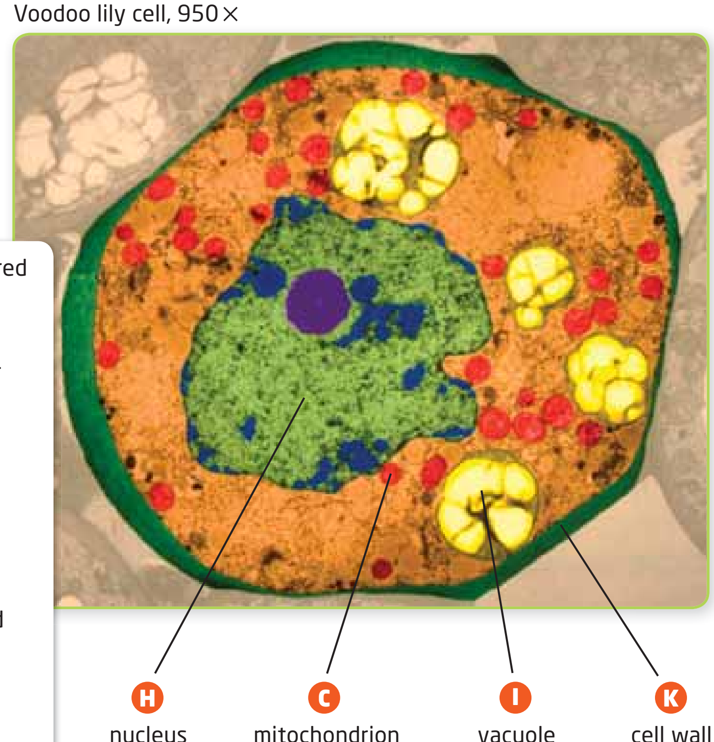
Suggested Investigation

Inquiry Investigation 1-A, Examining Cell Structures, on page 46

Go to **scienceontario** to find out more

Figure 1.6 This diagram and the micrograph below it show a typical plant cell. Like animal cells, plant cells vary in structure and function. For example, cells in the roots (and other non-green parts of the plant) usually have no chloroplasts. They do not need chloroplasts because they do not carry out photosynthesis.

Voodoo lily cell, 950×



E endoplasmic reticulum a network of membrane-covered channels that transport materials made in the cell; is connected to the nucleus

F vesicles membrane-covered sacs that transport and/or store materials inside the cell and sometimes help these materials cross the cell membrane to enter or exit the cell

G Golgi body sorts and packages proteins and other molecules for transport out of the cell

H nucleus controls all cell activities

I vacuoles contain water and other materials and are used to store or transport small molecules; plant cells tend to have one large vacuole; animal cells may have several smaller vacuoles

J cytoskeleton filaments and tubules that provide a framework for the cell, helping it maintain its structure and providing "tracks" along which vesicles and organelles can move

K cell wall a tough, rigid structure lying just outside a plant cell's membrane; provides support for the cell

L chloroplasts found only in plant cells; trap energy from the Sun to make glucose, which is broken down in the mitochondria to power cell activities (animals must get glucose from the food they eat)

Learning Check

1. Create a table to compare the organelles in plant and animals cells that are responsible for protein production, food storage, transportation of substances, and maintenance of the cell's structure.
2. Look back to **Figure 1.2** on pages 8 and 9. Name three types of microscopes and one feature that makes each unique.
3. What are the three main ideas in the cell theory?
4. What might be some disadvantages of electron microscopes? Specifically, why do you think you might not have electron microscopes in your school?

All Cells Use Energy

Some types of organelles are found in both plant and animal cells, while other types are found only in one or the other. For example, chloroplasts are found only in plant cells. Mitochondria, however, are found in both plant and animal cells—most cells cannot survive without the energy that mitochondria release from glucose. The process by which this occurs is common to most cells, and it is called cellular respiration.

Cellular respiration, shown in **Figure 1.7**, requires oxygen in order to occur. This is why we must breathe in air, which contains oxygen. As well as releasing energy, the process of cellular respiration produces carbon dioxide as a waste product. We get rid of carbon dioxide and water vapour when we breathe out.

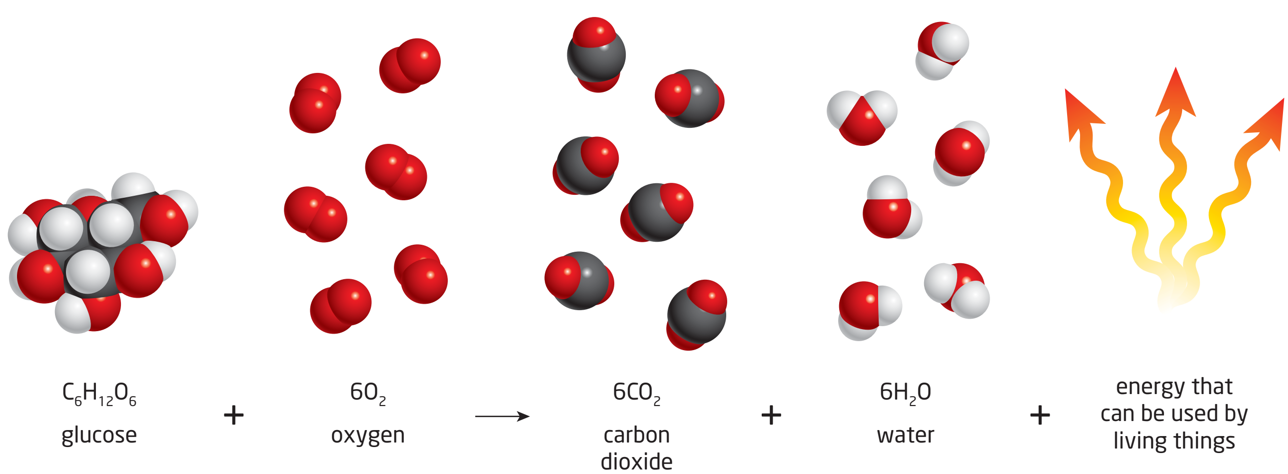


Figure 1.7 This is a very simplified version of the cellular respiration process. It shows the inputs and outputs. There are actually many steps between these inputs and outputs. For example, glucose gets broken down in a series of chemical reactions that release energy bit by bit.

Section 1.1 Review

Section Summary

- Developments in microscopy (microscope technology) have made it possible to look at the internal structures of cells.
- Cells contain a variety of organelles, each of which has its own structure and function. Some organelles are found in all cells, while others are found only in plant *or* animal cells.
- Advances in knowledge about cells have helped researchers find new ways to diagnose and treat diseases.

Review Questions

K/U **1.** Why are electron microscopes more useful than light microscopes for looking at organelles?

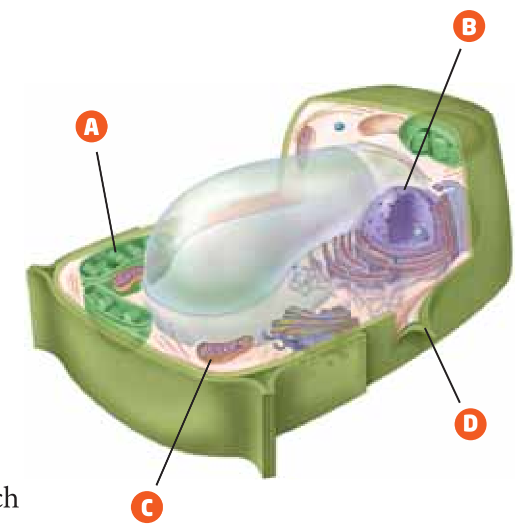
K/U **2.** Describe the functions of the following organelles: mitochondria, nucleolus, vacuole.

K/U **3.** Examine the diagram on the right.

a. Does the diagram show a plant cell or an animal cell?

b. Which of the lettered structures helped you decide?

c. What is this structure called?



C **4.** Draw a Venn diagram to compare the cell wall and the cell membrane.

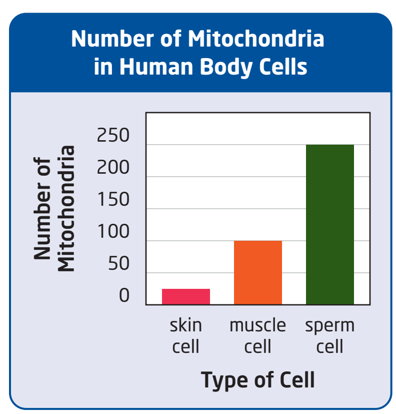
K/U **5.** Using **Figures 1.5** and **1.6** as a reference, draw diagrams or create a table to compare plant and animal cells. Focus on which organelles or other features they share and which parts are only found in one of these types of cells.

C **6.** Imagine that the cell is a factory and each of the organelles is a machine. Working in a small group, focus on one organelle. Create a diagram and a short statement to convince the factory president of the importance of your organelle. How is it essential to the operation of the factory? Combine the diagrams from all the groups into a class map of this cell factory.

A **7.** The graph on the right provides data on the number of mitochondria in each of three cell types.

a. Which cell type do you think requires the most food (in the form of the glucose it receives) for its functions?

b. Why do you think skin cells have the least number of mitochondria of the three types of cells studied?



T/I **8.** What do you think would happen to other forms of life on Earth if most or all of the plant life disappeared? Explain your answer in terms of what goes on inside cells.