7.1 Life Is Cellular

Key Questions

- *What is the cell theory?*
- *How do microscopes work?*
- *How are prokaryotic and eukaryotic cells different?*

Vocabulary

cell • cell theory • cell membrane • nucleus • eukaryote • prokaryote

Taking Notes

Outline Before you read, make an outline using the green and blue headings in the text. As you read, fill in notes under each heading.

THINK ABOUT IT What's the smallest part of any living thing that still counts as being "alive"? Is a leaf alive? How about your big toe? How about a drop of blood? Can we just keep dividing living things into smaller and smaller parts, or is there a point at which what's left is no longer alive? As you will see, there is such a limit, the smallest living unit of any organism—the cell.

The Discovery of the Cell

What is the cell theory?

"Seeing is believing," an old saying goes. It would be hard to find a better example of this than the discovery of the cell. Without the instruments to make them visible, cells remained out of sight and, therefore, out of mind for most of human history. All of this changed with a dramatic advance in technology—the invention of the microscope.

Early Microscopes In the late 1500s, eyeglass makers in Europe discovered that using several glass lenses in combination could magnify even the smallest objects to make them easy to see. Before long, they had built the first true microscopes from these lenses, opening the door to the study of biology as we know it today.

In 1665, Englishman Robert Hooke used an early compound microscope to look at a nonliving thin slice of cork, a plant material. Under the microscope, cork seemed to be made of thousands of tiny empty chambers. Hooke called these chambers "cells" because they reminded him of a monastery's tiny rooms, which were called cells. The term *cell* is used in biology to this day. Today we know that living cells are not empty chambers, that in fact they contain a huge array of working parts, each with its own function.

In Holland around the same time, Anton van Leeuwenhoek used a single-lens microscope to observe pond water and other things. To his amazement, the microscope revealed a fantastic world of tiny living organisms that seemed to be everywhere, in the water he and his neighbors drank, and even in his own mouth. Leeuwenhoek's illustrations of the organisms he found in the human mouth—which today we call bacteria—are shown in **Figure 7–1.**

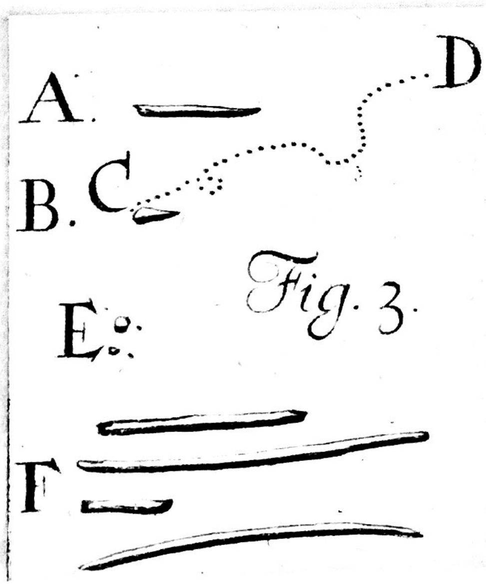
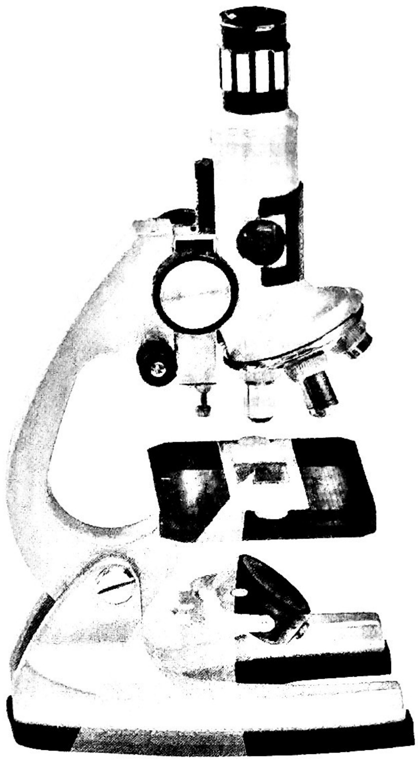


FIGURE 7–1 Early Microscope Images Using a simple microscope, Anton van Leeuwenhoek was the first to observe living microorganisms. These drawings, taken from one of his letters, show bacteria in the human mouth.

The Cell Theory Soon after van Leeuwenhoek, observations by scientists made it clear that **cells** are the basic units of life. In 1838, German botanist Matthias Schleiden concluded that all plants are made of cells. The next year, German biologist Theodor Schwann stated that all animals are made of cells. In 1855, German physician Rudolf Virchow concluded that new cells can be produced only from the division of existing cells, confirming a suggestion made by German Lorenz Oken 50 years earlier. These discoveries, confirmed by many biologists, are summarized in the **cell theory,** a fundamental concept of biology. **The cell theory states:**

- **All living things are made up of cells.**
- **Cells are the basic units of structure and function in living things.**
- **New cells are produced from existing cells.**



Exploring the Cell

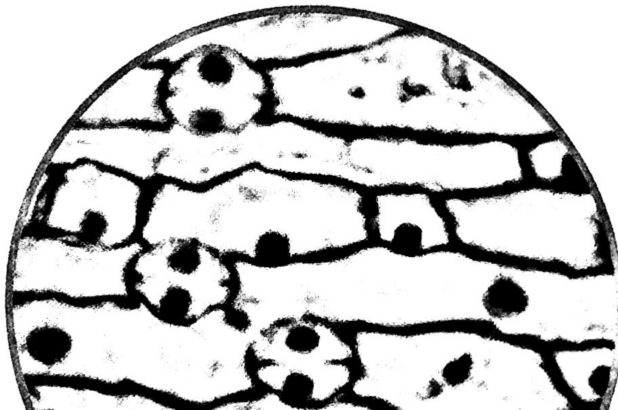
How do microscopes work?

A microscope, as you know, produces an enlarged image of something very small. **Most microscopes use lenses to magnify the image of an object by focusing light or electrons.** Following in the footsteps of Hooke, Virchow, and others, modern biologists still use microscopes to explore the cell. But today's researchers use technology more powerful than the pioneers of biology could ever have imagined.

Light Microscopes and Cell Stains The type of microscope you are probably most familiar with is the compound light microscope. A typical light microscope allows light to pass through a specimen and uses two lenses to form an image. The first lens, called the objective lens, is located just above the specimen. This lens enlarges the image of the specimen. Most light microscopes have several objective lenses so that the power of magnification can be varied. The second lens, called the ocular lens, magnifies this image still further. Unfortunately, light itself limits the detail, or resolution, of images in a microscope. Like all forms of radiation, lightwaves are diffracted, or scattered, as they pass through matter. Because of this, light microscopes can produce clear images of objects only to a magnification of about 1000 times.

Another problem with light microscopy is that most living cells are nearly transparent. Using chemical stains or dyes, as in **Figure 7–2,** can usually solve this problem. Some of these stains are so specific that they reveal only certain compounds or structures within the cell. Many of the slides you'll examine in your biology class laboratory will be stained this way.

A powerful variation on these staining techniques uses dyes that give off light of a particular color when viewed under specific wavelengths of light, a property called fluorescence. Fluorescent dyes can be attached to specific molecules and can then be made visible using a special fluorescence microscope. New techniques, in fact, enable scientists to engineer cells that attach fluorescent labels of different colors to specific molecules as they are produced. Fluorescence microscopy makes it possible to see and identify the locations of these molecules and even allows scientists to watch them move around in a living cell.



LM 35×

FIGURE 7–2 Light Microscope and Cell Stains This specimen of onion leaf skin has been stained with a compound called toluidine blue. The dye makes the cell boundaries and nuclei clearly visible.

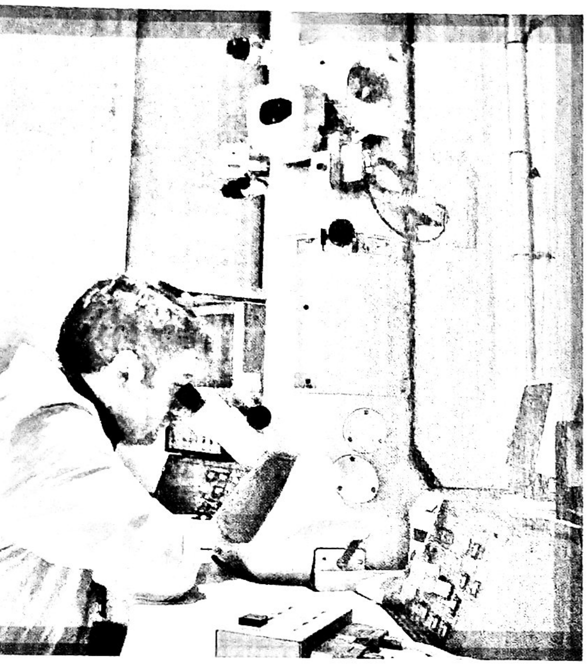
Electron Microscopes Light microscopes can be used to see cells and cell structures as small as 1 millionth of a meter—certainly pretty small! But what if scientists want to study something smaller than that, such as a virus or a DNA molecule? For that, they need electron microscopes. Instead of using light, electron microscopes use beams of electrons that are focused by magnetic fields. Electron microscopes offer much higher resolution than light microscopes. Some types of electron microscopes can be used to study cellular structures that are 1 billionth of a meter in size.

There are two major types of electron microscopes: transmission and scanning. Transmission electron microscopes make it possible to explore cell structures and large protein molecules. But because beams of electrons can only pass through thin samples, cells and tissues must be cut into ultrathin slices before they can be examined. This is the reason that such images often appear flat and two dimensional.

In scanning electron microscopes, a pencil-like beam of electrons is scanned over the surface of a specimen. Because the image is formed at the specimen's surface, samples do not have to be cut into thin slices to be seen. The scanning electron microscope produces stunning three-dimensional images of the specimen's surface.

Electrons are easily scattered by molecules in the air, which means samples must be placed in a vacuum to be studied with an electron microscope. As a result, researchers must chemically preserve their samples. Electron microscopy, then, can only be used to examine nonliving cells and tissues.

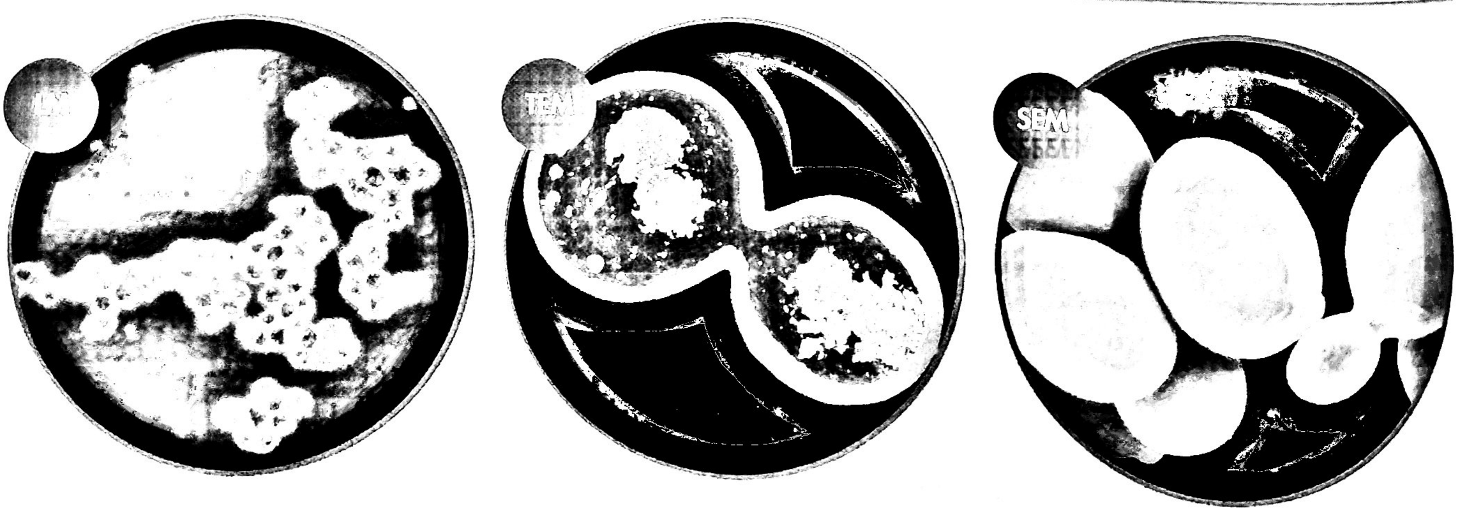
Look at **Figure 7–3,** which shows yeast cells as they might look under a light microscope, transmission electron microscope, and scanning electron microscope. You may wonder why the cells appear to be different colors in each micrograph. (A micrograph is a photo of an object seen through a microscope.) The colors in light micrographs come from the cells themselves, or from the stains and dyes used to highlight them. Electron micrographs, however, are actually black and white. Electrons, unlike light, don't come in colors. So scientists often use computer techniques to add "false color" to make certain structures stand out.



A Researcher Working With a Transmission Electron Microscope

In Your Notebook *You are presented with a specimen to examine. What are two questions you would ask to determine the best microscope to use?*

FIGURE 7–3 Micrographs Different types of microscopes can be used to examine cells. Here, yeast cells are shown in a light micrograph (LM 500×), transmission electron micrograph (TEM 4375×), and a scanning electron micrograph (SEM 3750×).
Infer ***If scientists were studying a structure found on the surface of yeast, which kind of microscope would they likely use?***



Quick Lab GUIDED INQUIRY

What Is a Cell?

❶ Look through a microscope at a slide of a plant leaf or stem cross section. Sketch one or more cells. Record a description of their shape and internal parts.

❷ Repeat step 1 with slides of nerve cells, bacteria, and paramecia.

❸ Compare the cells by listing the characteristics they have in common and some of the differences among them.

Analyze and Conclude

1. Classify Classify the cells you observed into two or more groups. Explain what characteristics you used to put each cell in a particular group.

Prokaryotes and Eukaryotes

How are prokaryotic and eukaryotic cells different?

Cells come in an amazing variety of shapes and sizes, some of which are shown in **Figure 7–4.** Although typical cells range from 5 to 50 micrometers in diameter, the smallest *Mycoplasma* bacteria are only 0.2 micrometer across, so small that they are difficult to see under even the best light microscopes. In contrast, the giant amoeba *Chaos chaos* can be 1000 micrometers (1 millimeter) in diameter, large enough to be seen with the unaided eye as a tiny speck in pond water. Despite their differences, all cells, at some point in their lives, contain DNA, the molecule that carries biological information. In addition, all cells are surrounded by a thin flexible barrier called a **cell membrane.** (The cell membrane is sometimes called the *plasma membrane* because many cells in the body are in direct contact with the fluid portion of the blood—the plasma.) There are other similarities as well, as you will learn in the next lesson.

Cells fall into two broad categories, depending on whether they contain a nucleus. The **nucleus** (plural: nuclei) is a large membrane-enclosed structure that contains genetic material in the form of DNA and controls many of the cell's activities. **Eukaryotes** (yoo KAR ee ohts) are cells that enclose their DNA in nuclei. **Prokaryotes** (pro KAR ee ohts) are cells that do not enclose DNA in nuclei.

MYSTERY CLUE

At the hospital, a sample of Michelle's blood was drawn and examined. The red blood cells appeared swollen. What kind of microscope was most likely used to study the blood sample?

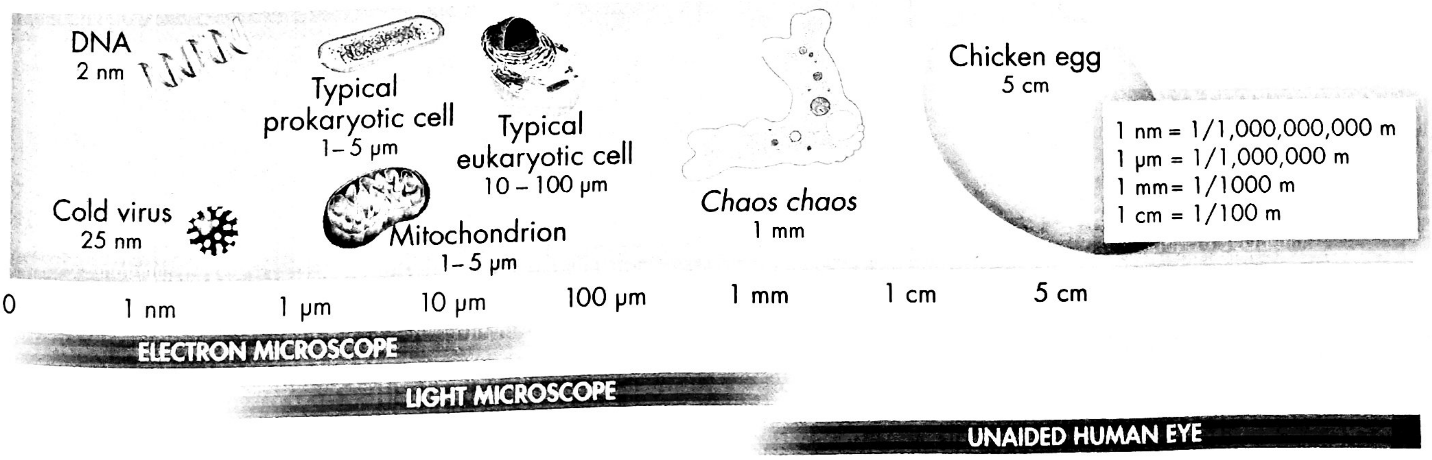


FIGURE 7–4 Cell Size Is Relative The human eye can see objects larger than about 0.5 mm. Most of what interests cell biologists, however, is much smaller than that. Microscopes make seeing the cellular and subcellular world possible.

BUILD Vocabulary

WORD ORIGINS The noun prokaryote comes from the Greek word *karyon*, meaning "kernel," or nucleus. The prefix *pro-* means "before." Prokaryotic cells first evolved before nuclei developed.

Prokaryotes As seen in **Figure 7–5**, prokaryotic cells are generally smaller and simpler than eukaryotic cells, although there are many exceptions to this rule. **Prokaryotic cells do not separate their genetic material within a nucleus.** Despite their simplicity, prokaryotes carry out every activity associated with living things. They grow, reproduce, respond to the environment, and, in some cases, glide along surfaces or swim through liquids. The organisms we call bacteria are prokaryotes.

Eukaryotes Eukaryotic cells are generally larger and more complex than prokaryotic cells. Most eukaryotic cells contain dozens of structures and internal membranes, and many are highly specialized. **In eukaryotic cells, the nucleus separates the genetic material from the rest of the cell.** Eukaryotes display great variety: some, like the ones commonly called "protists," live solitary lives as unicellular organisms; others form large, multicellular organisms—plants, animals, and fungi.

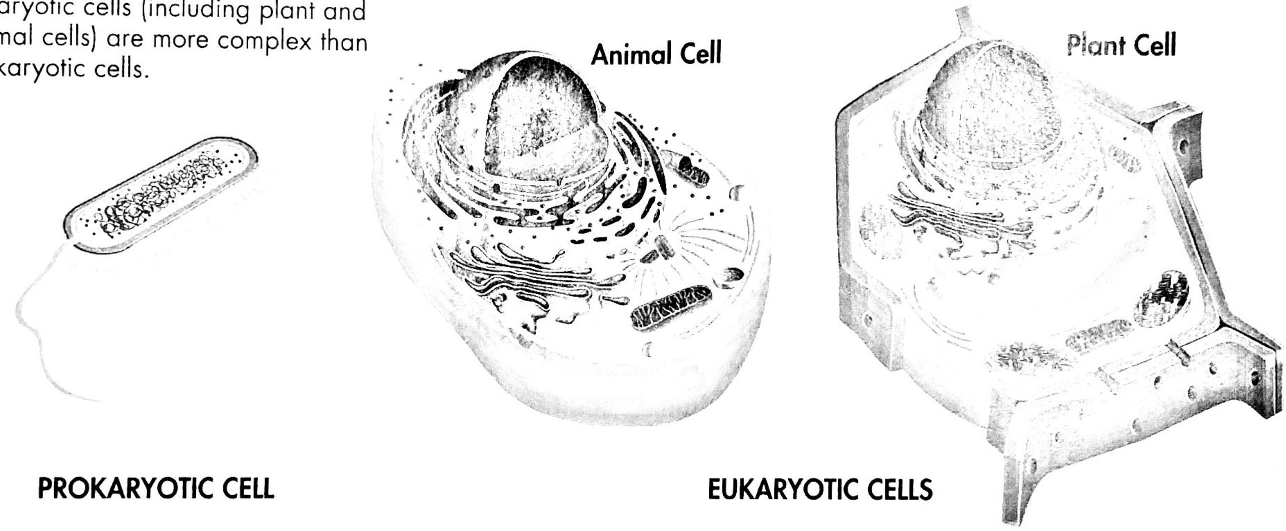


FIGURE 7–5 Cell Types In general, eukaryotic cells (including plant and animal cells) are more complex than prokaryotic cells.

7.1 Assessment

Review Key Concepts

1. **a. Review** What is a cell?
   b. Explain What three statements make up the cell theory?
   c. Infer How did the invention of the microscope help the development of the cell theory?
2. **a. Review** How do microscopes work?
   b. Apply Concepts What does it mean if a micrograph is "false-colored?"
3. **a. Review** What features do all cells have?
   b. Summarize What is the main difference between prokaryotes and eukaryotes?

PRACTICE PROBLEMS MATH

A light microscope can magnify images up to 1000 times. To calculate the total magnification of a specimen, multiply the magnification of the eyepiece lens by the magnification of the objective lens used. (For more information on microscopes, see Appendix B.)

4. **Calculate** What is the total magnification of a microscope that has an eyepiece magnification of 10× and an objective lens magnification of 50×.
5. **Calculate** A 10 micrometer cell is viewed through a 10× objective and a 10× eyepiece. How large will the cell appear to the microscope user?

WHST.9-10.9 Research to Build and Present Knowledge, WHST.9-10.10 Range of Writing

Careers & BIOLOGY

Cells are the basic unit of all known life. If cells interest you, you might want to consider one of the following careers.

LABORATORY TECHNICIAN

Ever wonder what happens to the blood your doctor collects during your annual physical? It goes to a laboratory technician. Laboratory technicians perform routine procedures using microscopes, computers, and other equipment. Many laboratory technicians work in the medical field, evaluating and analyzing test results.

MICROSCOPIST

The images in Figure 7–3 were captured by a microscopist. Microscopists make it possible to study structures too small to be seen without magnification. There are a variety of microscopy techniques, including staining and fluorescence, that microscopists can use to make images clear and informative for researchers. Some of these images are so striking that they have become a form of scientific art.

PATHOLOGIST

Pathologists are like detectives: They collect cellular information and tissue evidence to diagnose illness. Using a broad knowledge of disease characteristics and the best-available technology, pathologists analyze cells and tissues under a microscope and discuss their diagnoses with other doctors.

CAREER CLOSE-UP

Dr. Tanasa Osborne, Veterinary Pathologist

Dr. Tanasa Osborne studies osteosarcoma, the most common malignant bone tumor in children and adolescents. Her research with the National Institutes of Health and the National Cancer Institute is focused on improving outcomes for patients whose cancer has spread from one organ or system to another. Dr. Osborne is not a medical doctor, however—she is a veterinarian. Animals are often used as models to study human disease. Dr. Osborne's research, therefore, contributes to both animal and human health. Veterinary pathologists investigate many important issues in addition to cancer, including West Nile virus, avian flu, and other emerging infectious diseases that affect humans as well as animals.

"My distinctive background allows me to approach science from a global (or cross-species) and systemic perspective."

WRITING Based on this career close-up, explain how Dr. Osborne's research is an example of the effect science can have on society.