1.4 Biologists' Tools and Technology

KEY CONCEPT Technology continually changes the way biologists work.

MAIN IDEAS

- Imaging technologies provide new views of life.
- Complex systems are modeled on computers.
- The tools of molecular genetics give rise to new biological studies.

VOCABULARY

microscope, p. 19
gene, p. 23
molecular genetics, p. 23
genomics, p. 23

REVIEW AT CLASSZONE.COM

Connect Can you imagine life without cars, computers, or cell phones? Technology changes the way we live and work. Technology also plays a major part in the rapid increase of biological knowledge. Today, technology allows biologists to view tiny structures within cells and activity within a human brain. Technology allows biologists to study and change genes. What will technology allow next?

MAIN IDEA

Imaging technologies provide new views of life.

Until the late 1600s, no one knew about cells or single-celled organisms. Then the microscope was invented. Scientists suddenly had the ability to study living things at a level they never knew existed. Thus, the microscope was the first in a long line of technologies that have changed the study of biology.

Microscopes

A **microscope** provides an enlarged image of an object. Some of the most basic concepts of biology—such as the fact that cells make up all organisms—were not even imaginable before microscopes. The first microscopes magnified objects but did not produce clear images. By the 1800s, most microscopes had combinations of lenses that provided clearer images. Today's light microscopes, such as the one in **FIGURE 1.12** that you might use, are still based on the same principles. They are used to see living or preserved specimens, and they provide clear images of cells as small as bacteria. Light microscopes clearly magnify specimens up to about 1500 times their actual size, and samples are often stained with chemicals to make details stand out.

Electron microscopes, developed in the 1950s, use beams of electrons instead of light to magnify objects. These microscopes can be used to see cells, but they produce much higher magnifications, so they can also show much smaller things. Electron microscopes can clearly magnify specimens more than 100,000 times their actual size. They can even be used to directly study individual protein molecules. However, electron microscopes, unlike light microscopes, cannot be used to study living organisms because the specimens being studied have to be in a vacuum.

FIGURE 1.12 Biologists use microscopes to study cells, which are too small to be seen with the naked eye.

There are two main types of electron microscopes.

- A scanning electron microscope (SEM) scans the surface of a specimen with a beam of electrons. Usually, the specimen's surface is coated with a very thin layer of a metal that deflects the electrons. A computer forms a three-dimensional image from measurements of the deflected electrons.
- A transmission electron microscope (TEM) transmits electrons through a thin slice of a specimen. The TEM makes a two-dimensional image similar to that of a light microscope, but a TEM has a much higher magnification.

Often, SEM and TEM images are colorized with computers so that certain details are easier to see, as shown in **FIGURE 1.14**. Any time you see an SEM or TEM image in color, it has been given that color artificially.

Connecting CONCEPTS

Imaging Biologists use several types of micrographs, or images from microscopes. Whenever you see a micrograph in this book, LM stands for "light micrograph," SEM stands for "scanning electron micrograph," and TEM stands for "transmission electron micrograph."

Medical Imaging

Imaging technology is not limited to microscopes. In fact, technology used to study tissues inside living humans is commonly used in research and medicine. For example, doctors or dentists have probably taken x-ray images of you several times. An x-ray image is formed by x-rays, which pass through soft tissues, such as skin and muscle, but are absorbed by bones and teeth. Thus, x-ray images are very useful for looking at the skeleton but not so useful for examining soft tissues such as ligaments, cartilage, or the brain.

What if a doctor wants to examine ligaments in a person's knee? Another imaging technology called magnetic resonance imaging (MRI) is used. MRI uses a strong magnetic field to produce a cross-section image of a part of the body. A series of MRI images can be put together to give a complete view of all of the tissues in that area, as you can see in **FIGURE 1.13**. Advances in technology have led to new uses for MRI. For example, a technique called functional MRI (fMRI) can show which areas of the brain are active while a person is doing a particular task.

Compare and Contrast **How do SEMs and TEMs produce different images of the same specimen?**

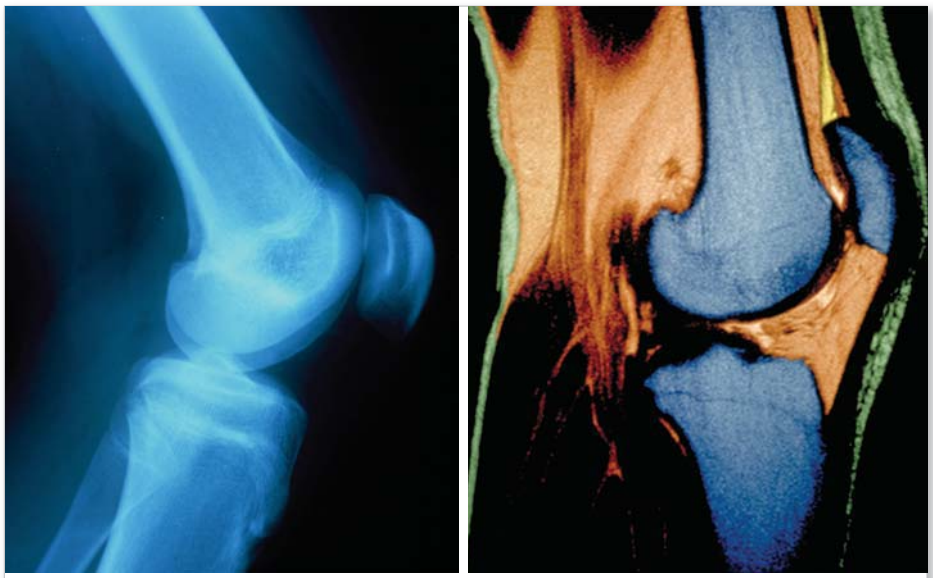


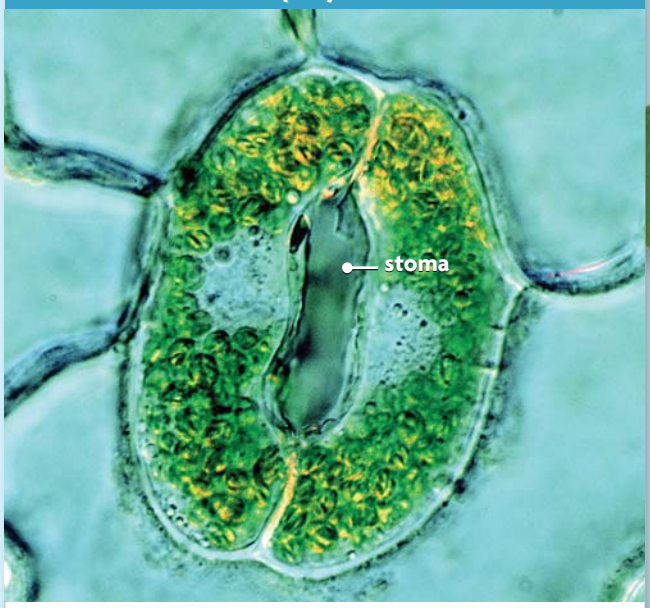
FIGURE 1.13 An x-ray of the human knee (left) shows dense tissues, such as bone, in detail. An MRI of the human knee (right) shows both soft and dense tissues in detail.

FIGURE 1.14 Comparing Micrographs

Different types of microscopes provide different views and magnifications, such as in these images of guard cells surrounding a stoma, or pore, in a leaf.

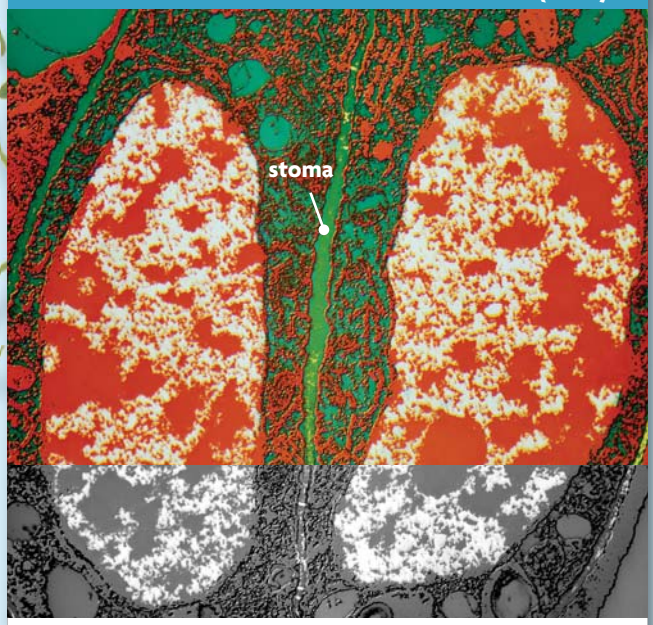
Animated BIOLOGY
View a set of cells through different microscopes at ClassZone.com.

LIGHT MICROGRAPH (LM)



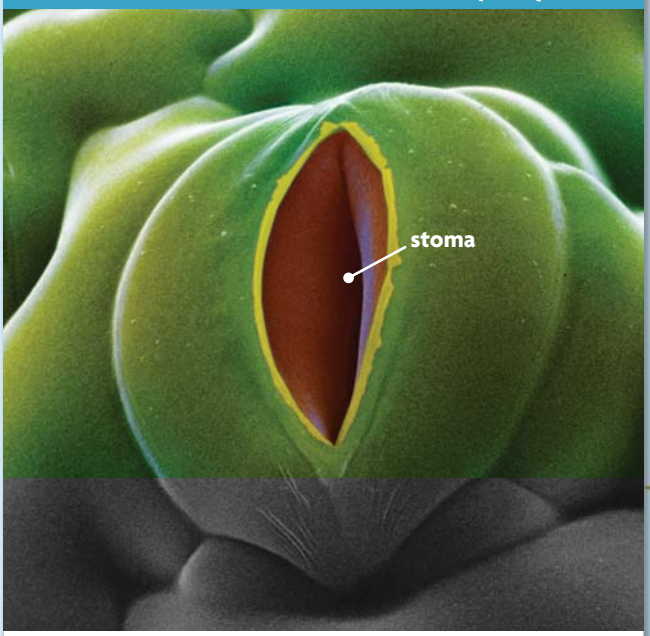
A light micrograph shows a two-dimensional image of a specimen. This light micrograph shows the actual color of the specimen. (LM; magnification 2000×)

TRANSMISSION ELECTRON MICROGRAPH (TEM)



A TEM shows a two-dimensional image of a thin slice of a specimen. A TEM is colorized by computer. The bottom part of the image shows the original black-and-white image. (colored TEM; magnification 5000×)

SCANNING ELECTRON MICROGRAPH (SEM)



An SEM shows a three-dimensional image of a specimen's surface. An SEM is colorized by computer. The bottom part of the image shows the original black-and-white image. (colored SEM; magnification 1500×)

CRITICAL VIEWING **What type of microscope would be best for showing details inside a cell? Why?**

QUICK LAB OBSERVING

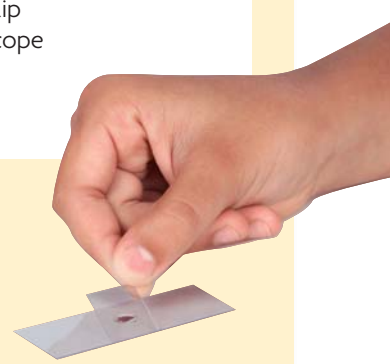
Life Under a Microscope

Using a microscope properly is an important skill for many biologists. In this lab, you will review microscope skills by examining a drop of water from the surface of a local pond.

PROBLEM What types of organisms can be found in pond water?

MATERIALS

- 1 drop pond water
- eyedropper
- microscope slide
- cover slip
- microscope



PROCEDURE

1. Make a wet mount slide. Place a drop of pond water in the center of a microscope slide and carefully put a cover slip over the water. For more information on making a wet mount, see page R8.
2. View the pond water sample under low power on the microscope. Use the coarse focus knob to bring the sample into focus. Draw and label any organisms that you see in the sample.
3. View the slide under high power. Use the fine focus knob to bring portions of the sample into focus. Draw and label any organisms, including details of their structures, that you see in the sample.

ANALYZE AND CONCLUDE

1. **Connect** Describe how organisms in the sample exhibit the characteristics of living things.
2. **Compare and Contrast** Make a table to compare and contrast the characteristics of organisms in the sample of pond water.

MAIN IDEA

Complex systems are modeled on computers.

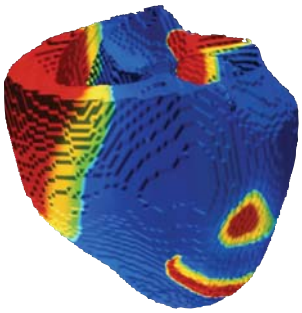
Computer-based technology has greatly expanded biological research. As computers have become faster and more powerful, biologists have found ways to use them to model living systems that cannot be studied directly. A computer model simulates the interactions among many different variables to provide scientists with a general idea of how a biological system may work.

Computers can model complex systems within organisms. For example, computer models are used to study how medicines might affect the body or, as you can see in **FIGURE 1.15**, the effects of a heart attack. Scientists have even used computer models to find out how water molecules travel into and out of cells. The scientists made a computer program that took into account more than 50,000 virtual atoms in a virtual cell. The computer model showed that water molecules must spin around in the middle of a channel, or a passage into the cell, to fit through the channel. Water molecules had a specific fit that other molecules could not match.

Computer models can also help biologists study complex systems on a much larger scale. Epidemiology, which is the study of how diseases spread, depends on computer models. For example, computer models can predict how fast and how far the flu might spread in a city. A model can calculate the number of people who might get sick, and suggest where in the city the illness began. This study cannot be done with people and cities. Computer models are used when actual experiments are not safe, ethical, or practical.

Infer **What are some reasons why biologists use computer models?**

Normal heartbeat



Heart attack

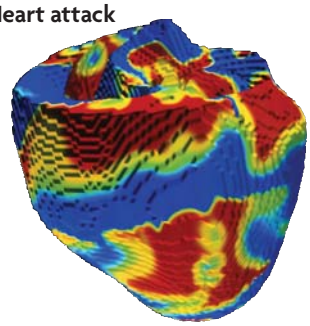


FIGURE 1.15 This computer-generated model shows that heart activity (red) is tightly regulated during a normal heartbeat. During a heart attack, heart activity is widespread and disorganized.

MAIN IDEA

The tools of molecular genetics give rise to new biological studies.

Computer-based technologies, such as those shown in **FIGURE 1.16**, have led to major changes in biology. But perhaps the greatest leap forward in our knowledge of life has happened in genetics. In just 40 years, we have gone from learning how the genetic code works, to changing genes, to implanting genes from one species into another. What is a gene? A **gene** is nothing more than a segment of DNA that stores genetic information. Our understanding of the DNA molecule has led to many technologies that were unimaginable when your parents were in high school—genetically modified foods, transgenic plants and animals, even replacement of faulty genes. These advances come from molecular genetics. **Molecular genetics** is the study and manipulation of DNA on a molecular level. Molecular genetics is used to study evolution, ecology, biochemistry, and many other areas of biology.

Entirely new areas of biology have arisen from combining molecular genetics with computer technology. For example, computers are used to quickly find DNA sequences. Through the use of computers, the entire DNA sequences, or genomes, of humans and other organisms have been found. **Genomics** (juh-NOH-mihks) is the study and comparison of genomes both within and across species. Here again, biologists need to use computers.

All of the information from genomics is managed by computer databases. By searching computer databases, a process called data mining, a biologist can find patterns, similarities, and differences in biological data. Suppose a biologist identifies a molecule that prevents the growth of cancerous tumors. The biologist could use computer databases to search for similar molecules.

This is the cutting edge of biology today. Where will biology be when your children are in high school?

Connect **What does the term *genetics* mean to you? Why?**

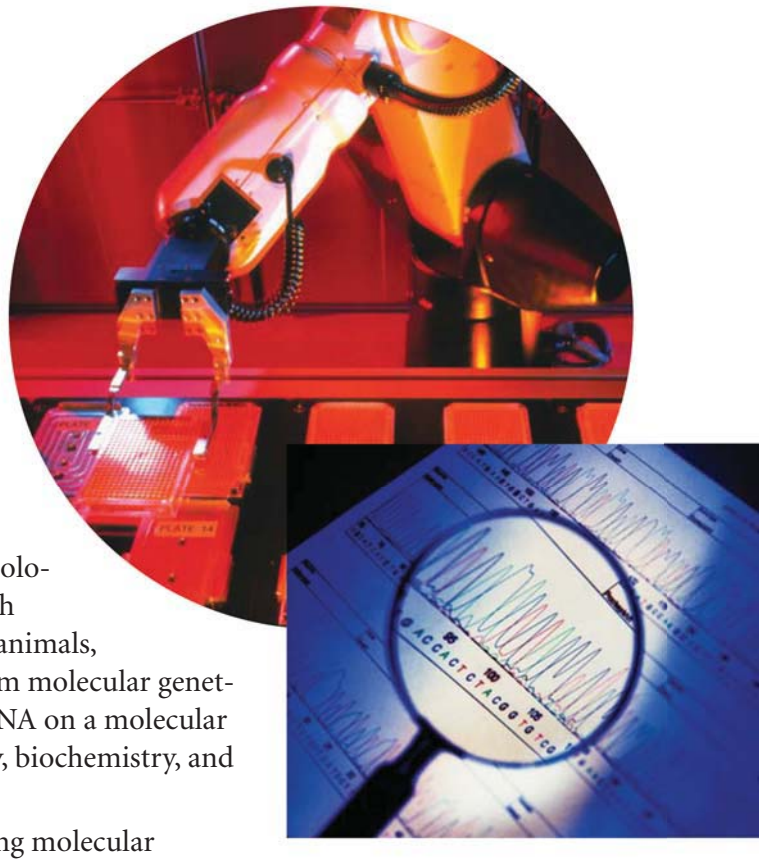


FIGURE 1.16 Robots are used to speed up research into the human genome (top). Computers are used to sequence human DNA (bottom).

Connecting CONCEPTS

Genetics You will learn much more about these and other genetics topics in **Unit 3.**

1.4 ASSESSMENT

ONLINE QUIZ ClassZone.com

REVIEWING MAIN IDEAS

1. How do light **microscopes** differ from electron microscopes?
2. Why is computer modeling used in biological studies?
3. How does **molecular genetics** add to our understanding of **genes**?

CRITICAL THINKING

4. **Apply** Viruses are smaller than cells. What types of microscopes could be used to study them? Explain.
5. **Synthesize** Provide an example of how technology has helped biologists gain a better understanding of life.

Connecting CONCEPTS

6. **Evolution** **Genomics** can be used to study the genetic relationships among species. Why might genomics be important for evolution research? Explain.