Quick Lab

To reinforce the **Main Idea** of how to use a microscope, perform the Quick Lab activity called Using a Compound Microscope on p. 1080.

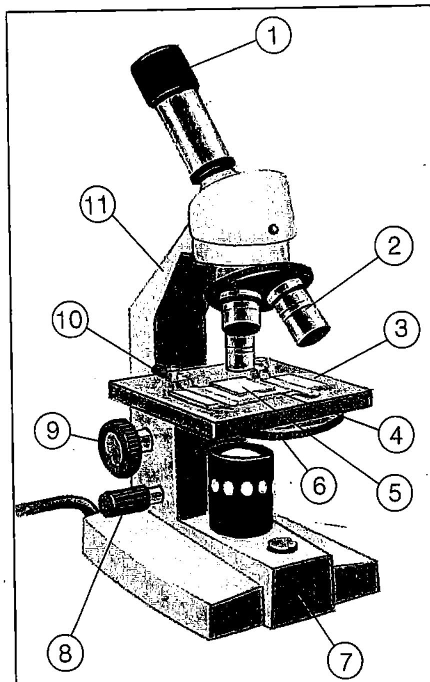
Tools of a Biologist

To accomplish their diverse goals, biologists may choose to use a wide variety of tools. In the laboratory, biologists may use pipettes and graduated cylinders to measure and transfer liquids. Solids, on the other hand, are usually measured on mechanical or electronic balances. Many experiments are performed inside enclosures, called hoods, that protect researchers from dangerous fumes or help to control contamination.

In almost all areas of biology, the computer has become an invaluable tool that can be used to perform complex tasks and analyze quantities of data. Many tools, however, are more specific to the type of biological work being undertaken. Global ecologists, for example, may use orbiting satellites to provide detailed maps of the temperature, moisture content, or vegetation of large areas. We shall discuss many more tools and the ways in which they are used throughout this textbook.

When you think of biology, there is probably one tool that comes to mind above all others. For almost all biologists need to examine organisms or parts of organisms that are too small to be seen with the unaided eye. **To study small organisms, researchers have developed several kinds of microscopes. Microscopes are instruments that produce larger-than-life images, pictures, or even videotapes.**

Figure 2–12 This diagram is of a typical compound light microscope. What is another word for the eyepiece?



Compound Light Microscope
1. Ocular lens (eyepiece)
2. Objective lens 3. Stage
4. Glass slide 5. Coverslip
6. Diaphragm (regulates light intensity)
7. Base
8. Fine adjustment knob
9. Coarse adjustment knob
10. Stage clips
11. Arm

THE COMPOUND LIGHT MICROSCOPE The most commonly used microscope is the light microscope. Figure 2–12 shows a light microscope similar to those in your high school laboratory. Light microscopes are useful to biologists because these instruments make it possible to observe many kinds of cells and small organisms while they are still alive.

To view most objects with the light microscope, you sandwich the object between a transparent microscope slide and a thin, transparent coverslip. This "sandwich" is then placed on the stage of the microscope so that light passes through it into the lenses of the microscope. The lens at the bottom of the microscope tube, the one closest to the object being studied, is called the objective lens. The viewing lens at the top of the tube is called the ocular lens. Because the instrument uses both lenses to form an image, it is properly known as a **compound light microscope.** If the objective lens produces a magnification of 100 times, and the ocular lens a magnification of 10 times, the resulting image that you see will be magnified 1000 times ($100 \times 10 = 1000$).

LIMITS OF RESOLUTION There are limits to what we can see with the compound light microscope. As we increase the magnifying power of a light microscope, we see more and more detail—up to a certain point. Beyond that point, called the **limit of resolution**, objects get blurry and detail is lost. For standard light microscopes, the limit of resolution is about 0.2 micrometers. (A typical cell is about 10 micrometers across.)

When the limit of resolution was first discovered, many people thought that if microscopes were made better, this problem would disappear. However, even a "perfect" microscope will have a limit of resolution. The reason for this has to do with the way light behaves. When light passes through a tiny opening or a lens, it is diffracted, or scattered in a way that makes it hard to form a clear image. When we look at something in the compound light microscope at 1000 times magnification, we have enlarged it just enough to see the limit of resolution of the best light microscopes we can make.

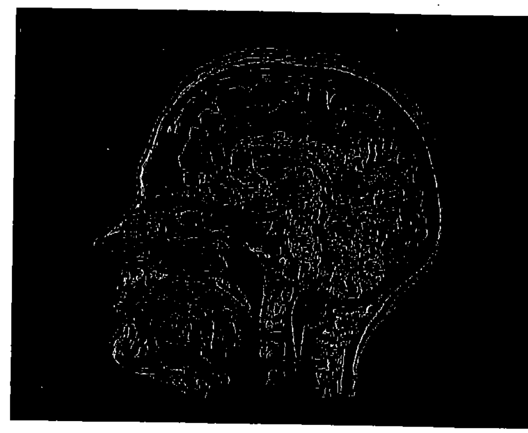


Figure 2–13 *Modern science has provided biologists with many tools unknown in centuries past. This image of a patient's brain was made by a medical scanner called a nuclear magnetic resonance scanner (NMR). What sort of tools do you think biologists will be using a century from now?*

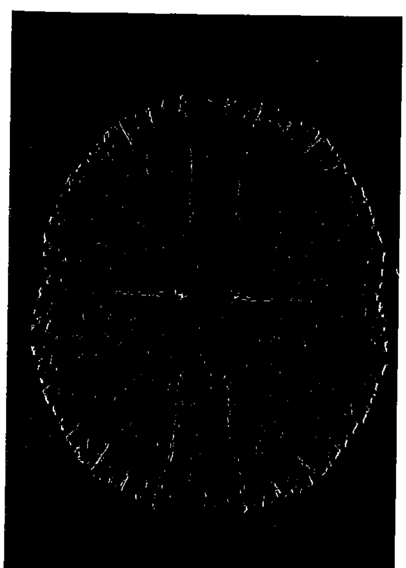
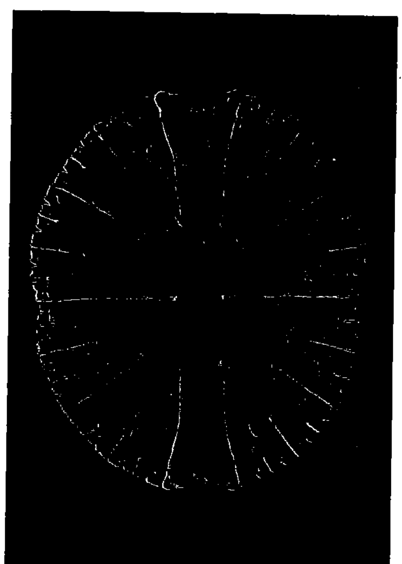
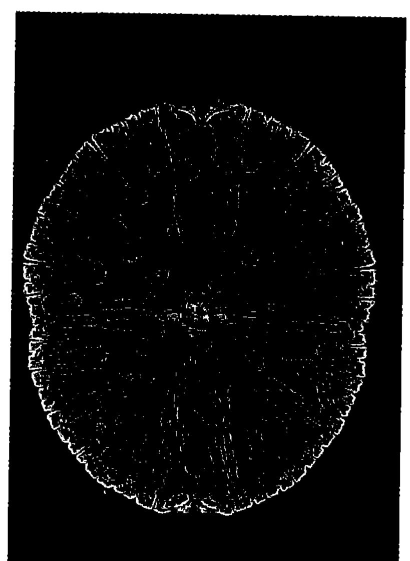
USING A COMPOUND LIGHT MICROSCOPE There are objects—such as dust, feathers, and pollen grains—that can be seen in the light microscope without any special preparation. But many cells and cell parts are so similar in appearance to their surroundings that they cannot be easily seen through the microscope. Researchers have developed several techniques to make such objects visible.

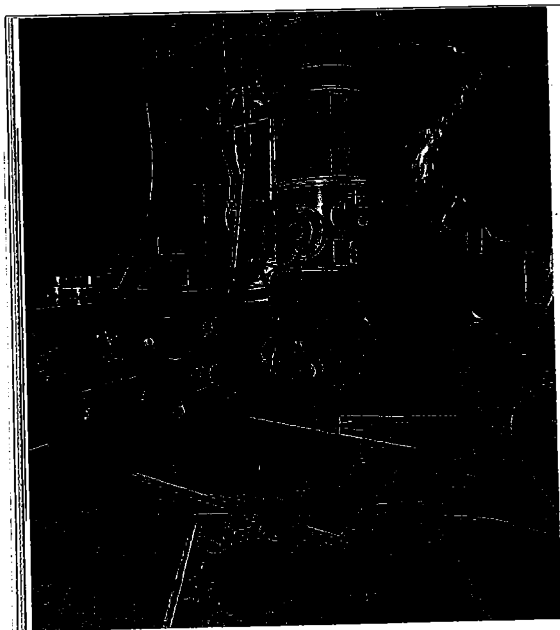
Many specimens are stained before they are observed under a microscope. Stains are used to color cells or parts of cells to make them clearly visible. Some stains color everything in a cell, whereas others color only a part of the cell. One such special stain, known as Feulgen, turns DNA a beautiful pinkish color. Some stains, which "stick" only to certain compounds, can be made to glow in the dark to highlight specific cell parts.

Because many stains kill living cells, special types of light microscopes that do not require staining are used to observe living specimens. Examples of these are the phase contrast microscope, the dark field microscope, and the Nomarski microscope. Each uses a different property of light rays to improve the contrast (clarity) of the image. See Figure 2–14.

ELECTRON MICROSCOPES Although light microscopes are very useful, their limit of resolution restricts their usefulness for studying very small objects such as viruses and individual molecules. Is there a way to see things smaller than light

Figure 2–14 *Notice the variations in this image of an alga as seen through a Nomarski microscope (left), a dark field microscope (center), and a phase contrast microscope (right).*



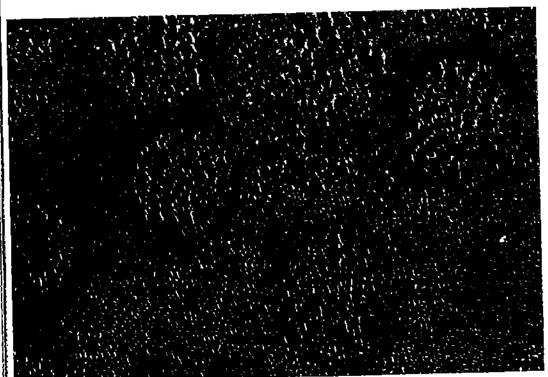


Figure 2–15 *A transmission electron microscope (TEM) sends a beam of electrons through an object to produce an image (top). This image of viruses, which has had color added by a computer, was taken through a TEM (bottom).*

can reveal? Indeed, there is. In the 1920s, physicists in Germany realized that electromagnets could bend streams of electrons in much the same way that glass lenses bend beams of light. They then learned to use electromagnets to build devices called electron microscopes. These same physicists used electromagnets to bend electrons to produce another tool you are probably familiar with: television.

The limit of resolution of electron microscopes is about 1000 times finer than the light microscope. There are several different types of electron microscopes.

Transmission electron microscopes (TEMs) shine a beam of electrons at a sample and then magnify the image of that sample onto a fluorescent screen at the bottom of the microscope. The electron beam can also be used to expose photographic film to produce a permanent image of the specimen. See Figure 2–15.

Scanning electron microscopes (SEMs) get their name from a pencillike beam of electrons that scans back and forth across the surface of a specimen. Electrons that bounce off the specimen are picked up by detectors that provide the information to form an image on a television screen. Rather than showing details inside living things, SEMs show realistic (and often dramatic) three-dimensional pictures of their surfaces. See Figure 2–16.

LIMITATIONS OF ELECTRON MICROSCOPES Electron microscopes are extremely useful, but they do have serious drawbacks. Because electrons are charged particles, they do not penetrate air, let alone thick specimens! Therefore specimens must be placed in a vacuum, or a chamber from which all the air has been removed, and samples for TEM work must be cut into very thin slices. TEM samples are usually stained to increase their visibility. Samples for both TEM and SEM work must be completely dried out before they are placed in the vacuum inside the microscope. As you might infer, living cells cannot be observed in the electron microscope—they are killed by the sample-preparation processes.

Figure 2–16 *A scanning electron microscope (SEM) bounces electrons off the surface of an object to form an image. This image of bacteria, which has been colored green through the use of a computer, was taken by using an SEM.*