Heath Biology

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1. Biology

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Preface

This course begins your first real experience with the subject of biology: the science of living things.

First, you should recognize that biology, like any science, consists of facts, principles, and theories that are based on research and experimentation. A large part of biology concerns theories on how living things have changed or evolved over millions of years. Evolutionary theories provide the best scientific interpretations for the data available. As new findings come to light, science dictates that these theories be modified or refined to continue to reflect the best scientific explanations. Keep in mind that evolutionary theories conform to the criteria set for a scientific theory. They are not to be treated as fact.

Heath Biology will be one of the primary tools you will use in your study. Before trying to use this tool, you should become familiar with how it can be used to make your work easier.

Heath Biology is organized to present a phylogenetic approach to biology. This type of approach means you will study the different groups of plants and animals according to their evolutionary relationships. Biological principles will be covered by studying representative organisms.

Each chapter of the text is divided into lessons. The first lesson heading is shown on page 3. The *Concepts* for this lesson are listed to the right of the lesson title. The *Concepts* can help you focus on what you will be expected to learn from the lesson. An expanded form of the *Concepts* is found in the *Summary* for each chapter. The *Summary* for Chapter 1 is found on page 16.

A lesson is further divided into short numbered sections, as shown on page 3. The headings highlight the major topics of the chapter. They can be used in helping you organize information in preparing an outline for review purposes.

An understanding of scientific terms is essential to a successful study of biology. Terms you should know, such as the word *microscope* on page 5, are highlighted in boldfaced type. Pronunciations are included for difficult terms, as with *hypothesis* on page 9. A listing of important terms for each chapter is found in the *Vocabulary* section of each Chapter Review. The *Vocabulary* list for Chapter 1 is on page 16. The *Glossary* at the back of the book can be used to find definitions of new terms quickly.

The *Checkpoints* and *Chapter Review* questions will help you in reviewing the important points in the chapter. *Unit Reviews* cover the major concepts of the unit. Answering all of the questions should adequately prepare you for a test.

Biology is both interesting and practical. *Do You Know?* notes, such as the one on page 3, reveal interesting practical sidelights about the topic you are studying. The basic unifying themes of biology are presented in the *Biology Insights*, such as the one on page 31. These *Insights* will often highlight the interrelationships among the material covered in several chapters. A broad understanding of these *Insights* should be one of your goals for the course.

At the end of each unit, you will find a brief overview of careers that require some knowledge of biology. The first of these career features is found on page 126. Since the study of biology is an ongoing process, topics of current biological research are covered briefly in the *Newsbreak* features like that on page 40.

Now that you are familiar with ***Heath Biology***, you've completed your first step toward a successful year.

The Authors

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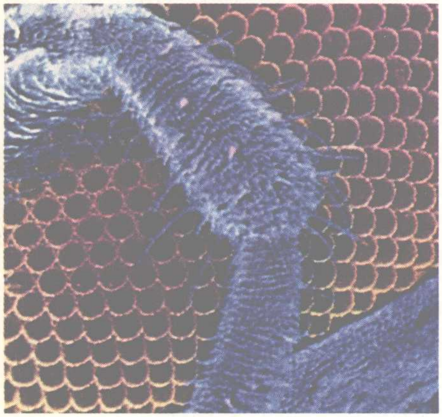

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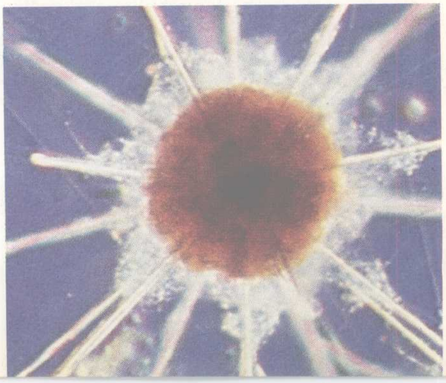

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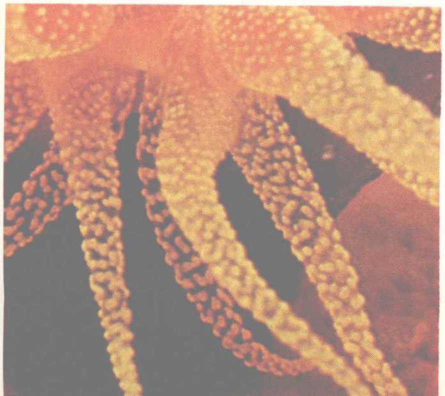

Unit Six

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The Science of Life

Head of a black fly photographed with a scanning electron microscope (color added)

1 The Process of Science

White storks nesting on a rooftop

If a bird the size of this one nested on your roof, you might be upset. In some parts of Europe, it happens all the time and people like it.

The bird is a white stork. Ever since the Middle Ages, the stork has been considered a sign of good luck in many countries. The stork is also famous for the legend that it delivers human babies. Such ideas are examples of superstitions. A superstition is a belief that two unrelated events are actually related.

Science, on the other hand, does not accept such explanations. Science is a way of finding out if one event actually causes another event. Science looks at explanations based on demonstrated relationships rather than on belief.

Although scientists have discovered many things about the stork, they have found no evidence that storks bring good luck or deliver babies. It is interesting that in countries where people do not believe this bird brings good luck, storks are not allowed to nest on houses and have become rare. Where storks are respected, they have remained common. So this human superstition has brought good fortune . . . to storks, at least.

Explanation through Science

CONCEPTS

- the unique characteristics of science
- the structure of a light microscope
- advantages of the electron microscope

Figure 1.1 shows a human skull many thousands of years old. Since this skull is older than human written records, scientists cannot be certain about what caused the hole in the skull. They think, however, that it was made on purpose and that the individual undergoing the surgery survived for many years after the hole was drilled. Scientists draw this conclusion because the bone around the edges of the hole shows signs of healing.

Some early cultures left written records about why they did this kind of surgery. They believed that severe headaches were caused by evil spirits. Drilling a hole in the skull supposedly allowed the evil spirits to escape. In the days before pain-free surgery and clean operating rooms, such surgery must have been difficult at best. Faced with such a "cure," these people probably did not often complain about headaches.

Evil spirits may seem to you to be a bizarre explanation for a disease. But in the absence of scientific knowledge, superstition was the only way ancient people could explain the cause of many events.

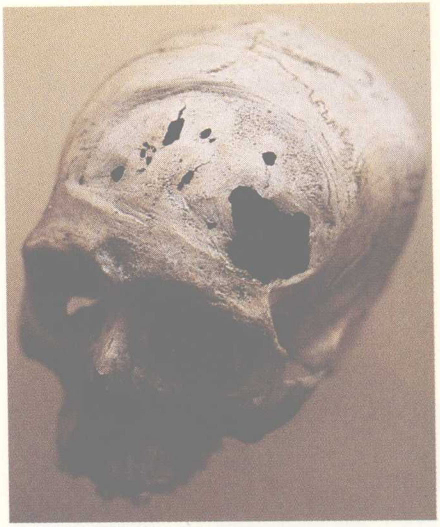

Figure 1.1 What caused the hole that you see in this prehistoric skull?

1–1 Characteristics of Science

Unlike superstition, science is knowledge gained through careful observation of objects and events. In order to explain events, scientists seek logical connections between observed facts. These connections often lead to general rules of cause and effect. But science is not just a set of facts and rules. Science is primarily a way of learning about the world. Of course, no one person could hope to understand everything about how the world works, so science is divided into many different branches. **Biology** is the branch that studies living things. **Biologists** are scientists who investigate life.

One of the most important characteristics of science is that *its conclusions are based on evidence.* In science all statements must be backed up by careful observation. You may believe that taking vitamin C prevents colds. Before scientists would accept this idea, however, they would need evidence to support it. Perhaps they would compare the frequency of colds among people who take vitamin C with the frequency of colds among people who do not.

A second characteristic of science is *objectivity*. That is, the results of a scientific investigation should not be influenced by the beliefs of the person making the observation. Other

Do You Know?

The bark of the cinchona tree was used in primitive societies as a treatment for malaria. The bark contains quinine, a drug still used to treat the disease.

Figure 1.2 During the Middle Ages many people believed that strange animals existed. Drawings documenting their existence appeared in authoritative books of the time.

scientists using similar methods should reach the same conclusion. If a scientist is objective in measuring the number of people who get colds after taking vitamin C, anyone else should get the same results. Results obtained scientifically can be repeated.

A third characteristic of science is that it is the *result of the work of many scientists around the world*. Developing scientific explanations requires many more observations than one person can make.

Since the work of each scientist builds upon the work of others, new information is continually added to existing knowledge. Evidence for new and better explanations is reported in writing. Scientific observations must be recorded because human memory is often inaccurate. Today scientists publish the results of their investigations in journals.

There are several reasons for publishing. Publishing saves time. Scientists can read what others have learned instead of having to do all the work over again. Publishing also allows other scientists to check each other's work. If different scientists cannot repeat a set of results, the conclusions will not be accepted. Another important reason for publishing is to ensure that those who make discoveries will receive credit for their work.

A final characteristic of modern science is the *use of tools* to aid investigation. Scientists use tools because they recognize that their senses are limited. For example, because it is hard to see long distances, biologists may use binoculars to observe the behavior of birds. Many tools used by scientists detect and precisely measure details that human senses might miss. By using a balance, a scientist can compare the masses of objects with great precision. Modern scientists use the international system of metric units to record their observations.

Figure 1.3 An excerpt from *Micrographia,* a publication by Robert Hooke. Hooke was an early scientist who made studies using a microscope.

Length

base unit: meter (m)

unit	*symbol*	*equivalent*
kilometer	km	1000 m
decimeter	dm	0.1 m
centimeter	cm	0.01 m
millimeter	mm	0.001 m
micrometer	μm	0.000001 m

Volume or Capacity

base unit: liter (L)

1 liter = 1000 cm^3

unit	*symbol*	*equivalent*
milliliter	mL	0.001 L

Mass

base unit: kilogram (kg)

unit	*symbol*	*equivalent*
gram	g	0.001 kg
centigram	cg	0.00001 kg
milligram	mg	0.000001 kg

Figure 1.4 Some units of measurement in the metric system

1–2 The Microscope

One of the most important tools used in biology to extend the senses is the microscope. The **microscope** is a device that provides an enlarged image of small objects. With a microscope biologists can often observe objects or details that would otherwise be too small to be seen.

The microscope has been in use for over 300 years. Some early microscopes are shown in Figure 1.5. Early microscopes were primitive compared to those used today.

You have probably used a hand lens to magnify, or enlarge, small objects. People have used such lenses for many hundreds of years. As you may know, the greater the curvature of a lens, the greater the magnification provided by the lens. In the late 1600s a Dutchman named Anton van Leeuwenhoek developed a way of making very tiny but strongly curved glass lenses. He mounted each lens in a metal support. A single lens magnifier like Leeuwenhoek's is called a **simple microscope**.

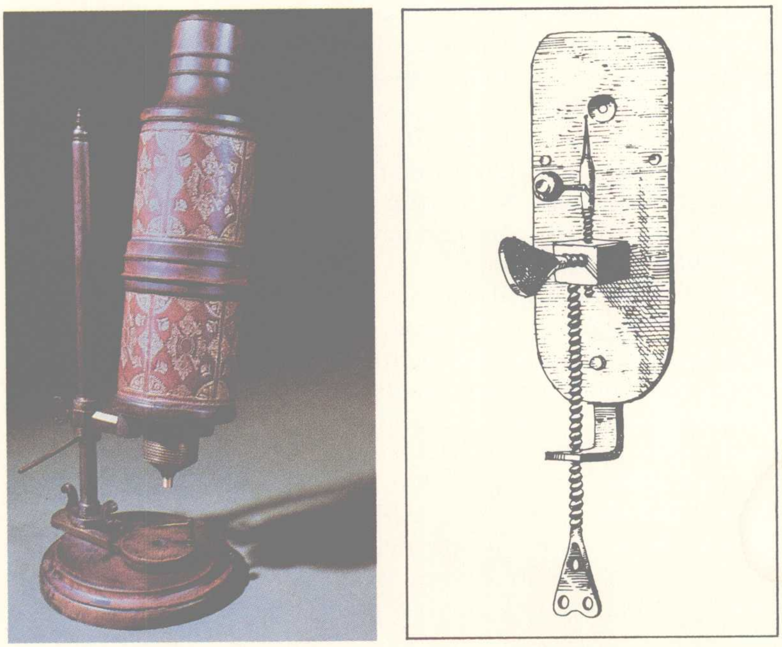

Figure 1.5 Some early microscopes. *Left:* One of Hooke's microscopes; *Right:* One of Leeuwenhoek's microscopes

Leeuwenhoek's microscopes could magnify objects to appear as much as 300 times actual size, but they all had a serious drawback. Strongly curved lenses bring objects into focus very near the lens itself. Such a microscope must be placed right up against the eye. The specimen must be held right against the other side of the lens. These microscopes were painful to use and very limited in how much could be seen. It was also difficult to illuminate the object being studied.

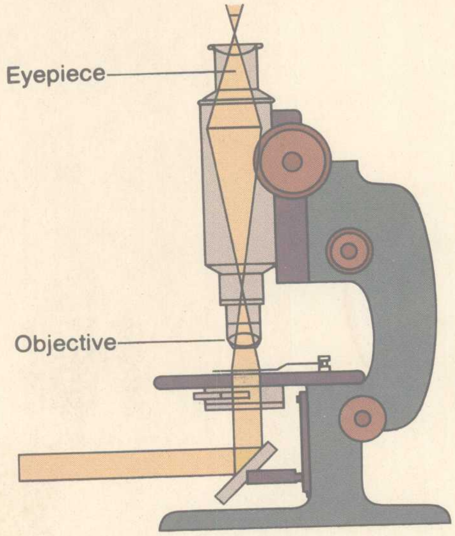

Figure 1.6 A compound microscope


Figure 1.7 How far away can you move and still see two distinct lines?

Other biologists living at the same time as Leeuwenhoek began to use the first compound microscopes. A **compound microscope** has two lenses. One lens magnifies the object being observed. This lens is called the **objective**. A second lens, called the **ocular** [AHK-yuh-lur] or **eyepiece**, magnifies the image produced by the objective. The lens arrangement of such a microscope is illustrated in Figure 1.6.

The total magnification of a compound microscope is the product of the objective magnification and the eyepiece magnification. For example, on many microscopes a typical objective lens has a magnification of 43 times (43×). A standard eyepiece has a magnification of 10 times (10×). The total magnification of the objective and the eyepiece combined is 43 × 10, or 430 times.

Compound microscopes can be illuminated by a light beneath the specimen. In some compound microscopes a mirror reflects light onto the specimen. Thus, compound microscopes have a wider field of vision and better illumination than simple microscopes.

In modern microscopes most of the problems of the early microscopes are solved. But there is one limitation on the performance of compound microscopes that cannot be overcome. A compound microscope has a maximum useful magnification of about 1,000 times. Although it is possible to build a microscope that magnifies far more than 1,000 times, this is rarely done. No matter how high the magnification, a compound microscope can never show any more detail than is visible at 1,000 times.

Limits on the ability of a lens to show detail are set by the resolving power of the lens. **Resolving power** is the ability of an instrument to separate and distinguish two objects. All lenses have a maximum resolving power. You can test the resolving power of a very handy lens — the one in your eye. Look at the two parallel black lines in Figure 1.7. You should have no difficulty telling that there are two separate lines. Keep your book open to this illustration and prop it up on a desk. Now slowly move away while gazing at the lines. You will soon get to a point where the two lines appear to fuse into a single line. At that point, your eye can no longer resolve the two lines.

Because of the characteristics of visible light, it is impossible for a compound microscope to resolve objects closer than 0.0002 mm, no matter what the magnification. Under ideal conditions, at 1,000 times the compound microscope will show objects as separate if they are more than 0.0002 mm apart. They will appear to be a single object if they are closer together. Therefore, detail that is less than 0.0002 mm long cannot be seen under any compound microscope — its image cannot be separated from its surroundings. Further magnification would give a bigger image but would show no more detail. In fact, any magnification greater than 1,000 times makes objects appear fuzzy. Unfortunately, many things that are of interest to biologists are smaller than those the best compound microscope can resolve.

1–3 The Electron Microscope

The problem of limited resolving power was largely solved in the 1940s with the invention of the **electron microscope**. Instead of directing light through an object, the electron microscope directs a beam of tiny particles called electrons. Instead of using glass lenses to focus an image, the electron microscope uses special doughnut-shaped magnets. Because the human eye cannot see electrons, the magnified image produced by an electron microscope must be projected onto either a television screen or photographic film. In order to produce this image, the electrons must pass through extremely thin slices of the material being viewed.

The major advantage of the electron microscope is its resolving power. It can resolve two objects as close together as 0.0000005 mm. Such resolution requires magnifications of close to 1 million times.

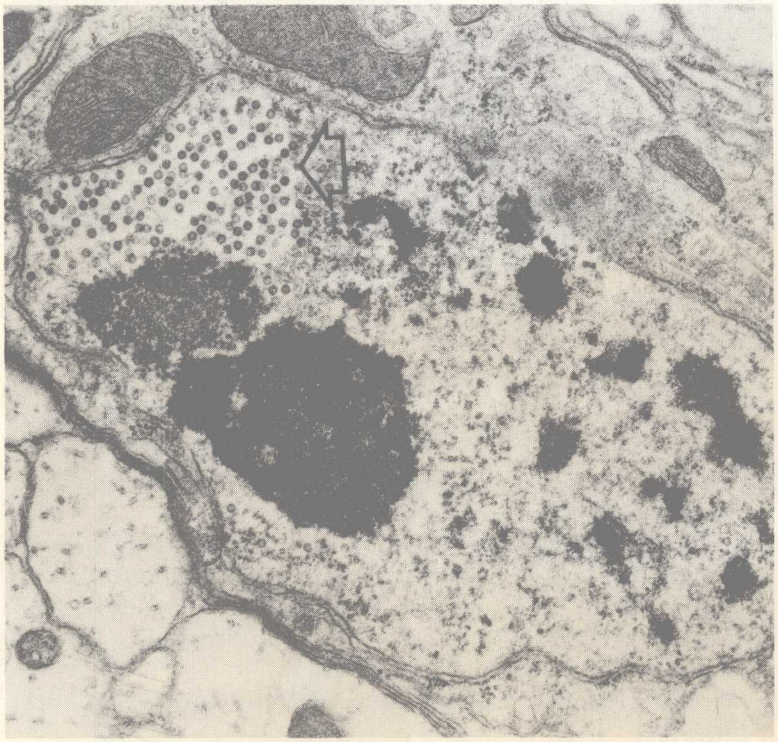

Figure 1.8 This photograph taken through an electron microscope shows a fruit fly nerve cell magnified 26,000 times. The arrow points to viruses within the cell.