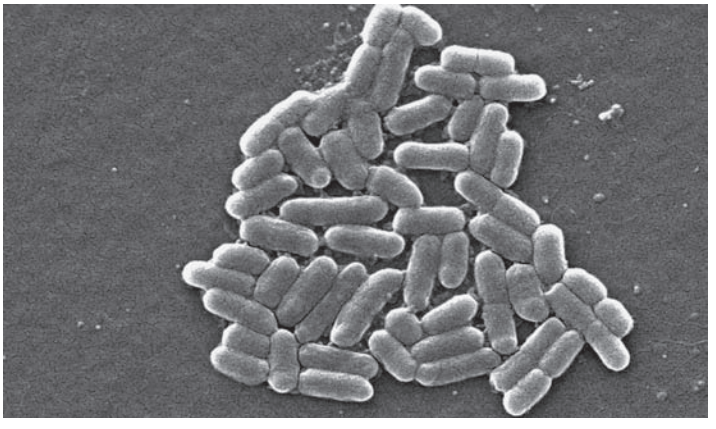
severely penalizes those who steal the ideas of others, perform shoddy science, or falsify data. Any of these infractions can lead to the loss of one's job and reputation.

Theoretical and Applied Science

The scientific method has helped us understand and control many aspects of our natural world. Some information is extremely important in understanding the structure and functioning of things in nature but at first glance appears to have little practical value. For example, the discovery of the structure of deoxyribonucleic acid (DNA) answered a fundamental question about the nature of genetic material. Many people asked why such research would be done or funded by their taxes. However, as individuals began to use this new knowledge, they developed many practical applications for it. For example, scientists known as *genetic engineers* have altered the chemical code system of microorganisms, in order to produce many new drugs, such as antibiotics, hormones, and enzymes. To do this, genetic engineers needed information from the basic, theoretical sciences of microbiology, molecular biology, and genetics (figure 1.7).

Another example of how fundamental research can lead to practical application is the work of Louis Pasteur (1822–1895), a French chemist and microbiologist. Pasteur was interested in the highly theoretical question, "Could life be generated from nonliving material?" Much of his theoretical work led to practical applications in disease control. His theory that microorganisms cause diseases and decay led to the development of vaccinations against rabies and the development of pasteurization for the preservation of foods (figure 1.8).



(a)

(b)

FIGURE 1.7 Genetic Engineering
Genetic engineers have modified the genetic code of bacteria, such as *Escherichia coli*, commonly found in the colon *(a)* to produce useful products, such as vitamins, protein, and antibiotics. The bacteria can be cultured in vats, where the genetically modified bacteria manufacture their products *(b)*. The products can be extracted from the mixture in the vat.

FIGURE 1.8 Louis Pasteur and Pasteurized Milk
Louis Pasteur (1822–1895) performed many experiments while he studied the question of the origin of life, one of which led directly to the food-preservation method now known as pasteurization.

Science and Nonscience

Both scientists and nonscientists seek to gain information and improve understanding in their fields of study. The differences between science and nonscience are based on the assumptions and methods used to gather and organize information and, most important, the way the assumptions are tested. The difference between a scientist and a nonscientist is that a scientist continually challenges and tests principles and assumptions to determine cause-and-effect relationships. A nonscientist may not be able to do so or may not believe that this is important. For example, a historian may have the opinion that, if President Lincoln had not appointed Ulysses S. Grant to be a general in the Union Army, the Confederate States of America would have won the Civil War. Although there can be considerable argument about the topic, there is no way that it can be tested. Therefore, such speculation about historical events is not scientific. This does not mean that

history is not a respectable field of study, only that it is not science. Historians simply use the standards of critical thinking that are appropriate to their field of study and that can provide insights into the role military leadership plays in the outcome of conflicts.

Once you understand the scientific method, you won't have any trouble identifying astronomy, chemistry, physics, geology, and biology as sciences. But what about economics, sociology, anthropology, history, philosophy, and literature? All of these fields may make use of certain central ideas that are derived in a logical way, but they are also nonscientific in some ways. Some things are beyond science and cannot be approached using the scientific method. Art, literature, theology, and philosophy are rarely thought of as sciences. They are concerned with beauty, human emotion, and speculative thought, rather than with facts and verifiable laws.

Many fields of study have both scientific and nonscientific aspects. For example, the styles of clothing people wear are often shaped by the artistic creativity of designers and shrewd marketing by retailers. Originally, animal hides, wool, cotton, and flax were the only materials available, and the color choices were limited to the natural colors of the material or dyes extracted from nature. Scientific discoveries led to the development of synthetic fabrics and dyes, machines to construct clothing, and new kinds of fasteners that allowed for new styles and colors (figure 1.9).

Similarly, economists use mathematical models and established economic laws to make predictions about future economic conditions. However, the reliability of predictions is a central criterion of science, so the regular occurrence of unpredicted economic changes indicates that economics is far from scientific. Many aspects of anthropology and sociology are scientific, but they cannot be considered true sciences, because many of the generalizations in these fields cannot be tested by repeated experimentation. They also do not show a significantly high degree of cause-and-effect, or they have poor predictive value.

(a) (b)

FIGURE 1.9 Science and Culture
Although the design of clothing is not a scientific enterprise, scientific discoveries have altered the choices available. *(a)* Originally, clothing could be made only from natural materials with simple construction methods. *(b)* The discovery of synthetic fabrics and dyes and the invention of specialized fasteners resulted in increased variety and specialization of clothing.

Pseudoscience

Pseudoscience (*pseudo* = false) is a deceptive practice that uses the appearance or language of science to convince, confuse, or mislead people into thinking that something has scientific validity. When pseudoscientific claims are closely examined, they are not found to be supported by unbiased tests.

For example, nutrition is a respectable scientific field; however, many individuals and organizations make unfounded claims about their products and diets (figure 1.10). Because of nutritional research, we all know that we must obtain certain nutrients, such as amino acids, vitamins, and minerals, from the food we eat or we may become ill. However, in most cases, it has not been demonstrated that the nutritional supplements so vigorously advertised are as useful or desirable as claimed. Rather, the advertisements select bits of scientific information about the fact that amino acids, vitamins, and minerals are essential to good health and then use this information to create the feeling that nutritional supplements are necessary or can improve health. In reality, the average person eating a varied diet can obtain all these nutrients in adequate amounts.

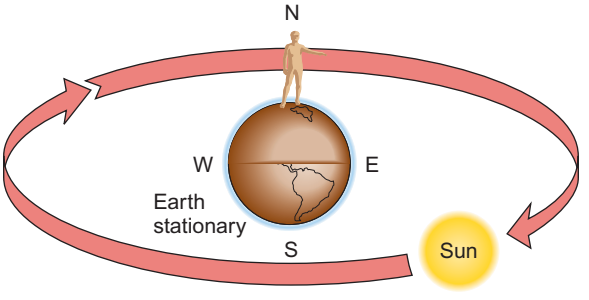
Another related example involves the labeling of products as organic or natural. Marketers imply that organic or natural

FIGURE 1.10 Pseudoscience—"Nine out of 10 Doctors Surveyed Recommend Brand X"
Pseudoscience is designed to mislead. There are several ways in which this image and the statement can be misleading. You can ask yourself two questions. First, is the person in the white coat a physician? Second, how many doctors were asked for a recommendation and how were they selected? If only 10 doctors were asked, the sample size was too small. Perhaps the doctors who participated were selected to obtain the desired outcome. Finally, the doctors could have been surveyed in such a way as to obtain the desired answer, such as "Would you recommend Brand X over Dr. Pete's snake oil?"

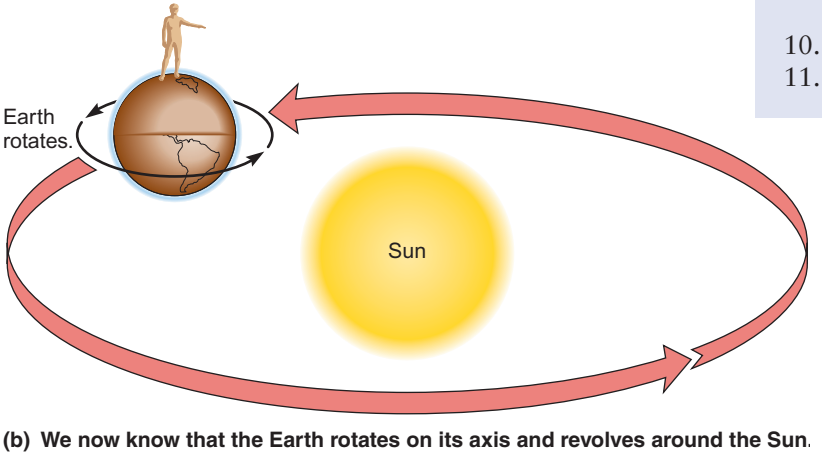
products have greater nutritive value because they are organically grown (grown without pesticides or synthetic fertilizers) or because they come from nature. Although there are questions about the health effects of trace amounts of pesticides in foods, no scientific study has shown that a diet of natural or organic products has any benefit over other diets. The poisons curare, strychnine, and nicotine are all organic molecules that are produced in nature by plants that can be grown organically, but we wouldn't want to include them in our diet.

The Limitations of Science

Science is a way of thinking that involves testing possible answers to questions. Therefore, the scientific method can be applied only to questions that have factual bases. Ethical, moral, and religious concerns are not scientific endeavors. Questions about such topics cannot be answered using the scientific method. What makes a painting great? What is the best type of music? Which wine is best? Is there a God? These questions are related to values, beliefs, and tastes; therefore, the scientific method cannot be used to answer them.



(a) Scientists thought that the Sun revolved around the Earth.



(b) We now know that the Earth rotates on its axis and revolves around the Sun.

FIGURE 1.11 Science Is Willing to Challenge Previous Beliefs
Science must always be aware that new discoveries may force a reinterpretation of previously held beliefs. *(a)* Early scientists thought that the Sun revolved around the Earth. This was certainly a reasonable theory at the time. People saw the Sun rise in the east and set in the west, and it looked as if the Sun moved through the sky. *(b)* Today, we know that the Earth revolves around the Sun and that the apparent motion of the Sun in the sky is caused by the Earth rotating on its axis.

Science is also limited by the ability of people to figure out how the natural world works. People are fallible and do not always come to the right conclusions because they lack information or misinterpret it. However science is self-correcting and, as new information is gathered, old, incorrect ways of thinking are changed or discarded. For example, at one time scientists were sure that the Sun went around the Earth. They observed that the Sun rose in the east and traveled across the sky to set in the west. Because scientists could not feel the Earth moving, it seemed perfectly logical that the Sun traveled around the Earth. Once they understood that the Earth rotated on its axis, they began to realize that the rising and setting of the Sun could be explained in other ways. A completely new concept of the relationship between the Sun and the Earth developed (figure 1.11). Although this kind of study seems rather primitive to us today, this change in thinking about the relationship between the Sun and the Earth was a very important step forward in our understanding of the universe.

People need to understand that science cannot answer all the problems of our time. Although science is a powerful tool, there are many questions it cannot answer and many problems it cannot solve. Most of the problems societies face are generated by the behavior and desires of people. Famine, drug abuse, war, and pollution are human-caused and must be resolved by humans. Science provides some important tools for social planners, politicians, and ethical thinkers. However, science does not have, nor does it attempt to provide, all the answers to the problems of the human race. Science is merely one of the tools at our disposal.

1.3 CONCEPT REVIEW

9. What is the difference between science and nonscience?
10. How can you identify pseudoscience?
11. Why is political science not a science?

1.4 The Science of Biology

The science of biology is, broadly speaking, the study of living things. However, there are many specialty areas of biology, depending on the kind of organism studied or the goals a person has. Some biological studies are theoretical, such as establishing an evolutionary tree of life, understanding the significance of certain animal behaviors, or determining the biochemical steps involved in photosynthesis. Other fields of biology are practical—for example, medicine, crop science, plant breeding, and wildlife management. There is also just plain fun biology—fly-fishing for trout or scuba diving on a coral reef.

At the beginning of the chapter, we defined *biology* as the science that deals with life. But what distinguishes