Life in the Balance: Human Health, Homeostasis, Evolution, Science, and Critical Thinking

- 1-1 Health and Homeostasis
- 1-2 Evolution and the Characteristics of Life
- 1-3 Understanding Science
- 1-4 Critical Thinking

THINKING CRITICALLY

Your local newspaper reports the results of an experiment a student in one of the local high schools performed to test the effects of a special healthy diet on the cholesterol content of chicken eggs. He obtained 20 chickens from two different breeders. Half of the chickens were fed his special diet; the other half were fed a diet of standard chicken feed, which he purchased at the local livestock feed store. The boy found that the eggs from the group of chickens fed his healthy diet had lower levels of cholesterol than the eggs from the other group. The story created quite a stir in the local media—so much so that the boy's father is trying to acquire funding to market his son's new feed. Do you see any potential problems with this study?

Three to four million years ago, humanlike organisms roamed the grasslands of Africa (Figure 1-1). Scientists dubbed them *Australopithecus afarensis* (aus-TRAL-owe-PITH-a-CUSS A-far-EN-suss).[1] Standing only three feet tall and walking upright, these creatures, one of our early ancestors, subsisted in large part on a diet of roots, seeds, nuts, and fruits. Studies suggest that they supplemented their primarily vegetarian diet with **carrion**, animals that had been killed by predators or that had died from other causes. They also may have captured and killed other animals for meat.

[1]As you will see in Chapter 23, scientists have discovered a number of earlier humanlike species. One species, *Sahelanthropus tchadensis,* inhabited Africa six to seven billion years ago.

Weak and slow compared to other large animals, they could have easily ended up as an evolutionary dead end. Fortunately, though, they possessed several anatomical features that tipped the scales heavily in their favor. Undoubtedly, one of the most important characteristics was their brain.

Thanks in large part to our brains, human beings have survived the test of time and have flourished. Today, we inhabit a world of marvelously complex technologies, which make our lives easier, more convenient, and more fun. Rather than roaming in small bands, as our early ancestors did, the majority of the world's people today live in cities and towns that offer amenities our ancestors never would have dreamed possible. Rather than collecting nuts and berries from the plants around them, most people in the modern world purchase their food from grocery stores supplied by highly mechanized farms. Many farmers are now using satellites and remote sensing devices, as well as computerized machinery to produce more food. Today, our scientists have begun to alter the genetic material of the cells of plants and animals to increase food production, or, in the case of animals, to produce tissues and organs that could be transplanted into human beings. Scientists have even begun to manipulate our hereditary material in an attempt to cure diseases long thought to be untreatable.

For better or for worse, humans have become a major player in **evolution,** a process of biological change that occurs in distinct groups of organisms known as populations. Evolution results in structural, functional, and behavioral changes in organisms in populations. These changes, in turn, result in organisms better equipped to cope with their environment—that is, better able to survive and reproduce.

From most perspectives, the human experiment has been an overwhelming success. However, a growing body of evidence shows that human success has its price. As society advances, we are also causing considerable damage to the life-support system of the planet upon which we and all other species depend.

Like other texts on human biology, the bulk of this book will take you on a journey through the human body. On this journey, you will learn a great deal about yourself—how you got here,

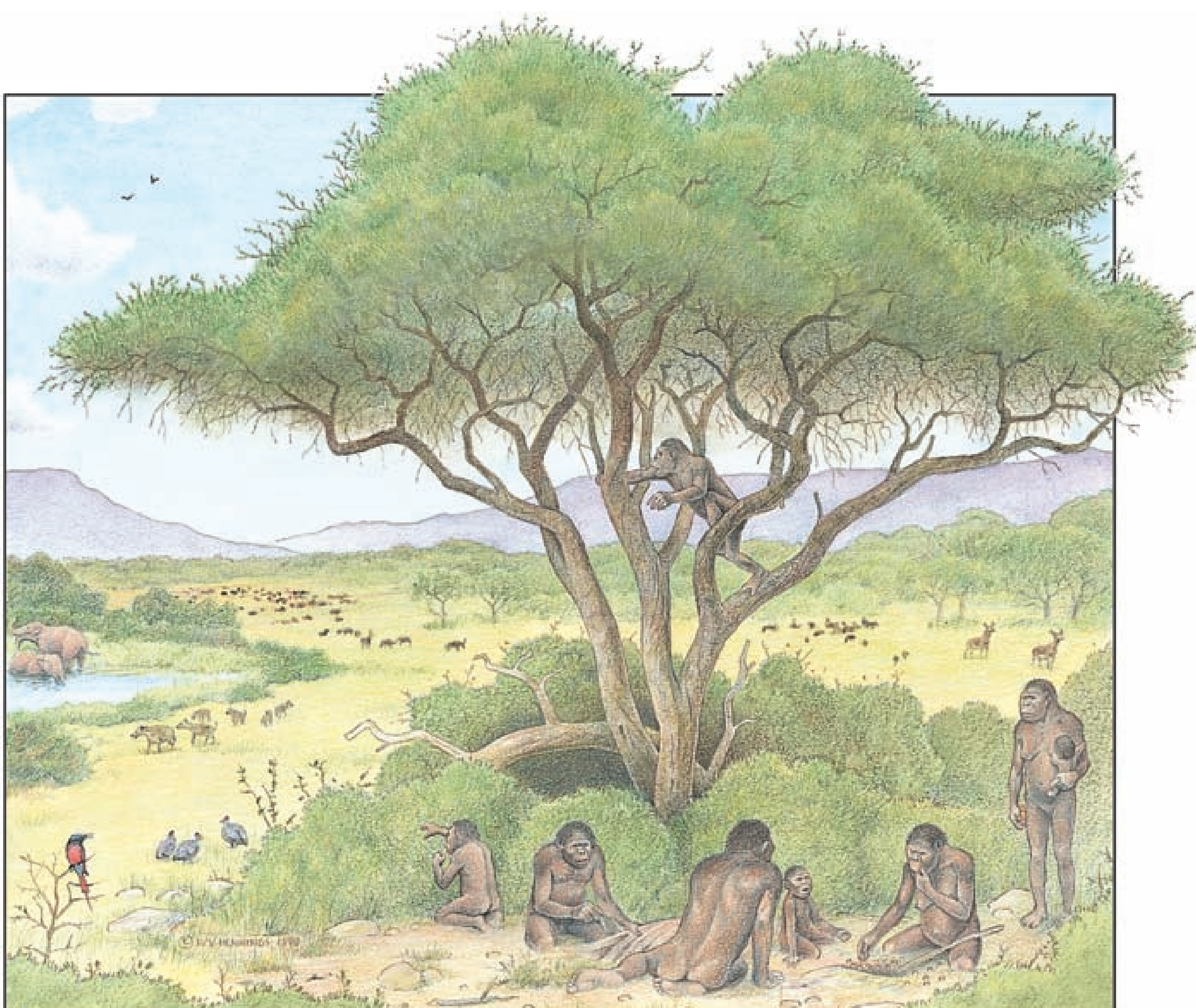


FIGURE 1-1 ***Australopithecus afarensis*** Current scientific evidence suggests that *Australopithecus afarensis* was the first humanlike ape. Its skeletal remains indicate that it walked upright.

how you inherited certain characteristics from your parents, and how your body functions. You will learn how broken bones mend and study the basics of nutrition. You will discover how your immune and nervous systems operate. You will learn about many common diseases and—perhaps more important—how to prevent them. You will learn about the many things you can do to live a long and healthy life. This is part of a new feature, called Health Tips, like the one to the right on this page.

As you will soon see, the information you learn from this book will prove useful to you in many ways. It will also help you understand important political debates over issues such as genetic engineering, stem cell research, vaccination, and even energy and pollution. As you proceed through this book, though, be sure to take some time to marvel at the wonders of the human body—the intricate details of the cell, the fascinating structure and function of organs, and the intriguing manner in which the various parts work together.

Health Tip 1-1

To learn more quickly, perform better in school, live a more emotionally stable life, and reduce your chances of getting sick, be sure to get plenty of sleep.

Why?

Inadequate sleep not only impairs memory, it makes it harder to learn. Inadequate sleep can also result in emotional instability and lowers immune defenses, increasing the likelihood that you will contract the common cold or the flu.

1-1 Health and Homeostasis

In this book, you will see how human health depends on numerous internal mechanisms that have evolved over many millions of years. These internal processes help to maintain a fairly constant internal condition, a state often referred to as *homeostasis* (home-e-oh-STAY-siss).

What Is Homeostasis?

Homeostasis is a state of relative constancy that helps ensure human health.

The term **homeostasis** comes from two Greek words, *homeo,* which means "the same," and *stasis,* which means "standing." Literally translated, homeostasis means "staying the same." Some people refer to homeostasis as a state of internal constancy. In reality, however, homeostasis is not a static state; it is a dynamic (ever-changing) state. To understand what I mean, let's look at a familiar example, body temperature.

Humans are warm-blooded creatures. We generate body heat internally and maintain body temperature at a fairly constant level—about 98.6° F. In reality, though, body temperature varies during the day, falling slightly at night when we sleep and rising during the daylight hours. It increases even more when we participate in strenuous physical activity.

Like many other internal conditions, then, body temperature fluctuates within a range. This is what is meant when we say that body temperature is in homeostasis: it is in a dynamic or ever-changing state but remains more or less the same (Figure 1-2).

Homeostasis is achieved through a variety of automatic mechanisms that compensate for internal and external changes. As Chapter 4 illustrates, homeostatic mechanisms require **sensors,** structures that detect internal and external change—for example, changes in air temperature. Sensors elicit a response that offsets the change, helping to maintain a fairly constant state. On very cold days, for example, sensors in our skin detect the cold, chilly air. If it is cold enough, they stimulate shivering, a rhythmic contraction of muscles that generates body heat, compensating for low temperatures. This is just one of many homeostatic mechanisms in our bodies. Homeostatic mechanisms also maintain fairly constant levels of nutrients in the blood, which is essential for health.

Homeostatic mechanisms also exist in **ecosystems.** An ecosystem is a biological system consisting of organisms and their environment. Homeostatic mechanisms help achieve balance in ecosystems.

A highly simplified example illustrates the point. In the grasslands of Kansas, rodent populations generally remain fairly constant from one year to the next. This phenomenon results, in part, from **predators,** animals that hunt and kill other organisms. Predators such as snakes, coyotes, foxes, and hawks feed on rodents and, thus, help to control rodent populations (Figure 1-3).

Although predators are a crucial element in maintaining environmental homeostasis in these grasslands and virtually

FIGURE 1-2 **Keeping Warm** The human body is remarkably able to tolerate a wide variety of conditions thanks to internal mechanisms that maintain relatively constant internal conditions. These children stay warm thanks to increased heat production by the body and protective clothing.

FIGURE 1-3 **Predator Control** Snakes play an important role in controlling rodent populations, thus helping to maintain ecosystem homeostasis.

all other natural systems, a host of other factors also contribute to it, such as weather and food supplies. It is the net effect of these factors that determines population sizes.

In this book, the term *homeostasis* is used to refer to the balance that occurs at all levels of biological organization—from cells to organisms to ecosystems. The abundance of homeostatic mechanisms in nature suggests their importance to life on Earth. These mechanisms are just one of the many positive outcomes of evolution. As you shall see, maintaining "balance" is essential to the health and welfare of all organisms, humans included. Without it, cells would fall into disarray, organisms would perish, and ecosystems would collapse.

Healthy Environments

Human health depends on maintaining healthy physical, psychological, and social environments.

Scientists have found that the health of the environment and the health of organisms, including human beings, are closely linked. For example, adverse changes in the chemical composition of the air we breathe can have significant negative impacts on human health. Only recently, it was discovered that certain emissions from trucks, buses, cars, and coal-fired power plants (called polycyclic aromatic hydrocarbons or PAHs) can result in lower birth weight and impaired mental development in young children who were exposed while still in their mother's womb.

The health of an organism is also affected by unfavorable social and psychological conditions. Highly stressful environments, for example, can lead to serious ailments in people unfortunate enough to be stuck in them day after day. Health and Homeostasis sections at the end of chapters in this book outline some of these connections.

Although humans are the central focus of this book, it is important to note that many of the species that share this world with us are affected by the condition of the environment. Scientists, for instance, are finding that many drugs that people take are excreted in their urine and end up in the effluent of sewage treatment plants. From there they enter rivers, lakes, and streams. These chemicals are having profound effects on the growth, reproduction, and survival of aquatic species, especially fish. Scientists are also concerned about antibiotics we take that eventually end up in our waterways. They think that bacteria in surface waters such as lakes and streams that are exposed to antibiotics could evolve resistance to them. Humans who ingest these bacteria in drinking water could become deathly ill. Doctors worry that they won't have antibiotics to treat the resistant strains. An even greater problem may be the extensive use of antibiotics—and lots of them—in the production of poultry and livestock for human consumption, a topic discussed in the health note in Chapter 23.

Dimensions of Health

Human health is a state of physical and mental well-being.

For many years, human health was defined as the absence of disease (Figure 1-4a). As long as a person had no obvious symptoms of a disease, that person was considered healthy. Although such a person may have had clogged arteries from a lifetime of fatty hamburgers and snack foods, it wasn't until symptoms of heart disease—for example, chest pain—became apparent that the patient was considered unhealthy.

Health Tip 1-2

To lose or maintain weight, take larger portions of vegetables and whole grains and smaller meat portions.

Why?

Vegetables and whole grains provide less fat—and therefore fewer calories—than meats. Vegetables also provide many nutrients the body needs for long-term health. They also contain fiber, which you will learn is important for good health. It is important to remember that only a small portion of meat is needed to satisfy the body's need for protein.

Today, health experts rely on a more comprehensive definition of health. It takes into account both physical and emotional well-being.

Physical health refers to the state of the body—how well it is working. Physical health can be measured by checking temperature, blood pressure, blood sugar levels, and a number of other variables. Abnormalities in these measurements may be a signal that one's physical health is in jeopardy, even though there are no obvious symptoms of illness. Medical scientists use the term **risk factors** to refer to abnormal conditions such as high blood pressure or high blood cholesterol levels that put a person at risk for disease. The presence of one or more risk factors is a

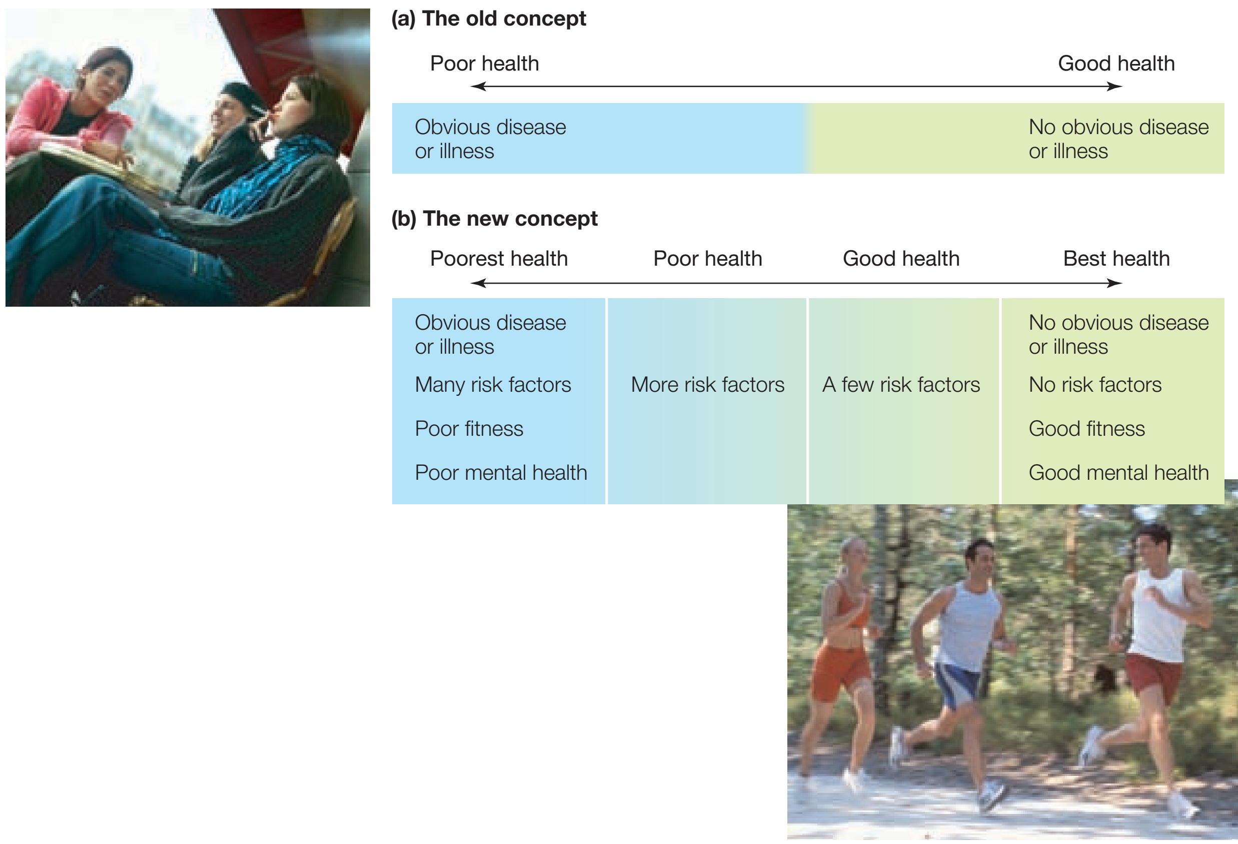


FIGURE 1-4 Old and New Concepts of Health

sign of less-than-perfect health. Obviously, the more risk factors there are, the worse one's physical health is (Figure 1-4b).

The new concept of health says that even though a person feels healthy and does not exhibit obvious signs of disease, such as a failing heart, the presence of risk factors indicates otherwise. As shown in Figure 1-4b, the absence of risk factors results in the best health. A few risk factors mean health is only good. More risk factors mean health is poor, even though the individual may not exhibit any other symptoms—yet.

Scientists also use the term *risk factor* to refer to activities that make an individual more likely to develop diseases. Smoking, lack of exercise, and a fatty diet, for example, are risk factors for heart and artery disease.

Physical health is also measured by one's level of physical fitness. If you can't walk up a set of stairs without gasping for air, you're not considered very physically fit. You're more likely to have other problems later in life—for example, heart disease.

Emotional well-being also factors into an assessment of a person's health. Especially relevant is your ability to cope with stress. Inability to cope may lead to physical problems, such as high blood pressure and heart disease.

Mental and physical fitness are measures of our abilities to meet the demands of life. Fit people are able to cope with daily psychological stresses and are able to move about without becoming short of breath. They're also better employees, less likely to take days off because of illness. For that and other reasons, some companies are now paying employees to adopt more healthy lifestyles. IBM, for instance, pays incentives to employees who exercise, lose weight, and stop smoking. Some employees receive an extra $600 a year in incentives for pursuing a path to a healthier life. Why would a company do this?

IBM estimates that for every dollar it spends on promoting wellness, it saves $3 in health care costs. As noted above, employees require much less sick time, too, which enhances productivity. Currently, more than half of IBM's workforce has signed up for the program.

Maintaining good health is a lifelong job that is best begun early on. Table 1-1 lists numerous healthy habits. By incorporating these habits into your lifestyle, you can increase your chances of living a long, healthy life.

Health Tip 1-3

Regular exercise is essential to good health, so, try to get *at least* 30 minutes of aerobic exercise (running, riding a bike, or swimming) at least 3 times a week. More is better.

Why?

Exercise helps us maintain a healthy weight. Being overweight increases the risk of many diseases, from heart attack and stroke to late-onset diabetes to breast cancer in women. It is important to remember that exercise burns calories directly, but also builds muscle mass. Muscle has a higher metabolic rate than fat, and it continues to burn calories after we're done exercising, providing prolonged benefits!

TABLE 1-1 Healthy Habits
Sleep seven to eight hours per day*
Eat a healthy breakfast every day
Eat a balanced diet
Avoid snacking on junk food (sweets or fatty foods) between meals
Maintain ideal weight
Do not smoke
Avoid alcohol or use it moderately
Exercise regularly
Manage stress in your life

*Not all people need this much sleep. If you're one of them, don't try to force yourself to sleep more than you need.

Health and Homeostasis

Human health is dependent on maintaining homeostasis.

As just pointed out, physical health depends on properly functioning homeostatic mechanisms. When these controls function improperly or break down completely, illness results. Persistent stress, for example, can disrupt several of the body's homeostatic mechanisms, leading to disease. If it is prolonged, stress can increase the risk of diseases of the heart and arteries. It may also weaken the immune system. Fortunately for us, stress can be alleviated by exercise, relaxation training, massage, acupuncture, and a number of other measures discussed in Health Note 1-1.

This discussion is not meant to imply that all diseases result from homeostatic imbalance. Some are produced by genetic defects; others are caused by bacteria or viruses. Interestingly, though, bacteria and viruses and even genetic defects often disrupt homeostasis. An excellent example is acquired immune deficiency syndrome, or AIDS. AIDS is a sexually transmitted disease caused by a virus that attacks certain cells of the immune system. This, in turn, results in a reduction in a key protective mechanism of the body, which is vital to homeostasis.

In some diseases, temporary upsets in homeostasis may make us more susceptible to infectious agents. According to a recent study, people under stress are twice as likely to suffer from colds and the flu as those who are not. To stay healthy, we need to reduce stress levels.

1-2 Evolution and the Characteristics of Life

Homeostasis is a central theme of this book because it is so essential to maintaining health and to the continuation of life. It is also important because so many human activities upset homeostatic mechanisms—to the detriment of humans and all living beings. Another key concept of biology and a subtheme of this book is evolution. A few words on the subject are essential to your understanding of human biology.

All life forms alive today exist because of evolution. In fact, every cell and every organ in the human body is a product of millions of years of evolution. As just noted, even the intricate homeostatic mechanisms evolved over long periods. How did life evolve?

Figure 1-5 shows the five major groups or **kingdoms** of organisms that exist today. This diagram also illustrates evolutionary relationships—how these kingdoms are related. The simplest, bacteria-like organisms, belonging to a group called the *monerans*, were the first to evolve. They gave rise to a more complex set of organisms, known as the *protistans*. The protistans consist of single-celled organisms such as amoebas and paramecia. During the course of evolution, the protistans gave rise to three additional major groups, or kingdoms: plants, fungi, and animals. We humans belong to the animal kingdom.

As evolutionary biologists have discovered, this common lineage is responsible for the striking similarities among the Earth's organisms. One common feature of all living organisms is that they rely on the same type of genetic material. Other similarities also exist. A comparison of certain anatomical features, such as the bones in a person's arm and in the wings of birds, reveals a remarkable resemblance that speaks of a common ancestry. Let's take a closer look at the common characteristics of living things.

Common Characteristics of Organisms

Humans are similar to all other living organisms in many ways.

An analysis of organisms reveals eight common features, referred to as the *characteristics of life*. A brief look at these characteristics not only shows our evolutionary connection with other organisms but also helps us understand human beings better.

The first characteristic of life is that all organisms, including humans, are made of cells. Cells are tiny structures that are the fundamental building blocks of living organisms. Cells, in turn, consist of molecules, nonliving particles composed of smaller units called atoms. Glucose molecules, for instance, contain carbon, hydrogen, and oxygen atoms. Molecules, in turn, combine to form the parts of the cell.

The second characteristic of life is that all organisms grow and maintain their complex organization by taking in molecules and energy from their surroundings. As you will see in subsequent chapters, humans must expend considerable amounts of energy to maintain their complex internal organization. In fact, 70% to 80% of the energy adults need is used just to maintain their bodies—to transport molecules in and out of cells, to make proteins in cells, and to perform other basic body functions. The rest is used for activity—walking, running, talking, and so on.

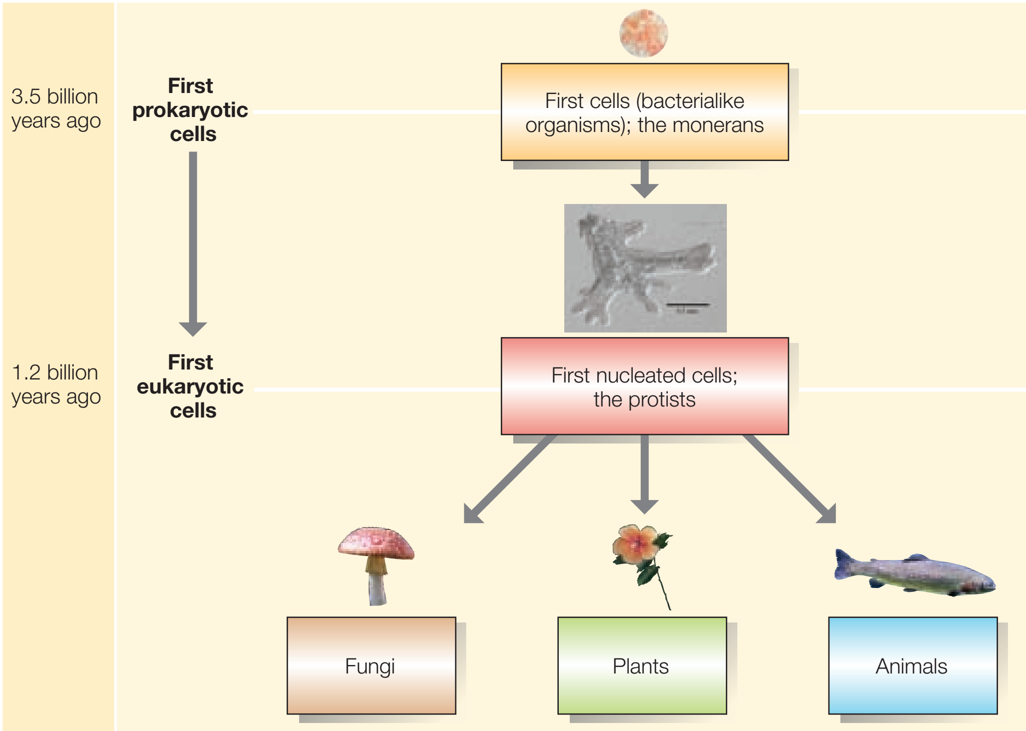


FIGURE 1-5 **Evolution of the Prokaryotic and Eukaryotic Cells** This diagram illustrates the evolutionary history of life. Organisms fall into one of five major groupings, or kingdoms. The first life-forms were the monerans, which are single-celled prokaryotic organisms. They gave rise to the protistans, single-celled eukaryotic organisms. Eukaryotic protistans, in turn, gave rise to plants, fungi, and animals.

The third characteristic of life is that all living things exhibit a feature called metabolism. **Metabolism** refers to the chemical reactions in the cells and tissues of organisms. These reactions consist of two types—those in which food substances are built up into living tissue (anabolic reactions) and those in which food is broken down into simpler substances, often releasing energy (catabolic reactions). In human body cells, millions of reactions occur each second to maintain life.

The fourth characteristic of life is homeostasis. All organisms depend heavily on homeostatic mechanisms. They ensure health, reproduction, and the survival of individual organisms and entire species (groups of similar organisms).

The fifth characteristic of living things is that they sense and respond to changes in their environment. The ability to perceive stimuli and respond to them is important in the day-to-day survival of all organisms and the survival of all species over time.

The sixth characteristic of life is reproduction and growth. All organisms are capable of reproduction and growth. Humans produce offspring by combining sex cells, sperm and eggs from males and females, respectively.

The seventh characteristic of life is evolution. All life is capable of evolving, that is, changing with changes in their environment. Over time, these changes may lead to the emergence of entirely new species. The mechanism by which species change is explored in Chapter 23.

The eighth characteristic of life is that all organisms are part of the Earth's ecosystems. Humans, like every other plant, animal, and microorganism, are dependent on the Earth's ecosystems. They depend on them for food, fiber, water, oxygen, and a host of free services such as natural flood control. The Earth's ecosystems are not only the life-support system of the planet, they are essential to the human economy. All wealth ultimately springs from the Earth and its ecosystems.

What Makes Humans Unique?

Humans are one form of life on Earth yet have many unique characteristics.

Human beings are one of evolution's many products. Although we are like many other species, we are a unique form of life. Several features distinguish us from other species.

One of the key differences between humans and other animals is our ability to acquire and use complex languages. Another distinguishing feature is our culture. Culture has been defined in many ways. Humorist Will Cuppy remarked that culture is anything we do that monkeys don't. On a more serious note, culture can be defined as the ideas, values, customs, skills, and arts of a people. While other species may have some rudiments of culture––for instance, some communication skills––humans are unique in the biological world because of the complexity of our cultural achievements (Figure 1-6a).

Humans also differ from other animals in our ability to plan for the future. Although a few other animals seem to share this ability, most "planning"—like a bird's nest-building activities—is probably the result of instinct programmed by the animal's genetic material. In contrast, building skyscrapers requires an extraordinary amount of forethought.

Another unique characteristic of humans is our unrivaled ability to shape the environment. Although other species can alter their environment, we possess an extraordinary capacity in this regard. We erect huge dams in steep-sided gorges to protect downstream areas against floods and to create a year-round supply of water. We till the soil to grow food. We remove entire mountaintops to access coal. We build islands to provide land to make new cities.

healthnote

1-1 Maintaining Balance: Reducing Stress in Your Life

Stress is a normal occurrence in everyday life. It's a psychological and physical reaction we have when we are exposed to certain stimuli.

Stress can be caused by non–life-threatening situations such as a blind date or a final exam. It also can be caused by potentially life-threatening situations such as exposure to dangerous machinery in a factory.

Stressful stimuli can be real or imagined. Either way, they elicit the same response in the body: an increase in heart rate, an increase in blood flow to the muscles and a decrease in blood flow to the digestive system, a rise in blood glucose levels, and a dilation of the pupils. All of these physical changes in the body help prepare us to respond to the stress. Once the stimulus is gone, though, the body typically returns to normal.

How stress affects us, however, depends on how long we're exposed to it. If the stressful stimulus is short-lived, our bodies recover nicely. Some argue that a little stress may actually improve a person's performance.

Long-term exposure to stressful stimuli, however, can have serious consequences. As a result, a prolonged period of stress may lead to disease. One reason this happens is that the body's immune system is often depressed by stress. The immune system protects us from bacteria and viruses that cause colds and flu and other diseases. Prolonged stress also results in changes in the blood vessels. These changes may accelerate the accumulation of cholesterol, which clogs the arteries and may eventually result in strokes and heart attacks.

Stress doesn't affect all people in the same way. Some people recognize the stress they're feeling and channel its energies into productive work. They are better able to cope with stress. Psychologists believe that people who handle stress the best have a sense of being in control, despite the stress of their work. They typically have clear objectives and a strong sense of purpose. They view their jobs and life as a challenge, not a threat.

Unfortunately, not all people are so lucky. Many people are not in a position of control; they feel expendable and often view themselves as victims. They experience stress that can cause health problems. What can be done to deal with stress?

One of the most important strategies is preventive: selecting an environment and creating a lifestyle that is as stress-free as possible. As a college student, for instance, you may want to select a realistic class load. If you must work or if you're taking hard courses, sign up for a class load that you can handle. And be sure to get plenty of sleep and spend time relaxing.

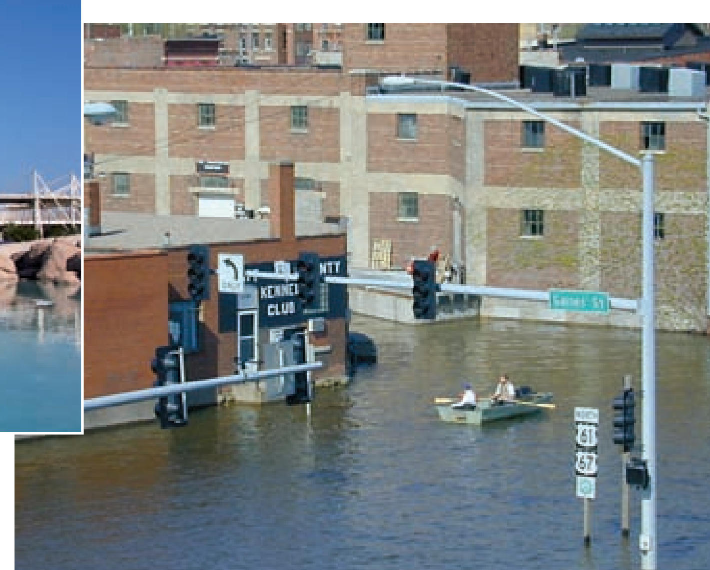
Coping with stress may also require physical and mental strategies. Let's consider the physical strategies first.

One of the easiest routes is to lessen the impact of stress through exercise. Studies show that a single workout at the gym, a bike ride, a swim, or a cross-country skiing trip reduces tension for 2 to 5 hours. A regular exercise program, however, reduces the overall stress in one's life. Individuals who are easily stressed usually find that stress levels decline after two weeks of exercise.

Exercise can be supplemented by relaxation training. As you prepare for a difficult test or get ready for a date that you are nervous about, tension often builds in your muscles. Periodically stopping to release that tension helps to reduce physical stress. Stretching or taking a walk can help. Some people find it useful to tighten their muscles forcefully and then let them relax. Massage therapy and acupuncture can also be used to reduce stress. Stress-reduction programs on CDs, videos, and DVDs can teach relaxation methods, as can trained therapists.

Dealing with the thoughts that exaggerate your stress can also help to eliminate it. This is a mental strategy. Start paying attention to the thoughts

(a)



(b)

FIGURE 1-6 **Human Culture: Progress and Setbacks** (a) Architecture is one of our greatest achievements. But in reshaping our environment, we sometimes create enormous backlashes. (b) Earthen walls, or levees, along the Mississippi River, for example, have been used to control flooding in the past 100 years but have led to more frequent flooding in downstream areas.

that provoke anxiety in your life. Are they exaggerated? If so, why? For example, are you nervous before exams? Why? Would better preparation reduce your anxiety?

Finding the source of your anxiety and taking positive action to alleviate it are helpful ways of reducing stress. However, stress reduction is not always easy. Test anxiety, for example, may be deeply rooted in feelings of inadequacy. Many people struggle with low self-esteem their entire life. A trained psychologist can help you find the causes of your problem and assist you in learning to feel better about yourself. Psychological help is as important as medical help these days, given the complexity and pace of our society. There is no shame in seeking counseling.

Biofeedback is another form of stress relief. A trained health care worker places sensors on you and connects them to a machine that monitors heart rate, breathing, muscle tension, or some other physiological indicator of stress (Figure 1). During a biofeedback session, your trainer first will help you relax, and then perhaps discuss a stressful situation. When one of the indicators shows that you are suffering from stress, a signal is given off. Your goal is to consciously reduce the frequency of the signal. For example, if your heart started beating faster when you thought about taking an exam, the machine will make a clicking sound. By breathing deeply and relaxing, you consciously slow down your heart rate; at that point the clicking sound slows down and then disappears.

Learning to recognize the symptoms of stress and to counter them is the goal of biofeedback. Eventually, you should be able to do it without the aid of a machine.

You can also reduce tension by managing your time and your workload efficiently. Numerous books on this subject can help you learn to budget your time more effectively. See the Study Skills section at the beginning of this book for ideas on ways to be a more efficient learner.

If these techniques don't work, you may want to see a doctor. He or she can prescribe medications that relieve anxiety and muscle tension, help you sleep, or combat depression. Herbal remedies such as valerien root are also available.

FIGURE 1 **Biofeedback** Student in a biofeedback session.

Relieving stress in our lives helps us reduce the risk of disease and enables us to relax and enjoy life. It also makes us more pleasant to be around. All in all, it is best to start learning early in life how to reduce or cope with stress. Lessons learned now will be useful for years to come.

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Visit Human Biology's Internet site for links to Web sites offering more information on this topic.

Despite the benefits of our remarkable technologies, attempts to control nature sometimes backfire, creating larger problems. For instance, studies show that efforts to control upstream flooding on the Mississippi River by building levees along sections of the river have led to more frequent floods and more damage downstream (Figure 1-6b). Levees prevent water from spilling over the banks of rivers. While this protects upstream communities, the result is a larger slug of water delivered to downstream communities and hence increased flooding in such areas—unless they too are protected by even higher levees.

1-3 Understanding Science

The systematic study of the universe and its many parts today falls into the realm of science. The term *science* comes from the Latin word *scientia*, which means "to know" or "to discern." Today, **science** is defined as a body of knowledge derived from observation and experimentation. It also involves ways of learning facts. In other words, it requires methods of acquiring information.

Many people view science as an uninteresting endeavor best left in the hands of a select brainy few (Figure 1-7). In reality, science is an exciting endeavor that often involves enormous creative energy. Because it teaches us about the workings of the world around us, science can be a source of great fascination. As the paleontologist Robert Bakker, a consultant to the company that made the dinosaurs for the movie *Jurassic Park*, once noted, science is "fun for the mind."

Science also has a practical side. It provides information that can improve our lives. It helps us understand important phenomena such as the weather and the spread of disease. Knowledge of science makes us better voters, better able to understand many complex issues. And an understanding of science, notably human biology, can help us make informed decisions about our lifestyle—what we eat, how much we eat, how much we sleep, and the amount of exercise we get.

FIGURE 1-7 **Not Just for Scientists** Science is essential to human progress and a benefit to all of us. It is a process that we all engage in.

The Scientific Method

The scientific method frequently starts with observations or measurements that lead to hypotheses and experiments to test them.

Scientists employ a technique called the **scientific method** to obtain information. As shown in Figure 1-8, the scientific method generally begins with observations and measurements. In some cases, these may be part of carefully conducted experiments. Others may occur more haphazardly. A scientist on vacation in the tropics, for instance, may notice a phenomenon that sparks her curiosity and leads to in-depth studies.

You may not realize that most of us use the scientific method in our day-to-day lives. To see how the scientific method works, suppose you sat down at a computer, turned on the switch, but nothing happened. You might also have noticed that the lights in the room hadn't come on. These two observations would lead to a **hypothesis** (high-POTH-eh-siss), a tentative explanation of the phenomenon. From your observations, you might hypothesize that the electricity in your house was off.

You could test your hypothesis by performing an **experiment.** An experiment is a procedure designed to test some idea. In this case, all you would need to do would be to try the light switch in the kitchen. If the lights in the kitchen worked, you would reject your original hypothesis and form a new one. Perhaps, you hypothesize, the circuit breaker to your study had been tripped. To test this idea, you would "perform" another experiment, locating the circuit breaker to see if it was turned off. If the circuit breaker was off, you would conclude that your second hypothesis was correct. To substantiate your conclusion, you would throw the switch and see if your computer worked.

This process involving observations, hypothesis, and experimentation forms the foundation of the scientific method. Although scientific experimentation may be much more complicated than discovering the reason for a computer failure, the process itself is the same.

Proper experimentation in biology usually requires two groups: experimental and control. The **experimental group** is the one that is tested or manipulated in some way. The **control group** is not tested or manipulated. Valid conclusions come from such comparisons because, in a properly run experiment, both groups are treated identically except in one way. The difference in treatment is known as the **experimental variable.** Consider an example to illustrate this point. In order to test the effect of a new drug on laboratory mice, a good scientist would start with a group of mice of the same age, sex, weight, genetic composition, and so on (Figure 1-9). These animals would be divided into

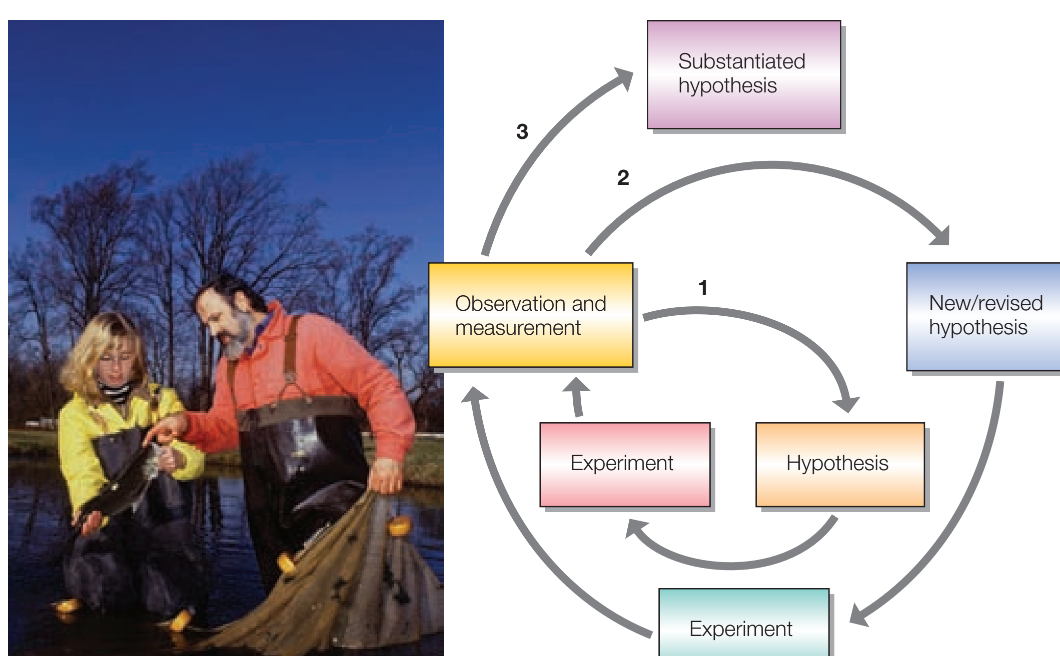

FIGURE 1-8 **Scientific Method** Scientific study begins with observation and measurement. These activities lead to hypotheses that can be tested by experiments. New and revised hypotheses are derived from experimentation.

two groups, the experimental and control groups. Both groups would be treated the same throughout the experiment, receiving the same diet and being housed in the same type of cage at the same temperature. The only difference between the two should be the drug given to the experimental group. Consequently, any observed differences between the groups could be attributed to the treatment (the experimental variable).

Besides having an experimental group and a control group, good experimentation requires an adequate number of subjects to ensure that any observed differences are real. Individual variation is natural. As a rule, the smaller the number of animals in each group, the less reliable the data will be—because of possible variation in response. In laboratory experiments, at least 10 test animals are required for both control and experimental groups for reliable statistical analysis; groups larger than 10 are even better. For human health studies, much larger groups are generally used because of the wider genetic variability among people. Because it is often unethical to experiment on humans—for example, to intentionally expose them to pollutants to determine their effect—researchers often extrapolate results from animal studies. They also use epidemiological studies, that is, studies on populations exposed unintentionally to toxic pollutants, for example, at work. If the researchers notice a higher than anticipated incidence of a disease, they can attribute it to the exposure. Although such studies don't necessarily prove causation, they can help us draw conclusions, especially if other researchers find similar results or if studies with animals support the findings.

In nutrition, researchers use epidemiological studies to assess the effect of nutrients or foods on human health. In such studies, researchers often follow a large group of subjects over a long period. The diets of those who develop a certain disease—say heart disease—are compared to those who do not. Differences in diet can be associated with the development of various diseases. While these studies are valuable, they often rely on people's memories of how much of certain foods they eat each day. Unfortunately, recall is often faulty. Human subjects who volunteer for studies can also be instructed to eat certain foods.

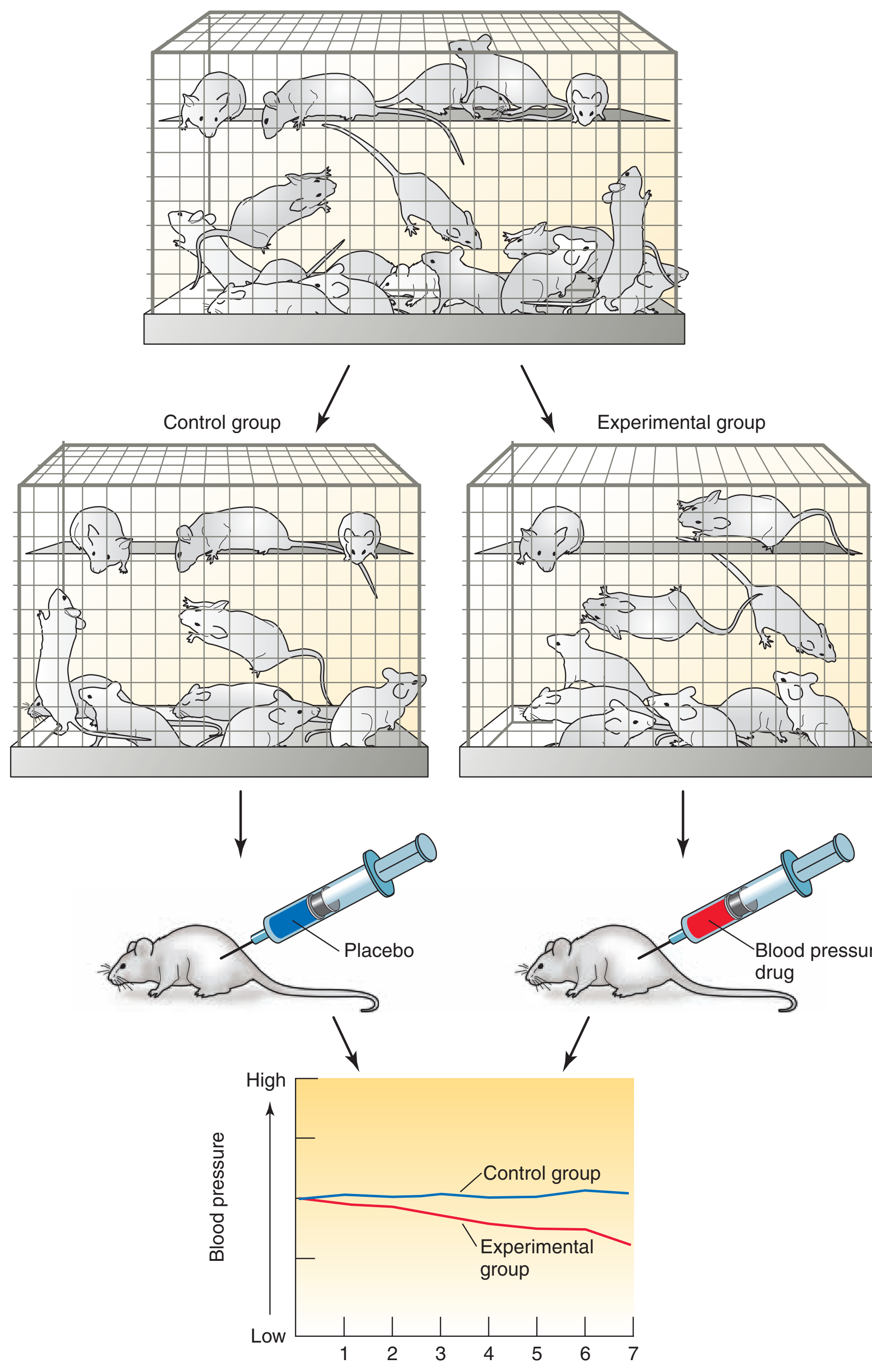

FIGURE 1-9 **Experimental Design** A good experiment uses a large number of identical subjects. They are placed into two groups: control and experimental. Both groups are treated the same, except for one variable. In this case, the experimental group is given an experimental blood pressure lowering drug. The control group is given an injection of saline, the solution the drug is dissolved in.

What Is a Theory?

Theories are generalizations based on many experimental observations.

Scientific method leads to the accumulation of scientific facts (really, well-tested hypotheses). Over time, as knowledge accumulates, scientists are able to gain a broader understanding of the way the world works. These broad generalizations are known as **theories.**

Theories are supported by numerous facts established by careful observation, measurement, and experimentation. Unlike hypotheses, theories cannot be tested by single experiments because they encompass many bits of information. Atomic theory, for instance, explains the structure of the atom and fits numerous observations made in different ways over many decades.

A theory commands respect in science because it has stood the test of time. This does not mean that theories always stand forever. As history bears out, numerous theories have been modified or discarded as new scientific evidence accumulated. Even widely held theories that persisted for hundreds of years have been overturned. In 140 A.D., for example, the Greek astronomer Ptolemy (TAL-eh-me) proposed a theory that placed Earth at the center of our solar system. This was called the *geocentric theory.* For nearly 1,500 years, the geocentric view held sway. Many astronomers vigorously defended this position while ignoring observations that did not fit the theory. In 1580, the astronomer Nicolaus Copernicus proposed a new theory—the *heliocentric view*—which placed the sun at the center of the solar system. His work stimulated considerable controversy, but it eventually prevailed because it fit the observations.

Because theories may require modifications or even rejection, scientists must be willing to analyze new evidence that throws into question their most cherished beliefs. For the most part, though, theories are talked about as if they were fact. Some people even object to calling a theory a "theory" for fear that it sounds tentative. That's not always the case, however. In physics, the term *theory* tends to be used much more loosely. As you will learn in Chapter 2, for instance, physicists speculate that the fundamental unit of all matter, even light, is a weird string of energy, known as a *superstring* or *string*, for short. These strings form subatomic particles. Interestingly, there is no scientific evidence to support this view, only complex mathematical equations that suggest that these strings might exist. As physicist Joseph D. Lykken notes in an article on superstrings in *Science Year* (a publication of World Book), "Physicists often think and work in mathematical terms before their ideas can be translated into concepts that can be tested in the laboratory." Based on this work, they construct theories, such as the superstring theory. They're more appropriately referred to as hypotheses.

Another word about theories before we move on; the word *theory* is commonly used in everyday conversation. A friend, for instance, might say, "My theory about why Jane missed the party is that she didn't want to see her ex-boyfriend." Jane's feelings aside, this is hardly worthy of the status of a theory. What your friend really meant was his "hypothesis," for his explanation was truly a tentative explanation that could be tested by experimentation—in this case, a phone call to Jane.

Inductive and Deductive Reasoning

Humans rely on inductive and deductive reasoning.

One of the features that sets us apart from most other animals is our ability to reason—to think about things and come to conclusions. Two types of reasoning are commonly used. The first is known as **inductive reasoning.** Inductive reasoning occurs when one makes a generalization based on observations. For example, suppose that, based on your observations of fellow students, you concluded that students tend to be a lot healthier (for example, suffer fewer colds) if they get a good night's sleep every night. This is inductive reasoning. You are relying on observations to reach a general conclusion.

Although this is a valuable strategy in science, it can lead to erroneous conclusions in our everyday life. For example, a patient suffering from cancer may fly to Mexico to receive a treatment not permitted in the United States. If that patient's cancer disappears after the treatment, we might be inclined to conclude that the treatment was worthwhile, when in fact there is no scientific evidence that the cure actually works. Why did the patient get better? Some cancers spontaneously remit. In this instance, we observe a coincidence but fail to realize it. We're led to an erroneous conclusion. Had we observed the same result in a dozen individuals, though and made the same conclusion, we would have been properly engaged in deductive reasoning.

Scientists practice inductive reasoning all the time. They infer general laws based on facts and observations. When supported by lots of data obtained from carefully controlled experiments, conclusions derived from inductive reasoning help us advance our knowledge.

The opposite process—drawing a conclusion based on a general rule—is called **deductive reasoning.** Scientists engage in this kind of thinking as well, as do nonscientists. Consider the sleep example once again. The general conclusion that a good night's sleep means better health might be used to explain why a student who misses sleep is always ill. "I think Marshall's sick all the time because he doesn't sleep much" is an example of deductive reasoning.

Science and Human Values

Scientific understanding can help shape our values.

Science and the scientific process are essential to modern existence. We wouldn't have the MP3 player or the cell phone if it weren't for science. Scientific knowledge can also influence political decisions regarding health care, environmental protection, and a host of other issues.

Many decisions in the public-policy arena, however, are not made on the basis of scientific facts. Rather, they are influenced by values—what we view as right or wrong—and economic needs. When values are framed in the absence of scientific knowledge, however, they can lead to less effective, even self-defeating, policies. How does science influence values?

Science can influence human values in many ways. The study of ecology, for example, helps us understand the importance of the ecosystems to human well-being as the source of all our resources, even the oxygen we breathe. Ecology also helps uncover relationships that are not obvious to most people, such as the role of bacteria in recycling nutrients. Understanding the importance of the natural world to human well-being, even economic well-being, shapes our values (what we think is important) and gives us good reason to protect the Earth's ecosystems.

1-4 Critical Thinking

Critical thinking rules allow us to carefully analyze problems, issues, and information for errors of reasoning.

Another benefit of your study of science is that it can help you learn to think more critically. **Critical thinking** is not being "critical" or judgmental. Rather, it's a process that allows us to objectively analyze facts, issues, problems, and information. Ultimately, critical thinking permits people to distinguish between beliefs (what we believe to be true) and knowledge (facts well supported by research). In other words, critical thinking is a process by which we separate judgment from facts. It is our most ordered kind of thinking. It is not just thinking deeply about a subject. Critical thinking subjects facts and conclusions to careful analysis, looking for errors of reasoning. Critical thinking skills, therefore, are essential to analyzing a wide range of facts, issues, problems, and information.

Table 1-2 summarizes seven critical thinking rules that will come in handy as you read the newspaper, watch the news, listen to speeches, and study new subjects in school. Here is a brief description of each one.

The first rule of critical thinking is gather complete information. Time and again people formulate opinions based on little, if any, information. We may adopt a position based on our parents' beliefs or the beliefs of friends. We hold fast to those beliefs, even in the face of conflicting information. Despite an enormous body of scientific research on biological evolution, many people still question its existence.

Critical thinking requires us to verify what we believe with facts—and lots of them. To think critically we must gather an abundance of information from reliable sources. Doing so will prevent you from mistaking your ignorance for perspective. By continually being on the lookout for new facts, you can develop an enlightened viewpoint.

Don't make the common mistake of only accepting facts that support your point of view, however. Many of us tend to employ *confirming strategies*, according to University of Massachusetts professor Thomas Kida, author of *Don't Believe Everything You Think*. That is, we selectively gather information that confirms an already established viewpoint, ignoring evidence that conflicts with it. "Information," he says, "that is consistent with our beliefs is readily accepted. That which is not, is dismissed or ignored."

The second rule of critical thinking is understand and define all terms. Critical thinking requires a clear understanding of all terms. Understanding terms and making sure that others define them in discussions brings clarity to issues and debates. The Greek philosopher Socrates, in fact, destroyed many an argument in his time by insisting on clear, concise definitions of terms. As you analyze any information or issue, always be certain that you understand the terms, and make sure that others define their terms as well.

The third rule of critical thinking is question the methods by which the facts are derived. In science, many debates over controversial topics hinge on the methods used to discover new information. The first question you should ask is was the information gained from careful experimentation, or is it the result of faulty observations or hearsay? You'd be amazed how often people's opinions are based on faulty observations or on what others tell us are facts. Many of us prefer stories to hard data. Many documentaries on television on a wide range of topics from the existence of UFOs to ghosts to extrasensory perception, for example, consist of stories. Producers ignore scientific data that suggest that the phenomena under discussion do not exist.

Surprisingly few opinions are based on real evidence. As you analyze a person's positions or statements, check to see if his or her conclusions are based on facts obtained from experiments or careful and accurate observation. Ask people for the data they have to back up their statements.

TABLE 1-2 Critical Thinking Rules

When analyzing an issue or fact, you may find it useful to employ these rules:

1. Gather complete information, not just from sources that support your viewpoint.
2. Understand and define all terms.
3. Question the methods by which data and information were derived:
   - Were the facts derived from experiments?
   - Were the experiments well executed?
   - Did the experiment include a control group and an experimental group?
   - Did the experiment include a sufficient number of subjects?
   - Has the experiment been repeated?
4. Question the conclusions:
   Are the conclusions appropriate?
   Was there enough information on which to base the conclusions?
5. Uncover assumptions and biases:
   Was the experimental design biased?
   Are there underlying assumptions that affect the conclusions?
6. Question the source of the information:
   Is the source reliable?
   Is the source an expert or supposed expert?
7. Understand your own biases and values.

Scientific Discoveries that Changed the World

1-1 Debunking the Theory of Spontaneous Generation

Featuring the Work of Aristotle, Redi, and Pasteur

The Greek philosopher and scientist Aristotle (384 to 322 B.C.) proposed a theory to explain the origin of living things. It was called the *theory of spontaneous generation.* This theory asserted that living things arose spontaneously from innate (nonliving) matter. Mice, he believed, arose from a pile of hay and rags placed in the corner of a barn. Flies could be produced by first killing a bull, then burying it with its horns protruding from the ground. After several days, one of the horns would be sawed off and flies would emerge. People, it was said, emerged from a worm that developed from the slime in the bottom of a mud puddle.

As absurd as the idea of spontaneous generation sounds today, the view remained compelling to many scientists well into the nineteenth century, despite observations that contradicted the theory, such as the phenomenon of childbirth itself.

Debunking the theory of spontaneous generation engaged some of the best scientific minds of the day. Although many scientists were involved in debunking the theory, two scientists, Francesco Redi and Louis Pasteur, played pivotal roles.

Redi, an Italian naturalist and physician, was one of the first scientists to refute spontaneous generation through experimentation. Around 1665, Redi performed a simple but effective experiment to determine whether houseflies were spontaneously generated in rotting meat. He began by placing three small pieces of meat in three separate glass containers. The first container was covered with paper. The second was left open, and the third was covered with gauze. Left at room temperature, the meat quickly began to rot and attract flies. Soon, the meat in the open container began to seethe with maggots, larvae hatched from fly eggs. The paper-covered container showed no evidence of maggots, nor did the meat in the gauze-covered container, although maggots did appear in the gauze itself. Redi's conclusion was that maggots (which give rise to flies) do not come from the meat itself but from the eggs deposited by flies.

Redi's experiments convinced many people that flies and other organisms did not arise by spontaneous generation, but this did not put the debate to rest. Soon after Redi's now-famous experiment, a Dutch linen merchant by the name of Anton Leeuwenhoek discovered bacteria using simple microscopes he had built. This discovery revived arguments for spontaneous generation on the microscopic level. Many scientists asserted that although flies and other organisms did not arise spontaneously, microorganisms probably did. As evidence, they cited studies showing that microorganisms could arise from boiled extracts of hay or meat. According to proponents of spontaneous generation, nonliving plant and animal matter possessed a life-generating force that could give rise to microorganisms.

The debate over spontaneous generation persisted for the next 200 years. In 1861, Louis Pasteur published the results of an experiment that helped put this debate to rest. He placed sterilized broth in a sterilized swan-necked flask, one with a long curved neck (Figure 1). The design of the flask permitted air to enter, eliminating criticism that he had destroyed any vital forces necessary for spontaneous generation, but it blocked airborne bacteria from entering. (Airborne bacteria probably were deposited on the tube leading to the flask and were prevented from entering the broth.) In his experiments, Pasteur clearly showed that bacteria could not arise spontaneously. Only when the broth was open to the air did bacteria emerge.

This brief history points out three important lessons. First, scientific discovery is usually the result of the work of many scientists, each examining different parts of the puzzle. Second, it shows how discoveries open up new ways of thinking. Third, it illustrates the persistence of ideas that shape the way we think and the resistance people often exhibit to new ideas even in the face of contradictory evidence.

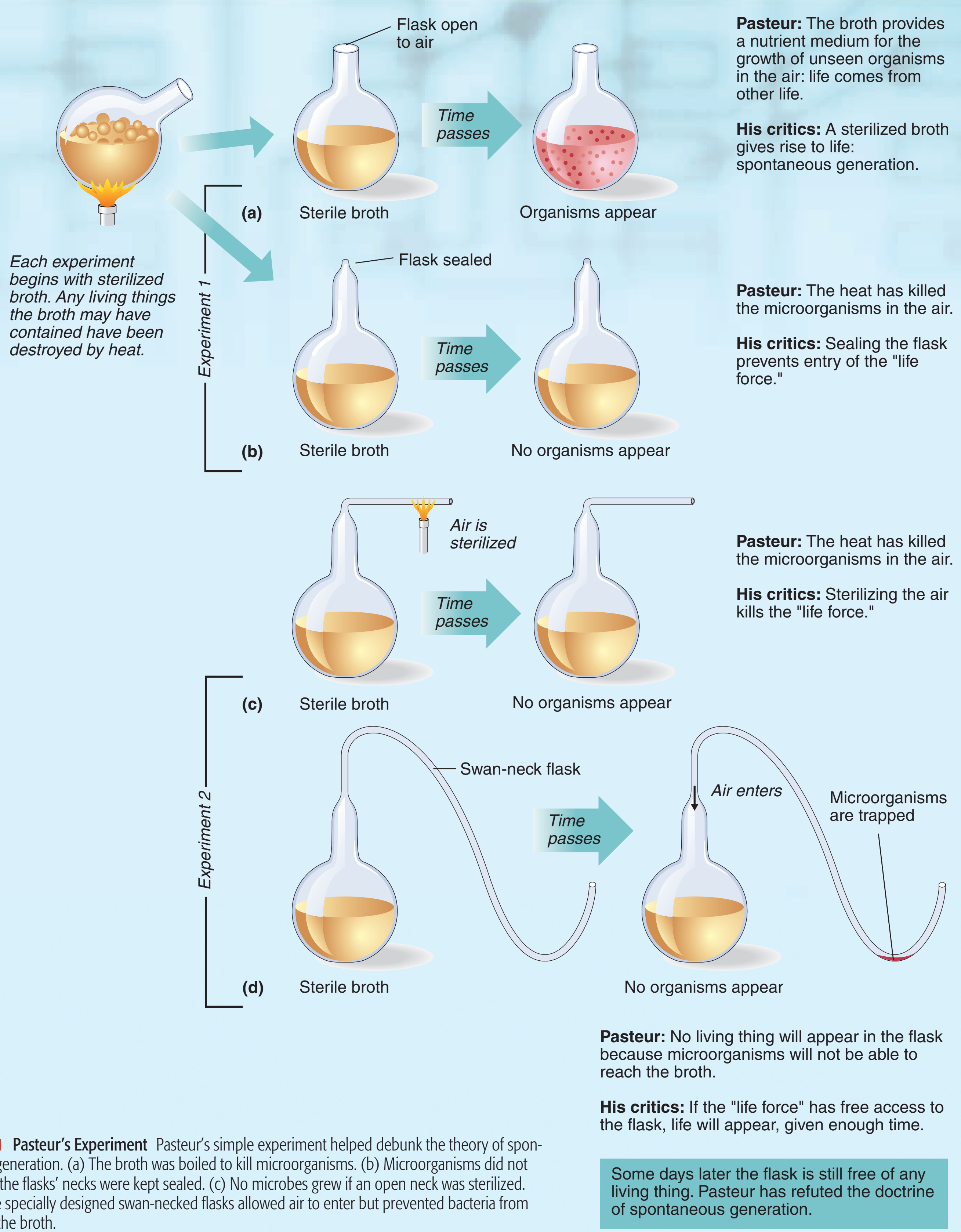

FIGURE 1 **Pasteur's Experiment** Pasteur's simple experiment helped debunk the theory of spontaneous generation. (a) The broth was boiled to kill microorganisms. (b) Microorganisms did not appear if the flasks' necks were kept sealed. (c) No microbes grew if an open neck was sterilized. (d) These specially designed swan-necked flasks allowed air to enter but prevented bacteria from entering the broth.

POINT ■ COUNTER POINT — Controversy Over the Use of Animals in Laboratory Research

Animal Research Is Essential to Human Health by Frankie L. Trull

Virtually every major medical advance of the last 100 years—from chemotherapy to bypass surgery, from organ transplantation to joint replacement—has depended on research with animals. Animal studies have provided the scientific knowledge that allows health care providers to improve the quality of life for humans and animals by preventing and treating diseases and disorders, and by easing pain and suffering.

Some people question animal research on the ground that data from animals cannot be extrapolated to humans. But physicians and scientists agree that the many similarities that exist provide the best insights into the complex systems of both humans and animals. Knowledge gained from animal research has contributed to a dramatically increased human life span, which has increased from 47 years in 1900 to more than 76.7 years in 1998. Much of this increase can be attributed to improved sanitation and better hygiene; the rest of this increased longevity is a result of health and medical advances made possible in part through animal research.

Frankie L. Trull is president of the Foundation for Biomedical Research, a nonprofit educational organization dedicated to improving the quality of human and animal health by promoting public understanding and support of the ethical use of animals in scientific and medical research.

Research on animals has also led to countless treatments, techniques, and medical technologies. Animal research was indispensable in the development of immunization against many diseases, including polio, mumps, measles, diphtheria, rubella, and hepatitis. One million insulin-dependent diabetics survive today because of the discovery of insulin and the study of diabetes using dogs, rabbits, rats, and mice. Organ transplantation, considered a dubious proposition just a few decades ago, has become commonplace because of research on mice, rats, rabbits, and dogs.

Animal research has contributed immeasurably to our understanding of tumors and has led to the discoveries of most cancer treatments and therapies. Virtually all cardiovascular advances, including the heart-lung machine, the cardiac pacemaker, and the coronary bypass, could not have been possible without the use of animals. Other discoveries made possible through animal research include an understanding of DNA; X-rays; radiation therapy; hypertension; artificial hips, joints, and limbs; monoclonal antibodies; surgical dressings; ultrasound; the artificial heart; and the CAT scan.

Animal research will be essential to medical progress in the future as well. With the use of animals, researchers are gaining understanding into the cause of—and treatments for—AIDS, Alzheimer's disease, cystic fibrosis, sudden infant death syndrome, and cancer in the hopes that these problems can be eliminated. Although many non-animal research models have been developed, no responsible scientist believes that the technology exists today or in the foreseeable future to conduct biological research without using animals.

Despite distortions and exaggerations put forth by those opposed to animal research, occurrences of poor animal care are extremely rare. Researchers care about the welfare of laboratory animals. Like everybody else, scientists don't want to see animals suffer or die. In fact, treating animals humanely is good science. Animals that are in poor health or under stress will provide inaccurate data.

Many people are under the false impression that laboratory animals are not protected by laws and regulations. In fact, many safeguards are in place to guarantee the welfare of animals used in research. A federal law, entitled the Animal Welfare Act, stipulates standards for care and treatment of laboratory animals, and the U.S. Public Health Service (PHS), the country's major source of funding for biomedical research, sets forth requirements with which research institutions must comply in order to qualify for grants for any biomedical research involving any kind of animal.

Both the Animal Welfare Act and the PHS animal welfare policy mandate review of all research by an animal care and use committee set up in each institution to ensure that laboratory animals are being used responsibly and cared for humanely. The committee, which must include one veterinarian and one person unaffiliated with the institution, has the power to reject any research proposal and stop projects if it believes proper standards are not being met.

Although animal research opponents portray the medical community as deeply divided over the merits of animal experimentation, the percentage of physicians opposed to animal research remains very small. A 1989 survey by the American Medical Association of a representative sample of all active physicians found that 99% believed animal research had contributed to medical progress, and 97% supported the continued use of animals for basic and clinical research.

The general public, when presented with the facts, has also been supportive of animal research. This support must not be allowed to erode through apathy or misconceptions. Should animal research be lost to the scientific community, the victims would be all people: our families, our neighbors, our fellow humans.

Vivisection: A Medieval Legacy by Elliot M. Katz

Vivisection, an outdated and extremely cruel form of biomedical research, is the purposeful burning, drugging, blinding, infecting, irradiating, poisoning, shocking, addicting, shooting, freezing, and traumatizing of healthy animals. In psychological studies, baby monkeys are separated from their mothers and driven insane; in smoking research, dogs have tobacco smoke forced into their lungs; in addiction studies, chimpanzees, monkeys, and dogs are addicted to cocaine, heroin, and amphetamines, then forced into convulsions and painful withdrawal symptoms; in vision research, kittens and monkeys are blinded; in spinal cord studies, kittens and cats have their spinal cords severed; in military research, cats, dogs, monkeys, goats, pigs, mice, and rats die slow, agonizing deaths after being exposed to deadly radiation, chemical, and biological agents.

Started at a time when the scientific community did not believe animals felt pain, vivisection has left a legacy of animal suffering of unimaginable proportions. Descartes, the father of vivisection, asserted that the cries of a laboratory animal had no more meaning than the metallic squeak of an overwound clock spring. Though the research community considers vivisection a "necessary evil," a growing number of scientists and health professionals see vivisection as simply evil.

As a veterinarian, I was taught that vivisection was essential to human health. My eyes were finally opened to the full horrors and futility of vivisection when years later, faculty members and campus veterinarians at the University of California informed me that animals were dying by the thousands from severe neglect and abuse; that vivisectors and campus officials were denying and concealing the abuses; and that experiments were conducted whose only benefit was to the school's finances and researchers' careers. I discovered that animal "care" committees, typically cited as assurance that animals are used responsibly, are in fact "rubber stamp" committees composed mostly of vivisectors who routinely approve each other's projects. Over the years, I have witnessed an ongoing pattern of university officials denying documented charges of misconduct, attempting instead to discredit critics of vivisection, ultimately defending even the most ludicrous and cruel experiments as necessary and humane.

I discovered that assertions by the biomedical community that vivisection is an essential and indispensable part of protecting the public's health are simply untrue. Vivisection can and should be ended. It is scientifically outdated and morally wrong. There is a plethora of modern biomedical technology that can be used to improve society's health without harming animals. The advent of sophisticated scanning technologies, including computerized tomography (CT), positron emission tomography (PET), and magnetic resonance imaging (MRI), has given scientists the ability to examine people and animals non-invasively. This technology has isolated abnormalities in the brains of patients with Alzheimer's disease, epilepsy, and autism, revolutionizing diagnosis and treatment of these diseases. Tissue and cell cultures are being increasingly used to screen cancer and AIDS drugs. Progress with AIDS has come from areas entirely unrelated to animal experimentation. Human skin cell cultures are used to test new products and drugs for toxicity and irritancy.

Why, then, is vivisection so entrenched and defended with an almost religious fervor? Dr. Murry Cohen summed it up when he stated, "Change is difficult for most people, but it is particularly painful for scientific and medical bureaucracies, which fight to maintain the status quo, especially if required change might imply admission of previously held incorrect ideas or flawed axioms." Vivisection continues today because of vested interests, habit, economics, and legal considerations, not for the real advancement of science and public health.

When presented with the facts, members of the public almost unanimously express their desire to see an end to the horrors of vivisection. Thousands of professionals have reevaluated the sense, efficacy, and worth of vivisection and have formed or joined organizations working to end this outdated and cruel form of research. The ending of vivisection will lead to improved public health and restore to medicine and science much needed excellence and compassion for all beings, human and nonhuman alike.

Elliot M. Katz, DVM (here with companion, MANCO) is a graduate of the Cornell University School of Veterinary Medicine. He is president and founder of In Defense of Animals, a national animal rights organization.

Sharpening Your Critical Thinking Skills

1. Summarize the main points of each author.
2. Do these authors use data or ethical, anecdotal (stories or experiences) arguments to make their cases?
3. Do you have a view on this issue? What factors weigh most heavily in making up your mind?

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Even if they do have data, be sure that it is valid. Some of the critical thinking exercises at the beginning of the chapters in this book show that data can easily be misinterpreted. If views were based on experiments, were the experiments well-planned and well-executed? Or were they based on pseudoscience? *Pseudoscience* produces data that is largely based on personal reporting (stories). It is not produced by well-controlled experiments. You can tell if a study fits into the category of science by the way the experiment was conducted. Did the experiment have a control group? Were the control and experimental groups treated identically except for the experimental variable? Did the experimenters use an adequate number of subjects?

Even if all of these conditions are met, beware. In science, one experiment is rarely adequate to permit you to draw firm conclusions. Careful scrutiny, for example, may show small but significant design flaws: perhaps mice being tested in a drug study were resistant to the drug under examination or were hypersensitive to it. As a rule of thumb, wait for scientific verification of the results. A second researcher may repeat the experiment with similar results. In some cases, a new researcher may find different results.

Nowhere is caution more necessary than when you encounter announcements of scientific breakthroughs on the television news and in magazine and newspaper articles. Ever eager to showcase new scientific studies, the media sometimes does a grave disservice to the advancement of scientific knowledge; further study may show that findings were invalid. Unfortunately, the media often fails to publish contradictory results from follow-up studies. Scientific journals often favor studies that have positive results, too. Researchers who write up a study that shows no effect may have a difficult time publishing their results. Ultimately, the public—even the scientific community—is left with a false impression of reality.

The fourth rule of critical thinking is: question the conclusions derived from facts. Surprisingly, even if an experiment is run correctly, there's no guarantee that the conclusions drawn from the results are correct. How can that be? The answer may lie in bias, ignorance, and error. Bias refers to personal beliefs that taint the interpretation of results. Ignorance is a lack of full knowledge. This, in turn, may lead a scientist to misinterpret his or her results. Finally, error does occur, in spite of our best efforts.

Two questions should be asked when one analyzes the conclusions of an experiment: (1) Do the facts support the conclusions? and (2) Are there alternative interpretations? Consider an example.

One of the earliest studies on lung cancer showed that people who consumed large quantities of table sugar (sucrose) had a higher incidence of lung cancer than those who ate table sugar in moderate amounts. The researchers concluded that lung cancer was caused by sugar consumption. Many people had trouble believing this conclusion, which forced a re-examination of the study. It, in turn, showed that the group with a higher incidence of lung cancer included a higher percentage of cigarette smokers. Subsequent studies showed that smoking, not sugar consumption, is the culprit. Smokers, it seems consume more sugar, but it is smoking that causes lung cancer, not sugar.

The health effects of coffee consumption may have fallen victim to a similar false correlation. A study of data from the British National Health Service, for instance, uncovered a link between coffee consumption and heart disease. The initial research showed that heavy coffee drinkers had a higher incidence of heart disease. Further study of the data, however, suggested that the link was probably between smoking and heart disease. Heavy coffee drinkers, it turns out, tend also to engage in a number of other unhealthy activities, especially smoking and alcohol consumption. A study published in 2006 that eliminated the influence of smoking showed that there was no link between coffee consumption and heart disease.

Besides showing the importance of scrutinizing the conclusions of a scientific study, this example illustrates a key principle of medical research: correlation does not necessarily mean causation. In other words, two factors that appear to be related (correlated) may, in fact, not be linked at all.

The fifth rule of critical thinking is: look for assumptions and biases. This rule is related to the previous rule, questioning conclusions, but is so important that it warrants closer examination. Biases and hidden assumptions are to thinking what cyanide is to food—a poison. Unfortunately, biases and hidden assumptions run rampant in today's society.

In many contemporary debates over a wide range of issues, proponents often present information that supports their point of view. This selective inclusion of supportive data and exclusion of contradictory information is often an expression of a hidden agenda. What happens is that people make up their mind about an issue and then seek out information that supports their point of view.

The sixth rule of critical thinking is: question the source of the facts—that is, who is telling them. Closely related to the previous rule, this one calls on us to learn about the people who performed various research studies or analyses. It asks us to familiarize ourselves with the people taking various positions. Bias can influence scientific researchers. Be especially wary of people with political motives. An association with a partisan group may be a red flag, warning that bias may have influenced their conclusions. Their penchant for "putting a spin" on things often results in doctored truths.

Sometimes a study of the biographies of the people delivering the information is as instructive as an examination of their conclusions. Beware of "experts" who have a hidden agenda. Experts from industry who swear under oath about the safety of their product may be biased or even deceitful. Environmental experts may also slant the data to support their view.

Also beware of people who may not know as much as you think they should. Although we think of physicians as experts on human health, most of them received little or no training in nutrition in medical school. Many medical students still graduate without a full understanding of the role of nutrition in preventing disease and promoting good health. For questions about diet, you may be better off consulting a registered dietitian.

Scientists can be biased, too. If a scientist is testing the effects of an experimental drug on humans, but financial support for the research comes from a pharmaceutical company that stands to make billions of dollars from the new product, his results may be unintentionally—or sometimes intentionally—biased. Fortunately, the scientific community has built-in mechanisms to weed out bad science. When a researcher submits a paper for publication, it is reviewed by his or her peers. If the peers find fault in the study, it may be rejected. If the study and its conclusions appear valid, it is published in scientific journals. After it is published, however, it is further scrutinized and sometimes criticized by other scientists. Additional work may substantiate or refute the findings, helping us slowly but surely advance our understanding of the world around us.

The seventh rule of critical thinking is: understand your own biases, hidden assumptions, and areas of ignorance. So far, this discussion on critical thinking has concentrated on ways you can uncover mistakes in reasoning that other people make. But what about your own biases, hidden assumptions, and areas of ignorance? Do they affect your ability to think critically? Do you continually seek out information that only supports your beliefs? Are you seeking information from biased sources?

Uncomfortable as it may be, it's essential to uncover—and correct—your own biases. Only then can you become a critical thinker. Remember, too, that despite the vast amount of information human society has accumulated over the years, we do not have all of the answers. We're constantly learning and refining our knowledge. Nowhere is this more evident than in the field of nutrition where new discoveries are continually throwing into question previous ideas and dietary recommendations. Bear in mind that occasional reversals don't mean that researchers aren't making progress in understanding health and nutrition. And, above all, be patient. Maybe in another 1,000 years, we will have all of the answers! In the meantime, we'll have to content ourselves with an incomplete and evolving knowledge base.

As you read this text, you will be presented with examples to help you sharpen your critical thinking skills. Each chapter starts with a critical thinking exercise. Even if your teacher doesn't assign these exercises, it is a good idea to take time to read and study them. The Point/Counterpoints in the book will also help you hone your critical thinking skills.

SUMMARY

Health and Homeostasis

1. Humans, like all other organisms, have evolved mechanisms that ensure relative internal constancy (homeostasis). These homeostatic mechanisms are vital to survival and reproduction.
2. Homeostatic mechanisms exist at all levels of biological organization, from cells to organisms to ecosystems.
3. The health of all species and ecosystems is dependent on the functioning of homeostatic mechanisms. When these mechanisms break down, illnesses often result.
4. Human health has traditionally been defined as the absence of disease, but a broader definition of health is now emerging. Under this definition, good health implies a state of physical and mental well-being.
5. Physical well-being is characterized by an absence of disease or symptoms of disease, a lack of risk factors that lead to disease, and good physical fitness.
6. Mental health is also characterized by a lack of mental illness and a capacity to deal effectively with the normal stresses and strains of life.
7. Human health and the health of the many species that share this planet with us depend on a properly functioning, healthy ecosystem. Thus, alterations of the environment can have severe repercussions for all species, including humans.

Evolution and the Characteristics of Life

8. Evolution results in structural, functional, and behavioral changes in populations. These changes, in turn, result in organisms better equipped to cope with their environment—that is, better able to survive and reproduce.
9. All life forms alive today exist because of evolution. In fact, every cell and every organ in the human body is a product of millions of years of evolution. Even the intricate homeostatic mechanisms evolved over long periods.
10. Living organisms belong to five major groups or kingdoms. Humans belong to the animal kingdom.
11. Evolution is responsible for the great diversity of life forms. However, because the Earth's organisms evolved from early cells that arose over 3.5 billion years ago, all organisms, including humans, share many common characteristics. Items 12–18 list the common characteristics of all life forms.
12. All organisms, including humans, are made up of cells.
13. All other organisms grow and maintain their complex organization by taking in molecules and energy from their surroundings.
14. All living things house many chemical reactions. These reactions are collectively referred to as metabolism.
15. All organisms possess homeostatic mechanisms.
16. All organisms exhibit the capacity to perceive and respond to stimuli.
17. All organisms are capable of reproduction and growth.
18. All organisms are the product of evolutionary development and are subject to evolutionary change.
19. All organisms are part of the Earth's ecosystems.
20. Although humans are similar to many other organisms, we also possess many unique abilities and features: culture, our ability to plan for the future, and an enormous ability to reshape the Earth through ingenuity and technology.

Understanding Science

21. Science is both a systematic method of discovery and a body of information about the world around us.
22. Scientists gather information and test ideas through the scientific method. The scientific method begins with observations and measurements, often made during experiments. Observations and measurements may lead to hypotheses, explanations of natural phenomena that can be tested in experiments. The results of experiments help scientists support or refute their hypotheses.
23. The body of scientific knowledge also contains theories, broad generalizations about the way the world works. Theories can change over time as new information becomes available.

Critical Thinking

24. Critical thinking is a useful tool in science and life and is defined as careful analysis that helps us distinguish knowledge from beliefs or judgments.
25. Critical thinking provides a way to analyze issues and information.
26. Table 1-2 summarizes the critical thinking rules.

KEY TERMS AND CONCEPTS

Carrion, p. 1
Control group, p. 10
Critical thinking, p. 13
Deductive reasoning, p. 12
Ecosystem, p. 3
Evolution, p. 2
Experiment, p. 10
Experimental group, p. 10
Experimental variable, p. 10
Homeostasis, p. 3
Hypothesis, p. 10
Inductive reasoning, p. 12
Kingdom, p. 6
Metabolism, p. 7
Predators, p. 3
Pseudoscience, p. 18
Risk factor, p. 4
Science, p. 9
Scientific method, p. 10
Sensors, p. 3
Theory, p. 11

CONCEPT REVIEW

1. How would you define life? p. 6
2. In what ways are a rock and a living organism (for example, a bird) similar, and in what ways are they different? p. 6
3. Describe the concept of homeostasis. How does it apply to humans? How does it apply to ecosystems? Give examples from your experiences. p. 3
4. Using the definition of health and the list of healthy habits in Table 1-1, assess your own health. What areas need improvement? p. 5
5. In what ways are humans different from other animals? In what ways are they similar? p. 7
6. Describe the scientific method, and give some examples of how you have used it recently in your own life. p. 10
7. How do a hypothesis and a theory differ? pp. 10–12
8. List and discuss the critical thinking skills presented in this chapter. Which skills seem to be most important for the kind of thinking you normally do? pp. 13–19
9. A graduate student injects 10 mice with a chemical commonly found in the environment and finds that all of his animals die within a few days. Eager to publish his results, the student comes to you, his adviser. What would you suggest the student do before publishing his results? pp. 10–11
10. Given your knowledge of scientific method and critical thinking, make a list of reasons why scientists might disagree on a particular issue or research finding. pp. 13–19

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SELF-QUIZ: TESTING YOUR KNOWLEDGE

1. __________ results in structural, functional, and behavioral changes in populations of organisms that make them better able to survive and reproduce. p. 2
2. ________________ is referred to as a state of relative internal constancy. p. 3
3. Abnormal conditions in the human body such as high blood pressure that may lead to ill health or serious conditions are called __________ factors. p. 5
4. Human health is dependent on physical health and ____________ well-being. p. 4
5. Organisms are organized into five major groups called ______________. p. 6
6. Chemical reactions in the body are known as __________________. p. 7
7. Scientists use a process called the ________ method to learn new information and test ideas. p. 10
8. A(n) ________________ is a testable assertion. p. 10
9. In many scientific experiments, two groups of subjects are used. One group, the __________ group is treated identically to the experimental group except that it is not exposed to the experimental variable. p. 10
10. ________________ ________________ is a process that allows us to analyze problems, assertions, conclusions, and research, distinguishing beliefs from knowledge. p. 13

THINKING CRITICALLY ANALYSIS

This analysis corresponds to the Thinking Critically scenario that was presented at the beginning of this chapter.

This experiment has several major flaws. First, the boy used chickens from two different farms, so the chickens could have been genetically dissimilar. Differences in genetics could have been responsible for the differences in cholesterol content in the eggs. Second, although differences were found in the cholesterol content of the eggs of the two groups, we don't know if they were statistically significant. Good statistical analysis is necessary to determine whether measured differences are substantial enough to be attributable to the treatment. Another problem is the small sample size. Before I donated any money to this new venture, I'd want to see it performed on a larger group of genetically similar chickens. The fourth problem is that no mention was made of the differences between the two feeds. A careful analysis is essential to solidify one's confidence.

Clearly, this simple experiment has some flaws, but there's an even larger problem that we haven't addressed yet—notably the underlying supposition that cholesterol in eggs raises blood cholesterol levels. As it turns out, the liver produces lots of cholesterol. It's responsible for most of the cholesterol floating around in our bloodstreams. Furthermore, recent studies have shown that eggs don't contain as much cholesterol as was once thought and that eating foods rich in saturated fat (like hamburgers and bacon) is linked to elevated cholesterol levels in your bloodstream. (You'll learn more about this in Chapter 5 on nutrition.) Because of these findings, the American Heart Association has raised its recommendation for egg consumption from three a week to one a day for healthy people. To control cholesterol, you're better off cutting back on foods that have a high content of saturated fat like hamburgers and bacon.