CHAPTER 1

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What Is Life?

Every day there is a new report on how to maintain or improve your health. These reports are changing the way we think about our health. As proof of this, look at the rise in popularity of personal fitness tracking devices. Between Fitbit's launch in 2009 and the introduction of four new devices in 2016, Fitbit has become a multi-billion dollar industry. Obviously people are interested. Does a monitoring device that tracks your every movement really help you improve your overall health? That remains to be seen, with current research indicating that activity trackers do little to motivate otherwise non-athletic people to take up any form of exercise. Perhaps the largest benefit of these devices is the interest they have generated in personal health.

It is a great idea to try to monitor and improve your fitness, but wading through the incredible amount of literature and propaganda on health-related issues can be daunting. To really understand what is being presented, you must be able to scientifically evaluate advertising claims, medical breakthroughs, and social media hype. Taking advantage of the critical thinking guides throughout this book will help you practice the skills needed to become a knowledgeable consumer!

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CHAPTER OUTLINE

1.1 Living Organisms Display Nine Specific Characteristics

LEARNING OBJECTIVES

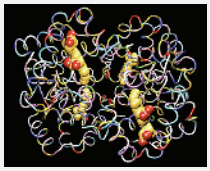
1. **List** the characteristics of life.
2. **Define** homeostasis and relate it to the study of life.
3. **Describe** how homeostasis plays a role in everyday activities.
4. **Contrast** negative and positive feedback systems.

Reflect on the start of your day. It has demonstrated many of the characteristics of life (**Table 1.1**). Several of these characteristics appeared during your first minutes of awakening. Life is defined by the ability to **respond to external stimuli** (remember waking to the alarm?). Objects that are alive can **alter their environment**, as you did by silencing the dreadful noise. You **sensed your environment** when you felt the chill of the morning, then you **adapted to your environment** by covering yourself with clothes to maintain your internal temperature. Living things **require energy**, which plants get by synthesizing compounds using solar power and which animals get by ingesting nutrients, aka breakfast. All of us are proof that living organisms **reproduce**. On the average foggy-headed morning, you undoubtedly failed to notice three other characteristics of life: (1) Life is composed of **materials found only in living objects** (your body contains proteins, lipids, carbohydrates, and nucleic acids—DNA and RNA); (2) living organisms maintain a stable internal environment, a property called **homeostasis**; and (3) life exhibits a **high degree of organization**, which extends from microscopic units, called **cells**, in increasingly complex **tissues**, **organs**, **organ systems**, and individual organisms.

Living Things Must Maintain Homeostasis

One key element of life is **homeostasis**, a word that means "staying the same" (*homeo* = unchanging; *stasis* = standing). Humans,

TABLE 1.1 Characteristics of life

Respond to external stimuli  Joel Sartore / NG Image Collection	Adapt to the environment  Masterfile	Contain materials found only in living organisms  Dr. Tim Evans / Science Source
Alter the environment  Image Source / John Harper / Getty Images, Inc.	Use energy  Skip Brown / NG Image Collection	Maintain a constant internal environment (homeostasis)  Stacy Gold / NG Image Collection
Sense the environment  Joel Sartore / NG Image Collection	Reproduce  Richard Lord / The Image Works	Have a high degree of organization  Photodisc / Rubberball / Getty Images

cell The smallest unit of life, contained in a membrane or cell wall.

tissue A cohesive group of similar cells performing a specific function.

organ A structure composed of more than one tissue having one or more specific functions.

organ system A group of organs that perform a broad biological function, such as respiration or reproduction.

Health, Wellness, and Disease

Homeostasis Is a Way of Life!

We have all felt tired or "out of sorts" at one time or another. Often, when we experience these episodes, we are functioning under a slight homeostatic imbalance. One accepted definition of disease is, in fact, a homeostatic imbalance with distinct signs and symptoms. Symptoms are the series of complaints we generate when we begin to feel ill. They include headache, nausea, fatigue, and muscle aches. Signs are the changes in bodily function that can be detected by a medical professional. Signs of homeostatic imbalance usually include a full description of the blood chemistry of the individual as well as tests of hormone levels and function.

There are many examples of subtle homeostatic imbalances that, if left unchecked, can lead to serious complications. For example, feeling tired may be due to a lack of oxygen-carrying capacity in the blood, a condition known as anemia. Adding iron to your diet might be all that is needed to reduce chronic fatigue.

Some people require regular food intake to maintain their homeostatic sugar balance. If they wait too long between meals, they may experience nervousness, sweating, trembling, and inability to concentrate, all caused by low blood sugar. Hypoglycemia is the clinical diagnosis for this. The brain responds very strongly to the lack of sugar, and will intensify feelings of hunger so that blood sugar does not reach critical levels. If there is no food immediately available, blood sugar may drop below 50 mg/dl causing more serious complications such as confusion, drowsiness, coma, or seizure.

Recent studies show that the onset of Alzheimer's disease may be heightened by an imbalance of the copper, iron, and zinc ions in the brain. Treatment for early signs of Alzheimer's disease includes restoring metal homeostasis. Patients whose metal balance is regulated experience a slower progression of the disease.

along with other organisms, can function properly only if they stay within narrow ranges of temperature and chemistry. Homeostasis allows you to respond to changes in your internal environment by modifying some aspect of your behavior, either consciously or unconsciously. When you are chilled, you consciously look for ways to warm yourself. This morning, you clothed yourself in an attempt to remain warm. If your clothing was not enough, your body would begin to shiver to generate internal heat through chemical reactions. Blood vessels near the surface of your skin would constrict and carry less blood, thereby reducing heat loss through **radiation**. These changes are attempts to maintain homeostasis. Each response to the chill is designed to remove or negate that feeling, in a typical negative feedback loop. (See *Health, Wellness, and Disease: Homeostasis Is a Way of Life!*)

Homeostasis Helps an Organism Stay Alive

Homeostasis helps an organism stay alive, often through the use of **feedback systems**, or loops, as shown in **Figure 1.1**. The most common type of feedback system in the human is **negative feedback**. Negative feedback systems operate to reduce or eliminate the changes detected by the stimulus receptor. Negative feedback prevents you from breathing fast enough to pass out or from drinking so much water that your blood chemistry becomes dangerously unbalanced. Positive feedback systems are rare in the body and include childbirth and blood clotting. The response in a positive feedback system serves to amplify the original stimulus. Feedback is so important that we will return to it when we discuss each organ system.

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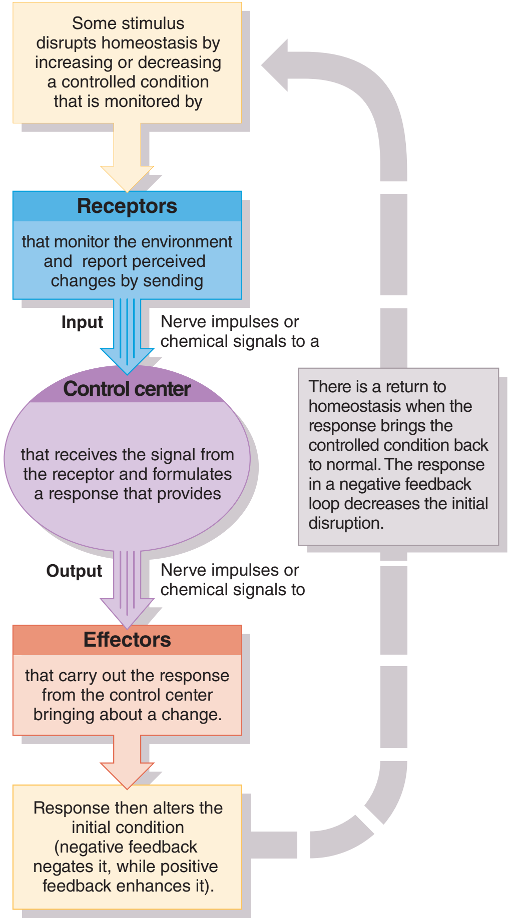
radiation The transfer of heat from a warm body to the surrounding atmosphere.

FIGURE 1.1 Feedback loop A simple homeostatic feedback loop has three main components that function as a whole to manipulate the environment.



Concept Check

1. **How** do you display characteristics that indicate you are living?
2. **Why** might a biologist want to understand the normal homeostatic ranges of her study subject?
3. **How** does homeostasis play a role in everyday activities?
4. **What** type of feedback is exemplified by the maintenance of blood calcium levels within a small range?

1.2 Human Biology Is Structured and Logical

LEARNING OBJECTIVES

1. **Explain** how atoms, and therefore the entire field of chemistry, relate to the study of life.
2. **Describe** the organizational pattern of all biology and the logic of taxonomy.
3. **Relate** taxonomy to human biology.
4. **List** the five processes that are most helpful in studying human physiology.

One of the oldest techniques for dealing with our world is to categorize it and divide it into manageable chunks. Imagine trying to understand this paragraph if the sentences were not divided into words through the use of spaces. Similarly, the natural world seems overwhelming and chaotic until we organize it. Biology is organized in steps, from microscopic to macroscopic: Small units make up larger units, which in turn form still larger units. We see this in both artificial and natural organization in biology. In artificial classification (taxonomy), a system of names is used to identify organisms and show their genetic relationship.

These names identify individual species and also group organisms, based on similar characteristics. The categories from species through genus, family, order, class, phylum, kingdom, and domain indicate groups of similar organisms, with each category broader than the last.

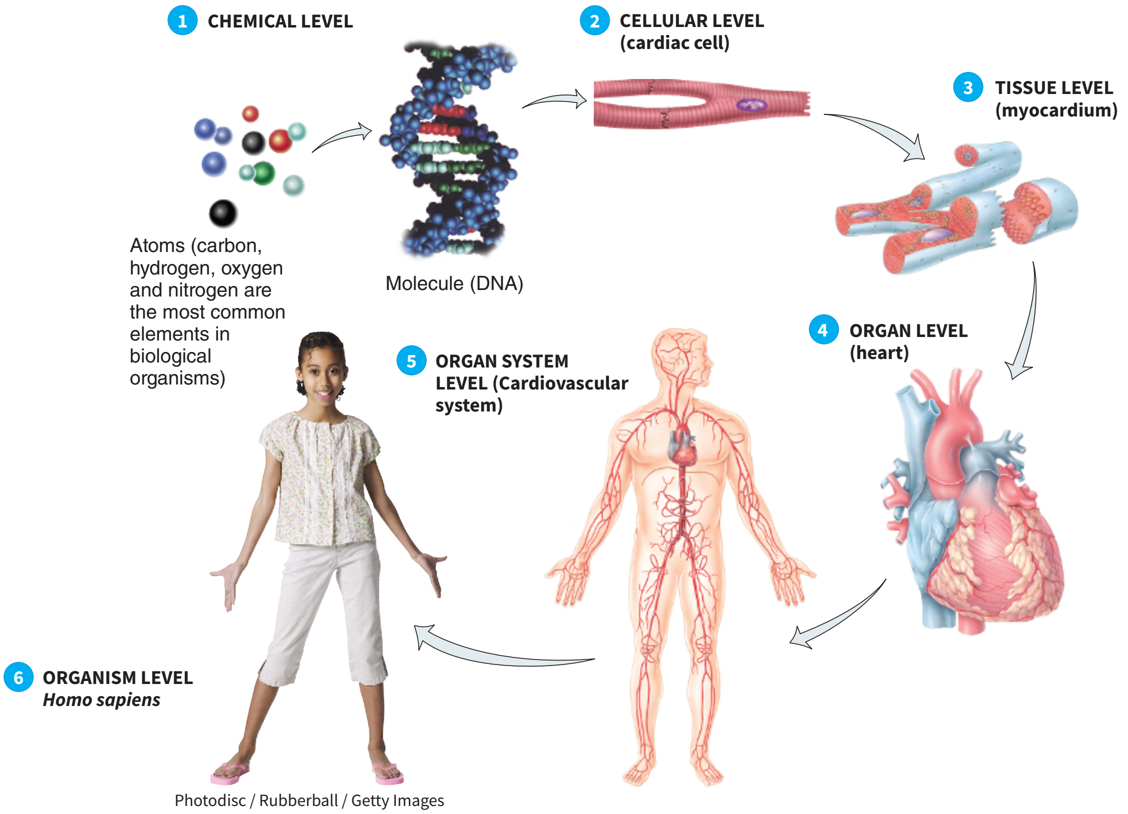
Organisms Are Structured

Natural organization emerges from the structure of organisms. Both natural and artificial organization help us make sense of the living world. Natural organization appears in the human body as it does in the rest of the living realm. Natural organization is based on a system of increasing complexity. Each level in the hierarchy is composed of groups of simpler units from the previous level, arranged to perform a specific function. The smallest particles that usually matter in biology are atoms, as shown in **Figure 1.2**. An atom is defined as the smallest unit of an element that has the properties of that element. Atoms combine to form molecules–larger units that can have entirely different properties than the atoms they contain. You already know some of the molecules we will discuss, such as water, glucose, and DNA. Molecules combine to form **cells**, which are the smallest unit of life. We will take a closer look at cells in Chapter 4. Groups of similar cells with similar function combine to form **tissues**.

The human body has four major tissue types: muscular, nervous, epithelial, and connective. Tissues working together form organs, such as the kidney, stomach, liver, and heart. **Organs** with the same general function combine to form **organ systems**. For example, the respiratory system includes organs that work together to exchange gas between cells and the atmosphere; organs in the skeletal system support the body and protect the soft internal organs. A suite of organ systems combine to form the human **organism**. Notice that each layer of complexity involves a group of related units from the preceding layer. This type of hierarchy is found throughout biology and the natural world.

Taking a global view of the organization found in the natural world, we see that the concept of hierarchy does not stop at the individual. The individual human organism lives in groups of humans called **populations**, as shown in **Figure 1.3**. Beyond populations are larger and more inclusive groups called communities, ecosystems, biomes and the biosphere.

FIGURE 1.2 **Hierarchy of organization of life** In the hierarchy of biology, each level gains in complexity, and demonstrates new properties. These emergent properties arise as smaller units interact, with consequences unattainable by the previous level.



Photodisc / Rubberball / Getty Images

Natural organization: from atom to organism

1. Chemical level: the chemical "components" that are arranged into cells (atoms to molecules)
2. Cellular level: the smallest unit of life; a component bounded by a membrane or cell wall; in multicellular organisms, cells are usually specialized to perform specific functions (for example, cardiac muscle cell)
3. Tissue level: an assemblage of similar cells (for example, cardiac muscle tissue, myocardium)
4. Organ level: an assemblage of tissues that often have several functions (for example, heart)
5. Organ system level: the group of organs that carries out a more generalized set of functions (for example, cardiovascular system)
6. Organism level: Homo sapiens

population All representatives of a specific organism found in a defined area.

FIGURE 1.3 **Hierarchy of life beyond the individual** Living organisms are grouped beyond the individual, to include populations, communities, ecosystems, and the all-inclusive biosphere.

James L. Stanfield / NG Image Collection

a. Individual or species

Raga Jose Fuste / Prisma / SuperStock

b. Human Population
Populations are composed of all individuals of a given species in a specified area.

Dugald Bremner Studio / NG Image Collection

c. Biological Community
Human populations live in concert with populations of other organisms, interacting in a larger concept called the community.

Raymond Gehman / NG Image Collection

d. Ecosystem
Communities are united in geographic areas, interacting with one another and the physical environment in a biome. Earth has many biomes, such as the open ocean, high sierra, desert, and tropical rain forest.

Todd Gipstein / NG Image Collection

e. Biosphere
Finally, all Earth's biomes comprise the biosphere.

Biological Classification Is Logical

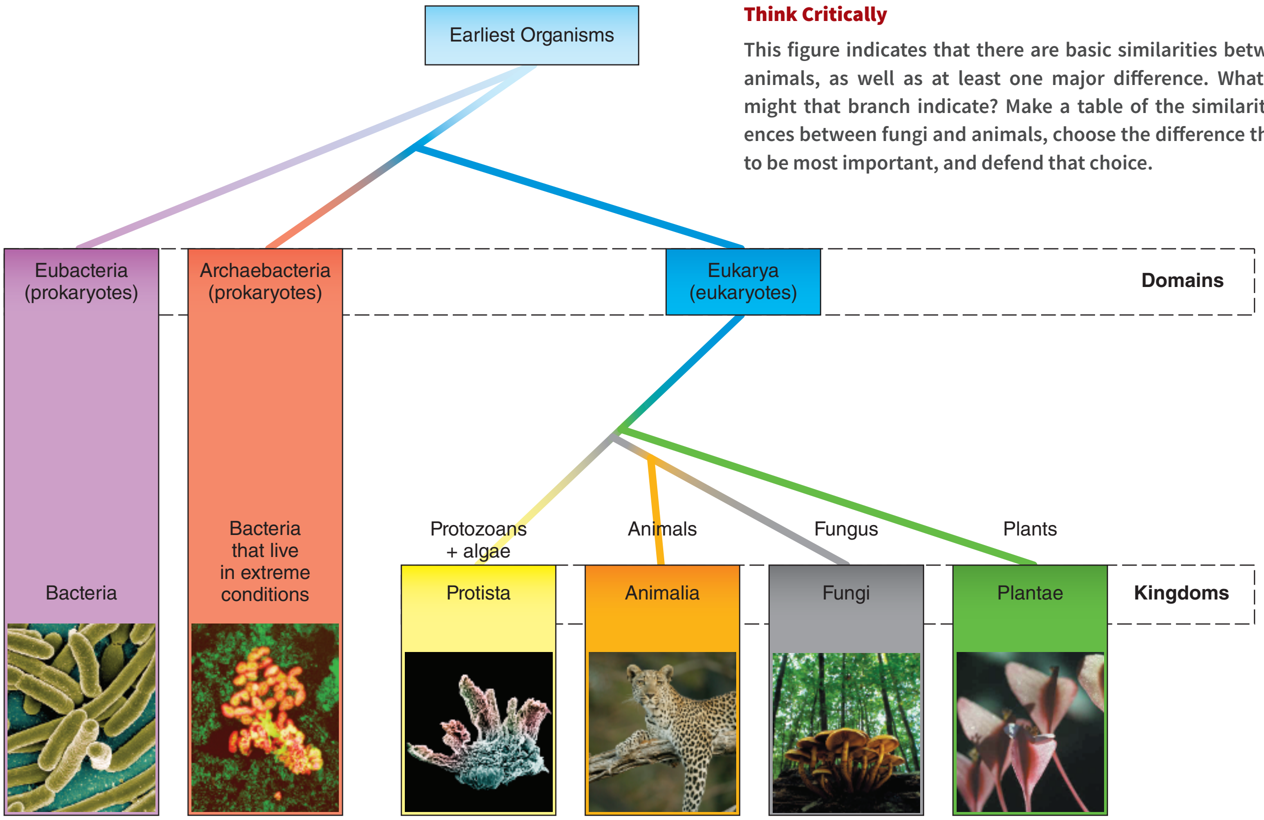
Biology tries to make sense of myriad observations of the biosphere by classifying organisms into groups with similar characteristics. The branch of science that deals with this organizational scheme is called **taxonomy**. One of the best-accepted taxonomic schemes starts from the most inclusive, with three domains and six **kingdoms** (see **Figure 1.4**). The domain Eukarya includes organisms whose cells contain nuclei and internal membranes. The four kingdoms in Eukarya are **Animalia** (the animals), **Plantae** (the plants), **Fungi** (the fungi), and **Protista** (the one-celled organisms that possess nuclei). The two remaining kingdoms are the prokaryotic **Eubacteria** and **Archaebacteria** (the bacteria and other one-celled organisms without nuclei). It is worth noting that unlike bacteria, viruses are not classified as living–see *I Wonder. . . Are Viruses Considered Living Organisms?* on the next page.

Each kingdom is further classified, based on similar characteristics, into divisions that get ever more narrow: **phylum**, **class**, **order**, **family**, **genus**, and **species**. Each category defines the organisms more tightly, resulting in a hierarchy of similarity. The final category, species, implies reproductive isolation, meaning (with very few exceptions) that members of a particular species can produce **viable** and fertile offspring only if they breed with each other.

Taxonomists capitalize the first letter of all classification terms except species (*Homo sapiens*). The species name is always preceded by the entire genus name, unless you have just mentioned the genus; then you can abbreviate it: "In regard to *Homo sapiens*, we must note that *H. sapiens* . . ." Genus and species names are either underlined or written in italics, as shown in **Figure 1.5**.

Each successive category refines the characteristics of "human" to the point where only humans are classified in the final category, *Homo sapiens*. Despite the amazingly complex and pervasive cultural

FIGURE 1.4 Domains and kingdoms There are three Domains into which all living organisms are classified.



Think Critically

This figure indicates that there are basic similarities between fungi and animals, as well as at least one major difference. What characteristic might that branch indicate? Make a table of the similarities and differences between fungi and animals, choose the difference that you believe to be most important, and defend that choice.

From left to right: NIAID / CDC / Science Source; T. Stevens & P. McKinley, PNNL / Science Source; Dr. Richard Kessel / Getty Images; Beverly Joubert / NG Image Collection; Norbert Rosing / NG Image Collection; Raymond Gehman / NG Image Collection

taxonomy The study of classification, based on structural similarities and common ancestry.

kingdom A high-level taxonomic classification.

species A precise taxonomic classification, consisting of organisms that can breed and produce offspring capable of breeding.

viable Capable of remaining alive.

I Wonder. . .

Are Viruses Considered Living Organisms?

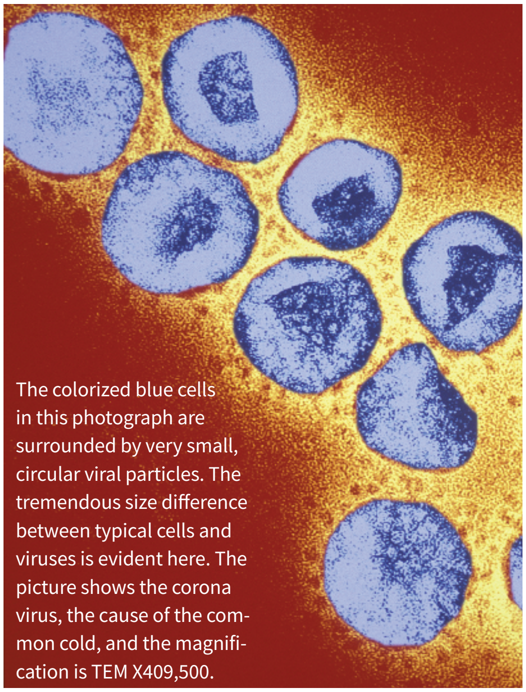
Viruses are among the smallest agents that can cause disease, and they cause some of the worst diseases around. Scientists think that smallpox, caused by the variola virus, killed more people in the past few centuries than all wars combined. HIV, human immunodeficiency virus, is thought to cause AIDS, whose death toll continues to mount year after year.

Because viruses are less than 1 micron (millionth of a meter) across, they were not discovered until early in the 19th century. Viruses are much smaller than bacteria, which are single-celled organisms that are truly alive.

We know viruses can kill. To determine whether they are alive, we refer to the required characteristics of life, and we observe that viruses lack many of them, such as:

- Cells (a virus is basically a protein coat surrounding a few genes, made of either DNA or RNA);
- The ability to reproduce;
- The ability to metabolize or respire; and
- A mechanism to store or process energy.

Viruses can reproduce but only if they can slip inside a host cell and seize control of its internal machinery. Viruses are more complex than prions, the distorted proteins that cause bovine spongiform encephalopathy—mad cow disease. However, viruses are far simpler than even a bacterial cell. So although viruses are not alive, they are the ultimate parasite.



The colorized blue cells in this photograph are surrounded by very small, circular viral particles. The tremendous size difference between typical cells and viruses is evident here. The picture shows the corona virus, the cause of the common cold, and the magnification is TEM X409,500.

Dr. Gopal Murti / Getty Images

FIGURE 1.5 **Human taxonomy** Meet your human taxonomy

KINGDOM
Animalia
(all multicellular organisms that ingest nutrients rather than synthesize them)

PHYLUM
Vertebrata
(all animals with a vertebral column or **dorsal hollow notocord**—a structure along the back of animals—that protects their central nervous system)

CLASS
Mammalia
(all vertebrates with placental development, mammary glands, hair or fur, and a tail located past the anus)

ORDER
Primates
(mammals adapted to life in trees, with opposable thumbs)

FAMILY
Hominidae
(primates that move primarily with bipedal—two-footed—locomotion)

GENUS
Homo
(hominids with large brain cases, or skulls)

SPECIES
H. sapiens
(The only living organisms in our species, with a unique set of combined characteristics from our family [bipedal], order [opposable thumbs], and genus [large brain case])

From left to right: George Grall / NG Image Collection; Tim Laman / NG Image Collection; Joel Sartore / NG Image Collection; Karine Aigner / NG Image Collection; Kenneth Garrett / NG Image Collection; Kenneth Garrett / NG Image Collection; Mark Cosslett/ NG Image Collection differences that exist between populations of humans, we are all members of the same species.

It is human nature to group similar ideas, processes, and organisms to make sense of the seemingly complex world in which we live. Just as there are characteristics that can be identified as common to all life forms in the domain Eukarya, there are basic processes that can be identified as common to the study of human physiology. There are arguably five basic processes on which human physiology hinges: osmosis and diffusion, energy transfer and storage, protein functioning, DNA actions, and cellular structure and function.

Osmosis and diffusion appear in Chapter 4. These processes are integral in the respiratory, digestive, urinary, and nervous systems. Energy transfer and storage are all about chemical bonds. The flow of energy through the biological world, introduced in Chapters 2 and 3, relies on this simple process. Humans are composed of both structural and functional proteins, introduced in Chapter 3. Structural proteins protect and maintain organ shape, hold our skin in place, and provide flexibility to bone. Functional proteins are the basis of digestion, oxygen transport, muscle contraction, immunology, endocrinology, and even reproduction. DNA is introduced in Chapter 3 and discussed in greater detail in Chapter 21. Molecular biology is the backbone of inheritance, evolution, and biotechnology. Cellular structure and function is the topic of Chapter 4. Understanding how organelles function and what differentiates cell types underlies every process we will study. As you go through the physiology presented in this book, the basic underlying process will be indicated. This will make it easier for you to understand the larger, more complicated processes by allowing you to relate them to their most basic components.

Concept Check

1. **How** do atoms relate to the study of life?
2. **What** is the largest taxonomic group that apes and humans share? What is the smallest taxonomic group they share?
3. **What** can you discover about an organism by comparing its full taxonomic classification to that of a human?
4. **How** will mastering protein functioning help in understanding other processes?

1.3 Scientists Approach Questions Using the Scientific Method

LEARNING OBJECTIVES

1. **List** the steps in the scientific method in order.
2. **Define** hypothesis and theory.

Science is a field with specific goals and rules. The overall goals are to provide sound theories regarding the phenomena we observe, using rules embodied by the **scientific method**. When a question arises about the natural world, the scientific method provides the accepted, logical path to the answer, as shown in **Figure 1.6**.

A scientific experiment is an exercise in logic: Our goal is to prove our hypothesis wrong. In the example below, our hypothesis is that the rooster's crow causes the sun to rise within the next 20 minutes. How could we test this hypothesis? Could we force the rooster to crow at midnight and wait 20 minutes for a glow on the eastern horizon? Could we prevent the rooster from crowing in the morning? In either case, if the sun rose as usual, our hypothesis would be disproved, and we would need to find a better hypothesis.

This silly example shows how scientists may manipulate factors that (according to the hypothesis) seem related to the observation, all in an attempt to disprove the hypothesis. We develop a hypothesis using **inductive reasoning**–creating a general statement from our observations. We design the experiment, however, with **deductive reasoning**, moving from the general hypothesis to a specific situation. An "if, then" statement is an ideal basis for a scientific experiment: "If situation A (rooster crows) occurs, then result B (sunrise) will follow." In our experiment, we changed situation A and monitored any changes in result B.

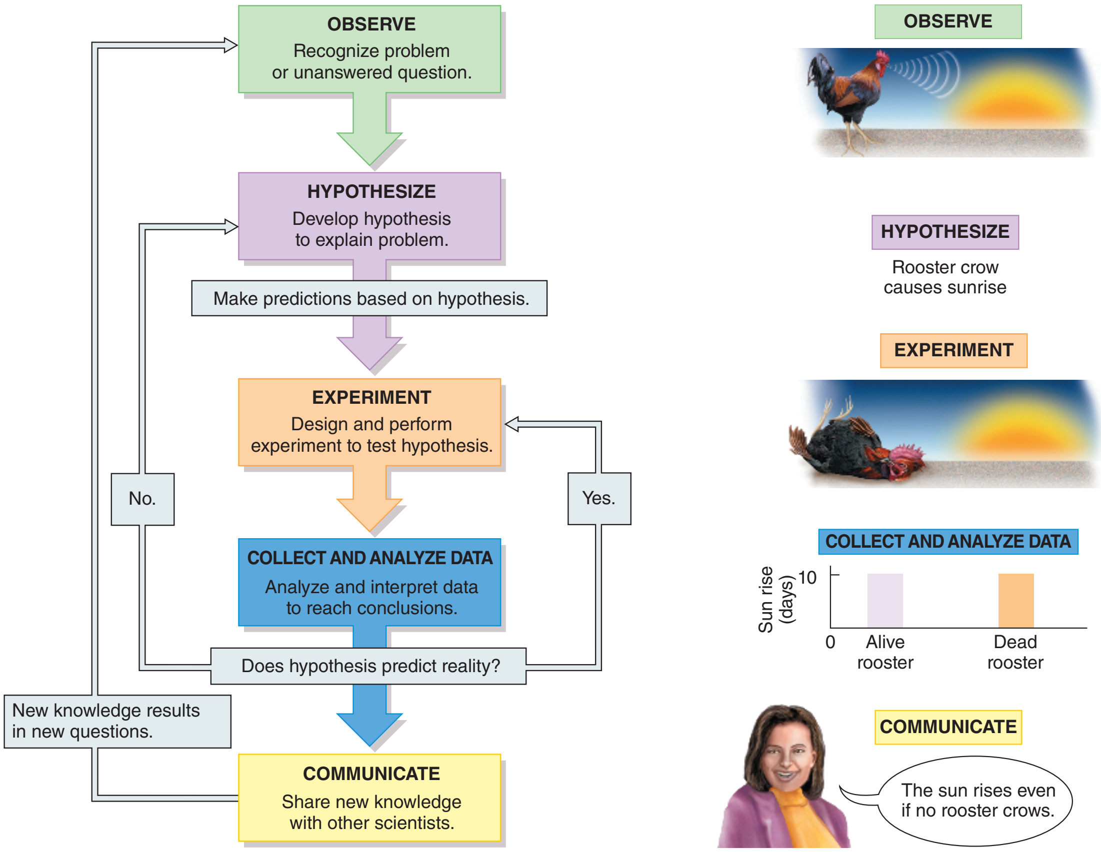
When designing and running an experiment, we must control all potential **variables**. Otherwise, we cannot draw any valid conclusions. In the rooster example, it would be a good idea to muzzle all nearby roosters. Otherwise, how would we know whether our bird or a bird in the next chicken coop had caused the sunrise? Similarly, in testing new medicines, scientists use a "double-blind" experiment: Only the scientist knows whether each research participant is getting real medicine or a fake, called a "placebo." Neither the patients nor the prescribing doctor know whether the patient is being given the drug or a placebo. This prevents expectations that the drug will work from actually causing a change in the participant's health. The placebo effect can be powerful, but the goal is to test the drug, not the research participant's expectations.

Finally, our hypothesis must be testable and falsifiable. If we cannot think of a situation where we could disprove it, there is no experiment to devise. Learning to assess situations with the scientific method takes some practice, but it's a skill that can be useful throughout life.

variable A factor that can be changed in an experiment to test whether and how it affects the outcome.

PROCESS DIAGRAM

FIGURE 1.6 The scientific method The scientific method is rooted in logic. If we can show that our hypothesis does not apply to even one situation, then our hypothesis is wrong. After we analyze the data and draw conclusions, we may have to throw out our hypothesis or conclude that it applies to a more limited range of circumstances.



Adapted from Visualizing Environmental Science by Linda R. Berg and Mary Catherine Hager, John Wiley & Sons Inc. Copyright 2007

Let's take an example from human biology to show the process of testing a hypothesis. Have you seen those hand lotions that claim to be "skin firming"? Sounds great, but how would we test this claim? Under the scientific method, we consider the marketing claim to be the observation, so we must develop a testable hypothesis from the observation: "Using this hand cream for one month will cause measurable tightening of the skin on the back of the hand." Now we restate the hypothesis as an "if, then" statement: "If the cream does firm the skin, then using the cream on the back of the hand for one month will reduce the skin-fold measurement." This is a testable statement that lends itself to controlled experimentation. First, we will assess each person's skin tautness by measuring the amount of skin that can be pulled up on the back of the hand. Then we will randomly divide the participants into two groups: a control group and an experimental group. We will treat each group in an identical manner, except that the control group will use Brand X hand cream without the firming agent, and the experimental group will get Brand X with the firming agent. After using the cream for one month, we will repeat the skin-fold measurements and analyze our data, looking for changes in skin tautness between the two groups as evidence for either accepting or refuting the hypothesis. If the experimental group displays an increase in tautness that would occur by chance in less than 1 experiment in 20, the change is said to have **statistical significance**, and the hypothesis is supported: The cream does tighten the skin.

It is important to note that any conclusions drawn from a scientific experiment must be supported by the data. If the results of your experiment could have happened by chance, you cannot say that the results were due to the experimental design. In that case, a new experiment must be designed and run.

Because biologists cannot always control all factors, or variables, that might affect the outcome, they often use observation as a form of

statistical significance An experimental result that would occur by chance in less than 1 experiment in 20; the accepted level in modern science.

experimentation. If you were interested in the effects of mercury on the human brain, it would not be ethical to dose people with mercury, but you could perform an observational study. You could measure blood levels of mercury, or you could ask your research participants about past diet. (Food, especially fish, is the major source of mercury exposure.) Then you would use statistical tests to look for a relationship between mercury exposure and intelligence. Finally, you could try to confirm or refute your results with controlled experiments in lab animals. Does mercury make rats faster or slower at negotiating a maze (a standard test for rat intelligence)? Observational studies are also a mainstay of field biology.

The Scientific Method Leads to Theories

Observation, experimentation, and analysis are the basis for scientific reasoning. Once a group of related hypotheses have survived rigorous testing without being disproved, they are accepted as a **theory**. Theories are not facts but rather extremely well supported explanations of the natural world that nobody has disproved. To a scientist, a theory is much more than a hypothesis or a belief–it's our best effort to date to explain nature. Many fields of science may be involved in supporting a theory. The theory of evolution through natural selection, for example, is supported by taxonomists, geologists, paleontologists, geneticists, and even embryologists. Many scientists have tried, but none has refuted the basic hypothesis first described by Charles Darwin in 1859. We will discuss another key theory, the cell theory, in Chapter 4.

Science is not a perfect, set-in-stone answer to questions about the natural world but rather a dynamic, ever-changing collection of ideas. New information can change or destroy accepted explanations for the natural world. For example, doctors once blamed contagious disease on ill humors, miasmas, and evil spirits. Through the work of 19th-century biologist Louis Pasteur, it became clear that many diseases were caused by microscopic organisms. In his breakthrough experiment, Pasteur sterilized some grape juice and showed that it did not ferment into wine. Then he added yeast, and the juice fermented. When Pasteur showed through experiment that invisible organisms can also cause disease, he helped establish the germ theory of disease. Although it's called a theory, the germ theory is the universally accepted scientific explanation for infectious disease. More recently, the accepted role of the cell nucleus has come into question. Based on experiments, biologists used to consider the nucleus the cell's control center, but new evidence suggests that it actually functions more like a library for genetic data. The actual control of gene expression and cellular activity seems to reside outside the nucleus, in specific RNA molecules. The theory of nuclear control in the cell is under serious scrutiny, and further experiments could alter it.

Scientific studies are part of the daily news. As technology advances, humans confront scientific hypotheses and experimental results almost every day. We see advertisements for new drugs. We hear that fossil fuels are warming the globe. We see countless new technologies in the field of consumer electronics. In medicine, we hear about a steady stream of new surgeries and wonder drugs. We are told of many ways in which humans are causing the loss of rain forests, coral reefs, natural forests, and plains, as well as the animals that live there. We worry about the causes of animal extinction (see *Ethics and Issues: Why Should Endangered Species Matter to Me?* for a discussion of this). About the only way to wade through the morass of information in the media is to understand and use the scientific process. Responsible citizens living in technological cultures sometimes must make decisions about contested scientific issues they read about in the media. Some reports have linked the radiation from cell phones to brain tumors, but other reports find no connection. A few concerned citizens have demanded that manufacturers produce "safer" cell phones, with lower radiation emissions. Can you think of an experiment that would resolve this issue, at least in principle? Would this be best answered by an observational or experimental approach? As you read about scientific studies on current issues, ask yourself: What types of controlled and observational experiments underlie the claims being made? Are the experiments convincing?

Critical Reasoning Is Useful in Human Biology

The ability to question and criticize–for example, our constantly changing understanding of obesity or the dangers posed by food additives or environmental chemicals–is useful in many aspects of human biology. Critically analyze the data, experiments, and claims before you accept what you read. There are plenty of opinions out there; don't accept any until you consider the evidence and reach an informed decision. Form your own opinion based on what you understand to be true.

In other words, become a critical reasoner! Critical reasoners are skeptical, logical, and open to new information, enjoying the way it changes their previous assumptions and ideas. Critical reasoners question assumptions and stated facts, using logic to arrive at their own conclusions. They find good analogies for information that they find to be true, often helping others make sense of the new information. Taking on the role of a critical thinker means recognizing that you don't have to settle for a story or a very small sample size when looking for facts about an issue. You should ask yourself, "Were there enough trials done to see that the results were repeated consistently?" Also, critical reasoners know that there are limits to certainty but do not allow this knowledge to prevent them from seeking as full an understanding of an issue as possible.

People have the ability not only to communicate in complex ways but also to record the past. We can consult studies, relate current affairs to similar historical events, and use statistics to support our reasoning. In so doing, we understand that the past proves the law of unintended

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theory A general uniting principle of science, upheld by observation and many experiments.

Ethics and Issues

Why Should Endangered Species Matter to Me?

About 20 years ago, biologists began to worry that they may start to run out of things to study due to the accelerating wave of extinctions shaking the planet. Extinctions occur for many reasons: Overhunting, destruction of habitat by fire, construction, ecological change, and invasion of exotic species can all play roles.

What's the big deal? Some extinction is natural, after all. Why is it important to prevent endangered species from going extinct? The answers range from scientific to economic to spiritual:

- Organisms can be useful. A species of plant called the rosy periwinkle was the source of a key drug that defeats one type of leukemia. Scientists are actively looking in many unusual ecosystems for useful chemicals that organisms have evolved for specific reasons. Many antibiotics, for example, were derived from fungi that evolved these compounds for protection against bacteria.
- Life is unique. As far as we know, this is the only planet with life. If we respect life, we should respect its myriad forms as well: the whales, swans, lobsters, and even the endangered fish and mussels in our streams.
- Life has scientific value. To understand the wonders of evolution, we need to study the results of evolution.
- Life is a web. Organisms in the wild have complex interactions that we are only beginning to understand. Extinguishing one organism can have cascading effects throughout an ecosystem.

It's hard to know exactly how far along we are in the current wave of extinction because biologists are not even sure how many species inhabit Earth. So far, about 1.9 million species have been described, but it is estimated that the total number is several times that. The World Conservation Union reports that 748 species are already extinct, and another 16,119 are threatened with extinction. These threatened organisms include one in three amphibians, one in four coniferous trees and mammals, and one bird in eight. The group also notes that "56% of the 252 endemic freshwater Mediterranean fish are threatened with extinction."

Beverly Joubert / NG Image Collection

Critical Reasoning Issues

Different organizations and governmental agencies may use different data to define *endangered.* For some, the term may refer to species of which fewer than 500 breeding pairs are known in a certain country; for others, the data set may encompass the whole continent. Knowing the expertise and motives of an organization or agency may be crucial to understanding how it uses and presents data. However, regardless of technical definitions of *endangered*, some of the organisms that are currently becoming extinct are ones we have not even yet identified, let alone studied. Their beauty and utility will go completely unrecognized as they fade from existence. Although evolution may eventually restore biodiversity to its current levels, that will take millions of years. Thus, in biodiversity, as in so many other things, a gram of prevention is worth a kilo of cure!

Think Critically

1. **What examples can you find of a government agency or organization that does not specify its definition of "endangered" and "threatened with extinction"?**
2. **What are some other reasons to value biodiversity besides the ones mentioned?**

consequences—that actions often have unexpected effects. For example, using naturally cool stream water as an industrial plant coolant saves money and seems to be a good use of the available resources. However, the practice dramatically increases the temperature of these streams below the plant. The temperature increase, in turn, changes the population of organisms that are able to survive there and often alters the productivity of the entire watershed below the plant.

Critical reasoning is not the kind of thinking illustrated by the fact that 87% of people rate themselves above average in intelligence. It is also not illustrated by the notion that because a woman was cured of her epilepsy after being bitten by a rattlesnake, the venom caused the cure. Rather, critical reasoning is the best way to understand complex interactions such as those that take place within the human body and between the body and its external environment. Studying human biology is the perfect way to practice your critical reasoning skills, as you will be investigating the most complex system we know—ourselves and our relationship to our environment.

Concept Check

1. **Why** must scientists constantly refine their hypotheses when conducting experiments?
2. **What** is the difference between a hypothesis and theory?

1.4 Scientific Findings Often Lead to Ethical Dilemmas

LEARNING OBJECTIVES

1. **Define** altruistic behavior.
2. **Briefly describe** why a basic knowledge of science is essential to being a productive citizen.

Humans have evolved as social animals, following the rules and expectations that make life possible in groups. This cultural structure that overlies the biological structure of human life certainly adds interest to our study of human biology. Culture generally requires that people accept responsibility for other individuals within the population rather than merely surviving and protecting their young. Although **altruistic** behavior does appear among some primates, it helps distinguish humans from other life-forms and creates one basis for the governments and laws people have established.

When individuals must make judgments and act for the good of the group rather than the individual, they must make **ethical decisions**, and ethical decisions should be informed decisions. Where does that information come from? Scientific research provides our basic understanding of the natural world. Although humans can and do add their interpretations and values to the results of science, science itself is judgment free. Scientific results are neither good nor bad; they are just the best current idea of how the material world operates. The discovery by Pasteur and his peers that germs cause many diseases was neither good nor bad–it was just true. The ability to analyze scientific issues is essential in an informed society and turns out to be more important as scientifically based issues become even more common and complex. Science seeks to explain the natural world, but the uses of science, both beneficial and harmful, grow from human choices. Sometimes people choose to use scientific discoveries to improve the environment and the human condition, and sometimes they use them to carry out seemingly evil designs. One example of this can be seen in **Figure 1.7**. Another example of this dual edge is the understanding that germs cause disease. Pasteur's germ theory of disease can be used to help cure disease—or to invent biological warfare.

Many ethically charged scientific issues–such as stem cell research, environmental conservation, and genetically modified food–have both

FIGURE 1.7 **Nuclear power** Nuclear power poses an interesting mix of scientific and political issues. Atomic fission can provide a large amount of energy, and it does not create greenhouse gases, which warm the globe and threaten harm to the biosphere. However, radioactive waste is dangerous, and nuclear plants can suffer accidents causing meltdowns that spew radiation. The decision to use nuclear power is a political decision, not a scientific one, so it is imperative that each member of society understands the scientific data on nuclear reactors, as well as the social ramifications of that information. Nuclear power has pluses and minuses. To take a position, you should know about global warming, radioactive waste, and the costs and benefits of other technologies for making electricity—all scientific issues.

Raymond Gehman / National Geographic Creative

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altruistic Putting the needs of others ahead of, or equal to, personal needs.

ethical decision A decision based on the principles of right and wrong rather than on financial, personal, or political gain.

personal and political ramifications. Each of these requires an understanding of the science and the societal issues. An informed voting public requires that each individual draw logical and defensible conclusions from scientific information.

Concept Check

1. **Do** you feel that laws requiring the wearing of a helmet while riding a motorcycle are altruistic?
2. **Why** is it important to understand scientific information?

Summary

1 Living Organisms Display Nine Specific Characteristics 2

- Cell biology is the study of life. One characteristic of life is organization. Living things are organized from microscopic to macroscopic. All life is also composed of cells and is responsive to the environment. Life adapts, uses energy, and reproduces.
- Living organisms are composed of carbohydrates, lipids, proteins, and nucleic acids. In order to maintain life, these organisms must maintain a relatively constant internal environment, called "homeostasis." This is accomplished through a feedback system, including a receptor, a control center, and an effector. The usual feedback system in the body is a negative feedback system.

2 Human Biology Is Structured and Logical 4

- The natural organization of life on Earth is based on a system of increasing complexity. The base of this hierarchy is the atom, meaning that the basis of biology is actually chemistry. Atoms combine to form molecules. Molecules join together to form cells. Similar cells form tissues; tissues with a common function form **organs**; organs with similar functions form **organ systems**; and a group of organ systems all functioning together form an **organism**.
- **Taxonomy** is the study of classification. Organisms are classified based on shared characteristics. Each successive level gets more restrictive, until only one interbreeding species is described.
- The five basic processes underlying human biology are osmosis and diffusion, energy transfer and storage, protein functioning, DNA function, and cellular structure and function.

3 Scientists Approach Questions Using the Scientific Method 9

- Science is more a way of thinking than a body of knowledge.
- The steps of the scientific method include:
  - Observation: witnessing an unusual or unexpected phenomenon
  - Hypothesis: formulating an educated guess as to why the phenome-Hon occurs
  - Experiment: designing and running a controlled experiment to test the validity of the hypothesis
  - Collection of results and analysis: recording the results of the experimental procedure and determining the meaning of the results obtained from the experiment
  - Communication of the findings: preparing a paper, presenting a poster, or speaking about the results of the experiment

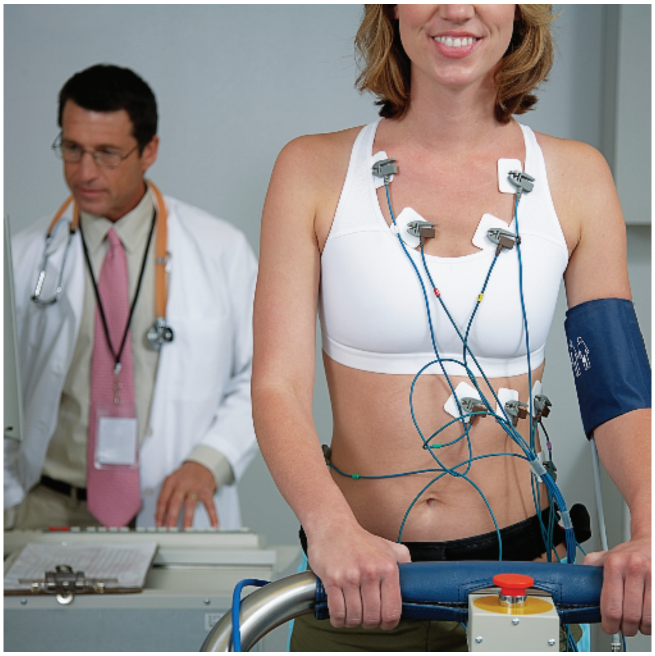
4 Scientific Findings Often Lead to Ethical Dilemmas 13

- Science in and of itself is neither inherently good nor bad. It is in the use of scientific principles that value judgments are made. Science can be used for either the betterment of society or its destruction.
- Individuals who understand the ramifications of a science are the ones who should decide about its use. In democratic nations, however, these ethical decisions are placed in the hands of the voters. In order to make the right choices, we must all understand at least a little bit about the functioning of the biological world in which we live. We must become critical reasoners.

Key Terms

- altruistic 13
- cell 2
- ethical decision 13
- kingdom 7
- organ 2
- organ system 2
- population 5
- radiation 3
- species 7
- statistical significance 10
- taxonomy 7
- theory 11
- tissue 2
- variable 9
- viable 7

What is happening in this picture?



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What is the Relationship between Exercise and Health

While it is well known that exercise increases muscle tone, the effect of strenuous exercise on other aspects of human physiology is not as clear. Here, scientists collect data on the heart rate, breathing rate, lung volume, and blood pH of an individual performing strenuous exercise.

Think Critically

1. **Devise a plausible hypothesis for the experimental data collection that you see here.**
2. **How might the results of the observations listed above (heart rate, breathing rate, lung volume, and blood pH) provide evidence of increased or decreased individual health following exercise?**