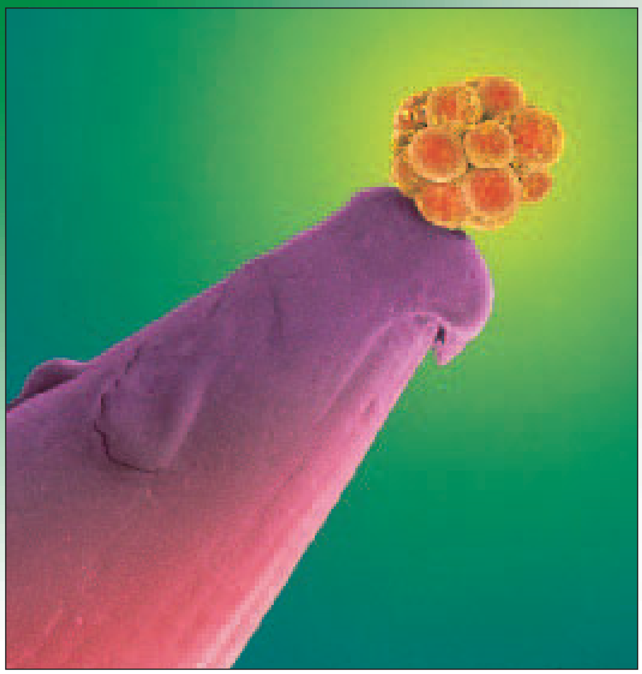


A new life begins—a human embryo on the point of a pin

CHAPTER

1

Major Themes of Anatomy and Physiology

CHAPTER OUTLINE

INSIGHTS

No branch of science hits as close to home as the science of our own bodies. We're grateful for the dependability of our hearts; we're awed by the capabilities of muscles and joints displayed by Olympic athletes; and we ponder with philosophers the ancient mysteries of mind and emotion. We want to know how our body works, and when it malfunctions, we want to know what is happening and what we can do about it. Even the most ancient writings of civilization include medical documents that attest to humanity's timeless drive to know itself. You are embarking on a subject that is as old as civilization, yet one that grows by thousands of scientific publications every week.

This book is an introduction to human structure and function, the biology of the human body. It is meant primarily to give you a foundation for advanced study in health care, exercise physiology, pathology, and other fields related to health and fitness. Beyond that purpose, however, it can also provide you with a deeply satisfying sense of self-understanding.

As rewarding and engrossing as this subject is, the human body is highly complex and a knowledge of it requires us to comprehend a great deal of detail. The details will be more manageable if we relate them to a few broad, unifying concepts. The aim of this chapter, therefore, is to introduce such concepts and put the rest of the book into perspective. We consider the historical development of anatomy and physiology, the thought processes that led to the knowledge in this book, the meaning of human life, and a central concept of physiology called *homeostasis.*

The Preface to Students describes some ways in which this book and its companion materials can be used to learn this subject most effectively. If you haven't already read it, I urge you to do so before continuing.

Figure 1.1 Early Medical Students in the Gross Anatomy Laboratory with Three Cadavers. Students of the health sciences have long begun their professional training by dissecting cadavers.

The Scope of Anatomy and Physiology

Anatomy is the study of structure, and **physiology** is the study of function. These approaches are complementary and never entirely separable. When we study a structure, we want to know, What does it do? Physiology lends meaning to anatomy and, conversely, anatomy is what makes physiology possible. This *unity of form and function* is an important point to bear in mind as you study the body. Many examples of it will be apparent throughout the book—some of them pointed out for you, and others you will notice for yourself.

Anatomy—The Study of Form

The simplest way to study human anatomy is the observation of surface structure, for example in performing a physical examination or making a clinical diagnosis from surface appearance. But a deeper understanding of the body depends on **dissection**—the careful cutting and separation of tissues to reveal their relationships. Both *anatomy*[1] and *dissection*[2] literally mean "cutting apart"; dissecting used to be called "anatomizing." The dissection of a dead human body, or **cadaver,**[3] is an essential part of the training of many health science students (fig. 1.1). Many insights into human structure are obtained from *comparative anatomy*—the study of more than one species in order to learn generalizations and evolutionary trends. Students of anatomy often begin by dissecting other animals with which we share a common ancestry and many structural similarities.

Dissection, of course, is not the method of choice when studying a living person! Physical examinations involve not only looking at the body for signs of normalcy or disease but also touching and listening to it. **Palpation**[4] is feeling structure with the fingertips, such as palpating a swollen lymph node or taking a pulse. **Auscultation**[5] (AWS-cul-TAY-shun) is listening to the natural sounds made by the body, such as heart and lung sounds. In **percussion,** the examiner taps on the body and listens to the sound for signs of abnormalities such as pockets of fluid or air.

Structure that can be seen with the naked eye, whether by surface observation or dissection, is called **gross anatomy.** Ultimately, though, the functions of the body result from its individual cells. To see those, we usually take tissue specimens, thinly slice and stain them, and observe them under the microscope. This approach is

[1] *ana* = apart + *tom* = cut
[2] *dis* = apart + *sect* = cut
[3] *cadere* = to fall or die
[4] *palp* = touch, feel
[5] *auscult* = listen

called **histology**[6] **(microscopic anatomy).** *Histopathology* is the microscopic examination of tissues for signs of disease. *Ultrastructure* refers to fine details, down to the molecular level, revealed by the electron microscope.

Physiology—The Study of Function

Physiology[7] uses the methods of experimental science discussed later. It has many subdisciplines such as *neurophysiology* (physiology of the nervous system), *endocrinology* (physiology of hormones), and *pathophysiology* (mechanisms of disease). Partly because of limitations on experimentation with humans, much of what we know about bodily function has been gained through *comparative physiology,* the study of how different species have solved problems of life such as water balance, respiration, and reproduction. Comparative physiology is also the basis for the development of new drugs and medical procedures. For example, a cardiac surgeon cannot practice on humans without first succeeding in animal surgery, and a vaccine cannot be used on human subjects until it has been demonstrated through animal research that it confers significant benefits without unacceptable risks.

The Origins of Biomedical Science

Objectives

When you have completed this section, you should be able to

- give examples of how modern biomedical science emerged from an era of superstition and authoritarianism; and
- describe the contributions of some key people who helped to bring about this transformation.

Health science has progressed far more in the last 25 years than in the 2,500 years before that, but the field did not spring up overnight. It is built upon centuries of thought and controversy, triumph and defeat. We cannot fully appreciate its present state without understanding its past—people who had the curiosity to try new things, the vision to look at human form and function in new ways, and the courage to question authority.

The Beginnings of Medicine

As early as 3,000 years ago, physicians in Mesopotamia and Egypt treated patients with herbal drugs, salts, physical therapy, and faith healing. The "father of medicine," however, is usually considered to be the Greek physician *Hippocrates* (c. 460–c. 375 B.C.E.). He and his followers established a code of ethics for physicians, the Hippocratic Oath, that is still recited in modern form by many graduating medical students. Hippocrates urged physicians to stop attributing disease to the activities of gods and demons and to seek their natural causes, which could afford the only rational basis for therapy. *Aristotle* (384–322 B.C.E.) believed that diseases and other natural events could have either supernatural causes, which he called *theologi,* or natural ones, which he called *physici* or *physiologi.* We derive such terms as *physician* and *physiology* from the latter. Until the nineteenth century, physicians were called "doctors of physic." In his anatomy book, *Of the Parts of Animals,* Aristotle tried to identify unifying themes in nature. Among other points, he argued that complex structures are built from a smaller variety of simple components—a perspective that we will find useful later in this chapter.

Think About It

When you have completed this chapter, discuss the relevance of Aristotle's philosophy to our current thinking about human structure.

Claudius Galen (129–c. 199), physician to the Roman gladiators, wrote the most noteworthy medical textbook of the ancient era—a book that was worshiped to excess by medical professors for centuries to follow. Cadaver dissection was banned in Galen's time because of some horrid excesses that preceded him, including dissection of living slaves and prisoners merely to satisfy an anatomist's curiosity or to give a public demonstration. Galen was limited to learning anatomy from what he observed in treating gladiators' wounds and by dissecting pigs, monkeys, and other animals. Galen saw science as a process of discovery, not as a body of fact to be taken on faith. He warned that even his own books could be wrong, and advised his followers to trust their own observations more than they trusted any book. Unfortunately, his advice was not heeded. For nearly 1,500 years, medical professors dogmatically taught what they read in Aristotle and Galen, and few dared to question the authority of these "ancient masters."

The Birth of Modern Medicine

Medical science advanced very little during the Middle Ages. Even though some of the most famous medical schools of Europe were founded during this era, the professors taught medicine primarily as a dogmatic commentary on Galen and Aristotle, not as a field of original research. Medieval medical illustrations were crude representations of the body that served more to decorate a page than to depict the body realistically (fig. 1.2). Some were astrological charts that showed which sign of the

[6] *histo* = tissue + *logy* = study of
[7] *physio* = nature + *logy* = study of

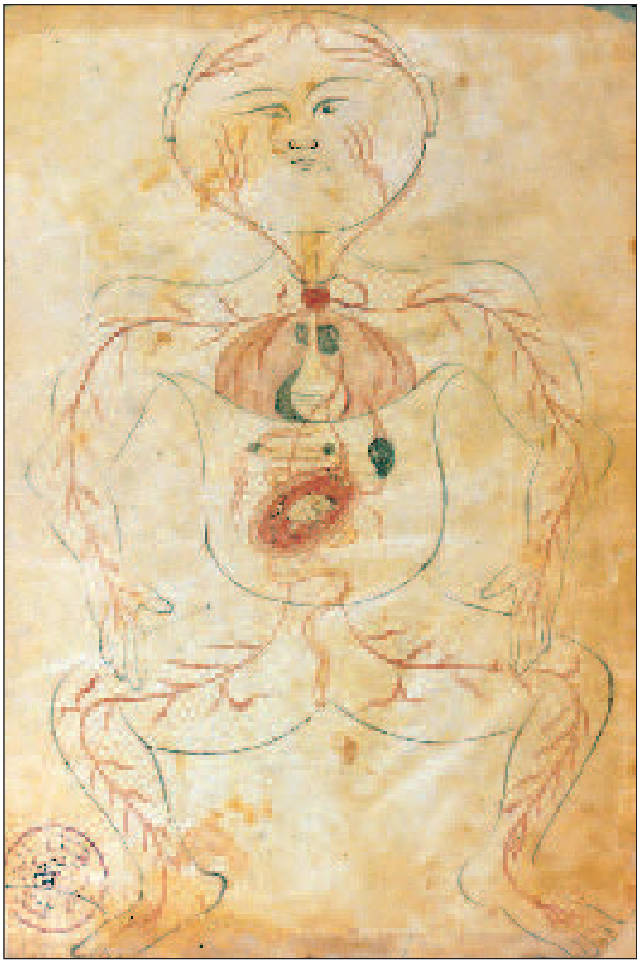


Figure 1.2 Medieval Medical Illustration. This figure depicts a pregnant woman with a fetus in the uterus and shows the heart, lungs, arteries, and digestive tract.

zodiac was thought to influence each organ of the body. From such pseudoscience came the word *influenza,* Italian for *influence.*

Free inquiry was less inhibited in the Muslim world than in Christendom. *Ibn Sina* (980–1037), known in the West as *Avicenna* or "the Galen of Islam," studied Galen and Aristotle, combined their findings with original discoveries, and questioned authority when the evidence demanded it. Muslim medicine soon became superior to Western medicine, and Avicenna's textbook, *The Canon of Medicine,* became the leading authority in European medical schools until the sixteenth century.

Modern medicine began around the sixteenth century in the innovative minds of such people as the anatomist Andreas Vesalius and the physiologist William Harvey. *Andreas Vesalius* (1514–64) taught anatomy in Italy. In his time, cadaver dissection had resumed for the purpose of autopsies and gradually found its way into the training of medical students throughout Europe. Dissection was an unpleasant business, however, and most professors considered it beneath their dignity. In these days before refrigeration or embalming, the odor from the decaying cadaver was unbearable. Dissections were conducted outdoors in a nonstop 4-day race against decay. Bleary medical students had to fight the urge to vomit, lest they incur the wrath of an overbearing professor. Professors typically sat in an elevated chair, the cathedra, reading dryly from Galen or Aristotle while a lower-ranking *barber-surgeon* removed putrefying organs from the cadaver and held them up for the students to see. Barbering and surgery were considered to be "kindred arts of the knife"; today's barber poles date from this era, their red and white stripes symbolizing blood and bandages.

Vesalius broke with tradition by coming down from the cathedra and doing the dissections himself. He was quick to point out that much of the anatomy in Galen's books was wrong, and he was the first to publish accurate illustrations for teaching anatomy (fig. 1.3). When others began to plagiarize his illustrations, Vesalius published the first atlas of anatomy, *De Humani Corporis Fabrica (On the Structure of the Human Body),* in 1543. This book began a rich tradition of medical illustration that has been handed down to us through such milestones as *Gray's Anatomy* (1856) and the vividly illustrated atlases and textbooks of today.

Anatomy preceded physiology and was a necessary foundation for it. What Vesalius was to anatomy, the Englishman *William Harvey* (1578–1657) was to physiology. Harvey is remembered especially for a little book he published in 1628, *On the Motion of the Heart and Blood in Animals.* Authorities before him believed that digested food traveled to the liver, turned into blood, and then traveled through the veins to organs that consumed it. Harvey measured cardiac output in snakes and other animals, however, and concluded that the amount of food eaten could not possibly account for so much blood. Thus, he inferred that blood must be recycled—pumped out of the heart by way of arteries and returned to the heart by way of veins. Capillaries, the connections between arteries and veins, had not been discovered yet, but Harvey predicted their existence.

Modern medicine also owes an enormous debt to two inventors from this era. *Antony van Leeuwenhoek* (an-TOE-nee vahn LAY-wen-hook) (1632–1723), a Dutch textile merchant, was the first to invent a microscope capable of visualizing single cells. In order to examine the weave of fabrics more closely, he ground a beadlike lens and mounted it in a metal plate equipped with a movable specimen clip (fig. 1.4). This *simple* (single-lens) *microscope* magnified objects 200 to 300 times. Out of curiosity, Leeuwenhoek examined a drop of lake water and was astonished to find a variety of microorganisms—"little animalcules," he called them, "very prettily a-swimming."

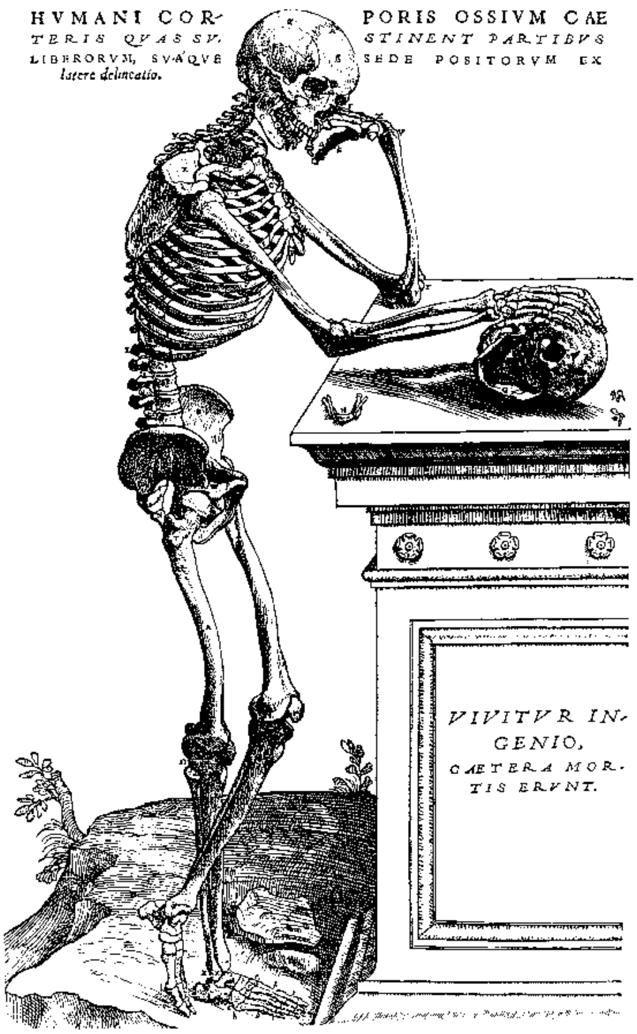


Figure 1.3 **The Art of Vesalius.** Andreas Vesalius revolutionized medical illustration with the comparatively realistic art prepared for his 1543 book, *De Humani Corporis Fabrica.*

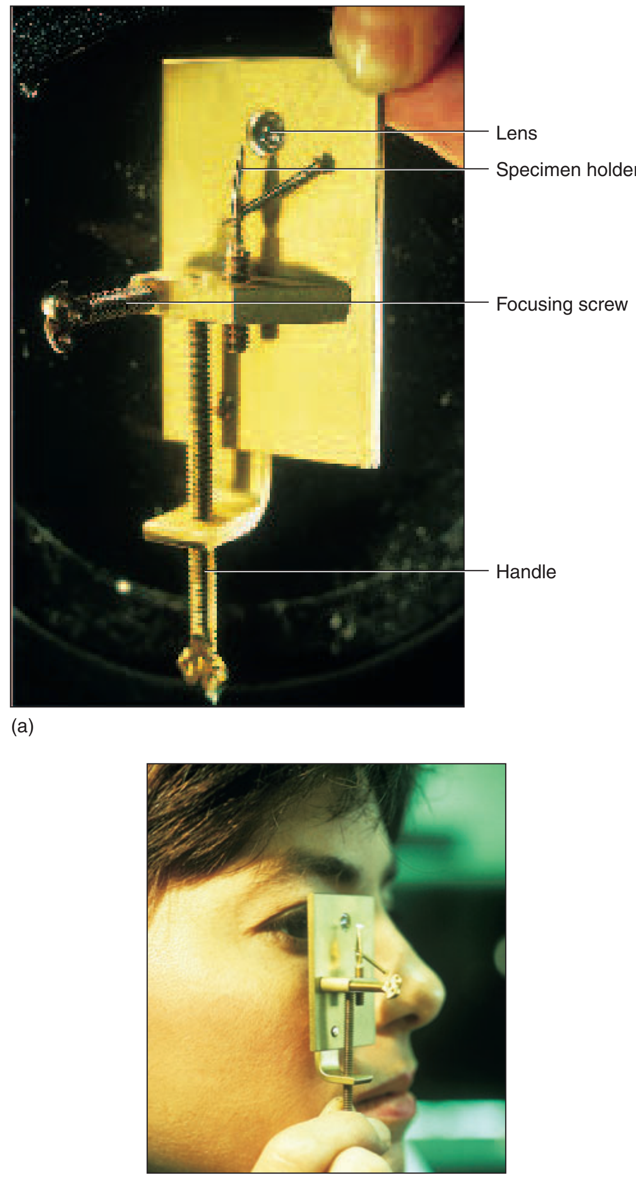


Figure 1.4 **Leeuwenhoek's Simple Microscope.** (*a*) Modern replica. (*b*) Viewing a specimen with a Leeuwenhoek microscope.

He went on to observe practically everything he could get his hands on, including blood cells, blood capillaries, sperm, and muscular tissue. Probably no one in history had looked at nature in such a revolutionary way. Leeuwenhoek opened the door to an entirely new understanding of human structure and the causes of disease. He was praised at first, and reports of his observations were eagerly received by scientific societies, but this public enthusiasm did not last. By the end of the seventeenth century, the microscope was treated as a mere toy for the upper classes, as amusing and meaningless as a kaleidoscope. Leeuwenhoek had even become the brunt of satire.

Leeuwenhoek's most faithful admirer was the Englishman *Robert Hooke* (1635–1703), who developed the first practical *compound microscope*—a tube with a lens at each end. The second lens further magnified the image produced by the first (fig. 1.5*a*). Hooke invented many of the features found in microscopes used today: a stage to hold the specimen, an illuminator, and coarse and fine focus controls. His microscopes produced poor images with blurry edges *(spherical aberration)* and rainbow-colored distortions *(chromatic aberration),* but poor images were better than none. Although Leeuwenhoek was the first to see cells,

(a) (b)

Figure 1.5 **Hooke's Compound Microscope.** (*a*) The compound microscope had a lens at each end of a tubular body. (*b*) Hooke's drawing of cork cells, showing the thick cell walls characteristic of plants.

Hooke named them. In 1663, he observed thin shavings of cork with his microscope and observed that they "consisted of a great many little boxes," which he called *cells* after the cubicles of a monastery (fig. 1.5*b*). He published these observations in his book, *Micrographia,* in 1665.

In nineteenth-century Germany, *Carl Zeiss* (1816–88) and his business partner, physicist *Ernst Abbe* (1840–1905), greatly improved the compound microscope, adding the condenser and developing superior optics that reduced chromatic and spherical aberration. Chapter 3 describes some more recently invented types of microscopes. With improved microscopes, biologists began eagerly examining a wider variety of specimens. By 1839, botanist *Matthias Schleiden* (1804–81) and zoologist *Theodor Schwann* (1810–82) concluded that all organisms were composed of cells. This was the first tenet of the **cell theory,** added to by later biologists and summarized in chapter 3. The cell theory was perhaps the most important breakthrough in biomedical history, because all functions of the body are now interpreted as the effects of cellular activity.

Although the philosophical foundation for modern medicine was largely established by the time of Leeuwenhoek, Hooke, and Harvey, clinical practice was still in a dismal state. Few doctors attended medical school or received any formal education in basic science or human anatomy. Physicians tended to be ignorant, ineffective, and pompous. Their practice was heavily based on expelling imaginary toxins from the body by bleeding their patients or inducing vomiting, sweating, or diarrhea. They performed operations with dirty hands and instruments, spreading lethal infections from one patient to another. Fractured limbs often became gangrenous and had to be amputated, and there was no anesthesia to lessen the pain. Disease was still widely attributed to demons and witches, and many people felt they would be interfering with God's will if they tried to treat it.

Living in a Revolution

This short history brings us only to the threshold of modern biomedical science; it stops short of such momentous discoveries as the germ theory of disease, the mechanisms of heredity, and the structure of DNA. In the twentieth century, basic biology and biochemistry have given us a much deeper understanding of how the body works. Technological advances such as medical imaging (see insight 1.5, p. 22) have enhanced our diagnostic ability and life-support strategies. We have witnessed monumental developments in chemotherapy, immunization, anesthesia, surgery, organ transplants, and human genetics. By the close of the twentieth century, we had discovered the chemical "base sequence" of every human gene and begun using gene therapy to treat children born with diseases recently considered incurable. As future historians look back on the turn of this century, they may exult about the Genetic Revolution in which you are now living.

Several discoveries of the nineteenth and twentieth centuries, and the men and women behind them, are covered in short historical sketches in later chapters. Yet, the stories told in this chapter are different in a significant way. The people discussed here were pioneers in establishing the scientific way of thinking. They helped to replace superstition with an appreciation of natural law. They bridged the chasm between mystery and medication. Without this intellectual revolution, those who followed could not have conceived of the right questions to ask, much less a method for answering them.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

1. In what way did the followers of Galen disregard his advice? How does Galen's advice apply to you?
2. Describe two ways in which Vesalius improved medical education and set standards that remain relevant today.
3. How is our concept of human form and function today affected by inventors from Leeuwenhoek to Zeiss?

Chapter 1

Scientific Method

Objectives

When you have completed this section, you should be able to

- describe the inductive and hypothetico-deductive methods of obtaining scientific knowledge;
- describe some aspects of experimental design that help to ensure objective and reliable results; and
- explain what is meant by *hypothesis, fact, law,* and *theory* in science.

Prior to the seventeenth century, science was done in a haphazard way by a small number of isolated individuals. The philosophers *Francis Bacon* (1561–1626) in England and *René Descartes* (1596–1650) in France envisioned science as a far greater, systematic enterprise with enormous possibilities for human health and welfare. They detested those who endlessly debated ancient philosophy without creating anything new. Bacon argued against biased thinking and for more objectivity in science. He outlined a systematic way of seeking similarities, differences, and trends in nature and drawing useful generalizations from observable facts. You will see echoes of Bacon's philosophy in the discussion of scientific method that follows.

Though the followers of Bacon and Descartes argued bitterly with each other, both men wanted science to become a public, cooperative enterprise, supported by governments and conducted by an international community of scholars rather than a few isolated amateurs. Inspired by their vision, the French and English governments established academies of science that still flourish today. Bacon and Descartes are credited with putting science on the path to modernity, not by discovering anything new in nature or inventing any techniques—for neither man was a scientist—but by inventing new habits of scientific thought.

When we say "scientific," we mean that such thinking is based on assumptions and methods that yield reliable, objective, testable information about nature. The assumptions of science are ideas that have proven fruitful in the past—for example, the idea that natural phenomena have natural causes and nature is therefore predictable and understandable. The methods of science are highly variable. **Scientific method** refers less to observational procedures than to certain habits of disciplined creativity, careful observation, logical thinking, and honest analysis of one's observations and conclusions. It is especially important in health science to understand these habits. This field is littered with more fads and frauds than any other. We are called upon constantly to judge which claims are trustworthy and which are bogus. To make such judgments depends on an appreciation of how scientists think, how they set standards for truth, and why their claims are more reliable than others.

The Inductive Method

The **inductive method,** first prescribed by Bacon, is a process of making numerous observations until one feels confident in drawing generalizations and predictions from them. What we know of anatomy is a product of the inductive method. We describe the normal structure of the body based on observations of many bodies.

This raises the issue of what is considered proof in science. We can never prove a claim beyond all possible refutation. We can, however, consider a statement as proven *beyond reasonable doubt* if it was arrived at by reliable methods of observation, tested and confirmed repeatedly, and not falsified by any credible observation. In science, all truth is tentative; there is no room for dogma. We must always be prepared to abandon yesterday's truth if tomorrow's facts disprove it.

The Hypothetico-Deductive Method

Most physiological knowledge was obtained by the **hypothetico-deductive method.** An investigator begins by asking a question and formulating a **hypothesis**—an educated speculation or possible answer to the question. A good hypothesis must be (1) consistent with what is already known and (2) capable of being tested and possibly falsified by evidence. **Falsifiability** means that if we claim something is scientifically true, we must be able to specify what evidence it would take to prove it wrong. If nothing could possibly prove it wrong, then it is not scientific.

Think About It

The ancients thought that gods or invisible demons caused epilepsy. Today, epileptic seizures are attributed to bursts of abnormal electrical activity in nerve cells of the brain. Explain why one of these claims is falsifiable (and thus scientific), while the other claim is not.

The purpose of a hypothesis is to suggest a method for answering a question. From the hypothesis, a researcher makes a deduction, typically in the form of an "if-then" prediction: *If* my hypothesis on epilepsy is correct and I record the brain waves of patients during seizures, *then* I should observe abnormal bursts of activity. A properly conducted experiment yields observations that either support a hypothesis or require the scientist to modify or abandon it, formulate a better hypothesis, and test that one. Hypothesis testing operates in cycles of conjecture and disproof until one is found that is supported by the evidence.

Experimental Design

Doing an experiment properly involves several important considerations. What shall I measure and how can I

measure it? What effects should I watch for and which ones should I ignore? How can I be sure that my results are due to the factors *(variables)* that I manipulate and not due to something else? When working on human subjects, how can I prevent the subject's expectations or state of mind from influencing the results? Most importantly, how can I eliminate my own biases and be sure that even the most skeptical critics will have as much confidence in my conclusions as I do? Several elements of experimental design address these issues:

- **Sample size.** The number of subjects (animals or people) used in a study is the sample size. An adequate sample size controls for chance events and individual variations in response and thus enables us to place more confidence in the outcome. For example, would you rather trust your health to a drug that was tested on 5 people or one tested on 5,000?
- **Controls.** Biomedical experiments require comparison between treated and untreated individuals so that we can judge whether the treatment has any effect. A **control group** consists of subjects that are as much like the **treatment group** as possible except with respect to the variable being tested. For example, there is evidence that garlic lowers blood cholesterol levels. In one study, a group of people with high cholesterol was given 800 mg of garlic powder daily for 4 months and exhibited an average 12% reduction in cholesterol. Was this a significant reduction, and was it due to the garlic? It is impossible to say without comparison to a control group of similar people who received no treatment. In this study, the control group averaged only a 3% reduction in cholesterol, so garlic *seems* to have made a difference.
- **Psychosomatic effects.** Psychosomatic effects (effects of the subject's state of mind on his or her physiology) can have an undesirable impact on experimental results if we do not control for them. In drug research, it is therefore customary to give the control group a **placebo** (pla-SEE-bo)—a substance with no significant physiological effect on the body. If we were testing a drug, for example, we could give the treatment group the drug and the control group identical-looking starch tablets. Neither group must know which tablets it is receiving. If the two groups showed significantly different effects, we could feel confident that it did not result from a knowledge of what they were taking.
- **Experimenter bias.** In the competitive, high-stakes world of medical research, experimenters may want certain results so much that their biases, even subconscious ones, can affect their interpretation of the data. One way to control for this is the **double-blind method.** In this procedure, neither the subject to whom a treatment is given nor the person giving it and recording the results knows whether that subject is receiving the experimental treatment or placebo. A researcher might prepare identical-looking tablets, some with the drug and some with placebo, label them with code numbers, and distribute them to participating physicians. The physicians themselves do not know whether they are administering drug or placebo, so they cannot give the subjects even accidental hints of which substance they are taking. When the data are collected, the researcher can correlate them with the composition of the tablets and determine whether the drug had more effect than the placebo.
- **Statistical testing.** If you tossed a coin 100 times, you would expect it to come up about 50 heads and 50 tails. If it actually came up 48:52, you would probably attribute this to random error rather than bias in the coin. But what if it came up 40:60? At what point would you begin to suspect bias? This type of problem is faced routinely in research—how great a difference must there be between control and experimental groups before we feel confident that the treatment really had an effect? What if a treatment group exhibited a 12% reduction in cholesterol level and the placebo group a 10% reduction? Would this be enough to conclude that the treatment was effective? Scientists are well grounded in **statistical tests** that can be applied to the data. Perhaps you have heard of the chi-square test, the *t* test, or analysis of variance, for example. A typical outcome of a statistical test might be expressed, "We can be 99.5% sure that the difference between group A and group B was due to the experimental treatment and not to random variation."

Peer Review

When a scientist applies for funds to support a research project or submits results for publication, the application or manuscript is submitted to **peer review**—a critical evaluation by other experts in that field. Even after a report is published, if the results are important or unconventional, other scientists may attempt to reproduce them to see if the author was correct. At every stage from planning to post-publication, scientists are therefore subject to intense scrutiny by their colleagues. Peer review is one mechanism for ensuring honesty, objectivity, and quality in science.

Facts, Laws, and Theories

The most important product of scientific research is understanding how nature works—whether it be the nature of a pond to an ecologist or the nature of a liver cell to a physiologist. We express our understanding as *facts, laws,* and *theories* of nature. It is important to appreciate the differences between these.

A scientific **fact** is information that can be independently verified by any trained person—for example, the fact that an iron deficiency leads to anemia. A **law of nature** is a generalization about the predictable ways in which matter and energy behave. It is the result of inductive reasoning based on repeated, confirmed observations. Some laws are expressed as concise verbal statements, such as the *first law of thermodynamics:* Energy can be converted from one form to another but cannot be created or destroyed. Others are expressed as mathematical formulae, such as the *law of Laplace:* $F = 2T/r$, where F is a force that tends to cause a microscopic air sac of the lung to collapse, T is the surface tension of the fluid lining the sac, and r is the sac's radius.

A **theory** is an explanatory statement, or set of statements, derived from facts, laws, and confirmed hypotheses. Some theories have names, such as the *cell theory,* the *fluid-mosaic theory* of cell membranes, and the *sliding filament theory* of muscle contraction. Most, however, remain unnamed. The purpose of a theory is not only to concisely summarize what we already know but, moreover, to suggest directions for further study and to help predict what the findings should be if the theory is correct.

Law and *theory* mean something different in science than they do to most people. In common usage, a law is a rule created and enforced by people; we must obey it or risk a penalty. A law of nature, however, is a description; laws do not *govern* the universe, they *describe* it. Laypeople tend to use the word *theory* for what a scientist would call a hypothesis—for example, "I have a theory why my car won't start." The difference in meaning causes significant confusion when it leads people to think that a scientific theory (such as the theory of evolution) is merely a guess or conjecture, instead of recognizing it as a summary of conclusions drawn from a large body of observed facts. The concepts of gravity and electrons are theories, too, but this does not mean they are merely speculations.

Think About It

Was the cell theory proposed by Schleiden and Schwann more a product of the hypothetico-deductive method or of the inductive method? Explain your answer.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

4. Describe the general process involved in the inductive method.
5. Describe some sources of potential bias in biomedical research. What are some ways of minimizing such bias?
6. Is there more information in an individual scientific fact or in a theory? Explain.

Human Origins and Adaptations

Objectives

When you have completed this section, you should be able to

- define *evolution* and *natural selection;*
- describe some human characteristics that can be attributed to the tree-dwelling habits of earlier primates;
- describe some human characteristics that evolved later in connection with upright walking; and
- explain why evolution is relevant to understanding human form and function.

If any two theories have the broadest implications for understanding the human body, they are probably the cell theory and the theory of natural selection. *Natural selection,* an explanation of how species originate and change through time, was the brainchild of *Charles Darwin* (1809–82)—probably the most influential biologist who ever lived. His book, *On the Origin of Species by Means of Natural Selection* (1859), has been called "the book that shook the world." In presenting the first well-supported theory of evolution, *On the Origin of Species* not only caused the restructuring of all of biology but also profoundly changed the prevailing view of our origin, nature, and place in the universe.

On the Origin of Species scarcely touched upon human biology, but its unmistakable implications for humans created an intense storm of controversy that continues even today. In *The Descent of Man* (1871), Darwin directly addressed the issue of human evolution and emphasized features of anatomy and behavior that reveal our relationship to other animals. No understanding of human form and function is complete without an understanding of our evolutionary history.

Evolution, Selection, and Adaptation

Evolution simply means change in the genetic composition of a population of organisms. Examples include the evolution of bacterial resistance to antibiotics, the appearance of new strains of the AIDS virus, and the emergence of new species of organisms. The theory of **natural selection** is essentially this: Some individuals within a species have hereditary advantages over their competitors—for example, better camouflage, disease resistance, or ability to attract mates—that enable them to produce more offspring. They pass these advantages on to their offspring, and such characteristics therefore become more and more common in successive generations. This brings about the genetic change in a population that constitutes evolution.

Natural forces that promote the reproductive success of some individuals more than others are called **selection pressures.** They include such things as climate, predators, disease, competition, and the availability of

food. **Adaptations** are features of an organism's anatomy, physiology, and behavior that have evolved in response to these selection pressures and enable the organism to cope with the challenges of its environment. We will consider shortly some selection pressures and adaptations that were important to human evolution.

Darwin could scarcely have predicted the overwhelming mass of genetic, molecular, fossil, and other evidence of human evolution that would accumulate in the twentieth century and further substantiate his theory. A technique called DNA hybridization, for example, suggests a difference of only 1.6% in DNA structure between humans and chimpanzees. Chimpanzees and gorillas differ by 2.3%. DNA structure suggests that a chimpanzee's closest living relative is not the gorilla or any other ape—it is us.

Several aspects of our anatomy make little sense without an awareness that the human body has a history (see insight 1.1). Our evolutionary relationship to other species is also important in choosing animals for biomedical research. If there were no issues of cost, availability, or ethics, we might test drugs on our nearest living relatives, the chimpanzees, before approving them for human use. Their genetics, anatomy, and physiology are most similar to ours, and their reactions to drugs therefore afford the best prediction of how the human body would react. On the other hand, if we had no kinship with any other species, the selection of a test species would be arbitrary; we might as well use frogs or snails. In reality, we compromise. Rats and mice are used extensively for research because they are fellow mammals with a physiology similar to ours, but they present fewer of the aforementioned issues than chimpanzees or other mammals do. An animal species or strain selected for research on a particular problem is called a *model*—for example, a mouse model for leukemia.

Insight 1.1 Evolutionary Medicine

Vestiges of Human Evolution

One of the classic lines of evidence for evolution, debated even before Darwin was born, is *vestigial organs.* These structures are the remnants of organs that apparently were better developed and more functional in the ancestors of a species. They now serve little or no purpose or, in some cases, have been converted to new functions.

Our bodies, for example, are covered with millions of hairs, each equipped with a useless little *piloerector muscle.* In other mammals, these muscles fluff the hair and conserve heat. In humans, they merely produce goose bumps. Above each ear, we have three *auricularis muscles.* In other mammals, they move the ears to receive sounds better, but most people cannot contract them at all. As Darwin said, it makes no sense that humans would have such structures were it not for the fact that we came from ancestors in which they were functional.

Primate Adaptations

We belong to an order of mammals called the Primates, which also includes the monkeys and apes. Some of our anatomical and physiological features can be traced to the earliest primates, descended from certain squirrel-sized, insect-eating, African mammals (insectivores) that took up life in the trees 55 to 60 million years ago. This **arboreal**[8] (treetop) habitat probably afforded greater safety from predators, less competition, and a rich food supply of leaves, fruit, insects, and lizards. But the forest canopy is a challenging world, with dim and dappled sunlight, swaying branches, and prey darting about in the dense foliage. Any new feature that enabled arboreal animals to move about more easily in the treetops would have been strongly favored by natural selection. Thus, the shoulder became more mobile and enabled primates to reach out in any direction (even overhead, which few other mammals can do). The thumbs became **opposable**—they could cross the palm to touch the fingertips—and enabled primates to hold small objects and manipulate them more precisely than other mammals can. Opposable thumbs made the hands **prehensile**[9]—able to grasp branches by encircling them with the thumb and fingers (fig. 1.6). The thumb is so important that it receives highest priority in the repair of hand injuries. If the thumb can be saved, the hand can be reasonably functional; if it is lost, hand functions are severely diminished.

[8] *arbor* = tree + *eal* = pertaining to
[9] *prehens* = to seize

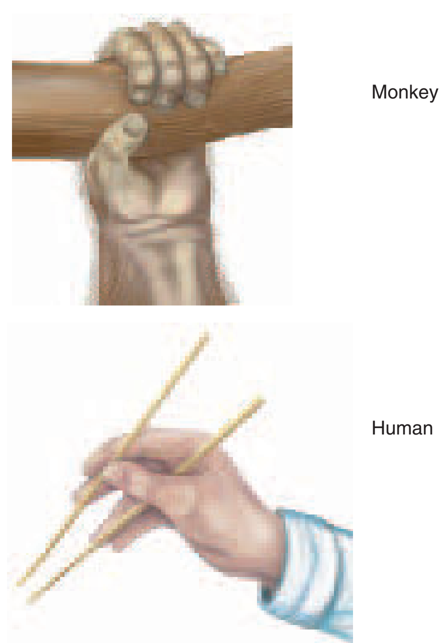


Figure 1.6 Primate Hands. The opposable thumb makes the primate hand prehensile, able to encircle and grasp objects.

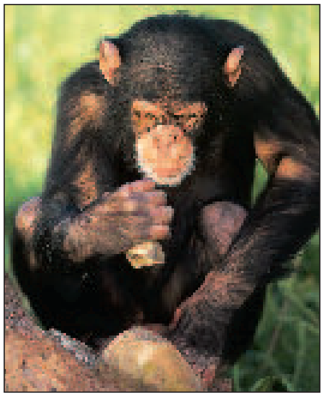


Figure 1.7 **Primitive Tool Use in a Primate.** Chimpanzees exhibit the prehensile hands and forward-facing eyes typical of primates. Such traits endow primates with stereoscopic vision (depth perception) and good hand-eye coordination, two supremely important factors in human evolution.

The eyes of primates moved to a more forward-facing position (fig. 1.7), which allowed for **stereoscopic**[10] **vision** (depth perception). This adaptation provided better hand-eye coordination in catching and manipulating prey, with the added advantage of making it easier to judge distances accurately in leaping from tree to tree. Color vision, rare among mammals, is also a primate hallmark. Primates eat mainly fruit and leaves. The ability to distinguish subtle shades of orange and red enables them to distinguish ripe, sugary fruits from unripe ones. Distinguishing subtle shades of green helps them to differentiate between tender young leaves and tough, more toxic older foliage.

Various fruits ripen at different times and in widely separated places in the tropical forest. This requires a good memory of what will be available, when, and how to get there. Larger brains may have evolved in response to the challenge of efficient food finding and, in turn, laid the foundation for more sophisticated social organization.

None of this is meant to imply that humans evolved from monkeys or apes—a common misconception about evolution that no biologist believes. Observations of monkeys and apes, however, provide insight into how primates adapt to the arboreal habitat and how certain human adaptations probably originated.

Walking Upright

About 4 to 5 million years ago, much of the African forest was replaced by savanna (grassland). Some primates adapted to living on the savanna, but this was a dangerous place with more predators and less protection. Just as squirrels and monkeys stand briefly on their hind legs to look around for danger, so would these early ground-dwellers. Being able to stand up not only helps an animal stay alert but also frees the forelimbs for purposes other than walking. Chimpanzees sometimes walk upright to carry food or weapons (sticks and rocks), and it is reasonable to suppose that our early ancestors did so too. They could also carry their infants.

These advantages are so great that they favored skeletal modifications that made **bipedalism**[11]—standing and walking on two legs—easier. The anatomy of the human pelvis, femur, knee, great toe, foot arches, spinal column, skull, arms, and many muscles became adapted for bipedal locomotion, as did many aspects of human family life and society. As the skeleton and muscles became adapted for bipedalism, brain volume increased dramatically (table 1.1). It must have become increasingly difficult for a fully developed, large-brained infant to pass through the mother's pelvic outlet at birth. This may explain why humans are born in a relatively immature, helpless state compared to other mammals, before their nervous systems have matured and the bones of the skull have fused.

The oldest bipedal primates (family Hominidae) are classified in the genus *Australopithecus* (aus-TRAL-oh-PITH-eh-cus). About 2.5 million years ago, *Australopithecus* gave rise to *Homo habilis,* the earliest member of our own genus. *Homo habilis* differed from *Australopithecus* in height, brain volume, some details of skull anatomy, and tool-making ability. It was probably the first primate able to speak. *Homo habilis* gave rise to *Homo erectus* about 1.1 million years ago, which in turn led to our own species, *Homo sapiens,* about 300,000 years ago (fig. 1.8). *Homo sapiens* includes the extinct Neanderthal and Cro-Magnon people as well as modern humans.

This brief account barely begins to explain how human anatomy, physiology, and behavior have been shaped by

Table 1.1 Brain Volumes of the Hominidae

Genus or Species	Time of Origin (millions of years ago)	Brain Volume (milliliters)
Australopithecus	3.9–4.2	400
Homo habilis	2.5	650
Homo erectus	1.1	1,100
Homo sapiens	0.3	1,350

[10] *stereo* = solid + *scop* = vision

[11] *bi* = two + *ped* = foot

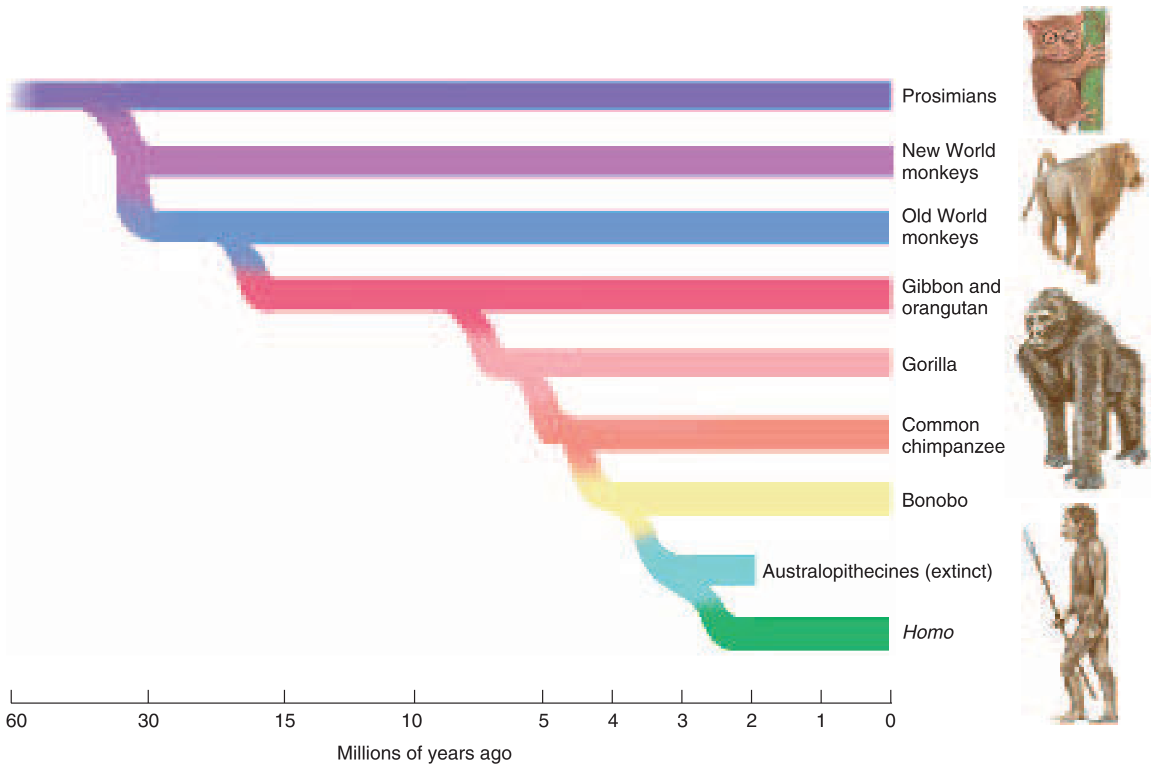


Figure 1.8 The Place of Humans in Primate Evolution. Figures at the *right* show some representative primates. The branch points in this "family tree" show the approximate times that different lines diverged from a common ancestor. Note that the time scale is not uniform; recent events are expanded for clarity.
Which is more closely related to humans, a gorilla or a monkey? How long ago did the last common ancestor of chimpanzees and humans exist?

ancient selection pressures. Later chapters further demonstrate that the evolutionary perspective provides a meaningful understanding of why humans are the way we are. Evolution is the basis for comparative anatomy and physiology, which have been so fruitful for the understanding of human biology. If we were not related to any other species, those sciences would be pointless. The emerging science of **evolutionary (darwinian) medicine** traces some of our diseases and imperfections to our evolutionary past.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

7. Define *adaptation* and *selection pressure*. Why are these concepts important in understanding human anatomy and physiology?
8. Select any two human characteristics and explain how they may have originated in primate adaptations to an arboreal habitat.
9. Select two other human characteristics and explain how they may have resulted from adaptation to a grassland habitat.

Human Structure

Objectives

When you have completed this section, you should be able to

- list the levels of human structure from the most complex to the simplest;
- discuss the value of both reductionistic and holistic viewpoints to understanding human form and function; and
- discuss the clinical significance of anatomical variation among humans.

Earlier in this chapter, we observed that human anatomy is studied by a variety of techniques—dissection, palpation, and so forth. In addition, anatomy is studied at several levels of detail, from the whole body down to the molecular level.

The Hierarchy of Complexity

Consider for the moment an analogy to human structure: The English language, like the human body, is very complex, yet an endless array of ideas can be conveyed with a limited number of words. All words in English are, in turn,

composed of various combinations of just 26 letters. Between an essay and an alphabet are successively simpler levels of organization: paragraphs, sentences, words, and syllables. We can say that language exhibits a hierarchy of complexity, with letters, syllables, words, and so forth being successive levels of the hierarchy. Humans have an analogous hierarchy of complexity, as follows (fig. 1.9):

The organism is composed of organ systems,
organ systems are composed of organs,
organs are composed of tissues,
tissues are composed of cells,
cells are composed (in part) of organelles,
organelles are composed of molecules, and
molecules are composed of atoms.

The **organism** is a single, complete individual.

An **organ system** is a group of organs with a unique collective function, such as circulation, respiration, or digestion. The human body has 11 organ systems, illustrated in atlas A immediately following this chapter: the integumentary, skeletal, muscular, nervous, endocrine, circulatory, lymphatic, respiratory, urinary, digestive, and reproductive systems. Usually, the organs of one system are physically interconnected, such as the kidneys, ureters, urinary bladder, and urethra, which compose the urinary system. Beginning with chapter 6, this book is organized around the organ systems.

An **organ** is a structure composed of two or more tissue types that work together to carry out a particular function. Organs have definite anatomical boundaries and are visibly distinguishable from adjacent structures. Most organs and higher levels of structure are within the domain of gross anatomy. However, there are organs within organs—the large organs visible to the naked eye often contain smaller organs visible only with the microscope. The skin, for example, is the body's largest organ. Included within it are thousands of smaller organs: each hair, nail, gland, nerve, and blood vessel of the skin is an organ in itself.

A **tissue** is a mass of similar cells and cell products that forms a discrete region of an organ and performs a specific function. The body is composed of only four primary classes of tissue—epithelial, connective, nervous, and muscular tissues. Histology, the study of tissues, is the subject of chapter 5.

Cells are the smallest units of an organism that carry out all the basic functions of life; nothing simpler than a cell is considered alive. A cell is enclosed in a *plasma membrane* composed of lipids and proteins. Most cells have one nucleus, an organelle that contains its DNA. *Cytology,* the study of cells and organelles, is the subject of chapters 3 and 4.

Organelles[12] are microscopic structures in a cell that carry out its individual functions. Examples include mitochondria, centrioles, and lysosomes.

Organelles and other cellular components are composed of **molecules.** The largest molecules, such as proteins, fats, and DNA, are called *macromolecules.* A molecule is a particle composed of at least two **atoms,** the smallest particles with unique chemical identities.

The theory that a large, complex system such as the human body can be understood by studying its simpler components is called **reductionism.** First espoused by Aristotle, this has proven to be a highly productive approach; indeed, it is essential to scientific thinking. Yet the reductionistic view is not the last word in understanding human life. Just as it would be very difficult to predict the workings of an automobile transmission merely by looking at a pile of its disassembled gears and levers, one could never predict the human personality from a complete knowledge of the circuitry of the brain or the genetic sequence of DNA. **Holism**[13] is the complementary theory that there are "emergent properties" of the whole organism that cannot be predicted from the properties of its separate parts—human beings are more than the sum of their parts. To be most effective, a health-care provider does not treat merely a disease

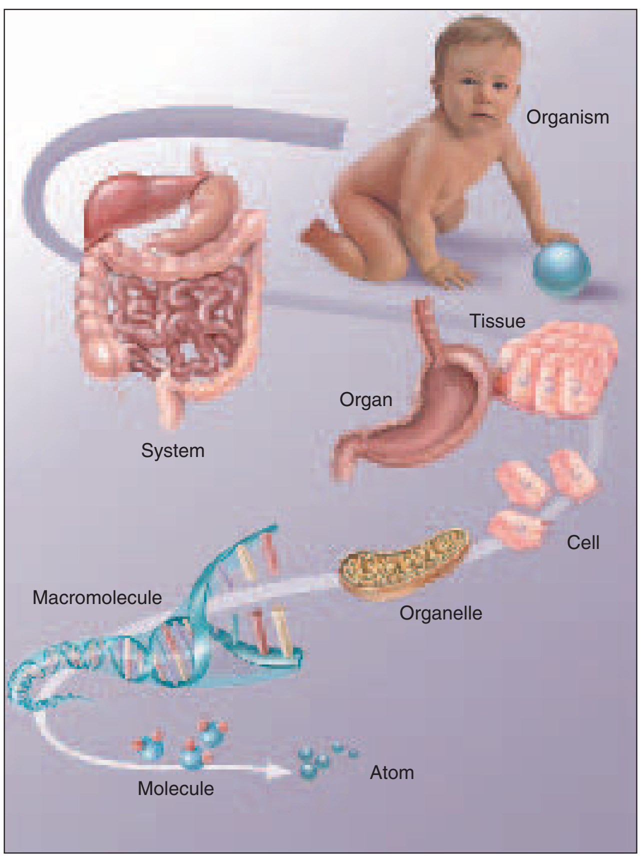


Figure 1.9 **The Body's Structural Hierarchy.**

[12] *elle* = little
[13] *holo* = whole, entire

Chapter 1

or an organ system, but a whole person. A patient's perceptions, emotional responses to life, and confidence in the nurse, therapist, or physician profoundly affect the outcome of treatment. In fact, these psychological factors often play a greater role in a patient's recovery than the physical treatments administered.

Anatomical Variation

Anatomists, surgeons, and students must be constantly aware of how much one body can differ from another. A quick look around any classroom is enough to show that no two humans are exactly alike; on close inspection, even identical twins exhibit differences. Yet anatomy atlases and textbooks can easily give you the impression that everyone's internal anatomy is the same. This simply is not true. Books such as this one can only teach you the most common structure—the anatomy seen in about 70% or more of people. Someone who thinks that all human bodies are the same internally would make a very confused medical student or an incompetent surgeon.

Some people lack certain organs. For example, most of us have a *palmaris longus* muscle in the forearm and a *plantaris* muscle in the lower leg, but these are absent from some people. Most of us have five lumbar vertebrae (bones of the lower spine), but some people have six and some have four. Most of us have one spleen and two kidneys, but some have two spleens or only one kidney. Most kidneys are supplied by a single *renal artery,* but some have two renal arteries. Figure 1.10 shows some common variations in human anatomy, and insight 1.2 describes a particularly dramatic and clinically important variation.

Insight 1.2 Clinical Application

Situs Inversus and Other Unusual Anatomy

In most people, the spleen, pancreas, sigmoid colon, and most of the heart are on the left, while the appendix, gallbladder, and most of the liver are on the right. The normal arrangement of these and other internal organs is called *situs* (SITE-us) *solitus.* About 1 in 8,000 people, however, are born with an abnormality called *situs inversus*—the organs of the thoracic and abdominal cavities are reversed between right and left. A selective right-left reversal of the heart is called *dextrocardia.* In *situs perversus,* a single organ occupies an atypical position—for example, a kidney located low in the pelvic cavity instead of high in the abdominal cavity.

Conditions such as dextrocardia in the absence of complete situs inversus can cause serious medical problems. Complete situs inversus, however, usually causes no functional problems because all of the viscera, though reversed, maintain their normal relationships to each other. Situs inversus is often discovered in the fetus by sonography, but many people remain unaware of their condition for decades until it is discovered by medical imaging, on physical examination, or in surgery. You can easily imagine the importance of such conditions in diagnosing appendicitis, performing gallbladder surgery, interpreting an X ray, or auscultating the heart valves.

Think About It

People who are allergic to aspirin or penicillin often wear Medic Alert bracelets or necklaces that note this fact in case they need emergency medical treatment and are unable to communicate. Why would it be important for a person with situs inversus to have this noted on a Medic Alert bracelet?

Before You Go On

Answer the following questions to test your understanding of the preceding section:

10. In the hierarchy of human structure, what is the level between organ system and tissue? Between cell and molecule?
11. How are tissues relevant to the definition of an organ?
12. Why is reductionism a necessary but not sufficient point of view for fully understanding a patient's illness?
13. Why should medical students observe multiple cadavers and not be satisfied to dissect only one?

Human Function

Objectives

When you have completed this section, you should be able to

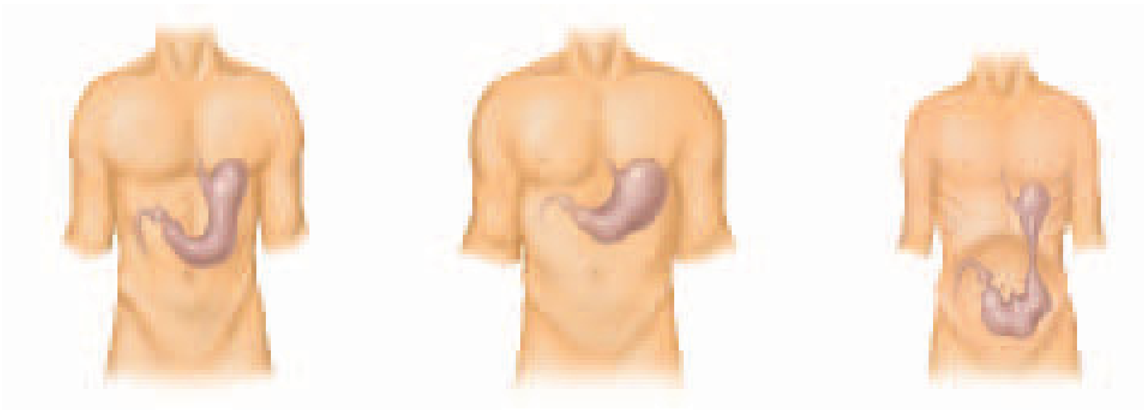
- state the characteristics that distinguish living organisms from nonliving objects;
- explain the importance of defining a reference man and woman;
- define *homeostasis* and explain why this concept is central to physiology;
- define *negative feedback,* give an example of it, and explain its importance to homeostasis; and
- define *positive feedback* and give examples of its beneficial and harmful effects.

Characteristics of Life

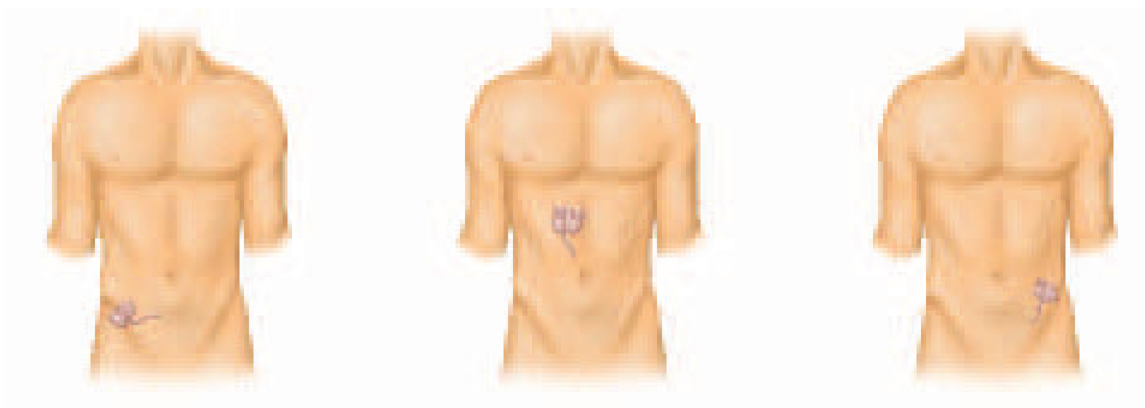
Why do we consider a growing child to be alive, but not a growing crystal? Is abortion the taking of a human life? If so, what about a contraceptive foam that kills only sperm? As a patient is dying, at what point does it become ethical to disconnect life-support equipment and remove organs for donation? If these organs are alive, as they must be to serve someone else, then why isn't the donor considered alive? Such questions have no easy answers, but they demand a concept of what life is—a concept that may differ with one's biological, medical, or legal perspective.

From a biological viewpoint, life is not a single property. It is a collection of properties that help to distinguish living from nonliving things:

- **Organization.** Living things exhibit a far higher level of organization than the nonliving world around them. They expend a great deal of energy to maintain order,



(a)



(b)

(c)

Figure 1.10 **Variation in Human Anatomy.** The left-hand figure in each case depicts the most common anatomy. (*a*) Variations in stomach shape correlated with body physique. (*b*) Variations in the position of the appendix. (*c*) Variations in the bile passages of the liver and gallbladder.

and a breakdown in this order is accompanied by disease and often death.

- **Cellular composition.** Living matter is always compartmentalized into one or more cells.
- **Metabolism** and **excretion.** Living things take in molecules from the environment and chemically change them into molecules that form their own structures, control their physiology, or provide them with energy. **Metabolism**[14] is the sum of all this internal chemical change. It consists of two classes of reactions: *anabolism,*[15] in which relatively complex molecules are synthesized from simpler ones (for example, protein synthesis), and *catabolism,*[16] in which relatively complex molecules are broken down into simpler ones (for example, protein digestion). Metabolism inevitably produces chemical wastes, some of which are toxic if they accumulate. Metabolism therefore requires **excretion,** the separation of wastes from the tissues and their elimination from the body. There is a constant turnover of molecules in the body; few of the molecules now in your body have been there for more than a year. It is food for thought that although you sense a continuity of personality and experience from your childhood to the present, nearly all of your body has been replaced within the past year.
- **Responsiveness** and **movement.** The ability of organisms to sense and react to **stimuli** (changes in their environment) is called *responsiveness, irritability,* or *excitability.* It occurs at all levels from the single cell to the entire body, and it characterizes all living things from bacteria to you. Responsiveness is especially obvious in animals because of nerve and muscle cells that exhibit high sensitivity to environmental stimuli, rapid transmission of information, and quick reactions. Most living organisms are capable of self-propelled movement from place to place, and all organisms and cells are at least capable of moving substances internally, such as moving food along the digestive tract or moving molecules and organelles from place to place within a cell.
- **Homeostasis.** While the environment around an organism changes, the organism maintains relatively stable internal conditions. This ability to maintain internal stability, called *homeostasis,* is explored in more depth shortly.
- **Development.** Development is any change in form or function over the lifetime of the organism. In most organisms, it involves two major processes: (1) **differentiation,** the transformation of cells with no specialized function into cells that are committed to a particular task, and (2) **growth,** an increase in size. Some nonliving things grow, but not in the way your body does. If you let a saturated sugar solution evaporate, crystals will grow from it, but not through a change in the composition of the sugar. They merely add more sugar molecules from the solution to the crystal surface. The growth of the body, by contrast, occurs through chemical change (metabolism); for the most part, your body is not composed of the molecules you ate but of molecules made by chemically altering your food.
- **Reproduction.** All living organisms can produce copies of themselves, thus passing their genes on to new, younger containers—their offspring.
- **Evolution.** All living species exhibit genetic change from generation to generation and therefore evolve. This occurs because *mutations* (changes in DNA structure) are inevitable and because environmental selection pressures endow some individuals with greater reproductive success than others. Unlike the other characteristics of life, evolution is a characteristic seen only in the population as a whole. No single individual evolves over the course of its life.

Clinical and legal criteria of life differ from these biological criteria. A person who has shown no brain waves for 24 hours, and has no reflexes, respiration, or heartbeat other than what is provided by artificial life support, can be declared legally dead. At such time, however, most of the body is still biologically alive and its organs may be useful for transplant.

Physiological Variation

Earlier we considered the clinical importance of variations in human anatomy, but physiology is even more variable. Physiological variables differ with sex, age, weight, diet, degree of physical activity, and environment, among other things. Failure to consider such variation leads to medical mistakes such as overmedication of the elderly or medicating women on the basis of research that was done on men. If an introductory textbook states a typical human heart rate, blood pressure, red blood cell count, or body temperature, it is generally assumed that such values are for a healthy young adult unless otherwise stated. A point of reference for such general values is the reference man and reference woman. The **reference man** is defined as a healthy male 22 years old, weighing 70 kg (154 lb), living at a mean ambient (surrounding) temperature of 20°C, engaging in light physical activity, and consuming 2,800 kilocalories (kcal) per day. The **reference woman** is the same except for a weight of 58 kg (128 lb) and an intake of 2,000 kcal/day.

[14]*metabol* = change + *ism* = process
[15]*ana* = up
[16]*cata* = down

Homeostasis and Negative Feedback

Homeostasis[17] (ho-me-oh-STAY-sis) is one of the theories that will arise most frequently in this book as we study mechanisms of health and disease. The human body has a remarkable capacity for self-restoration. Hippocrates commented that it usually returns to a state of equilibrium by itself, and people recover from most illnesses even without the help of a physician. This tendency results from homeostasis, the ability to detect change and activate mechanisms that oppose it.

French physiologist *Claude Bernard* (1813–78) observed that the internal conditions of the body remain fairly stable even when external conditions vary greatly. For example, whether it is freezing cold or swelteringly hot outdoors, the internal temperature of your body stays within a range of about 36° to 37°C (97°–99°F). American physiologist *Walter Cannon* (1871–1945) coined the term *homeostasis* for this tendency to maintain internal stability. Homeostasis has been one of the most enlightening concepts in physiology. Physiology is largely a group of mechanisms for maintaining homeostasis, and the loss of homeostatic control tends to cause illness or death. Pathophysiology is essentially the study of unstable conditions that result when our homeostatic controls go awry.

Do not, however, overestimate the degree of internal stability. Internal conditions are not absolutely constant but fluctuate within a limited range, such as the range of body temperatures noted earlier. The internal state of the body is best described as a **dynamic equilibrium** (balanced change), in which there is a certain **set point** or average value for a given variable (such as 37°C for body temperature) and conditions fluctuate slightly around this point.

The fundamental mechanism that keeps a variable close to its set point is **negative feedback**—a process in which the body senses a change and activates mechanisms that negate or reverse it. By maintaining stability, negative feedback is the key mechanism for maintaining health.

These principles can be understood by comparison to a home heating system (fig. 1.11). Suppose it is a cold winter day and you have set your thermostat for 20°C (68°F)—the set point. If the room becomes too cold, a temperature-sensitive switch in the thermostat turns on the furnace. The temperature rises until it is slightly above the set point, and then the switch breaks the circuit and turns off the furnace. This is a negative feedback process that reverses the falling temperature and restores it to something close to the set point. When the furnace turns off, the temperature slowly drops again until the switch is reactivated—thus, the furnace cycles on and off all day. The room temperature does not stay at exactly 20°C but *fluctuates* a few degrees either way—the system maintains a state of dynamic equilibrium in which the temperature averages 20°C and deviates from the set point by only a few degrees. Because feedback mechanisms alter the original changes that triggered them (temperature, for example), they are often called **feedback loops.**

Body temperature is also regulated by a "thermostat"—a group of nerve cells in the base of the brain that monitors the temperature of the blood. If you become overheated, the thermostat triggers heat-losing mechanisms (fig. 1.12). One of these is **vasodilation** (VAY-zo-dy-LAY-shun), the widening of blood vessels. When blood vessels of the skin dilate, warm blood flows closer to the body surface and loses heat to the surrounding air. If this is not enough to return your temperature to normal, sweating occurs; the evaporation of

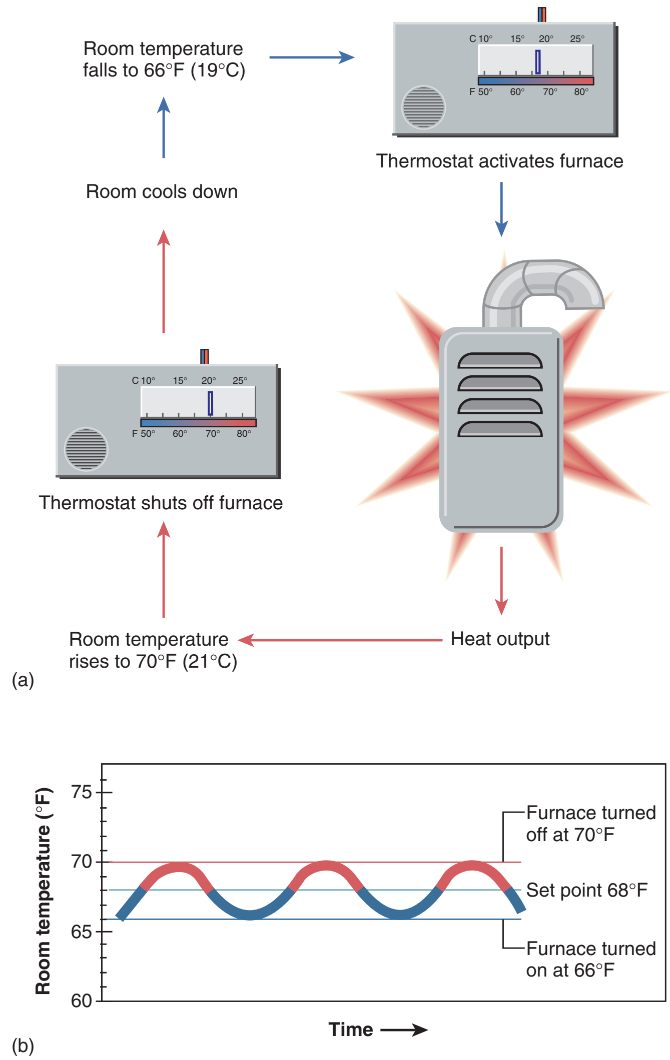


Figure 1.11 Negative Feedback in a Home Heating System.
(*a*) The negative feedback loop that maintains room temperature.
(*b*) Fluctuation of room temperature around the thermostatic set point.
What component of the heating system acts as the sensor? What component acts as the effector?

[17] *homeo* = the same + *stas* = to place, stand, stay

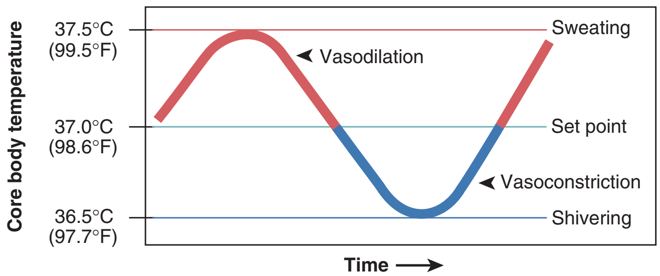


Figure 1.12 Negative Feedback in Human Thermoregulation. Negative feedback keeps the human body temperature homeostatically regulated within about 0.5°C of a 37°C set point. Sweating and cutaneous vasodilation lower the body temperature; shivering and cutaneous vasoconstriction raise it.
Why does vasodilation reduce the body temperature?

water from the skin has a powerful cooling effect (see insight 1.3). Conversely, if it is cold outside and your body temperature drops much below 37°C, these nerve cells activate heat-conserving mechanisms. The first to be activated is **vasoconstriction,** a narrowing of the blood vessels in the skin, which serves to retain warm blood deeper in your body and reduce heat loss. If this is not enough, the brain activates shivering—muscle tremors that generate heat.

Insight 1.3 Medical History

Men in the Oven

English physician Charles Blagden (1748–1820) staged a rather theatrical demonstration of homeostasis long before Cannon coined the word. In 1775, Blagden spent 45 minutes in a chamber heated to 127°C (260°F)—along with a dog, a beefsteak, and some research associates. Being alive and capable of evaporative cooling, the dog panted and the men sweated. The beefsteak, being dead and unable to maintain homeostasis, was cooked.

To take another example, a rise in blood pressure is sensed by stretch receptors in the wall of the heart and the major arteries above it. These receptors send nerve signals to a *cardiac center* in the brainstem. The cardiac center integrates this input with other information and sends nerve signals back to the heart to slow it and lower the blood pressure. Thus we can see that homeostasis is maintained by self-correcting negative feedback loops. Many more examples are found throughout this book.

It is common, although not universal, for feedback loops to include three components: a receptor, an integrator, and an effector. The **receptor** is a structure that senses a change in the body, such as the stretch receptors that monitor blood pressure. The **integrating (control) center,** such as the cardiac center of the brain, is a mechanism that processes this information, relates it to other available information (for example, comparing what the blood pressure is with what it should be), and "makes a decision" about what the appropriate response should be. The **effector,** in this case the heart, is the structure that carries out the response that restores homeostasis. The response, such as a lowering of the blood pressure, is then sensed by the receptor, and the feedback loop is complete.

Positive Feedback and Rapid Change

Positive feedback is a self-amplifying cycle in which a physiological change leads to even greater change in the same direction, rather than producing the corrective effects of negative feedback. Positive feedback is often a normal way of producing rapid change. When a woman is giving birth, for example, the head of the baby pushes against her cervix (the neck of the uterus) and stimulates its nerve endings (fig. 1.13). Nerve signals travel to the brain, which, in turn, stimulates the pituitary gland to secrete the hormone oxytocin. Oxytocin travels in the blood and stimulates the uterus to contract. This pushes the baby downward, stimulating the cervix still more and causing the positive feedback loop to be repeated. Labor contractions therefore become more and more intense until the baby is expelled. Other cases of beneficial positive feedback are seen later in the book; for example, in blood clotting, protein digestion, and the generation of nerve signals.

Frequently, however, positive feedback is a harmful or even life-threatening process. This is because its self-amplifying nature can quickly change the internal state of the body to something far from its homeostatic set point. Consider a high fever, for example. A fever triggered by infection is beneficial up to a point, but if the body temperature rises much above 42°C (108°F), it may create a dangerous positive feedback loop (fig. 1.14). This high temperature raises the metabolic rate, which makes the body produce heat faster than it can get rid of it. Thus, temperature rises still further, increasing the metabolic rate and heat production still more. This "vicious circle" becomes fatal at approximately 45°C (113°F). Thus, positive feedback loops often create dangerously out-of-control situations that require emergency medical treatment.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

14. List four biological criteria of life and one clinical criterion. Explain how a person could be clinically dead but biologically alive.
15. What is meant by *dynamic equilibrium?* Why would it be wrong to say homeostasis prevents internal change?
16. Explain why stabilizing mechanisms are called *negative* feedback.
17. Explain why positive feedback is more likely than negative feedback to disturb homeostasis.

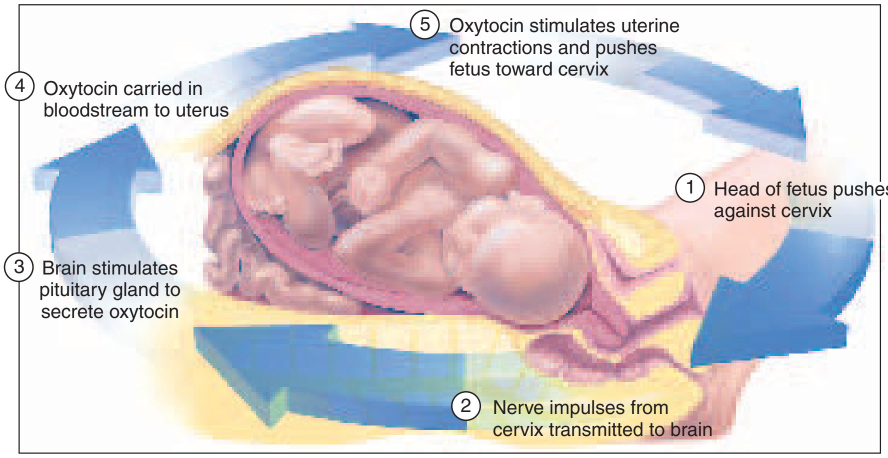


Figure 1.13 **Positive Feedback in Childbirth.** This is one of several cases in which positive feedback produces beneficial rapid change.

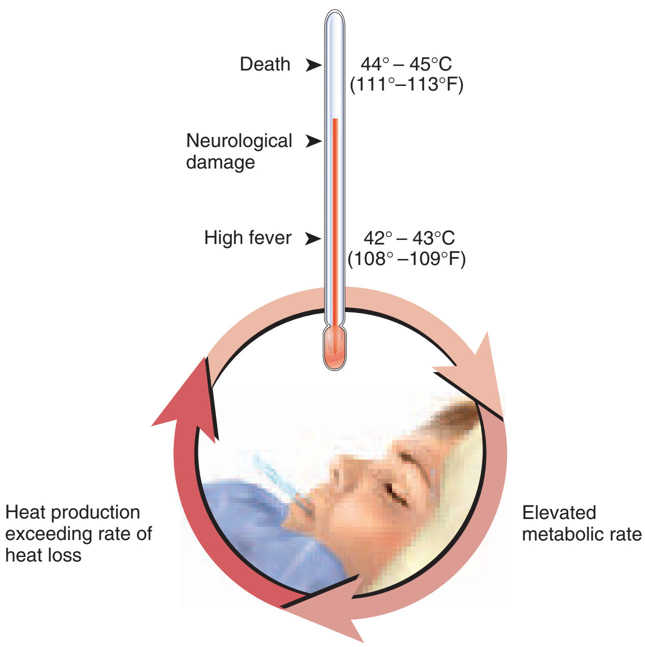


Figure 1.14 **Positive Feedback in Fever.** In such cases as this, positive feedback can produce a life-threatening loss of homeostatic control.

The Language of Medicine

Objectives

When you have completed this section, you should be able to

- explain why modern anatomical terminology is so heavily based on Greek and Latin;
- recognize eponyms when you see them;
- describe the efforts to achieve an internationally uniform anatomical terminology;
- break medical terms down into their basic word elements;
- state some reasons why the literal meaning of a word may not lend insight into its definition;
- relate singular noun forms to their plural forms; and
- discuss why precise spelling is important in anatomy and physiology.

One of the greatest challenges faced by students of anatomy and physiology is the vocabulary. In this book, you will encounter such Latin terms as *corpus callosum* (a brain structure), *ligamentum arteriosum* (a small fibrous band near the heart), and *extensor carpi radialis longus* (a forearm muscle). You may wonder why structures aren't named in "just plain English," and how you will ever remember such formidable names. This section will give you some answers to these questions and some useful tips on mastering anatomical terminology.

The History of Anatomical Terminology

The major features of human gross anatomy have standard international names prescribed by a book titled the *Terminologia Anatomica* (TA). The TA was codified in 1998 by an international body of anatomists, the Federative Committee on Anatomical Terminology, and approved by professional associations of anatomists in more than 50 countries.

About 90% of today's medical terms are formed from just 1,200 Greek and Latin roots. Scientific investigation began in ancient Greece and soon spread to Rome. The Greeks and Romans coined many of the words still used in human anatomy today: *uterus, prostate, cerebellum, diaphragm, sacrum, amnion,* and others. In the Renaissance, the fast pace of anatomical discovery required a

profusion of new terms to describe things. Anatomists in different countries began giving different names to the same structures. Adding to the confusion, they often named new structures and diseases in honor of their esteemed teachers and predecessors, giving us such nondescriptive terms as the *crypts of Lieberkühn* and *duct of Santorini.* Terms coined from the names of people, called **eponyms,**[18] afford little clue as to what a structure or condition is.

In hopes of resolving this growing confusion, anatomists began meeting as early as 1895 to try to devise a uniform international terminology. After several false starts, anatomists agreed on a list of terms titled the *Nomina Anatomica* (NA), which rejected all eponyms and gave each structure a unique Latin name to be used worldwide. Even if you were to look at an anatomy atlas in Japanese or Arabic, the illustrations may be labeled with the same Latin terms as in an English-language atlas. The NA served for many decades until recently replaced by the TA, which prescribes both Latin names and accepted English equivalents. The terminology in this book conforms to the TA except where undue confusion would result from abandoning widely used, yet unofficial terms.

Analyzing Medical Terms

The task of learning medical terminology seems overwhelming at first, but there is a simple trick to becoming more comfortable with the technical language of medicine. People who find scientific terms confusing and difficult to pronounce, spell, and remember usually feel more confident once they realize the logic of how terms are composed. A term such as *hyponatremia* is less forbidding once we recognize that it is composed of three common word elements: *hypo-* (below normal), *natri-* (sodium), and *-emia* (blood condition). Thus, hyponatremia is a deficiency of sodium in the blood. Those word elements appear over and over in many other medical terms: *hypothermia, natriuretic, anemia,* and so on. Once you learn the meanings of *hypo-, natri-,* and *-emia,* you already have the tools at least to partially understand hundreds of other biomedical terms. In appendix C, you will find a lexicon of the 400 word elements most commonly footnoted in this book.

Scientific terms are typically composed of one or more of the following elements:

- At least one *root (stem)* that bears the core meaning of the word. In *cardiology,* for example, the root is *cardi-* (heart). Many words have two or more roots. In *cytochrome,* the roots are *cyt-* (cell) and *chrom-* (color).
- *Combining vowels* that are often inserted to join roots and make the word easier to pronounce. In *cytochrome,* for example, the first *o* is a combining vowel. Although *o* is the most common combining vowel, all vowels of the alphabet are used in this way, such as *a* in *ligament, e* in *vitreous,* the first *i* in *spermicidal, u* in *ovulation,* and *y* in *tachycardia.* Some words have no combining vowels. A combination of a root and combining vowel is called a *combining form:* for example, *ost* (bone) + *e* (a combining vowel) make the combining form *oste-,* as in *osteology.*
- A *prefix* may be present to modify the core meaning of the word. For example, *gastric* (pertaining to the stomach or to the belly of a muscle) takes on a wide variety of new meanings when prefixes are added to it: *epigastric* (above the stomach), *hypogastric* (below the stomach), *endogastric* (within the stomach), and *digastric* (a muscle with two bellies).
- A *suffix* may be added to the end of a word to modify its core meaning. For example, *microscope, microscopy, microscopic,* and *microscopist* have different meanings because of their suffixes alone. Often two or more suffixes, or a root and suffix, occur together so often that they are treated jointly as a *compound suffix;* for example, *log* (study) + *y* (process) form the compound suffix *-logy* (the study of).

To summarize these basic principles, consider the word *gastroenterology,* a branch of medicine dealing with the stomach and small intestine. It breaks down into: gastro/entero/logy

gastro = a combining form meaning "stomach"

entero = a combining form meaning "small intestine"

logy = a compound suffix meaning "the study of"

"Dissecting" words in this way and paying attention to the word-origin footnotes throughout this book will help make you more comfortable with the language of anatomy. Knowing how a word breaks down and knowing the meaning of its elements make it far easier to pronounce a word, spell it, and remember its definition. There are a few unfortunate exceptions, however. The path from original meaning to current usage has often become obscured by history (see insight 1.4). The foregoing approach also is no help with eponyms or **acronyms**—words composed of the first letter, or first few letters, of a series of words. For example, *calmodulin,* a calcium-binding protein found in many cells, is cobbled together from a few letters of the three words, *cal*cium *modul*ating prote*in.*

Insight 1.4 Medical History

Obscure Word Origins

The literal translation of a word doesn't always provide great insight into its modern meaning. The history of language is full of twists

[18] *epo* = after, related to + *nym* = name

and turns that are fascinating in their own right and say much about the history of human culture, but they can create confusion for students.

For example, the *amnion* is a transparent sac that forms around the developing fetus. The word is derived from *amnos,* from the Greek for "lamb." From this origin, *amnos* came to mean a bowl for catching the blood of sacrificial lambs, and from there the word found its way into biomedical usage for the membrane that emerges (quite bloody) as part of the afterbirth. The *acetabulum,* the socket of the hip joint, literally means "vinegar cup." Apparently the hip socket reminded an anatomist of the little cups used to serve vinegar as a condiment on dining tables in ancient Rome. The word *testicles* literally means "little witnesses." The history of medical language has several amusing conjectures as to why this word was chosen to name the male gonads.

Singular and Plural Forms

A point of confusion for many beginning students is how to recognize the plural forms of medical terms. Few people would fail to recognize that *ovaries* is the plural of *ovary,* but the connection is harder to make in other cases: for example, the plural of *cortex* is *cortices* (COR-ti-sees), the plural of *corpus* is *corpora,* and the plural of *epididymis* is *epididymides* (EP-ih-DID-ih-MID-eze). Table 1.2 will help you make the connection between common singular and plural noun terminals.

Table 1.2 Singular and Plural Forms of Some Noun Terminals

Singular Ending	Plural Ending	Examples
-a	-ae	axilla, axillae
-ax	-aces	thorax, thoraces
-en	-ina	lumen, lumina
-ex	-ices	cortex, cortices
-is	-es	diagnosis, diagnoses
-is	-ides	epididymis, epididymides
-ix	-ices	appendix, appendices
-ma	-mata	carcinoma, carcinomata
-on	-a	ganglion, ganglia
-um	-a	septum, septa
-us	-era	viscus, viscera
-us	-i	villus, villi
-us	-ora	corpus, corpora
-x	-ges	phalanx, phalanges
-y	-ies	ovary, ovaries
-yx	-ices	calyx, calices

The Importance of Precision

A final word of advice for your study of anatomy and physiology: Be precise in your use of terms. It may seem trivial if you misspell *trapezius* as *trapezium,* but in doing so, you would be changing the name of a back muscle to the name of a wrist bone. Similarly, changing *occipitalis* to *occipital* or *zygomaticus* to *zygomatic* changes other muscle names to bone names. A "little" error such as misspelling *ileum* as *ilium* changes the name of the final portion of the small intestine to the name of the hip bone. Changing *malleus* to *malleolus* changes the name of a middle-ear bone to the name of a bony protuberance of your ankle. *Elephantiasis* is a disease that produces an elephant-like thickening of the limbs and skin. Many people misspell this *elephantitis;* if such a word existed, it would mean inflammation of an elephant.

The health professions demand the utmost attention to detail and precision—people's lives may one day be in your hands. The habit of carefulness must extend to your use of language as well. Many patients have died because of miscommunication in the hospital.

Before You Go On

Answer the following questions to test your understanding of the preceding section:

18. Explain why modern anatomical terminology is so heavily based on Greek and Latin.
19. Distinguish between an eponym and an acronym, and explain why both of these present difficulties for interpreting anatomical terms.
20. Break each of the following words down into its roots and affixes and state their meanings, following the example of *gastroenterology* analyzed earlier: *pericardium, appendectomy, subcutaneous, phonocardiogram, otorhinolaryngology.* Consult the list of word elements in appendix C for help.
21. Write the singular form of each of the following words: *pleurae, gyri, nomina, ganglia, fissures.* Write the plural form of each of the following: *villus, tibia, encephalitis, cervix, stoma.*

Review of Major Themes

To close this chapter, let's distill a few major points from it. These themes can provide you with a sense of perspective that will make the rest of the book more meaningful and not just a collection of disconnected facts. These are some key unifying principles behind all study of human anatomy and physiology:

- **Cell theory.** *All structure and function result from the activity of cells.* Every physiological concept in this book ultimately must be understood from the standpoint of how cells function. Even anatomy is a result of cellular function. If cells are damaged or destroyed, we see the results in disease symptoms of the whole person.

- **Homeostasis.** *The purpose of most normal physiology is to maintain stable conditions within the body.* Human physiology is essentially a group of mechanisms that produce stable internal conditions favorable to cellular function. Any serious departure from these conditions can be harmful or fatal to cells.
- **Evolution.** *The human body is a product of evolution.* Like every other living species, we have been molded by millions of years of natural selection to function in a changing environment. Many aspects of human anatomy and physiology reflect our ancestors' adaptations to their environment. Human form and function cannot be fully understood except in light of our evolutionary history.
- **Hierarchy of structure.** *Human structure can be viewed as a series of levels of complexity.* Each level is composed of a smaller number of simpler subunits than the level above it. These subunits are arranged in different ways to form diverse structures of higher complexity. For example, all the body's organs are made of just four primary classes of tissue, and the thousands of proteins are made of various combinations of just 20 amino acids. Understanding these simpler components is the key to understanding higher levels of structure.
- **Unity of form and function.** *Form and function complement each other; physiology cannot be divorced from anatomy.* This unity holds true even down to the molecular level. Our very molecules, such as DNA and proteins, are structured in ways that enable them to carry out their functions. Slight changes in molecular structure can destroy their activity and threaten life.

Think About It

Architect Louis Henri Sullivan coined the phrase, "Form ever follows function." What do you think he meant by this? Discuss how this idea could be applied to the human body and cite a specific example of human anatomy to support it.

Insight 1.5 Clinical Application

Medical Imaging

The development of techniques for looking into the body without having to do exploratory surgery has greatly accelerated progress in medicine. A few of these techniques are described here.

Radiography

X rays, a form of high-energy radiation, were discovered by William Roentgen in 1885. X rays can penetrate soft tissues of the body and darken photographic film on the other side. They are absorbed, however, by dense tissues such as bone, teeth, tumors, and tuberculosis nodules, which leave the film lighter in these areas (fig. 1.15*a*). The process of examining the body with X rays is called *radiography.* The term *X ray* also applies to a photograph *(radiograph)* made by this method. Radiography is commonly used in dentistry, mammography, diagnosis of fractures, and examination of the chest. Hollow organs can be visualized by filling them with a *radiopaque* substance that absorbs X rays. Barium sulfate is given orally for examination of the esophagus, stomach, and small intestine or by enema for examination of the large intestine. Other substances are given by injection for *angiography,* the examination of blood vessels (fig. 1.15*b*). Some disadvantages of radiography are that images of overlapping organs can be confusing and slight differences in tissue density are not easily detected. Nevertheless, radiography still accounts for over half of all clinical imaging. Until the 1960s, it was the only method widely available.

Sonography

Sonography[19] is the second oldest and second most widely used method of imaging. It is an outgrowth of sonar technology developed in World War II. A handheld device held firmly to the skin produces high-frequency ultrasound waves and receives the signals that echo back from internal organs. Although sonography was first used medically in the 1950s, images of significant clinical value had to wait until computer technology had developed enough to analyze differences in the way tissues reflect ultrasound. Sonography is not very useful for examining bones or lungs, but it is the method of choice in obstetrics, where the image *(sonogram)* can be used to locate the placenta and evaluate fetal age, position, and development. Sonography avoids the harmful effects of X rays, and the equipment is inexpensive and portable. Its primary disadvantage is that it does not produce a very sharp image (fig. 1.16).

Computed Tomography (CT)

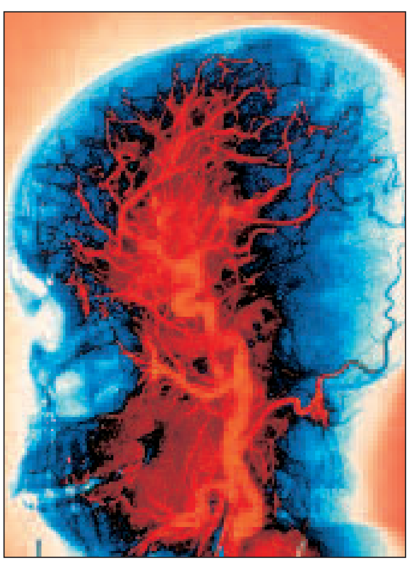
The *CT scan,* formerly called a computerized axial tomographic[20] (CAT) scan, is a more sophisticated application of X rays developed in 1972. The patient is moved through a ring-shaped machine that emits low-intensity X rays on one side and receives them with a detector on the opposite side. A computer analyzes signals from the detector and produces an image of a "slice" of the body about as thin as a coin (fig. 1.17). The computer can "stack" a series of these images to construct a three-dimensional image of the body. CT scanning has the advantage of imaging thin sections of the body, so there is little overlap of organs and the image is much sharper than a conventional X ray. CT scanning is useful for identifying tumors, aneurysms, cerebral hemorrhages, kidney stones, and other abnormalities. It has virtually eliminated exploratory surgery.

Positron Emission Tomography (PET)

The *PET scan,* developed in the 1970s, is used to assess the metabolic state of a tissue and to distinguish which tissues are most active at a given moment (fig. 1.18). The procedure begins with an injection of radioactively labeled glucose, which emits positrons (electron-like particles with a positive charge). When a positron and electron meet, they annihilate each other and give off a pair of gamma rays that can be detected by sensors and analyzed by computer. The computer displays a color image that shows which tissues were using the most glucose at the moment. In cardiology, PET scans can show the extent of damaged

[19] *sono* = sound + *graphy* = recording process
[20] *tomo* = section, cut, slice + *graphic* = pertaining to a recording

(a)



(b)

Figure 1.15 Radiography. (*a*) An X ray (radiograph) of the head and neck. (*b*) A cerebral angiogram, made by injecting a substance opaque to X rays into the circulation and then taking an X ray of the head to visualize the blood vessels. The arteries are enhanced with false color in this photograph.

Figure 1.16 Fetal Sonogram. Shows the head and right arm of a 28-week-old fetus sucking its thumb.

heart tissue. Since it consumes little or no glucose, the damaged tissue appears dark. The PET scan is an example of *nuclear medicine*—the use of radioactive isotopes to treat disease or to form diagnostic images of the body.

Magnetic Resonance Imaging (MRI)

MRI, once known as *nuclear magnetic resonance (NMR) imaging*, was developed in the 1970s as a technique superior to CT scanning for visualizing soft tissues. The patient lies within a cylindrical chamber surrounded by a large electromagnet that creates a magnetic field 3,000 to 60,000 times as strong as the earth's. Hydrogen atoms in the tissues align themselves with the magnetic field. The patient is then bombarded with radio waves, which cause the hydrogen atoms to absorb additional energy and align in a different direction. When the radio waves are turned off, the hydrogen atoms abruptly realign themselves to the magnetic field, giving off their excess energy at different rates that depend on the type of tissue. A computer analyzes the emitted energy to produce an image of the body. MRI can "see" clearly through the skull and spinal column to produce images of the nervous tissue. Moreover, it is better than CT for distinguishing between soft tissues such as the white and gray matter of the nervous system (fig. 1.19).

Figure 1.17 Computed Tomographic (CT) Scan of the Head at the Level of the Eyes. The eyes and skin are shown in blue, bone in red, and the brain in green.

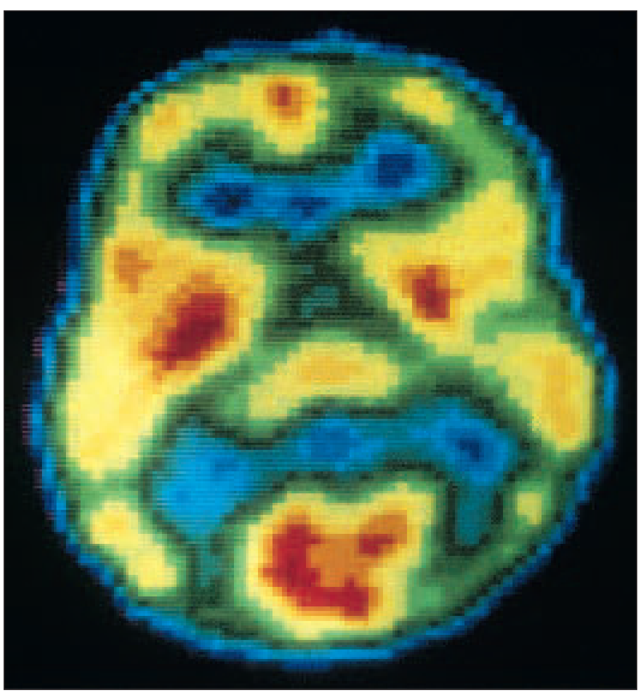


Figure 1.18 Positron Emission Tomographic (PET) Scan of the Brain of an Unmedicated Schizophrenic Patient. Red areas indicate high glucose consumption (high metabolism). In this patient, the visual center of the brain (rear of head, *bottom of photo*) was especially active when the scan was made.

Figure 1.19 Magnetic Resonance Image (MRI) of the Head at the Level of the Eyes. The optic nerves appear in red and the muscles that move the eyes appear in green.

Functional MRI (fMRI) is a variation on this technique that visualizes moment-to-moment changes in tissue function. fMRI scans of the brain, for example, show shifting patterns of activity as the brain applies itself to a specific task. fMRI has lately replaced the PET scan as the most important method for visualizing brain function. The use of fMRI in brain imaging is further discussed in chapter 14.

Chapter Review

Review of Key Concepts

The Scope of Anatomy and Physiology (p. 2)

1. Human *anatomy,* or structure, is studied at gross and microscopic (histological) levels.
2. The methods of anatomy include dissection, palpation, and imaging techniques such as X rays, sonography, and CT, PET, and MRI scans.
3. Human *physiology,* or function, is studied by experimental methods, and often by comparison to other species.

The Origins of Biomedical Science (p. 3)

1. Hippocrates and Aristotle first put medicine on a scientific basis by distinguishing natural causes from the supernatural.
2. Galen wrote the first notable medical textbook, which dominated western medicine for 1,500 years.
3. In the Middle Ages, Avicenna and other Muslims were largely responsible for the survival of medical science.
4. In the sixteenth century, revolutionary work in anatomy by Vesalius and in physiology by Harvey created a foundation for modern medicine.
5. Improvements in the microscope by Leeuwenhoek, Hooke, and later Zeiss and Abbe opened the door to understanding anatomy, physiology, and disease at a cellular level.

Scientific Method (p. 7)

1. Philosophers Bacon and Descartes first established a systematic scientific way of thought.
2. The *inductive method,* common in anatomy, consists of generalizing about nature from numerous observations.
3. The *hypothetico-deductive method,* common in physiology, consists of formulating hypotheses and testing them by carefully crafted observational strategies.
4. The objectivity of medical science depends on experimental designs that include an adequate sample size, experimental controls such as placebos and the double-blind method, statistical analysis of the significance of the data, and peer review by other experts.
5. Science generates facts, laws, and theories. Theories are summations of our present knowledge of natural phenomena and are the basis of much of our study in anatomy and physiology.

Human Origins and Adaptations (p. 9)

1. Human form and function have been shaped by millions of years of *natural selection.*
2. Many aspects of anatomy and physiology today, such as stereoscopic vision and opposable thumbs, are *adaptations* to the environments in which our prehistoric ancestors lived, including the arboreal and grassland habitats of Africa.
3. *Evolutionary medicine* is the analysis of human form, function, and disease in light of the evolutionary history of the human body.

Human Structure (p. 12)

1. Human structure is organized around a hierarchy of complexity. Levels of human complexity from most complex to simplest are *organism, organ systems, organs, tissues, cells, organelles, molecules,* and *atoms.*
2. Introductory textbooks teach only the most common human structure, but there are many variations in both internal and external anatomy.

Human Function (p. 14)

1. Life can be defined only as a collection of properties including *organization, cellular composition, metabolism, excretion, responsiveness, movement, homeostasis, development, reproduction,* and *evolution.*
2. For clinical purposes, life and legal death are differentiated on the basis of brain waves, reflexes, respiration, and heartbeat.
3. Humans vary greatly in their physiology. Data given in introductory and general textbooks are typically based on a young adult *reference male* and *reference female.*
4. An important unifying theory in physiology is *homeostasis,* mechanisms of maintaining internal constancy in spite of environmental change. Homeostasis keeps such variables as blood pressure and body temperature within a narrow range of an average called the *set point.*
5. Homeostasis is maintained by self-correcting chain reactions called *negative feedback*. This often involves detection of a change by a *receptor,* processing of this information by an *integrating center,* and reversal of the change by an *effector.*
6. *Positive feedback* is a self-amplifying chain of events that tends to produce rapid change in the body. It can be valuable in such cases as childbirth and blood clotting, but is often a cause of dysfunction and death.

The Language of Medicine (p. 19)

1. Anatomists the world over adhere to a lexicon of standard international terms called the *Terminologia Anatomica* (TA). Anatomy students must learn many Latin or English TA terms.
2. Biomedical terms can usually be simplified by breaking them down into familiar roots, prefixes, and suffixes. The habit of analyzing words in this way can greatly ease the difficulty of learning biomedical vocabulary, and is aided by footnotes throughout this book.
3. Precision in medical language is highly important. What may seem to be trivial spelling errors can radically change the meaning of a word, potentially causing dangerous medical errors.

Selected Vocabulary

anatomy 2
physiology 2
palpation 2
auscultation 2
gross anatomy 2
hypothesis 7
law of nature 9
theory 9
evolution 9
adaptation 10
organ system 13
organ 13
tissue 13
cell 13
metabolism 16
differentiation 16
reference man 16
reference woman 16
homeostasis 17
set point 17
negative feedback 17
vasodilation 17
vasoconstriction 18
positive feedback 18

Testing Your Recall

1. Structure that can be observed with the naked eye is called
   a. gross anatomy.
   b. ultrastructure.
   c. microscopic anatomy.
   d. macroscopic anatomy.
   e. cytology.
2. The word root *homeo-* means
   a. tissue.
   b. metabolism.
   c. change.
   d. human.
   e. same.
3. The simplest structures considered to be alive are
   a. organisms.
   b. organs.
   c. tissues.
   d. cells.
   e. organelles.
4. Which of the following people revolutionized the teaching of gross anatomy?
   a. Vesalius
   b. Aristotle
   c. Hippocrates
   d. Leeuwenhoek
   e. Cannon
5. Which of the following embodies the greatest amount of scientific information?
   a. a fact
   b. a law of nature
   c. a theory
   d. a deduction
   e. a hypothesis
6. An informed, uncertain, but testable conjecture is
   a. a natural law.
   b. a scientific theory.
   c. a hypothesis.
   d. a deduction.
   e. a scientific fact.
7. A self-amplifying chain of physiological events is called
   a. positive feedback.
   b. negative feedback.
   c. dynamic constancy.
   d. homeostasis.
   e. metabolism.
8. Which of the following is *not* a human organ system?
   a. integumentary
   b. muscular
   c. epithelial
   d. nervous
   e. endocrine
9. _____ means studying anatomy by touch.
   a. Gross anatomy
   b. Auscultation
   c. Osculation
   d. Palpation
   e. Percussion
10. The prefix *hetero-* means
    a. same.
    b. different.
    c. both.
    d. solid.
    e. below.
11. Cutting and separating tissues to reveal structural relationships is called _____.
12. _____ invented many components of the compound microscope and named the cell.
13. By the process of _____, a scientist predicts what the result of a certain experiment will be if his or her hypothesis is correct.
14. Physiological effects of a person's mental state are called _____ effects.
15. The tendency of the body to maintain stable internal conditions is called _____.
16. Blood pH averages 7.4 but fluctuates from 7.35 to 7.45. A pH of 7.4 can therefore be considered the _____ for this variable.
17. Self-corrective mechanisms in physiology are called _____ loops.
18. A/an _____ is the simplest body structure to be composed of two or more types of tissue.
19. Depth perception, or the ability to form three-dimensional images, is also called _____ vision.
20. Our hands are said to be _____ because they can encircle an object such as a branch or tool. The presence of an _____ thumb is important to this ability.

Answers in Appendix B

True or False

Determine which five of the following statements are false, and briefly explain why.

1. The technique for listening to the sounds of the heart valves is auscultation.
2. The inventions of Carl Zeiss and Ernst Abbe are necessary to the work of a modern histopathologist.
3. Abnormal skin color or dryness could be one piece of diagnostic information gained by auscultation.
4. There are more organelles than cells in the body.
5. The word *scuba,* derived from the words *self-contained underwater breathing apparatus,* is an acronym.
6. Leeuwenhoek was a biologist who invented the simple microscope in order to examine organisms in lake water.
7. A scientific theory is just a speculation until someone finds the evidence to prove it.
8. In a typical clinical research study, volunteer patients are in the treatment group and the physicians and scientists who run the study constitute the control group.
9. The great mobility of the primate shoulder joint is an adaptation to the arboreal habitat.
10. Negative feedback usually has a negative (harmful) effect on the body.

Answers in Appendix B

Testing Your Comprehension

1. What aspect of William Harvey's view of blood circulation could be considered a scientific hypothesis? What would you predict from that hypothesis? What observation could you carry out today to test this hypothesis?
2. Which of the characteristics of living things are possessed by an automobile? What bearing does this have on our definition of life?
3. About 1 out of every 120 live-born infants has a structural defect in the heart such as a hole between two heart chambers. Such infants often suffer pulmonary congestion and heart failure, and about one-third of them die as a result. Which of the major themes in this chapter does this illustrate? Explain your answer.
4. How might human anatomy be different today if the forerunners of humans had never inhabited the forest canopy?
5. Suppose you have been doing heavy yard work on a hot day and sweating profusely. You become very thirsty, so you drink a tall glass of lemonade. Explain how your thirst relates to the concept of homeostasis. Which type of feedback—positive or negative—does this illustrate?

Answers at the Online Learning Center

Answers to Figure Legend Questions

1.8 A gorilla. About 4.5 million years.
1.11 The thermostat is the sensor. The furnace is the effector.
1.12 It allows blood to circulate closer to the skin surface and lose heat through the skin.