The Human Body
Essentials of Anatomy and Physiology
Black and white edition

By Bruce Wingerd

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THE HUMAN BODY
Essentials of Anatomy & Physiology
Second Color Edition

Bruce Wingerd
Bruce Wingerd is Associate Dean of Biology at Broward Community College in Florida and previously taught at San Diego State University for 25 years. He has taught human anatomy, advanced human anatomy, medical terminology, and anatomy and physiology. Between his numerous writing projects, he has run workshops on teaching anatomy and physiology for the benefit of local high school and junior high school teachers.

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A study guide along with full-color versions of all illustrations are available to students enrolled in a class using this textbook. Go to http://www.universityreaders/publish/wingerd/students
About 14 years ago, a new idea for reaching students struggling through the mountains of terminology in anatomy and physiology was proposed: Create a textbook that helps students learn the essential information by using the process of concept building. If a student is able to form a mental image of a technical term’s meaning or a process, learning becomes easier and lasts longer due to the mental connections that are forged. Instead of memorizing a term by its definition or literal description, the student is encouraged to visualize its meaning and its place within a larger mental picture. Of course, some memorizing is unavoidable, but providing students with concept-building tools empowers them to learn the information. When this style is combined with a carefully constructed balance between anatomy and physiology, and with a selection of information that is at an essential level of learning, the result can lead to personal and professional growth.

From this basic idea of learning, the first edition of The Human Body: Concepts of Anatomy and Physiology was produced. This new, second edition provides an opportunity to make the book an even better tool for learning. Many suggestions for improving the first edition came from colleagues who have read the book, and many from thousands of student readers who have used the book in their courses. Still other ideas have arisen from the changes that have occurred in scientific knowledge and medical practice. These ideas have been collectively integrated with the first edition to produce an improved learning tool for students. It remains my hope that students will not only gain important insights into the human body by using this text, but will also experience a sense of marvel and wonder at the body’s amazing design and intricate workings.

NEW TO THE SECOND EDITION

A new edition requires a critical appraisal of every statement in the original text, in addition to recognizing opportunities for including changes that reviewers have asked to see. In general, this second edition is a more balanced text that includes more parallels with everyday life experiences and a more reader-friendly style. The level of information has been fine tuned in response to requests from reviewers, with some terms added and others deleted. Explanations of many physiological processes have been refreshed to reflect new information and technologies.

THE APPROACH AND MAIN THEME

Human anatomy and physiology is a challenging topic for introductory-level learners, and mastering the material requires an investment of time and effort. The second edition of The Human Body meets this challenge by providing an approach that encourages learning. The approach includes three components: integrating structure and function, learning with the aid of concept-building tools, and using the process of homeostasis as an interwoven theme.

Integrating Structure and Function

Keeping in line with the successes of the first edition, the book’s main approach is to establish a comfortable balance of structure and function for the beginning student. At the outset of a chapter, students are presented with a “big picture,” which offers a general view of the overall structure and function of a particular system. The more detailed information follows, usually beginning with anatomical terms. Only the terms needed to fully understand and communicate function are provided. Then function is described, using the building-block terms that were just discussed. With each body part discussion, the functional importance of a structure is emphasized.

Learning with Concept-Building Tools

The book’s approach is also based on the notion that learning new technical information becomes more attainable and complete if a conceptual foundation is provided. Numerous concept-building tools are employed to establish this foundation. Each tool enables a student to establish a mental image of a body structure or body function, which will become beneficial when the task of learning details becomes necessary. The conceptual foundation is reinforced by logical explanations that tie new information to previously learned material, correlations with everyday experiences, accurate and current information, and many high-quality illustrations that correspond directly to the text material.
The Theme of Homeostasis
The main theme of the text is the body’s remarkable ability to maintain homeostasis. How the body achieves homeostasis despite changing conditions, the body components involved in its maintenance, and the consequences of the body’s failure to maintain it effectively are topics that are interwoven throughout. In many chapters, the role of body tissues, organs, and systems in maintaining and supporting homeostasis is discussed along with their other functions. To emphasize the importance of homeostasis in the daily maintenance of health, this vital body function is also presented as a separate topic at the end of most chapters. This feature serves to connect homeostasis with the main functions of the body system discussed in the chapter.

IMPROVED COVERAGE

Every chapter in the second edition of The Human Body: Essentials of Anatomy and Physiology includes improvements to both the text and the art program, following the suggestions of colleagues and students, and in response to changing technologies. Five chapters were more substantially revised than others.

Chapter 2: The Chemical Basis of the Body
Chemistry is a common stumbling ground for beginning students, but it doesn’t need to be if it is presented clearly. To make the introduction of chemistry more accessible for students, this chapter was rewritten with an emphasis on clarity and real-world examples of chemical principles.

Chapter 3: Cells: The Basis of Life
The field of cell biology has experienced many changes in the past decade, mainly due to an increased understanding that has arisen from research. This chapter was rewritten to reflect these changes. For example, new information has been included to reflect breakthroughs in human genetics and cell membrane function.

Chapter 4: Tissues
Although histology is an older, well-established field, the advent of new microscopic and tissue preparation technologies has provided new information. The improved understanding of tissues and their functional relationship to structure is included in this rewritten chapter. Also, the histological micrographs have been replaced with new, clearer images and illustrations.

Chapter 8: Organization of the Nervous System
The nervous system is an extremely complex body system. Consequently, it is often one of the most difficult systems to teach and learn. To make this task more reasonable, the chapter was rewritten to improve upon its clarity of presentation, logical flow of information, and appropriate level of information for beginning students.

Chapter 13: The Cardiovascular System
The cardiovascular system has been studied intensively for decades, resulting in an explosion of new information on normal structure and function, and also on pathology and medical treatment of cardiovascular disease. In an effort to bring this new information to light, the chapter has been rewritten.

CONCEPT-BUILDING TOOLS

As in the first edition, numerous concept-building tools are incorporated into the text to assist student learning.

Chapter Openers
Each chapter opens with a chapter outline and list of learning objectives, and is followed by a chapter introduction. The introductory paragraphs summarize and integrate the main points within the chapter. This early overview material benefits students by presenting a “big picture” of the chapters, giving them a vision of what is to come.

Concepts and Concepts Checks
At each major heading within a chapter, one or more brief concept statements are provided. The concept statement identifies the key idea to be discussed, telling the student the essential information that should be learned. For each chapter there is a list of questions called Concepts Check. The questions are designed to engage the student in thinking about the key points in the section in order to extend a helping hand in learning. The questions are located in the free online student resources at: http://www.universityreaders.com/publish/wingerd/students.

Tables and Figures
Tables concisely organize and summarize large blocks of information, and they serve as a useful review tool. An abundant number of figures is provided. Each figure legend is accompanied by a question that challenges the student to take an active part in the learning process. Answers to the figure legend questions are provided in the free online student resources.
Health Clinic and Sports Clinic
Selected topics in biological research and medicine are provided in special boxes called Health Clinic in every chapter. These topics have been rewritten with updated information in the second edition. In each case, they are based on recent information from research publications, such as The New England Journal of Medicine, Scientific American, Nature, and Science. Also, selected topics that relate text material to sports activities are provided in special boxes called Sports Clinic. This information has also been updated. The careful selection and placement of Health Clinic and Sports Clinic topics in the text serve to reinforce the concepts, and also may spark further interest in the learning material. Additional Clinics are located in the free online student resources.

Pronunciation Guides and Word Part Origins
Learning new terminology can be difficult, and it helps if students are shown how to pronounce new terms correctly. In the text, pronunciation guides follow many new terms in parentheses. The learning process is also strengthened if students are informed of the actual meaning of terms, based on Latin and Greek word parts. These word part origins are also within the text where appropriate.

Chapter Review Questions
Chapter Review Questions including objective questions and critical thinking questions with their answers are provided in the online student resource guide. Additionally, the online guide contains answers to the questions posed in the text with the Concept Check boxes and the figures captions.

Glossary
A Glossary is provided in the online student resources. It contains all of the terms emphasized in boldface and italic type in the text.
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A NOTE TO THE STUDENT

The Human Body: Essentials of Anatomy and Physiology, Second Edition, contains a number of features that are designed to help you learn the material. However, to benefit from these features you must be able to recognize them and use them properly. This introduction will identify the features so that when you begin to study, you will be ready to learn the material.

The book is designed to be used with free online resources for students at: www.universityreaders.com/publish/wingerd/students. You may find it works best for you to read the book with your online resources at hand.

When you begin your study of a particular chapter, read through the chapter outline first. The chapter outline gives you a “bird’s-eye view” of the topics in that chapter. Next to the chapter outline is a list of learning objectives. Read through this list to become acquainted with the learning goals of the chapter. It is best to return to this list after studying the chapter. By doing so, you will be reminded of the primary learning goals and learn if you have achieved them.

Within the body of each chapter are other helpful features. At the beginning of most major sections is a brief sentence or two in italics beginning with the word Concepts that includes the concepts you will be learning. These are the “big ideas” that are to be described in the text that follows. A list of short-answer questions called Concepts Check follows each main section. It’s important that you try to answer these questions immediately after reading the section. If you’re stumped by a question, go back through the section to find the information you need for the correct answer. In doing so, you will reinforce the concepts and important ideas in your mind.

A set of review questions and their answers is provided in the online resource pertaining to each chapter of the text, giving you an opportunity to quiz yourself after reading through the chapter. Answers to the figure legend questions follow. As you read the text and look at a referenced figure to think about what you have just read, try to answer the question associated with the figure in order to visualize what you’ve learned. You will also find the answers to the Concepts Check boxes in the online resources.

Most medical and scientific terms that you may be required to learn are provided with their word parts to show you the Latin or Greek origin of the word. With new terms, it is often helpful to learn how the word is constructed in order to remember what it means. Once you have mastered a few key word parts, you’ll be able to recognize and understand many scientific and medical words. Terms that relate to the same body organ or to the same condition often share the same word parts. For example, carditis (card = heart + itis = inflammation) means simply “inflammation of the heart,” and cardiology (card = heart + ology = study of) means “study of the heart.” Dermatitis (derma = skin + itis) means “skin inflammation,” while epidermis (epi = outer + dermis = skin) is the outer layer of skin. If you enjoy puzzles, you’ll have fun mastering this new vocabulary.

Also, when you come upon a new term that you don’t know how to pronounce, use the pronunciation guide that usually appears in the text after the term in parentheses. If a pronunciation cannot be found, look up the term in the Glossary in the online resources. Pronunciation guides are based on a pronunciation key, which is provided here and in the Glossary.

PRONUNCIATION KEY

1. A phonetic “sounds like” spelling of difficult terms is provided in parentheses next to the term. To pronounce the term properly, read the phonetic spelling literally and out loud if possible. For example, the term phonetic (foh-NET-ik).
2. The syllable with the strongest accent appears in capital letters. For example, science (SI-ens) and learning (LER-neeng).
3. In words with a secondary accent, the syllable with the secondary accent is identified by a single quote mark (‘). For example, homeostasis (hoh’-mee-oh-STAY-sis).
4. Phonetic clues to sounds may be found in the following examples:

   oo as in blue
   oh as in boat
   air as in fair
   oy as in oil
   ah as in father (FAH-ther)

I hope this text will provide you with a complete picture of the human body’s incredible design of structure and function. As you have just seen, the book has many learning tools that are intended to give you a helping hand. But suc-
cess is really up to you. You must decide to commit your time and energy to read the material and practice the review questions and exercises in order to reap the benefits. It has been my personal experience, and the experience of thousands of my students, that the gain is very much worth the pain.
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  Organ Level
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  The Complete Organism

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  Metabolism
  Movement
  Excitability
  Growth
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  Body Planes

The Body Plan
  Body Regions
  Body Cavities

Homeostasis: The Balance of Life
  Process of Homeostasis
  Negative Feedback
  Positive Feedback
  Health and Disease

After studying this chapter you should be able to:

1. Define anatomy and physiology.
2. Identify the directional terms of anatomy.
3. Describe the structural organization of the human body.
4. Identify the 11 systems that make up the human organism.
5. Explain the six characteristics of life.
6. Define the major directional terms used in human anatomy.
7. Describe homeostasis and the feedback systems maintaining it.
INTRODUCTION

Perhaps you’ve noticed some of the health-related headlines in the newspapers over the past several years, such as “Flesh-eating Bacteria Takes Another Victim,” “Breast Cancer On The Rise,” or “Diet Linked to Heart Disease,” and wondered how these issues might affect you or your loved ones - and what you could do to prevent it. We are all concerned about our wellbeing and these types of articles tend to intensify that concern. Fortunately, we can all do something to minimize our chances of falling victim to failing health: we can learn and use information that is available about body structure and function. The experience can become a unique opportunity for you to understand your own body, thereby enabling you to actively participate in your own health care decisions. It will also empower you with the ability to make informed choices about your lifestyle, such as self-examination routines, diet, and exercise.

Your interest in your health and that of others may have also led you to pursue a health-related career. If this is the case, your study of body structure and function takes on added significance. It will provide you with an important foundation of knowledge for later application in the clinical fields. Knowledge of normal structure and function is essential for identifying the various types and stages of disease. It also enables you to communicate with other health care providers, to interpret diagnostic exams, and to determine the best course of treating the sick and injured.

This chapter begins your study of human body structure and function. It serves as a starting point by establishing a foundation of basic information, upon which new information will be added in the chapters that follow. The chapter opens by introducing the sciences of structure and function: anatomy and physiology. You will then be introduced to the general organization of the body, followed by an exploration of the meaning of the word “living.” A bit later, you will learn about the delicate balance that is maintained every day between health and disease, and the very nature of human disease. The chapter concludes with some basic terms of anatomy, how these and other terms are actually formed, and the general organization of body parts.

ANATOMY AND
PHYSIOLOGY DEFINED

Concept: The study of the human body is an interdisciplinary science. It consists of fields that focus on structure or function at many levels.

The traditional study of the human body is divided into two primary areas of discipline: anatomy and physiology. Anatomy is the study of body structure, and physiology is the study of body function.

Anatomy

Anatomy is the field of study that is concerned with the structure of body parts. It describes the location, appearance, and relationships of the various components of the body. The goal of the anatomist is to answer the basic questions: where is it located?; what does it look like?; and how does it relate to other body parts?

The most important tool of the anatomist in determining body structure is the power of observation. In the early years of science and medicine before the 20th century, anatomists relied on their eyesight during postmortem (after death) studies of human bodies to study body structure. Their careful observations resulted in a library of artistic drawings and detailed descriptions. From this early body of information arose a basic understanding of gross anatomy, which is the study of body structure that is visible without the aid of a microscope.

With the introduction of the microscope during the 17th century, the examination of the body’s minute components became possible. This important discovery eventually evolved into a separate area of specialized study, called microanatomy, which has brought us a more complete understanding of body structure. Over the years the microscope has been vastly improved and modified to its present forms, which include powerful electron microscopes capable of amplifying body components by as many as one million times! Other advanced instruments have also been added to the anatomist’s toolbox, including computed axial tomography (CAT), magnetic resonance imaging (MRI), and ultrasound imaging instruments. These instruments and others have provided exciting breakthroughs in the study of anatomy and medicine, for they make it possible to view most body structures without the need for invasive techniques like surgery. Today, the anatomist may utilize any one or all of these tools to further our understanding of human body structure.

As knowledge of body structure has grown over the years, it has become necessary to divide anatomy into more specific areas of study. For example, we have already seen that anatomy is divided into the study of large structures, or gross anatomy, and the study of microscopic structures, termed microanatomy. Under gross anatomy is included surface anatomy, which refers to a study of general form and surface markings, and medical anatomy, which is concerned with structural features that undergo change during disease. A study of microanatomy that focuses on the study of cells is known as cytology, and one that studies combinations of cells to form tissues is known as histology. Also, systematic anatomy is an approach that studies body structure within a given organ system, such as the skeletal system or muscular system. Regional anatomy, by contrast, examines all structures within a given region of the body, such as the head or leg. This book is organized using the systematic approach to anatomy, and combines both gross anatomy and microanato-
my when examining body structures.

**Chemical Level**

The most basic group of building blocks that form our bodies is the chemical level. **Chemicals** are substances that cannot be simplified further under natural conditions. The simplest type of chemical is the **atom**, which is the smallest form of matter that contains its own unique set of physical properties. When atoms react together, they may form **molecules**. Large molecules, called **macromolecules**, provide the structural foundation for the body and include proteins, fats, carbohydrates, and nucleic acids. An example of an atom and molecule is shown in Figure 1.1.

**Cellular Level**

Molecules and macromolecules may combine together to form yet larger, more organized structures known as cellular organelles. Each organelle forms an important part of the most basic living unit of the body, the **cell**. As a living unit, each cell performs the functions that are necessary to sustain life. There are many types of cells in the body, each with its own role to play for the benefit of the body as a whole. A single cell is illustrated in Figure 1.1.

**Tissue Level**

Cells usually form connections with other cells or cell products to form larger, more organized structures known as tissues. The individual cells that form a tissue are usually similar in structure, and their combination together results in the tissue performing a more widespread function that provides a greater benefit to the body than an individual cell could provide. For example, a tissue may provide protection for larger body structures, movement to a body part, or a means of communication between distant body areas. Thus, a tissue is defined as a group of similar cells that combine to perform a common function. As we will see in Chapter 4, there are only four major types of tissues in the body: epithelial, **connective**, muscle, and nervous. Figure 1.1 shows a group of cells organized to form a tissue. In this case, they are epithelial cells of the liver.

**Organ Level**

Tissues are often combined to form the next level of organization, an **organ**. Organs consist of two or more different types of tissues that, when combined, perform a general function. For example, the liver is an organ that contains all four types of tissues, and performs the general function of processing digested nutrients. The liver is shown in Figure 1.1, along with its building block components.
System Level

A system is an organization of two or more different organs, along with their associated structures. Because a system contains more than one organ, the functions it performs are of a more general nature. For example, the liver, stomach, and intestines are organs of the digestive system (Figure 1.1). Their combined function is the digestion of food into nutrients that can be utilized by all cells of the body. The eleven systems of the body are listed in Table 1.1.

Figure 1.1
Structural levels of organization. The human organism is made of small parts that combine to form more complex larger parts.

What is the organized combination of two or more different types of tissue into a single structure called?
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>MAJOR ORGANS</th>
<th>ORGAN SYSTEM FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integumentary</td>
<td>Skin</td>
<td>Protection of underlying structures, prevention of fluid loss, temperature regulation.</td>
</tr>
<tr>
<td>Skeletal</td>
<td>Bones, joints</td>
<td>Support and protection of softer body parts, store minerals, produce blood cells.</td>
</tr>
<tr>
<td>Muscular</td>
<td>Skeletal muscles</td>
<td>Provide body movement, produce heat.</td>
</tr>
<tr>
<td>Nervous</td>
<td>Brain, spinal cord, nerves</td>
<td>Monitors changes in the environment, interprets the changes, and initiates responses.</td>
</tr>
<tr>
<td>Endocrine</td>
<td>Pituitary gland, thyroid gland, parathyroid glands, adrenal glands, pancreas, gonads</td>
<td>Alters the activities of cells by the release of hormones, in an effort to respond to changes in the body.</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>Heart, blood vessels</td>
<td>Transport of blood throughout all areas of the body.</td>
</tr>
<tr>
<td>Lymphatic</td>
<td>Spleen, thymus, tonsils, lymph nodes, lymphatic vessels</td>
<td>Protection of the body from foreign particles and cells, removal of dead and diseased cells, recycle of fluid back to cardiovascular system.</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Nasal cavities, pharynx, larynx, trachea, bronchi, lungs</td>
<td>Exchange of gases between the bloodstream and the external environment.</td>
</tr>
<tr>
<td>Digestive</td>
<td>Mouth, salivary glands, pharynx, esophagus, stomach, small intestine, pancreas, liver, large intestine</td>
<td>Simplify food particles into their basic components to enable their absorption into the bloodstream.</td>
</tr>
<tr>
<td>Urinary</td>
<td>Kidneys, ureters, urinary bladder, urethra</td>
<td>Form urine in order to maintain water balance, salt balance, pH, and nitrogenous waste levels in the blood.</td>
</tr>
<tr>
<td>Reproductive</td>
<td>Male: testes, ductus deferens, urethra, penis, scrotum. Female: ovaries, uterine tube, uterus, vagina, vulva</td>
<td>Produce gametes for fertilization in order to create new individuals.</td>
</tr>
</tbody>
</table>
The Complete Organism

The organism is composed of many systems, each of which depends on one another to perform its tasks. When all of the systems of the body are operating in harmony, the organism, or whole individual, is capable of surviving. Survival and reproduction are the ultimate goals underlying all of the body’s internal activities.

Concepts Check
4. How is the structural organization of the body similar to that of a building?
5. What is the basic structural and functional unit of life?
6. How is a tissue different than an organ?

THE CHARACTERISTICS OF LIFE

Concept: All living cells are capable of organization, metabolism, movement, excitability, growth, and reproduction.

You have just learned that cells are the most basic unit of life. Thus, a cell is alive, but its smaller chemical components are not alive. How does science make the distinction between something that is alive and something that is not? Biologists have arrived at a basic explanation of life following many years of investigation. It can be summed up as any single entity that is capable of organization, metabolism, movement, excitability, growth, and reproduction is capable of life. All living cells in the human body share these six functions. Should one or more of life’s functions fail, the life of the cell becomes threatened.

Organization

The molecules that make up our world are governed by a set of physical laws. These laws control the properties of the molecules, such as their mass, their reaction rates, and how fast they move. Because all molecules that make up the cell are governed by the same physical laws, they are able to provide the cell with a structural basis that is relatively stable. The stable structure, or organization, of the cell makes it possible for the cell to perform its various functions. The stable organization of the cell, in turn, provides a structural foundation for the organization of the body as well.

Metabolism

The process by which the body obtains and uses energy is called metabolism (meh-TAB-oh-lizm). It requires the exchange of materials with the external environment, for we are not capable of producing our own energy as plants do. When food is consumed, it is brought into the body to be broken down into smaller particles - a process of metabolism known as digestion. The particles that are useful to the body as fuel find their way into cells, where they are broken down further to release energy. Oxygen is required to release energy from molecules, and carbon dioxide is produced as a waste material. The energy produced by the breakdown of molecules is either used immediately by the cell or is stored within molecules for later use. Energy is used to power all of life’s activities, including the synthesis of new materials, the movement of cells and their components, the transport of materials, and the generation of heat.

There are two categories of metabolic processes. They are called anabolism (ah-NAB-oh-lizm) and catabolism (kah-TAB-oh-lizm). Anabolic processes are the ways in which the body uses energy to build large molecules, cells, and tissues from simple molecules; it is the process of growth and repair. Catabolic processes break apart large molecules, reducing them into simple molecules for the purpose of releasing energy that is immediately available to power body functions.

Movement

The constant movement of molecules within and around a cell is an important feature of a cell’s dynamic nature. It is necessary for the transport of vital materials in and out of a cell, the transport of materials through different regions of a cell, and the transport of waste products out of a cell. Substances that are needed by a cell, such as oxygen and nutrients that are necessary ingredients for anabolic and catabolic processes, must be provided continuously if the cell is to survive. Without these materials the cell would be unable to manufacture important molecules or produce energy to power its functions, and would consequently perish. Oxygen and nutrients must be obtained from the environment, and thus must be transported into the cell. Also, waste products resulting from catabolic processes, such as carbon dioxide and urea, must be transported out of the cell to prevent their poisoning effects.

The cell itself may also move about its environment. For example, many white blood cells wander throughout the body actively searching for invading microorganisms. Muscle cells that are attached to bone also move about, for they change their length by contracting and relaxing to produce the movement of body parts such as arms, legs, and fingers.

Excitability

The capability of a cell to respond to changes in its environment is called excitability, or irritability. An environmental change may be a change in temperature, a change in pressure, an invasion by a foreign substance, exposure to a form of ra-
Growth

All cells are capable of growth at some stage in their life history. Cellular growth occurs when a cell increases in size as a result of anabolic activities that produce new molecules from smaller particles. An increase in cell volume is a condition of the cell known as hypertrophy. In organisms that contain many cells, the new molecules may also be involved in an increase in the number of cells. An increase in cell number produces the organismal growth that occurs during childhood and adolescent years.

Reproduction

Cellular reproduction, or cell division, is the process by which a single cell divides into two or more cells. It is the method in which dead cells are replaced, and the growth of tissues and organs occurs. An increase in the size of an organ or tissue that is due to the increased number of cells is called hyperplasia. Cell division also provides for the creation of a new organism, through the process of sexual reproduction.

Concepts Check
7. What is the collective goal of the functions that are characteristic of life?
8. What is metabolism?
9. What is the difference between the two metabolic processes, anabolism and catabolism?
10. How is the movement of molecules important for life?

Basic Terminology

Concept: The language used to describe the human body is universal, with an established set of terms.

One of the greatest challenges that a health professional faces is the correct communication of ideas. It is very important for physicians, researchers, clinical staff members, and patients to understand one another, despite barriers in language and culture. Therefore, a universal language, which can be understood in all nations despite different native languages and cultural differences, would be an ideal solution to the problem of communication.

However, a truly universal language that is spoken by everyone is not available - at least not yet. But a universal language that is used to describe the human body is available, and is in general use in universities and hospitals around the world. It is based on Greek and Latin word parts, which are put together to form new words. In most cases, the word parts are descriptive of the body part or function that they are used to identify. Therefore, they eliminate the need for lengthy explanations. For example, let’s look at the term hypothalamus, which is a part of the brain that lies below the thalamus in the center of the brain. The prefix, hypo, is Greek for “below,” and the word root, thalamus, is Greek for “middle chamber.” Another example is renal tubule, which is a microscopic tube within the kidney; ren is the Latin word for “kidney,” and tubule is Latin for “tiny tube.” Yet another example is the term for red blood cell, erythrocyte (erythro = red + cyte = cell). To assist your learning efforts, the important terms of anatomy and physiology are explained in the following chapters by presenting their Greek and Latin word parts along with their meanings.

Directional Terms

The set of terms that are used to describe the location of a body structure relative to another is directional terminology. It is a valuable tool in anatomy because it abbreviates otherwise lengthy descriptions of body parts. Also, it describes body parts using a universally accepted position of the body, which serves as a point of reference. For example, let’s say you wish to describe the location of the heart to someone who doesn’t know where it is located, but instead knows where the head is located. Using directional terminology, you would simply say “the heart is inferior to the head.” In this example, the point of reference is the known location of the head, and the directional term “inferior” is used to abbreviate the explanation, which means “away from the head end.”

The universally accepted position of the body that is used as part of directional terminology is known as the anatomical position. By definition, the anatomical position describes a body standing erect (upright) facing the observer, with the arms at the sides and the toes and palms turned forward (Figure 1.2). This position provides a point of reference, much like a direction key on a map pointing north, south, east, and west. It thereby provides directional bearings when you are studying a “map” of the human body. The directional terms that you will be using throughout your study are presented with their definitions in Figure 1.3 and summarized in Table 1.2.
Table 1.2: Descriptive Terms

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior (cranial)</td>
<td>Toward the head end or upper part of the body.</td>
<td>The heart is superior to the pelvis.</td>
</tr>
<tr>
<td>Inferior (caudal)</td>
<td>Away from the head end or toward the lower part of the body.</td>
<td>The chest is inferior to the head.</td>
</tr>
<tr>
<td>Anterior (ventral)</td>
<td>Toward the front or belly side.</td>
<td>The nose is on the anterior side of the head.</td>
</tr>
<tr>
<td>Posterior (dorsal)</td>
<td>Toward the back.</td>
<td>The spinal cord extends down the posterior side of the body.</td>
</tr>
<tr>
<td>Medial</td>
<td>Toward the midline, which is an imaginary line that extends vertically down the middle.</td>
<td>The sternum (breastbone) is medial to the ribs.</td>
</tr>
<tr>
<td>Lateral</td>
<td>Away from the midline.</td>
<td>The ears are lateral to the nose.</td>
</tr>
<tr>
<td>Superficial (external)</td>
<td>Toward the surface of the body.</td>
<td>The skin is located superficial to the visceral organs.</td>
</tr>
<tr>
<td>Deep (internal)</td>
<td>Away from the surface of the body.</td>
<td>The heart lies deep to the sternum.</td>
</tr>
<tr>
<td>Proximal</td>
<td>Toward a structure’s origin or point of attachment to the trunk.</td>
<td>The shoulder is proximal to the elbow.</td>
</tr>
<tr>
<td>Distal</td>
<td>Away from a structure’s origin or point of attachment to the trunk.</td>
<td>The wrist is distal to the shoulder.</td>
</tr>
</tbody>
</table>

Sectional Planes

The problem of describing the structure of our complex, three-dimensional bodies is partly solved by the use of planes. A plane is a flat surface that results from a slice, or section, through the body. The section may be oriented in any direction so that it may pass through the body at a certain angle to reveal a particular plane. There are three primary body planes typically used by anatomists: frontal, sagittal (SA-jih-tal), and horizontal (Figure 1.4).

The frontal plane extends through the long axis of the body (that is, along the body’s length). Also called the coronal plane, it divides the body into anterior (front) and posterior (back) portions. When the subject is standing upright in the anatomical position, the frontal plane extends in a vertical direction.

The sagittal plane also extends through the body’s long axis, but it divides the body into right and left portions. A sagittal plane dividing the body into equal right and left halves is called midsagittal, whereas one that divides unequally is called parasagittal (para means “away from normal”).
Figure 1.2
The human figure in the anatomical position. This position provides a point of reference for studying the body.
How are the hands oriented in the anatomical position?

Figure 1.3
(a) Posterior view and (b) lateral view of the body illustrating the most frequently used directional terms. These terms help describe the locations of body parts.
Can you identify a body part that is proximal to the hand?
Chapter 1

Body Regions

The major areas of the body that are structurally distinguishable are called regions. They include the head, the neck, the trunk, the upper appendages, and the lower appendages. Each major region is divided further into smaller regions. For example, the anterior side of the trunk is divided into an upper portion, the thorax, a middle portion, the abdomen, and a lower portion, the pelvis. The posterior side of the trunk is simply called the back region. The major regions of the body and their useful divisions are shown in Figure 1.5. Surface features, or landmarks, that are routinely used by physicians during physical examinations are also included in Figure 1.5. Knowledge of the regions of the body and their landmarks aid the anatomist in describing the relative location of parts, and the physician in identifying internal causes of surface pain.

Figure 1.4

Body planes. The body may be sectioned along any of these planes to observe internal parts.

A sagittal plane divides the body into what parts?

The horizontal plane extends in a direction perpendicular to the frontal and sagittal planes, since it divides the body into superior (upper) and inferior (lower) portions. The horizontal plane is also called the transverse plane. A section made along the horizontal plane is often referred to as a cross section.

Concepts Check

11. What is the purpose of constructing scientific terms from Latin and Greek word parts?
12. Why should you use directional terms when describing the location of body parts instead of more common descriptions, such as on top of, below, or to the side?
13. What is a sectional plane?
14. How may sectional planes be used to view body structures?

The Body Plan

Concept: The human body is divided into regions. Some regions contain spaces called cavities that house organs.

Before studying minor details, it is often helpful to look at the “big picture” as a first step. As an early step in our study of the human body, let us turn now to the “big picture” of human anatomy and observe how the body is organized into regions and cavities.

Figure 1.5

Regions of the body. The regions shown in this anterior view represent many of the important body regions. What is the location of the axilla relative to the thigh (in directional terms)?
The major body regions, their divisions, and important surface features are summarized in Table 1.3.

**Body Cavities**

The body is internally divided into several spaces, or cavities, which contain many of the organs (Figure 1.6). In addition to housing organs, each body cavity is associated with thin sheets of cells known as membranes (membranes will be discussed further in Chapter 4). In many cavities, an outer membrane lines the cavity walls, while an inner membrane covers the outer surface of organs that are contained within the cavity. In general, the outer membrane is referred to as the *parietal layer* while the inner membrane is called the *visceral layer*. The term parietal means “wall,” and visceral means “inner organs.” The organs contained within a cavity are generally known as *visceral organs*.

There are two major cavities in the body. The smaller of the two, called the **dorsal cavity**, is located in the posterior (dorsal) side of the body. It contains a **cranial cavity** within the skull and a **vertebral canal** that extends through the center of the vertebral column (backbone). The cranial cavity is

<table>
<thead>
<tr>
<th>PRIMARY BODY REGIONS</th>
<th>SUBDIVISIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Face</td>
</tr>
<tr>
<td></td>
<td>Cranium</td>
</tr>
<tr>
<td>Neck</td>
<td>Anterior neck</td>
</tr>
<tr>
<td></td>
<td>Posterior neck</td>
</tr>
<tr>
<td>Trunk</td>
<td>Thorax</td>
</tr>
<tr>
<td></td>
<td>Abdomen</td>
</tr>
<tr>
<td></td>
<td>Pelvis</td>
</tr>
<tr>
<td></td>
<td>Back</td>
</tr>
<tr>
<td>Upper Extremity</td>
<td>Shoulder</td>
</tr>
<tr>
<td></td>
<td>Axilla (armpit)</td>
</tr>
<tr>
<td></td>
<td>Brachium (upper arm)</td>
</tr>
<tr>
<td></td>
<td>Elbow</td>
</tr>
<tr>
<td></td>
<td>Antebrachium (forearm)</td>
</tr>
<tr>
<td></td>
<td>Carpus (wrist)</td>
</tr>
<tr>
<td></td>
<td>Manus (hand)</td>
</tr>
<tr>
<td></td>
<td>Palm</td>
</tr>
<tr>
<td></td>
<td>Digits</td>
</tr>
<tr>
<td>Lower Extremity</td>
<td>Gluteal (buttock)</td>
</tr>
<tr>
<td></td>
<td>Femoral (thigh)</td>
</tr>
<tr>
<td></td>
<td>Knee</td>
</tr>
<tr>
<td></td>
<td>Crus (leg)</td>
</tr>
<tr>
<td></td>
<td>Tarsus (ankle)</td>
</tr>
<tr>
<td></td>
<td>Pes (foot)</td>
</tr>
<tr>
<td></td>
<td>Sole</td>
</tr>
<tr>
<td></td>
<td>Digits</td>
</tr>
</tbody>
</table>
Chapter 1

The larger ventral cavity is in the anterior (ventral) side of the body. It includes an upper portion called the thoracic (thoh-RAS-ik) cavity and a lower portion called the abdominopelvic (ab-dom-ih-noh-PEL-vik) cavity. The two are separated by a thin sheet of muscle known as the diaphragm (DIE-ah-fram). The word diaphragm means “partition or barrier.”

The thoracic cavity is bordered on its anterior side by the ribcage and on its posterior side by the vertebral column. The bones of the ribcage and vertebral column provide the thoracic cavity’s vital organs, the right and left lungs and the heart, with a limited amount of protection. Each lung is associated with another cavity, which lies between the membrane attached to the thoracic wall (the parietal pleura) and the membrane attached to the lung’s surface (the visceral pleura). This narrow cavity is called the pleural (PLOO-ral) cavity. The word pleural means “lung.”

Located between the two lungs is the heart. Like the lungs, the heart is surrounded by a small cavity, which lies between an outer membrane (the parietal pericardium) and an inner membrane (the visceral pericardium), both of which envelop the heart. This cavity is the pericardial (pair-ih-KAR-dee-al) cavity. The word pericardial means “surrounding the heart.”

With the exception of the two lungs, all structures within the thoracic cavity form a partition, or septum, between the two pleural cavities in the center of the chest. They are collectively referred to as the mediastinum (mee’-dee-ah-STAHT-num) and include the heart, a soft gland above the heart known as the thymus, part of the trachea, part of the esophagus, and the major vessels of the heart. The term mediastinum means “middle sternum,” which refers to the vertical midline of the chest.

In the region inferior to the diaphragm, the abdominopelvic cavity is divided into two main cavities that are separated by an imaginary line extending between the upper tips of the hipbones (called the iliac crests). The upper area is called the abdominal cavity. It contains many organs including the stomach, small intestine, liver, gallbladder, pancreas, spleen, and most of the large intestine. The smaller pelvic cavity lies below the iliac crests and is in the shape of a bowl that is formed by the hipbones (the word pelvic means “washbasin”). It contains the urinary bladder, the final segment of the large intestine, and internal reproductive organs. The membranes of the abdominopelvic cavity include the large parietal peritoneum, which lines the abdominal wall, and the visceral peritoneum, which covers the surfaces of the organs. The narrow space between these two membranes is known as the peritoneal cavity. The term peritoneum is derived from a Latin word that means “to stretch over.”
The abdominopelvic cavity is divided yet further into smaller regions. The additional subdivision of this large cavity aids health care workers in identifying the location of internal body parts and in relating sources of pain on the surface that might originate from within. The smaller regions are separated by invisible lines that are similar to the latitudinal and longitudinal lines on a map. In one method of division, there are two horizontal lines and two vertical lines dividing the cavity into nine regions; these are shown in Figure 1.7a. A second method uses just two lines, one horizontal and one vertical, to divide the cavity into four regions, or quadrants. This method is shown in Figure 1.7b.
HOMEOSTASIS: 
THE BALANCE OF LIFE

**Concept:** Homeostasis is the process by which the internal environment of the body is kept relatively stable despite changes in the world around us.

If the world were a perfect place to live, survival would be very easy. There would be plenty of healthy food to eat, the climate would remain comfortably constant, there would be no disease; in other words, there would be little stress upon the body. However, our world is by no means perfect. Our bodies are subjected to unpredictable changes in environmental temperature, pressure, water and salt availability, and in many areas of the world, food availability; microorganisms that are well-suited for invading our cells and destroying them abound; and we are being exposed to increasing levels of radiation and chemicals that can alter and destroy cells. How are we able to survive in this world of changing environmental conditions and other hazards?

The human body has the remarkable ability to sense a change in the environment, like a change in temperature or the invasion of a population of microorganisms, and respond by making changes in body functions. As a result of the changes in functions, the body’s internal environment is kept relatively stable. The preferred, stable state of the body is called homeostasis (hoh’-mee-oh-STAY-sis), a term that literally means “same standing still.” The term also refers to the process by which the body maintains a stable internal environment despite changes within and around us. Thus, homeostasis means stability, but it is also a dynamic process that keeps the internal conditions of the body in balance within narrow ranges.

**The Process of Homeostasis**

Maintaining a stable internal environment, or the process of homeostasis, is a primary goal of many body functions. These functions are of vital importance because a failure in any one of them can lead to disease or even death within a relatively short period of time. Most of these functions are regulated by the nervous system or endocrine system or both, and often involve the integration of numerous tissues, organs, and even systems in order to maintain internal stability.

An example of a homeostatic process is the control of internal body temperature when the body is exposed to cold weather (Figure 1.8). When you are cold, sensory receptors in your skin that can detect temperature changes relay this information to the brain. The region of the brain that receives this information, the hypothalamus, functions as a thermostat for the body. It operates in much the same way as the thermostat in your house: when the temperature is perceived as being too cold, it “turns the heat on” and keeps it on until the temperature returns to the desired level. Body heat is provided by the contraction of small groups of muscles that are stimulated involuntarily by the hypothalamus. Contraction of these muscles causes you to “shiver” from the cold. While groups of muscles are contracting to produce heat, blood vessels in the skin are directed by the hypothalamus to reduce blood flow by closing up, or constricting. This reduces the amount of heat that is normally lost through the surface of the
The process of homeostasis is also active when the body becomes overheated. When the hypothalamus receives the information of increased temperature from nerve cells, it directs the body to make changes that will keep the body from getting too hot. The changes include perspiration, which cools the skin surface as the water evaporates; blood vessel dilation, which opens blood vessels in the skin to carry a larger volume of heat-carrying blood from the deeper regions of the body to be lost through the skin surface; and increased respiration, in which an increased breathing rate moves heated air from the lungs to the outside.

Regulating body temperature is one example of homeostatic mechanisms at work in the body. There are many others, all with the similar objective of keeping the internal environment of the body stable despite changing conditions. All homeostatic mechanisms are performed in one of two ways: by negative feedback, or by positive feedback.

**Negative Feedback**

Most homeostatic processes at work in the body operate by negative feedback (Figure 1.9). The use of the term “negative” refers to a mechanism that reverses a response; in this case, back to a normal state. The term “feedback” refers to the ability of the body to sense information, and send this information back to a control center (usually the brain) where it can be interpreted and a response initiated. Thus, negative feedback is a process by which the body maintains homeostasis by first perceiving a change, then reversing the direction of the change until the normal state is returned.

**Positive Feedback**

Positive feedback mechanisms are quite rare in the healthy body (Figure 1.10). The term “positive” means that when a change from the normal state occurs, the mechanism promotes the change yet further. For example, if a thermostat in your house is wired so that an increase in room temperature causes the heater to turn on, rather than the air conditioner, the room temperature would increase even more.

**Health and Disease**

Maintaining the body’s internal environment at a constant, steady state demands that all body systems are operating effectively. This ideal state is called optimum health, since it provides the individual with a level of physical health and wellbeing that cannot be improved upon. Any reduction from
this ideal state, regardless of its relative impact, is regarded as disease, a term that means “ill at ease.”

In a sense, optimum health and a serious, life-threatening disease may be regarded as two extremes of a continuum. Between the two extremes are many levels of health and disease, including mild or short-term illnesses, minor injuries, and moderately good health that falls somewhat short of the ideal state. Most of us are somewhere between the middle of this continuum and the ideal state of optimum health much of the time, since our bodies are normally challenged by minor homeostatic disturbances during every moment of our lives. Fortunately, most of these disturbances, such as a minor bacterial invasion caused by a scratch, a bruise resulting from a fall, or a minor change in salt levels in the blood following a meal, are managed efficiently to minimize their effect on health. However, the pendulum can quickly swing toward serious disease if the body’s homeostatic mechanisms are unable to return functions to internal stability.

Concepts Check
19. What is the definition of homeostasis?
20. What is an example of a homeostatic mechanism?
21. How does a negative feedback mechanism operate?
22. How does negative feedback differ from positive feedback?