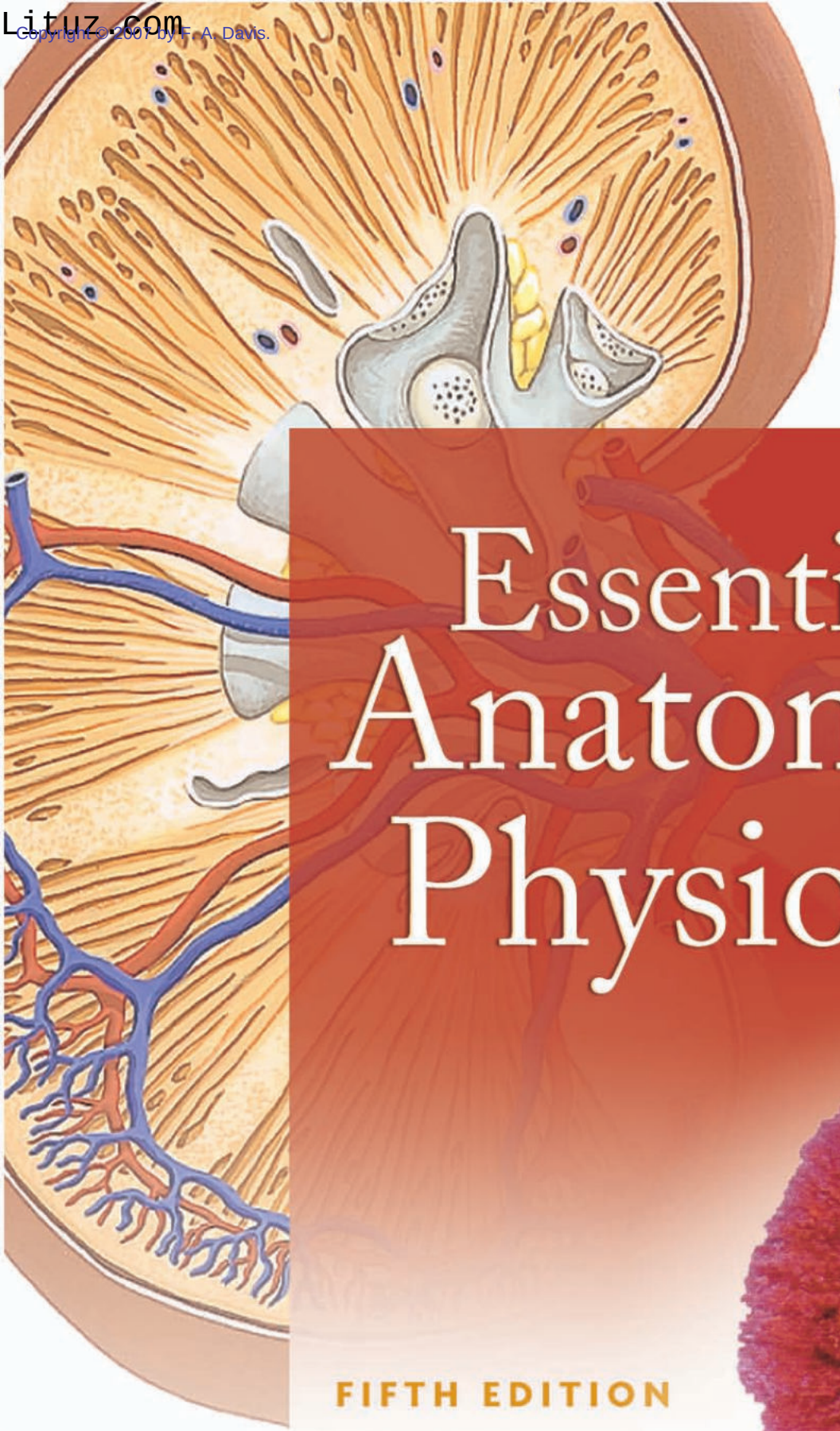

Valerie C. Scanlon
Tina Sanders

Essentials of Anatomy and Physiology

FIFTH EDITION

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Essentials of Anatomy and Physiology

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Valerie C. Scanlon, PhD
College of Mount Saint Vincent
Riverdale, New York

Tina Sanders
Medical Illustrator
Castle Creek, New York
Formerly
Head Graphic Artist
Tompkins Cortland Community College
Dryden, New York

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Preface

A fifth edition of *Essentials of Anatomy and Physiology* is very gratifying, and again we have the pleasure of thanking all of our colleagues in teaching who continue to use our textbook and of welcoming new teachers and students.

Changes have been made in the content of the book to keep the material as current as possible. Most of these are small changes, such as a new cell organelle, the proteasome, in Chapter 3; a clarification of blood cell production in Chapters 4, 11, and 14; and the addition of concentric and eccentric contractions to Chapter 7. The most extensive revision is in Chapter 14: The section on immunity has been rewritten using the categories of innate and adaptive immunity.

New illustrations in this edition include positive and negative feedback mechanisms in Chapter 1, cellular transport mechanisms in Chapter 3, hormones that affect blood pressure in Chapter 13, innate immunity in Chapter 14, and synthesis uses of foods in Chapter 17. Illustrations that have been revised include protein structure, active site theory, and DNA and RNA structure in Chapter 2, blood cells in Chapter 11, and adaptive immunity in Chapter 14.

Also new to this edition are illustration questions. Each figure legend is followed by a question for the student; the answers are in Appendix G.

As always, your comments and suggestions will be most welcome, and they may be sent to us in care of the publisher: F. A. Davis Company, 1915 Arch Street, Philadelphia, PA 19103.

Valerie C. Scanlon
Dobbs Ferry, New York

Tina Sanders
Castle Creek, New York

To the Instructor

As the science and arts of medicine and health care become increasingly complex, so too does the education of those who pursue careers in nursing and other health-related fields. Human anatomy and physiology is often a first course in many education programs, and is the basis for so many of the more specialized courses. Teachers of introductory anatomy and physiology thus take on a special challenge: We must distill and express the complexities of human structure and function in a simple way, without losing the essence and meaning of the material. That is the goal of this textbook: to make this material readily accessible to students with diverse backgrounds and varying levels of educational preparation.

No prior knowledge of biology or chemistry is assumed, and even the most fundamental terms are defined thoroughly. Essential aspects of anatomy are presented clearly and reinforced with excellent illustrations. Essential aspects of physiology are discussed simply, yet with accuracy and precision. Again, the illustrations complement the text material and foster comprehension on the part of the student. These illustrations were prepared especially for students for whom this is a first course in anatomy and physiology. As you will see, these are images in which detail is readily apparent. All important parts have been labeled, but the student is not overwhelmed with unnecessary labels. Illustrations of physiology lead the student step-by-step. Wherever appropriate, the legends refer students to the text for further description or explanation. Each illustration also has a question for the student; the illustration questions in a chapter form an ongoing self-test. (The answers are given in Appendix G.)

The text has three unifying themes: the relationship between physiology and anatomy, the interrelations among the organ systems, and the relationship of each organ system to homeostasis. Although each type of cell, tissue, organ, or organ system is discussed simply and thoroughly in itself, applicable connections are made to other aspects of the body or to the functioning of the body as a whole. Our goal is to provide your students with the essentials of anatomy and physiology, and in doing so, to help give them a solid foundation for their future work, and an appreciation for the incredible living organism that is the human body.

The sequence of chapters is a very traditional one. Cross-references are used to remind students of what they have learned from previous chapters. Nevertheless, the textbook is very flexible, and, following the introductory four chapters, the organ systems may be covered in almost any order, depending on the needs of your course.

Each chapter is organized from the simple to the more complex, with the anatomy followed by the physiology. The Instructor's Guide presents modifications of the topic sequences that may be used, again depending on the needs of your course. Certain more advanced topics may be omitted from each chapter without losing the meaning or flow of the rest of the material, and these are indicated, for each chapter, in the Instructor's Guide.

Clinical applications are set apart from the text in boxed inserts. These are often aspects of pathophysiology that are related to the normal anatomy or physiology in the text discussion. Each box presents one particular topic and is referenced at the appropriate point in the text. This material is intended to be an integral part of the chapter

but is set apart for ease of reference and to enable you to include or omit as many of these topics as you wish. The use of these boxes also enables students to read the text material without interruption and then to focus on specific aspects of pathophysiology. A comprehensive list of the boxes appears inside the book's front and back covers, and another list at the beginning of each chapter cites the boxes within that chapter.

Tables are utilized as summaries of structure and function, to present a sequence of events, or additional material that you may choose to include. Each table is referenced in the text and is intended to facilitate your teaching and to help your students learn.

New terms appear in bold type within the text, and all such terms are fully defined in an extensive glossary, with phonetic pronunciations. Bold type may also be used for emphasis whenever one of these terms is used again in a later chapter.

Each chapter begins with a chapter outline and student objectives to prepare the student for the chapter itself. New terminology and related clinical terms are also listed, with phonetic pronunciations. Each of these terms is fully defined in the glossary, with cross-references back to the chapter in which the term is introduced.

At the end of each chapter are a study outline and review questions. The study outline includes all of the essentials of the chapter in a concise outline form. The review questions may be assigned as homework, or used by the students as a review or self-test. Following each question is a page reference in parentheses. This reference cites the page(s) in the chapter on which the content needed to answer the question correctly can be found. The answers themselves are included in the Instructor's Guide. The questions in the sections titled For Further Thought may be used in a variety of ways, and the answers are in the Instructor's Guide.

An important supplementary learning tool for your students is available in the form of a *Student Workbook* that accompanies this text. For each chapter in the textbook, the workbook offers fill-in and matching-column questions, figure-labeling and figure-coloring exercises, and crossword puzzles based on the chapter's vocabulary list. Also included are two comprehensive, multiple-choice chapter tests to provide a thorough review. All answers are provided at the end of the workbook.

Ancillary materials for the teacher using this text are all on a CD-ROM: a complete Instructor's Guide, two computerized test banks, and an Image Ancillary presentation of the text illustrations. The Instructor's Guide contains notes on each chapter's organization and content (useful for modifying the book to your specific teaching needs), topics for class discussion, answers to the chapter review questions from the textbook, and detailed answers to the For Further Thought questions. The multiple-choice test bank contains more than 2600 questions that have been organized in relation to the chapter review questions, and further explanation may be found in the Instructor's Guide. The fill-in test bank contains more than 2100 questions organized by textbook chapter. The Image Ancillary presentation contains many of the illustrations from the textbook, with suggested points for use in classroom lectures.

Suggestions and comments from colleagues are always valuable, and yours would be greatly appreciated. When we took on the task of writing and illustrating this textbook, we wanted to make it the most useful book possible for you and your students. Any suggestions that you can provide to help us achieve that goal are most welcome, and they may be sent to us in care of F. A. Davis Company, 1915 Arch Street, Philadelphia, PA 19103.

Valerie C. Scanlon
Dobbs Ferry, New York

Tina Sanders
Castle Creek, New York

To the Student

This is your textbook for your first course in human anatomy and physiology, a subject that is both fascinating and rewarding. That you are taking such a course says something about you. You may simply be curious as to how the human body functions or you may have a personal goal of making a contribution in one of the healthcare professions. Whatever your reason, this textbook will help you to be successful in your anatomy and physiology course.

The material is presented simply and concisely, yet with accuracy and precision. The writing style is informal yet clear and specific; it is intended to promote your comprehension and understanding.

ORGANIZATION OF THE TEXTBOOK

To use this textbook effectively, you should know the purpose of its various parts. Each chapter is organized in the following way:

Chapter Outline—This presents the main topics in the chapter, which correspond to the major headings in the text.

Student Objectives—These summarize what you should know after reading and studying the chapter. These are not questions to be answered, but are rather, with the chapter outline, a preview of the chapter contents.

New Terminology and Related Clinical Terminology—These are some of the new terms you will come across in the chapter. Read through these terms before you read the chapter, but do not attempt to memorize them just yet. When you have finished the chapter, return to the list and see how many terms you can define. Note those you may not be sure of and look them up. All of these terms are fully defined in the glossary.

Study Outline—This is found at the end of the chapter. It is a concise summary of the essentials in the chapter. You may find this outline very useful as a quick review before an exam.

Review Questions—These are also at the end of the chapter. Your instructor may assign some or all of them as homework. If not, the questions may be used as a self-test to evaluate your comprehension of the chapter's content. The page number(s) in parentheses following each question refers you to the page(s) in the chapter on which the content needed to answer the question correctly can be found.

For Further Thought—The heading tells you what these are for: thinking. Your instructor may use these for class discussion, and, if so, please do not ever be afraid to be wrong. Being wrong in the classroom is one of the ways each and every one of us learns. Contribute, raise your hand and speak up with your best thoughts, and listen to those of others. Together you will find the answers.

OTHER FEATURES WITHIN EACH CHAPTER

Illustrations—These are an essential part of this textbook. Use them. Study them carefully, and they will be of great help to you as you learn. They are intended to help you develop your own mental picture of the body and its parts and processes. You may not have thought of mental pictures as being important, but they are, and each new one you create is a major step in learning. Each illustration is referenced in the text, so you will know when to consult it. With a little concentration, you will have it in your mind for whenever you need it. You will see that each illustration also has a question after the legend. These questions provide an ongoing quiz; try to answer each one as you come to it. (Will it matter if you're wrong? No, but answering the questions will help you to learn.) The answers are given in Appendix G, just before the glossary.

Boxes—Discussions of clinical applications are in separate boxes in the text so that you may find and refer to them easily. Your instructor may include all or some of these as required reading. If you are planning a career in the health professions, these boxes are an introduction to pathophysiology, and you will find them interesting and helpful.

Bold Type—This is used whenever a new term is introduced, or when an old term is especially important. The terms in bold type are fully defined in the glossary, which includes phonetic pronunciations.

Tables—This format is used to present material in a very concise form. Some tables are summaries of text material and are very useful for a quick review. Other tables present additional material that complements the text material.

Glossary—Not within the chapters but at the end, the glossary is the dictionary of the book. All of the terms in bold type, as well as others, are defined here. Make use of it, rather than wonder what a word means. The sooner you have a definition firmly in your mind, the sooner it is truly part of your knowledge.

To make the best use of your study time, a *Student Workbook* is available that will help you to focus your attention on the essentials in each chapter. Also included are comprehensive chapter tests to help you determine which topics you have learned thoroughly and which you may have to review. If your instructor has not made the workbook a required text, you may wish to ask that it be ordered and made available in your bookstore. You will find it very helpful.

SOME FINAL WORDS OF ENCOURAGEMENT

Your success in this course depends to a great extent on you. Try to set aside study time for yourself every day; a little time each day is usually much more productive than trying to cram at the last minute.

Ask questions of yourself as you are studying. What kinds of questions? The simplest ones. If you are studying a part of the body such as an organ, ask yourself: What is its name? Where is it? What is it made of? What does it do? That is: name, location, structure, and function. These are the essentials. If you are studying a process, ask yourself: What is happening here? What is its purpose? That is: What is going on? And what good is it? Again, these are the essentials.

We hope this textbook will contribute to your success. If you have any suggestions or comments, we would very much like to hear them. After all, this book was written for you, to help you achieve your goals in this course and in your education. Please send your suggestions and comments to us in care of F. A. Davis Company, 1915 Arch Street, Philadelphia, PA 19103.

Valerie C. Scanlon
Dobbs Ferry, New York

Tina Sanders
Castle Creek, New York

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VCS

TS

To my students, past and present
VCS

To Brooks, for his encouragement
TS

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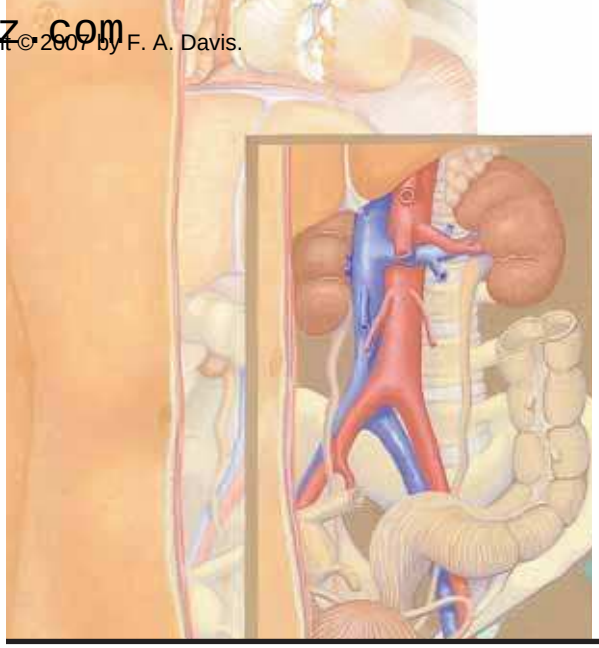
CHAPTER 1

Organization and General Plan of the Body



CHAPTER 1

Chapter Outline

Levels of Organization
Chemicals
Cells
Tissues
Organs
Organ Systems
Metabolism and Homeostasis
Terminology and General Plan of the Body
Body Parts and Areas
Terms of Location and Position
Body Cavities and Their Membranes
    Dorsal cavity
    Ventral cavity
Planes and Sections
Areas of the Abdomen

Box 1–1 REPLACING TISSUES AND ORGANS
Box 1–2 VISUALIZING THE INTERIOR OF THE BODY

Student Objectives

- Define the terms *anatomy*, *physiology*, and *pathophysiology*. Use an example to explain how they are related.
- Name the levels of organization of the body from simplest to most complex, and explain each.
- Define the terms *metabolism*, *metabolic rate*, and *homeostasis*, and use examples to explain.
- Explain how a negative feedback mechanism works, and how a positive feedback mechanism differs.
- Describe the anatomic position.
- State the anatomic terms for the parts of the body.
- Use proper terminology to describe the location of body parts with respect to one another.
- Name the body cavities, their membranes, and some organs within each cavity.
- Describe the possible sections through the body or an organ.
- Explain how and why the abdomen is divided into smaller areas. Be able to name organs in these areas.

Organization and General Plan of the Body

New Terminology

Anatomy (uh-**NAT**-uh-mee)
Body cavity (**BAH**-dee **KAV**-i-tee)
Cell (SELL)
Homeostasis (HOH-me-oh-**STAY**-sis)
Inorganic chemicals (**IN**-or-GAN-ik **KEM**-i-kuls)
Meninges (me-**NIN**-jeez)
Metabolism (muh-**TAB**-uh-lizm)
Negative feedback (**NEG**-ah-tiv **FEED**-bak)
Organ (**OR**-gan)
Organ system (**OR**-gan **SIS**-tem)
Organic chemicals (or-**GAN**-ik **KEM**-i-kuls)
Pathophysiology (PATH-oh-FIZZ-ee-**AH**-luh-jee)
Pericardial membranes (PER-ee-**KAR**-dee-uhl **MEM**-brayns)
Peritoneum/Mesentery (PER-i-toh-**NEE**-um/**MEZ**-en-TER-ee)
Physiology (FIZZ-ee-**AH**-luh-jee)
Plane (PLAYN)
Pleural membranes (**PLOOR**-uhl **MEM**-brayns)
Positive feedback (**PAHS**-ah-tiv **FEED**-bak)
Section (**SEK**-shun)
Tissue (**TISH**-yoo)

Related Clinical Terminology

Computed tomography (CT) scan (kom-**PEW**-ted toh-**MAH**-grah-fee SKAN)
Diagnosis (DYE-ag-**NO**-sis)
Disease (di-**ZEEZ**)
Magnetic resonance imaging (MRI) (mag-**NET**-ik **REZ**-ah-nanse **IM**-ah-jing)
Positron emission tomography (PET) (**PAHZ**-i-tron e-**MISH**-un toh-**MAH**-grah-fee)

*Terms that appear in **bold type** in the chapter text are defined in the glossary, which begins on page 547.*

The human body is a precisely structured container of chemical reactions. Have you ever thought of yourself in this way? Probably not, and yet, in the strictly physical sense, that is what each of us is. The body consists of trillions of atoms in specific arrangements and thousands of chemical reactions proceeding in a very orderly manner. That literally describes us, and yet it is clearly not the whole story. The keys to understanding human consciousness and self-awareness are still beyond our grasp. We do not yet know what enables us to study ourselves—no other animals do, as far as we know—but we have accumulated a great deal of knowledge about what we are made of and how it all works. Some of this knowledge makes up the course you are about to take, a course in basic human anatomy and physiology.

Anatomy is the study of body structure, which includes size, shape, composition, and perhaps even coloration. **Physiology** is the study of how the body functions. The physiology of red blood cells, for example, includes what these cells do, how they do it, and how this is related to the functioning of the rest of the body. Physiology is directly related to anatomy. For example, red blood cells contain the mineral iron in molecules of the protein called hemoglobin; this is an aspect of their anatomy. The presence of iron enables red blood cells to carry oxygen, which is their function. All cells in the body must receive oxygen in order to function properly, so the physiology of red blood cells is essential to the physiology of the body as a whole.

Pathophysiology is the study of disorders of functioning, and a knowledge of normal physiology makes such disorders easier to understand. For example, you are probably familiar with the anemia called iron-deficiency anemia. With insufficient iron in the diet, there will not be enough iron in the hemoglobin of red blood cells, and hence less oxygen will be transported throughout the body, resulting in the symptoms of the iron-deficiency disorder. This example shows the relationship between anatomy, physiology, and pathophysiology.

The purpose of this text is to enable you to gain an understanding of anatomy and physiology with the emphasis on normal structure and function. Many examples of pathophysiology have been included, however, to illustrate the relationship of **disease** to normal physiology and to describe some of the procedures used in the **diagnosis** of disease. Many of the examples are clinical applications that will help you begin to apply what you have learned and demonstrate that your knowledge of anatomy and physiology will become the basis for your further study in the health professions.

LEVELS OF ORGANIZATION

The human body is organized into structural and functional levels of increasing complexity. Each higher level incorporates the structures and functions of the previous level, as you will see. We will begin with the simplest level, which is the chemical level, and proceed to cells, tissues, organs, and organ systems. All of the levels of organization are depicted in Fig. 1–1.

CHEMICALS

The chemicals that make up the body may be divided into two major categories: inorganic and organic. **Inorganic chemicals** are usually simple molecules made of one or two elements other than carbon (with a few exceptions). Examples of inorganic chemicals are water (H_2O); oxygen (O_2); one of the exceptions, carbon dioxide (CO_2); and minerals such as iron (Fe), calcium (Ca), and sodium (Na). **Organic chemicals** are often very complex and always contain the elements carbon and hydrogen. In this category of organic chemicals are carbohydrates, fats, proteins, and nucleic acids. The chemical organization of the body is the subject of Chapter 2.

CELLS

The smallest living units of structure and function are **cells**. There are many different types of human cells, though they all have certain similarities. Each type of cell is made of chemicals and carries out specific chemical reactions. Cell structure and function are discussed in Chapter 3.

TISSUES

A **tissue** is a group of cells with similar structure and function. There are four groups of tissues:

Epithelial tissues—cover or line body surfaces; some are capable of producing secretions with specific functions. The outer layer of the skin and sweat glands are examples of epithelial tissues. Internal epithelial tissues include the walls of capillaries (squamous epithelium) and the kidney tubules (cuboidal epithelium), as shown in Fig. 1–1.

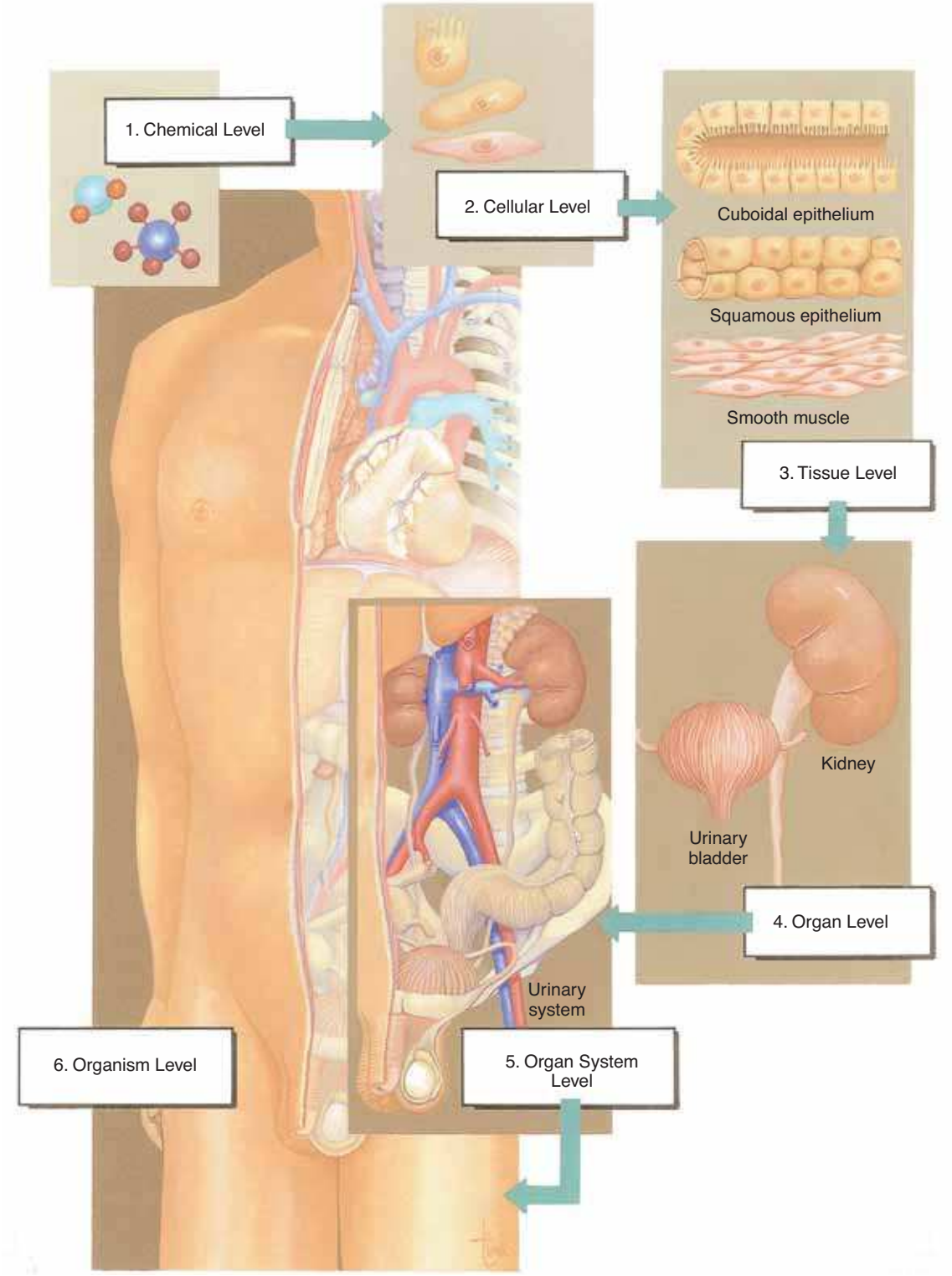


Figure 1–1. Levels of structural organization of the human body, depicted from the simplest (chemical) to the most complex (organism). The organ system shown here is the urinary system.
QUESTION: What other organ system seems to work directly with the urinary system?

Connective tissues—connect and support parts of the body; some transport or store materials. Blood, bone, cartilage, and adipose tissue are examples of this group.

Muscle tissues—specialized for contraction, which brings about movement. Our skeletal muscles and the heart are examples of muscle tissue. In Fig. 1–1, you see smooth muscle tissue, which is found in organs such as the urinary bladder and stomach.

Nerve tissue—specialized to generate and transmit electrochemical impulses that regulate body functions. The brain and optic nerves are examples of nerve tissue.

The types of tissues in these four groups, as well as their specific functions, are the subject of Chapter 4.

ORGANS

An **organ** is a group of tissues precisely arranged so as to accomplish specific functions. Examples of organs are the kidneys, individual bones, the liver, lungs, and stomach. The kidneys contain several kinds of epithelial, or surface tissues, for their work of absorption. The stomach is lined with epithelial tissue that secretes gastric juice for digestion. Smooth muscle tissue in the wall of the stomach contracts to mix food with gastric juice and propel it to the small intestine. Nerve tissue carries impulses that increase or decrease the contractions of the stomach (see Box 1–1: Replacing Tissues and Organs).

ORGAN SYSTEMS

An **organ system** is a group of organs that all contribute to a particular function. Examples are the urinary system, digestive system, and respiratory system. In Fig. 1–1 you see the urinary system, which consists of the kidneys, ureters, urinary bladder, and urethra. These organs all contribute to the formation and elimination of urine.

As a starting point, Table 1–1 lists the organ systems of the human body with their general functions, and some representative organs, and Fig. 1–2 depicts

Box 1–1 REPLACING TISSUES AND ORGANS

Blood transfusions are probably the most familiar and frequent form of "replacement parts" for people. Blood is a tissue, and when properly typed and cross-matched (blood types will be discussed in Chapter 11) may safely be given to someone with the same or a compatible blood type.

Organs, however, are much more complex structures. When a patient receives an organ transplant, there is always the possibility of rejection (destruction) of the organ by the recipient's immune system (Chapter 14). With the discovery and use of more effective immune-suppressing medications, however, the success rate for many types of organ transplants has increased. Organs that may be transplanted include corneas, kidneys, the heart, the liver, and the lungs.

The skin is also an organ, but skin transplanted from another person will not survive very long. Several kinds of artificial skin are now available to temporarily cover large areas of damaged skin. Patients with severe burns, for example, will eventually need skin grafts from their own unburned skin to form permanent new skin over the burn sites. It is possible to "grow" a patient's skin in laboratory culture, so that a small patch of skin may eventually be used to cover a large surface. Other cells grown in culture include cartilage, bone, pancreas, and liver. Much research is being done on liver implants (not transplants), clusters of functional liver cells grown in a lab. Such implants would reduce or eliminate the need for human donors. Tissue engineering is also being used to create arteries and urinary bladders.

Many artificial replacement parts have also been developed. These are made of plastic or metal and are not rejected as foreign by the recipient's immune system. Damaged heart valves, for example, may be replaced by artificial ones, and sections of arteries may be replaced by tubular grafts made of synthetic materials. Artificial joints are available for every joint in the body, as is artificial bone for reconstructive surgery. Cochlear implants are tiny instruments that convert sound waves to electrical impulses the brain can learn to interpret, and have provided some sense of hearing for people with certain types of deafness. Work is also progressing on the use of a featherweight computer chip as an artificial retina, on devices that help damaged hearts pump blood more efficiently, and on small, self-contained artificial hearts.

Table 1–1 THE ORGAN SYSTEMS

System	Functions	Organs*
Integumentary	• Is a barrier to pathogens and chemicals • Prevents excessive water loss	skin, subcutaneous tissue
Skeletal	• Supports the body • Protects internal organs and red bone marrow • Provides a framework to be moved by muscles	bones, ligaments
Muscular	• Moves the skeleton • Produces heat	muscles, tendons
Nervous	• Interprets sensory information • Regulates body functions such as movement by means of electrochemical impulses	brain, nerves, eyes, ears
Endocrine	• Regulates body functions such as growth and reproduction by means of hormones • Regulates day-to-day metabolism by means of hormones	thyroid gland, pituitary gland, pancreas
Circulatory	• Transports oxygen and nutrients to tissues and removes waste products	heart, blood, arteries
Lymphatic	• Returns tissue fluid to the blood • Destroys pathogens that enter the body and provides immunity	spleen, lymph nodes
Respiratory	• Exchanges oxygen and carbon dioxide between the air and blood	lungs, trachea, larynx, diaphragm
Digestive	• Changes food to simple chemicals that can be absorbed and used by the body	stomach, colon, liver, pancreas
Urinary	• Removes waste products from the blood • Regulates volume and pH of blood and tissue fluid	kidneys, urinary bladder, urethra
Reproductive	• Produces eggs or sperm • *In women*, provides a site for the developing embryo-fetus	*Female*: ovaries, uterus *Male*: testes, prostate gland

*These are simply representative organs, not an all-inclusive list.

all of the organ systems. Some organs are part of two organ systems; the pancreas, for example, is both a digestive and an endocrine organ, and the diaphragm is part of both the muscular and respiratory systems. All of the organ systems make up an individual person. The balance of this text discusses each system in more detail.

METABOLISM AND HOMEOSTASIS

Metabolism is a collective noun; it is all of the chemical reactions and physical processes that take place within the body. Metabolism includes growing, repairing, reacting, and reproducing—all the characteristics of life. The pumping of the heart, the digestion of food in the stomach, the diffusion of gases in the lungs and tissues, and the production of energy in each cell of the body are just a few of the thousands of aspects of metabolism. *Metabolism* comes from a Greek word meaning "change," and the body is always changing in visible ways (walking down the street), microscopic ways (cells dividing in the skin to produce new epidermis), and submicroscopic or molecular ways (RNA and enzymes constructing new proteins). A related concept, **metabolic rate**, is most often used to mean the speed at which the body produces energy and heat, or, put another way, energy production per unit of time, such as 24 hours. Metabolic rate, therefore, is one aspect of metabolism.

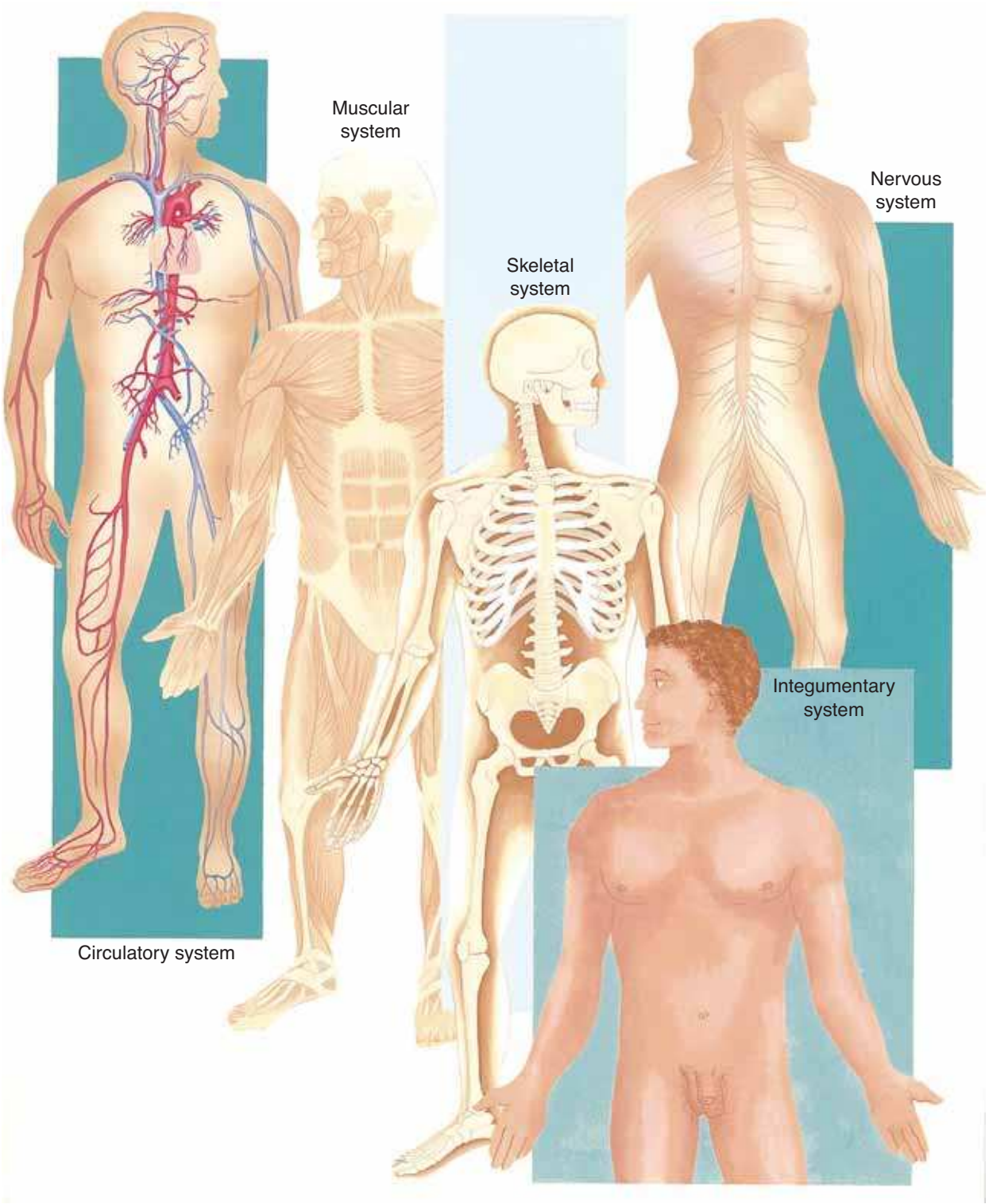


Figure 1–2. Organ systems. Compare the depiction of each system to its description in Table 1–1.
QUESTION: Name at least one organ shown in each system.

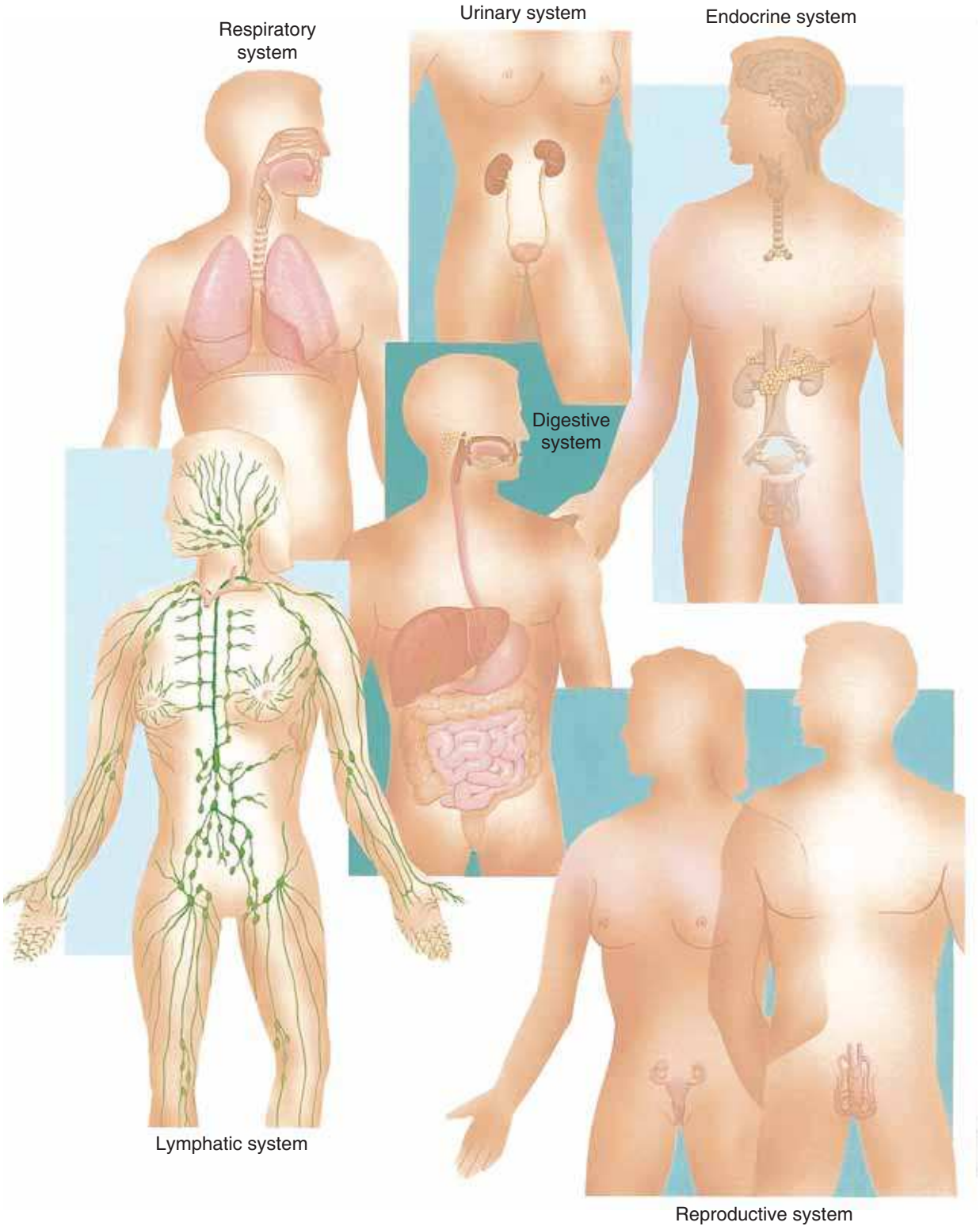


Figure 1–2. (Continued)

A person who is in good health may be said to be in a state of **homeostasis**. Homeostasis reflects the ability of the body to maintain a relatively stable metabolism and to function normally despite many constant changes. The changes that are part of normal metabolism may be internal or external, and the body must respond appropriately.

Eating breakfast, for example, brings about an internal change. Suddenly there is food in the stomach, and something must be done with it. What happens? The food is digested or broken down into simple chemicals that the body can use. The protein in a hard-boiled egg is digested into amino acids, its basic chemical building blocks; these amino acids can then be used by the cells of the body to produce their own specialized proteins.

An example of an external change is a rise in environmental temperature. On a hot day, the body temperature would also tend to rise. However, body temperature must be kept within its normal range of about 97° to 99°F (36° to 38°C) in order to support normal functioning. What happens? One of the body's responses to the external temperature rise is to increase sweating so that excess body heat can be lost by the evaporation of sweat on the surface of the skin. This response, however, may bring about an undesirable internal change, dehydration. What happens? As body water decreases, we feel the sensation of thirst and drink fluids to replace the water lost in sweating. Notice that when certain body responses occur, they reverse the event that triggered them. In the preceding example a rising body temperature stimulates increased sweating, which lowers body temperature, which in turn decreases sweating. Unnecessary sweating that would be wasteful of water is prevented. This is an example of a **negative feedback mechanism**, in which the body's response reverses the stimulus (in effect, turning it off for a while) and keeps some aspect of the body metabolism within its normal range.

Look at Fig. 1–3 for another negative feedback mechanism, one in which the hormone thyroxine regulates the metabolic rate of the body. As metabolic rate decreases, the hypothalamus (part of the brain) and pituitary gland detect this decrease and secrete hormones to stimulate the thyroid gland (on the front of the neck just below the larynx) to secrete the hormone thyroxine. Thyroxine stimulates the cellular enzyme systems that produce energy from food, which increases the metabolic rate. The rise in energy and heat production is detected by the brain and pituitary gland. They then decrease secretion of their hormones, which in turn inhibits any further secretion of thyroxine until the metabolic rate decreases again. Metabolic rate does rise and fall, but is kept within normal limits.

You may be wondering if there is such a thing as a positive feedback mechanism. There is, but they are rare in the body and quite different from a negative feedback mechanism. In a **positive feedback mechanism**, the response to the stimulus does not stop or reverse the stimulus, but instead keeps the sequence of events going. A good example is childbirth, in which the sequence of events, simply stated, is as follows: Stretching of the uterine cervix stimulates secretion of the hormone oxytocin by the posterior pituitary gland. Oxytocin stimulates contraction of the uterine muscle, which causes more stretching, which stimulates more oxytocin and, hence, more contractions. The mechanism stops with the delivery of the baby and the placenta. This is the "brake," the interrupting event.

Any positive feedback mechanism requires an external "brake," something to interrupt it. Blood clotting is such a mechanism, and without external controls, clotting may become a vicious cycle of clotting and more clotting, doing far more harm than good (discussed in Chapter 11). Inflammation following an injury is beneficial and necessary for repair to begin, but the process may evolve into a cycle of damage and more damage. The rise of a fever may also trigger a positive feedback mechanism. Notice in Fig. 1–3 that bacteria have affected the body's thermostat in the hypothalamus and caused a fever. The rising body temperature increases the metabolic rate, which increases body temperature even more, becoming a cycle. Where is the inhibition, the brake? For this infection, the brake is white blood cells destroying the bacteria that caused the fever. An interruption from outside the cycle is necessary. It is for this reason, because positive feedback mechanisms have the potential to be self-perpetuating and cause harm, that they are rare in the body.

Negative feedback mechanisms, however, contain their own brakes in that inhibition is a natural part of the cycle, and the body has many of them. The secretion of most hormones (Chapter 10) is regulated by negative feedback mechanisms. The regulation of heart rate (Chapter 12) and blood pressure (Chapter 13) involves several negative feedback mechanisms.

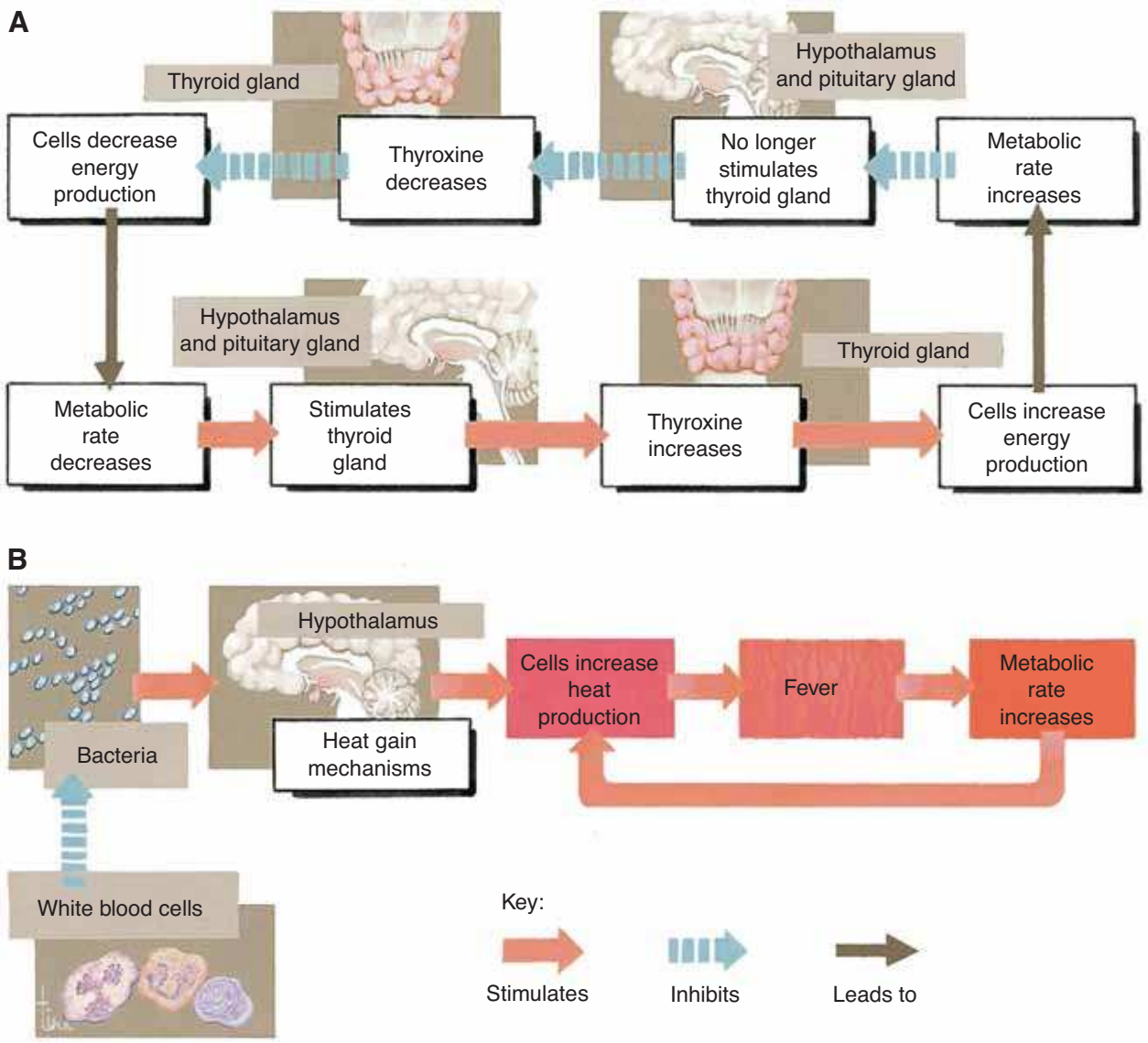


Figure 1–3. Feedback mechanisms. (**A**) The negative feedback mechanism of regulation of metabolic rate by thyroxine. (**B**) The positive feedback mechanism triggered by a fever. See text for description.
QUESTION: For each mechanism, where is the source of the "brake" or inhibition?

The result of all of these mechanisms working together is that all aspects of body functioning, that is, of metabolism, are kept within normal limits, a steady state or equilibrium. This is homeostasis.

In the chapters to come, you will find many more examples of homeostasis. As you continue your study of the human body, keep in mind that the proper functioning of each organ and organ system contributes to homeostasis. Keep in mind as well that what we call the normal values of metabolism are often ranges, not single numbers. Recall that normal body temperature is a range: 97° to 99°F (36° to 38°C). Normal pulse

rate, another example, is 60 to 80 beats per minute; a normal respiratory rate is 12 to 20 breaths per minute. Variations within the normal range are part of normal metabolism.

TERMINOLOGY AND GENERAL PLAN OF THE BODY

As part of your course in anatomy and physiology, you will learn many new words or terms. At times you may feel that you are learning a second language, and indeed you are. Each term has a precise meaning, which is understood by everyone else who has learned the language. Mastering the terminology of your profession is essential to enable you to communicate effectively with your coworkers and your future patients. Although the number of new terms may seem a bit overwhelming at first, you will find that their use soon becomes second nature to you.

The terminology presented in this chapter will be used throughout the text in the discussion of the organ systems. This will help to reinforce the meanings of these terms and will transform these new words into knowledge.

BODY PARTS AND AREAS

Each of the terms listed in Table 1–2 and shown in Fig. 1–4 refers to a specific part or area of the body. For example, the term *femoral* always refers to the thigh. The femoral artery is a blood vessel that passes through the thigh, and the quadriceps femoris is a large muscle group of the thigh.

Another example is *pulmonary*, which always refers to the lungs, as in pulmonary artery, pulmonary edema, and pulmonary embolism. Although you may not know the exact meaning of each of these terms now, you do know that each has something to do with the lungs.

TERMS OF LOCATION AND POSITION

When describing relative locations, the body is always assumed to be in anatomic position: standing upright facing forward, arms at the sides with palms forward, and the feet slightly apart. The terms of location are listed in Table 1–3, with a definition and example for each. As you read each term, find the body parts used as examples in Figs. 1–4 and 1–5. Notice also that these are pairs of terms and that each pair is a set of opposites. This will help you recall the terms and their meanings.

Table 1–2 DESCRIPTIVE TERMS FOR BODY PARTS AND AREAS

Term	Definition (Refers to)
Antebrachial	forearm
Antecubital	front of elbow
Axillary	armpit
Brachial	upper arm
Buccal (oral)	mouth
Cardiac	heart
Cervical	neck
Cranial	head
Cutaneous	skin
Deltoid	shoulder
Femoral	thigh
Frontal	forehead
Gastric	stomach
Gluteal	buttocks
Hepatic	liver
Iliac	hip
Inguinal	groin
Lumbar	small of back
Mammary	breast
Nasal	nose
Occipital	back of head
Orbital	eye
Parietal	crown of head
Patellar	kneecap
Pectoral	chest
Pedal	foot
Perineal	pelvic floor
Plantar	sole of foot
Popliteal	back of knee
Pulmonary	lungs
Renal	kidney
Sacral	base of spine
Scapular	shoulder blade
Sternal	breastbone
Temporal	side of head
Umbilical	navel
Volar (palmar)	palm

BODY CAVITIES AND THEIR MEMBRANES

The body has two major cavities: the dorsal cavity (posterior) and the ventral cavity (anterior). Each of these cavities has further subdivisions, which are shown in Fig. 1–5.

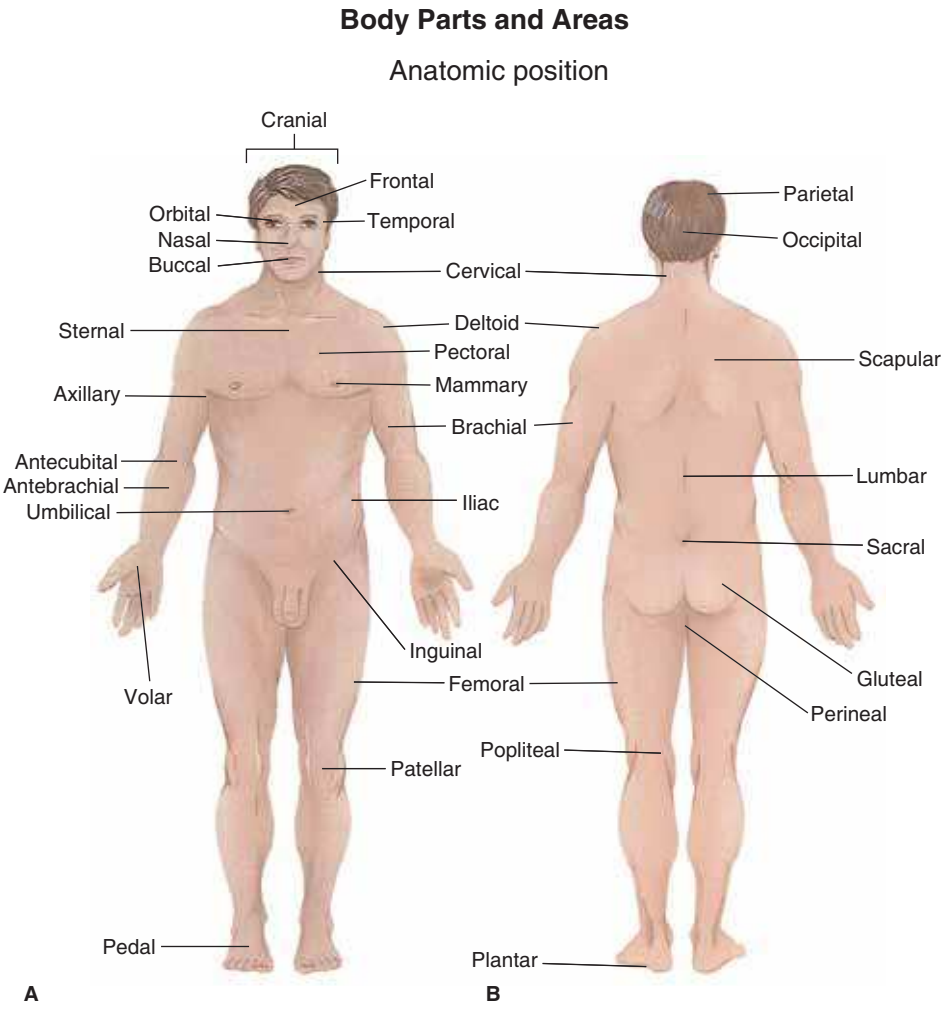


Figure 1–4. Body parts and areas. The body is shown in anatomic position. (**A**) Anterior view. (**B**) Posterior view. (Compare with Table 1–2.)
QUESTION: Name a body area that contains a bone with a similar name. Can you name two more?

Dorsal Cavity

The dorsal cavity contains the central nervous system, and consists of the cranial cavity and the vertebral or spinal cavity. The dorsal cavity is a continuous one; that is, no wall or boundary separates its subdivisions. The cranial cavity is formed by the skull and contains the brain. The spinal cavity is formed by the backbone (spine) and contains the spinal cord. The membranes that line these cavities and cover the brain and spinal cord are called the **meninges**.

Ventral Cavity

The ventral cavity consists of two compartments, the thoracic cavity and the abdominal cavity, which are separated by the diaphragm. The diaphragm is a large, dome-shaped respiratory muscle. It has openings for the esophagus and for large blood vessels, but otherwise is a wall between the thoracic and abdominal cavities. The pelvic cavity may be considered a subdivision of the abdominal cavity (there is no wall between them) or as a separate cavity.

Table 1–3 TERMS OF LOCATION AND POSITION

Term	Definition	Example
Superior	above, or higher	The heart is superior to the liver.
Inferior	below, or lower	The liver is inferior to the lungs.
Anterior	toward the front	The chest is on the anterior side of the body.
Posterior	toward the back	The lumbar area is posterior to the umbilical area.
Ventral	toward the front	The mammary area is on the ventral side of the body.
Dorsal	toward the back	The buttocks are on the dorsal side of the body.
Medial	toward the midline	The heart is medial to the lungs.
Lateral	away from the midline	The shoulders are lateral to the neck.
Internal	within, or interior to	The brain is internal to the skull.
External	outside, or exterior to	The ribs are external to the lungs.
Superficial	toward the surface	The skin is the most superficial organ.
Deep	within, or interior to	The deep veins of the legs are surrounded by muscles.
Central	the main part	The brain is part of the central nervous system.
Peripheral	extending from the main part	Nerves in the arm are part of the peripheral nervous system.
Proximal	closer to the origin	The knee is proximal to the foot.
Distal	farther from the origin	The palm is distal to the elbow.
Parietal	pertaining to the wall of a cavity	The parietal pleura lines the chest cavity.
Visceral	pertaining to the organs within a cavity	The visceral pleura covers the lungs.

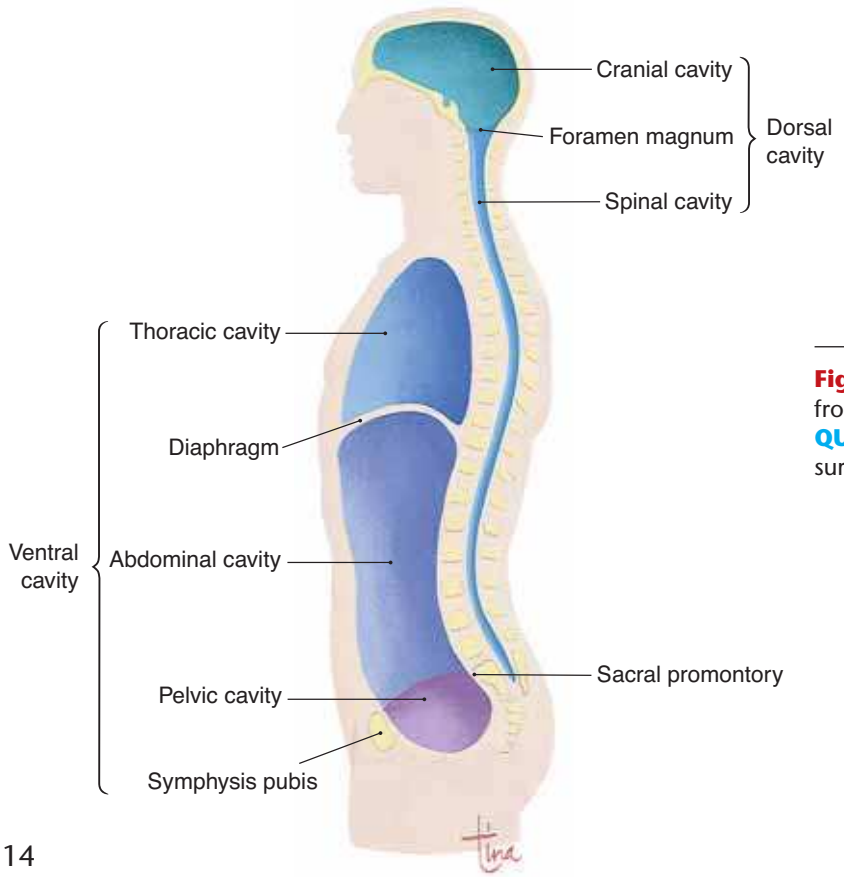


Figure 1–5. Body cavities (lateral view from the left side).
QUESTION: Which of these cavities are surrounded by bone?

Organs in the **thoracic cavity** include the heart and lungs. The membranes of the thoracic cavity are serous membranes called the **pleural membranes**. The parietal pleura lines the chest wall, and the visceral pleura covers the lungs. The heart has its own set of serous membranes called the **pericardial membranes**. The parietal pericardium lines the fibrous pericardial sac, and the visceral pericardium covers the heart muscle.

Organs in the **abdominal cavity** include the liver, stomach, and intestines. The membranes of the abdominal cavity are also serous membranes called the peritoneum and mesentery. The **peritoneum** is the membrane that lines the entire abdominal wall, and the **mesentery** is the continuation of this membrane, folded around and covering the outer surfaces of the abdominal organs.

The **pelvic cavity** is inferior to the abdominal cavity. Although the peritoneum does not line the pelvic cavity, it covers the free surfaces of several pelvic organs. Within the pelvic cavity are the urinary bladder and reproductive organs such as the uterus in women and the prostate gland in men.

PLANES AND SECTIONS

When internal anatomy is described, the body or an organ is often cut or sectioned in a specific way so as to make particular structures easily visible. A **plane** is an imaginary flat surface that separates two portions of

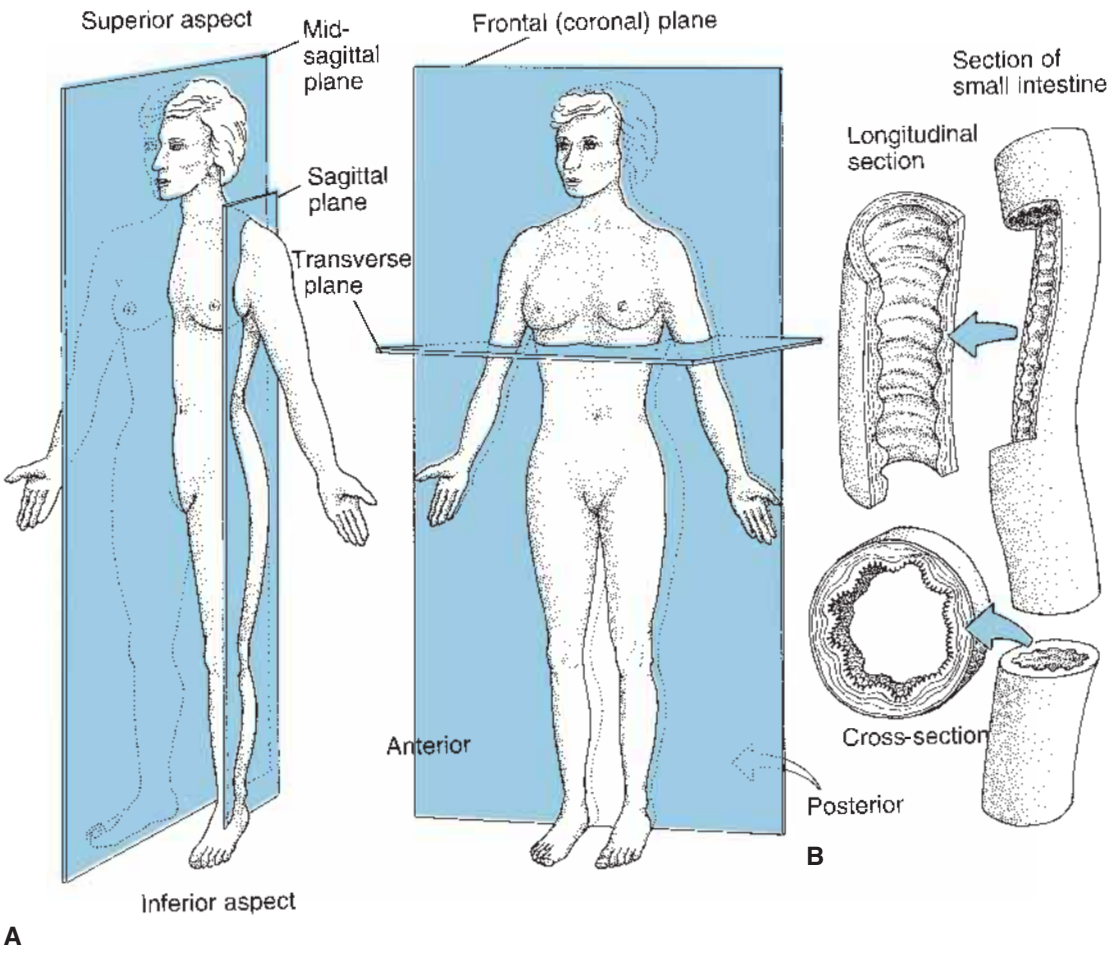
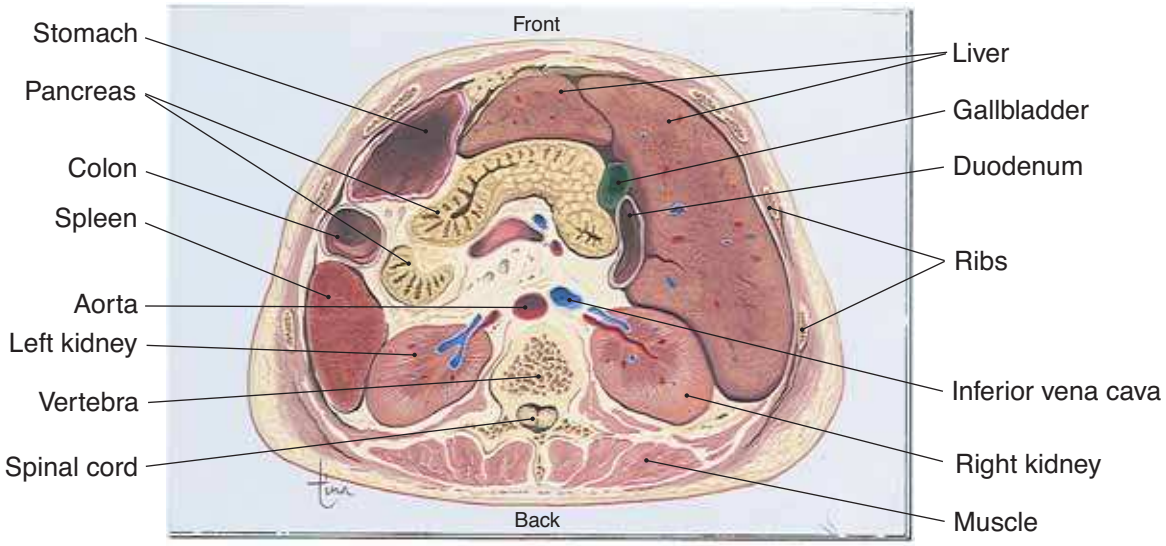


Figure 1–6. (**A**) Planes and sections of the body. (**B**) Cross-section and longitudinal section of the small intestine.
QUESTION: What other organs would have sections that look like those of the small intestine?



C

Figure 1–6. (Continued) (**C**) Transverse section through the upper abdomen.

the body or an organ. These planes and **sections** are shown in Fig. 1–6 (see Box 1–2: Visualizing the Interior of the Body).

Frontal (coronal) section—a plane from side to side separates the body into front and back portions.

Sagittal section—a plane from front to back separates the body into right and left portions. A midsagittal section creates equal right and left halves.

Transverse section—a horizontal plane separates the body into upper and lower portions.

Cross-section—a plane perpendicular to the long axis of an organ. A cross-section of the small intestine (which is a tube) would look like a circle with the cavity of the intestine in the center.

Longitudinal section—a plane along the long axis of an organ. A longitudinal section of the intestine is shown in Fig. 1–6, and a frontal section of the femur (thigh bone) would also be a longitudinal section (see Fig. 6–1 in Chapter 6).

AREAS OF THE ABDOMEN

The abdomen is a large area of the lower trunk of the body. If a patient reported abdominal pain, the physician or nurse would want to know more precisely where the pain was. To determine this, the abdomen may be divided into smaller regions or areas, which are shown in Fig. 1–7.

Quadrants—a transverse plane and a midsagittal plane that cross at the umbilicus will divide the abdomen into four quadrants. Clinically, this is probably the division used more frequently. The pain of gallstones might then be described as in the right upper quadrant.

Nine areas—two transverse planes and two sagittal planes divide the abdomen into nine areas:

Upper areas—above the level of the rib cartilages are the left hypochondriac, epigastric, and right hypochondriac.

Middle areas—the left lumbar, umbilical, and right lumbar.

Lower areas—below the level of the top of the pelvic bone are the left iliac, hypogastric, and right iliac.

These divisions are often used in anatomic studies to describe the location of organs. The liver, for example, is located in the epigastric and right hypochondriac areas.

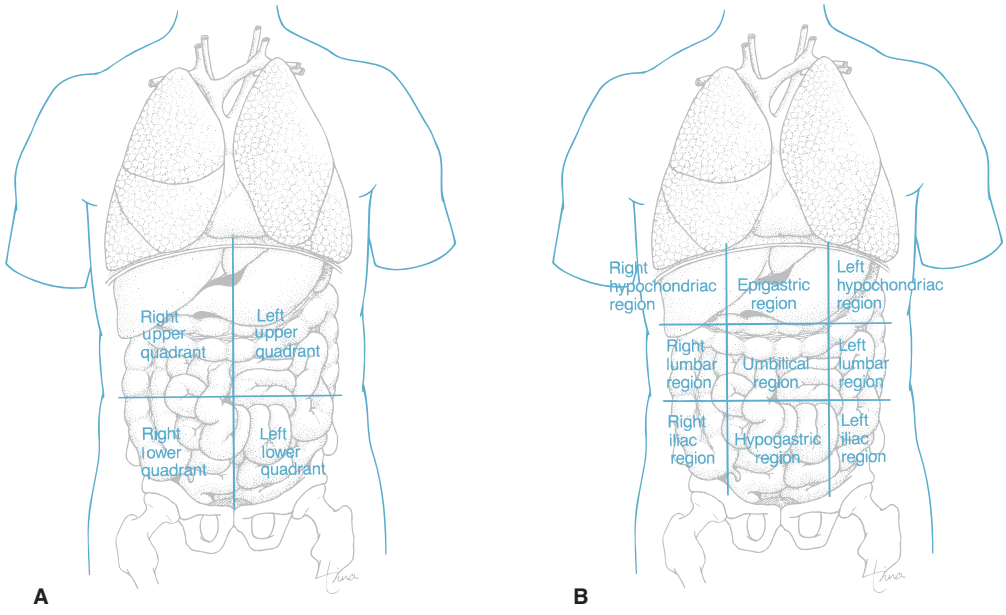


Figure 1–7. Areas of the abdomen. (**A**) Four quadrants. (**B**) Nine regions.
QUESTION: Are there any organs found in all four abdominal quadrants?

SUMMARY

As you will see, the terminology presented in this chapter is used throughout the text to describe the anatomy of organs and the names of their parts. All organs of the body contribute to homeostasis, the healthy state of the body that is maintained by constant and appropriate responses to internal and external changes. In the chapters that follow, you will find detailed descriptions of the physiology of each organ and organ system, and how the metabolism of each is necessary to homeostasis. We will now return to a consideration of the structural organization of the body and to more extensive descriptions of its levels of organization. The first of these, the chemical level, is the subject of the next chapter.

Box 1–2 VISUALIZING THE INTERIOR OF THE BODY

In the past, the need for exploratory surgery brought with it hospitalization, risk of infection, and discomfort and pain for the patient. Today, however, several technologies and the extensive use of computers permit us to see the interior of the body without surgery.

Computed tomography (CT) scanning uses a narrowly focused x-ray beam that circles rapidly around the body. A detector then measures how much radiation passes through different tissues, and a computer constructs an image of a thin slice through the body. Several images may be made at different levels—each takes only a few seconds—to provide a more complete picture of an organ or part of the body. The images are much more detailed than are those produced by conventional x-rays.

Magnetic resonance imaging (MRI) is another diagnostic tool that is especially useful for visualizing soft tissues, including the brain and spinal cord. Recent refinements have produced images of individual nerve bundles, which had not been possible using any other technique. The patient is placed inside a strong magnetic field, and the tissues are pulsed with radio waves. Because each tissue has different proportions of various atoms, which resonate or respond differently, each tissue emits a characteristic signal. A computer then translates these signals into an image; the entire procedure takes 30 to 45 minutes.

Positron emission tomography (PET) scanning creates images that depict the rates of physiological processes such as blood flow, oxygen usage, or glucose metabolism. The comparative rates are depicted by colors: Red represents the highest rate, followed by yellow, then green, and finally blue representing the lowest rate.

One drawback of these technologies is their cost; they are expensive. However, the benefits to patients are great: Highly detailed images of the body are obtained without the risks of surgery and with virtually no discomfort in the procedures themselves.

Box Figure 1–A Imaging techniques. (**A**) CT scan of eye in lateral view showing a tumor *(arrow)* below the optic nerve. (**B**) MRI of midsagittal section of head (compare with Figs. 8–6 and 15–1). (**C**) PET scan of brain in transverse section (frontal lobes at top) showing glucose metabolism. (From Mazziotta, JC, and Gilman, S: Clinical Brain Imaging: Principles and Applications. FA Davis, Philadelphia, 1992, pp 27 and 298, with permission.)

STUDY OUTLINE

Introduction

1. Anatomy—the study of structure.
2. Physiology—the study of function.
3. Pathophysiology—the study of disorders of functioning.

Levels of Organization

1. Chemical—inorganic and organic chemicals make up all matter, both living and non-living.
2. Cells—the smallest living units of the body.

3. Tissues—groups of cells with similar structure and function.
4. Organs—groups of tissues that contribute to specific functions.
5. Organ systems—groups of organs that work together to perform specific functions (see Table 1–1 and Fig. 1–2).
6. Person—all the organ systems functioning properly.

Metabolism and Homeostasis

1. Metabolism is the sum of all of the chemical and physical changes that take place in the body. Metabolic rate is the amount of energy and heat production per unit of time.
2. Homeostasis is a state of good health maintained by the normal metabolism (functioning) of the organ systems.
3. The body constantly responds to internal and external changes, yet remains stable; its many aspects of metabolism are kept within normal limits (usually a range of values, not a single value).
4. Negative feedback mechanism—a control system in which a stimulus initiates a response that reverses or reduces the stimulus, thereby stopping the response until the stimulus occurs again and there is a need for the response (see Fig. 1–3).
5. Positive feedback mechanism—a control system that requires an external interruption or brake. Has the potential to become a self-perpetuating and harmful cycle, therefore is rare in the body (see Fig. 1–3).

Terminology and General Plan of the Body

1. Body parts and areas—see Table 1–2 and Fig. 1–4.
2. Terms of location and position—used to describe relationships of position (see Table 1–3 and Figs. 1–4 and 1–5).
3. Body cavities and their membranes (see Fig. 1–5).
   - Dorsal cavity—lined with membranes called meninges; consists of the cranial and vertebral cavities.
     - Cranial cavity contains the brain.
     - Vertebral cavity contains the spinal cord.
   - Ventral cavity—the diaphragm separates the thoracic and abdominal cavities; the pelvic cavity is inferior to the abdominal cavity.
     - Thoracic cavity—contains the lungs and heart.
       - Pleural membranes line the chest wall and cover the lungs.
       - Pericardial membranes surround the heart.
     - Abdominal cavity—contains many organs including the stomach, liver, and intestines.
       - The peritoneum lines the abdominal cavity; the mesentery covers the abdominal organs.
     - Pelvic cavity—contains the urinary bladder and reproductive organs.
4. Planes and sections—cutting the body or an organ in a specific way (see Fig. 1–6).
   - Frontal or coronal—separates front and back parts.
   - Sagittal—separates right and left parts.
   - Transverse—separates upper and lower parts.
   - Cross—a section perpendicular to the long axis.
   - Longitudinal—a section along the long axis.
5. Areas of the abdomen—permits easier description of locations:
   - Quadrants—see Fig. 1–7.
   - Nine areas—see Fig. 1–7.

REVIEW QUESTIONS

1. Explain how the physiology of a bone is related to its anatomy. Explain how the physiology of the hand is related to its anatomy. (p. 4)
2. Describe anatomic position. Why is this knowledge important? (p. 12)
3. Name the organ system with each of the following functions: (p. 7)
   a. Moves the skeleton
   b. Regulates body functions by means of hormones
   c. Covers the body and prevents entry of pathogens
   d. Destroys pathogens that enter the body
   e. Exchanges oxygen and carbon dioxide between the air and blood

4. Name the two major body cavities and their subdivisions. Name the cavity lined by the peritoneum, meninges, and parietal pleura. (pp. 13, 15)
5. Name the four quadrants of the abdomen. Name at least one organ in each quadrant. (p. 17)
6. Name the section through the body that would result in each of the following: equal right and left halves, anterior and posterior parts, superior and inferior parts. (pp. 15–16)
7. Review Table 1–2, and try to find each external area on your own body. (pp. 12–13)
8. Define cell. When similar cells work together, what name are they given? (p. 4)
9. Define organ. When a group of organs works together, what name is it given? (p. 6)
10. Define metabolism, metabolic rate, and homeostasis. (pp. 7, 10)
    a. Give an example of an external change and explain how the body responds to maintain homeostasis
    b. Give an example of an internal change and explain how the body responds to maintain homeostasis
    c. Briefly explain how a negative feedback mechanism works, and how a positive feedback mechanism differs

FOR FURTHER THOUGHT

1. The human foot is similar to the human hand, but does have anatomic differences. Describe two of these differences, and explain how they are related to the physiology of the hand and the foot.
2. Complete each statement using the everyday term for the body part.
    a. The distal femoral area is immediately superior to the ____.
    b. The proximal brachial area is immediately inferior to the ____.
    c. The patellar area is directly proximal to the ____.
    d. The volar area is directly distal to the ____.
3. Name a structure or organ that is both superior and inferior to the brain. Name one that is both anterior and posterior.
4. If a person has appendicitis (inflammation of the appendix caused by bacteria), pain is felt in which abdominal quadrant? (If you're not sure, take a look at Fig. 16–1 in Chapter 16.) Surgery is usually necessary to remove an inflamed appendix before it ruptures and causes peritonitis. Using your knowledge of the location of the peritoneum, explain why peritonitis is a very serious condition.
5. Keep in mind your answer to Question 4, and explain why bacterial meningitis can be a very serious infection.
6. Use a mental picture to cut the following sections. Then describe in simple words what each section looks like, and give each a proper anatomic name.

   First: a tree trunk cut top to bottom, then cut side to side.

   Second: a grapefruit cut top to bottom (straight down from where the stem was attached), then sliced through its equator.

CHAPTER 2

Some Basic Chemistry