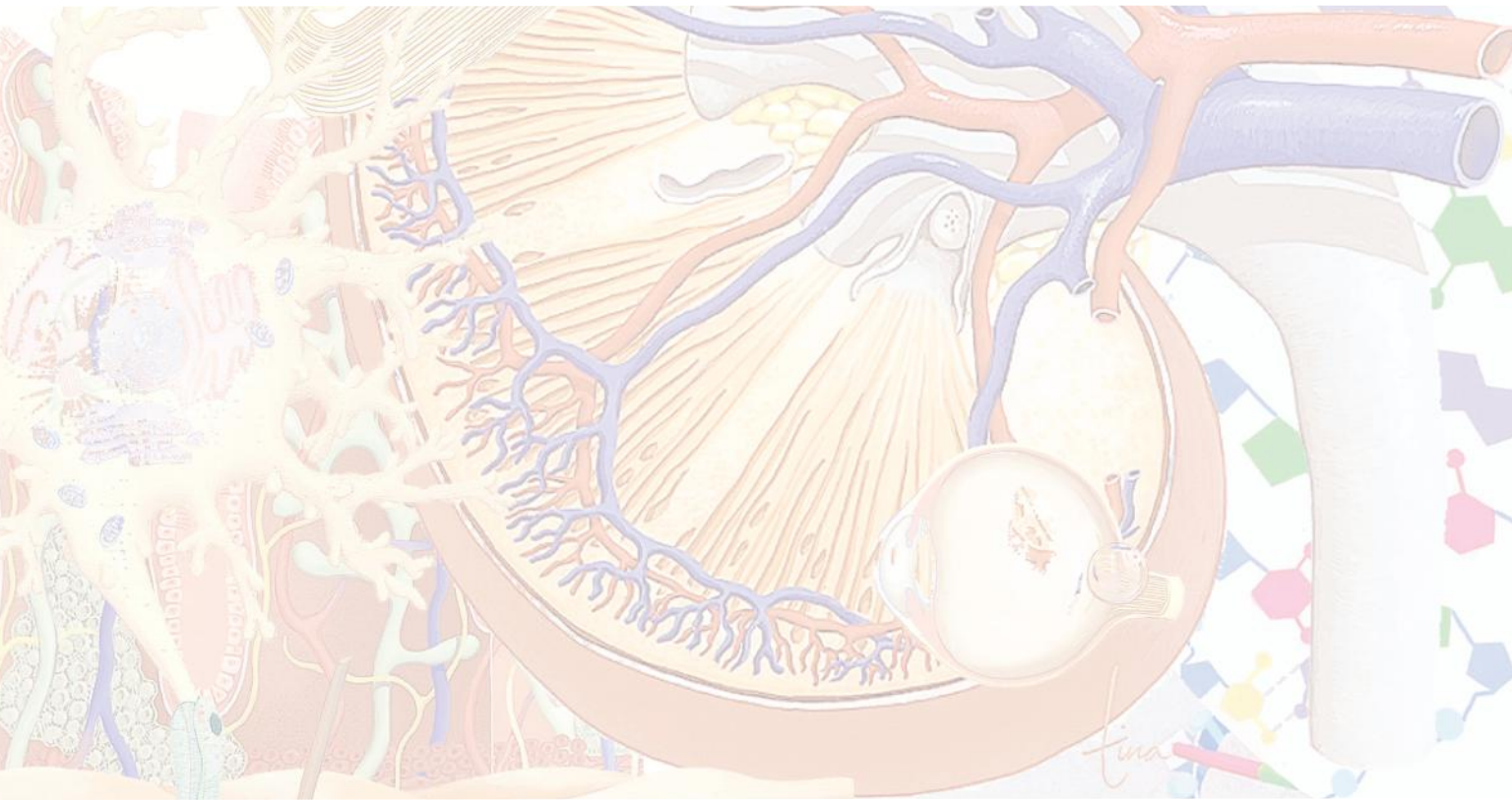
SEVENTH EDITION

ESSENTIALS OF ANATOMY AND PHYSIOLOGY

VALERIE C. SCANLON and TINA SANDERS

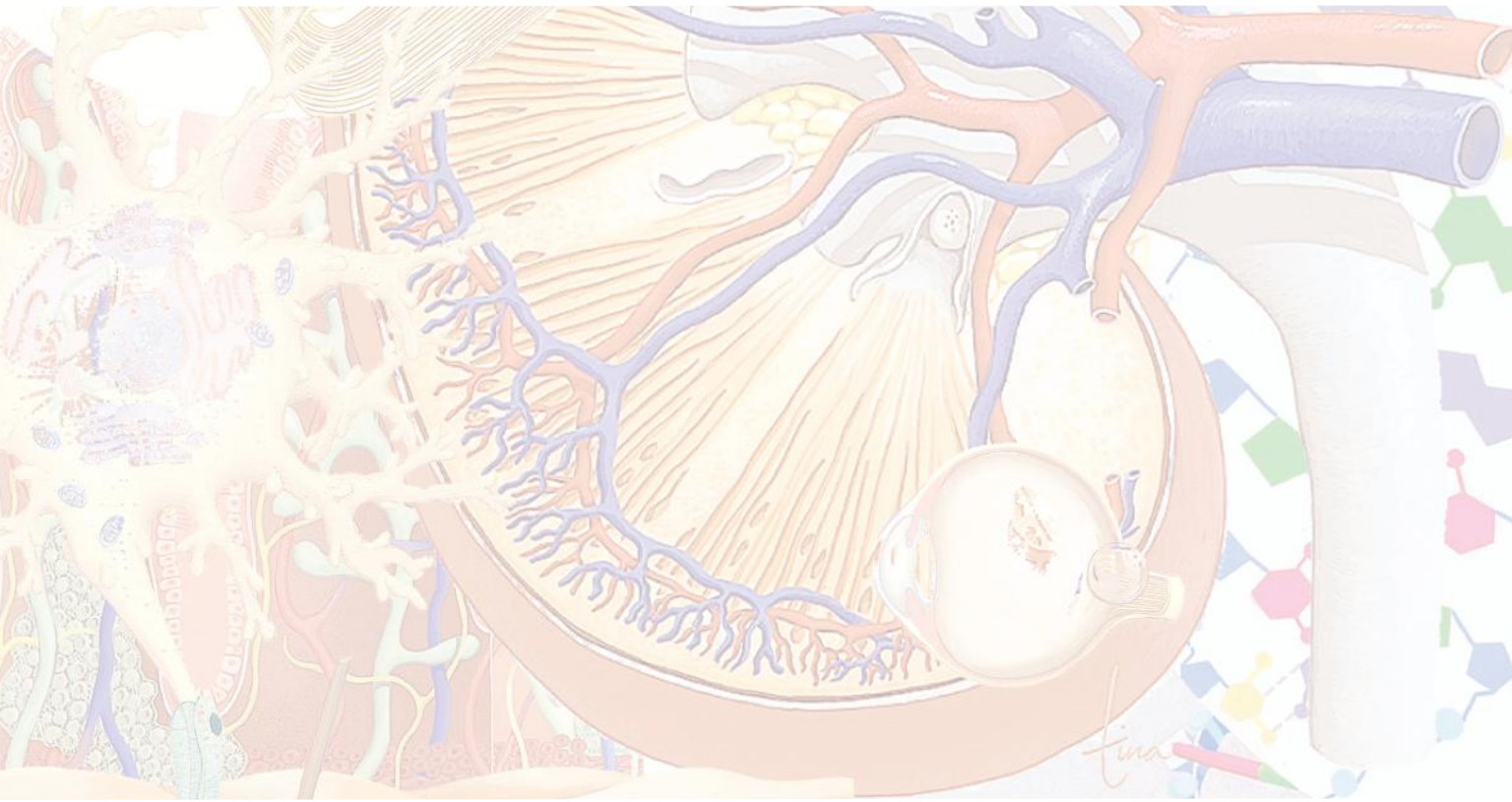
SEVENTH EDITION

ESSENTIALS OF ANATOMY AND PHYSIOLOGY



SEVENTH EDITION

ESSENTIALS OF ANATOMY AND PHYSIOLOGY



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 Courtland Community College
Dryden, New York

F.A. Davis Company • Philadelphia

F. A. Davis Company
1915 Arch Street
Philadelphia, PA 19103
www.fadavis.com

Printed in the United States of America

Last digit indicates print number: 10 9 8 7 6 5 4 3 2 1

Publisher, Nursing: Lisa B. Houck
Director of Content Development: Darlene D. Pedersen
Content Project Manager: Echo Gerhart
Electronic Project Editor: Katherine Crowley
Manager of Design and Illustration: Carolyn O'Brien

Library of Congress Cataloging-in-Publication Data

Scanlon, Valerie C., 1946- author.
Essentials of anatomy and physiology / Valerie C. Scanlon, Tina Sanders. — Seventh edition.
p. ; cm.
Includes index.
ISBN 978-0-8036-3957-7
I. Sanders, Tina, 1943- author. II. Title.
[DNLM: 1. Anatomy. 2. Physiological Phenomena. QS 4]
QP34.5
612—dc23

2014012086

To my students, past and present
VCS

To Brooks, for his encouragement
TS

PREFACE TO THE SEVENTH EDITION

Once again, we extend our gratitude to all of you who have used previous editions of *Essentials of Anatomy and Physiology* and are considering adopting our seventh edition. We are pleased to welcome new readers as well, and we thank you for choosing our book.

The seventh edition remains focused on presenting basic anatomy and physiology with the clarity of the text complemented and enhanced by superb illustrations. The text has been updated in many small ways to remain contemporary. These include brief discussions of our microbiota in Chapter 1 (and appropriate later chapters), the oligosaccharides in breast milk in Chapter 2, epigenetics and primary cilia in Chapter 3, connective tissue disorders in Chapter 4, motor units and the muscle hormone irisin in Chapter 7, celiac disease in Chapter 16, human papillomavirus in Chapter 20, and evaluation of fetal DNA in maternal blood for prenatal testing in Chapter 21. Chapter 12 has been revised and now begins with a description of cardiac muscle tissue, pulling together material from previous chapters.

All of the For Further Thought sections now end with at least one illustration question. New ones include the relationship of organ systems in Chapter 1, the hydrogen bonds formed by water molecules in Chapter 2, effects of sunlight on the skin in Chapter 5, a nerve pathway (to be named by the student) in Chapter 8, the hormones of stressful situations in Chapter 10, a time line of immune responses in Chapter 14, hormones of the duodenum in Chapter 16, regulation of body temperature in Chapter 17, and relationships of the reproductive organs to other organ systems in Chapter 20. When the students have labeled the picture and answered the questions, the whole then becomes an integral part of the chapter. We hope you will consider assigning these questions, and that students will find them enjoyable and helpful.

Colleagues, please keep in mind that the Instructor's Guide contains a full list of these additions in the "New to This Edition" section for each chapter of the textbook, as well as detailed answers to all of the For Further Thought questions.

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

The start of the 21st century has already brought many advances in the science and art of medicine and health care; many of these were made possible by research and discoveries in the basic sciences. Teachers of introductory anatomy and physiology may wish to include some of these discoveries yet will want to maintain their emphasis on the normal structure and function of the human body. Those are the goals of this textbook: to add a little of the new to the foundation of long-standing knowledge and to make all of 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 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. The illustrations complement the text material and foster comprehension on the part of the student. As you will see, these are images in which detail is readily apparent and all important parts have been labeled. 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 each 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 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 review questions and a study outline. The study outline includes all of the essentials of the chapter in a concise 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 three 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 available on the F.A. Davis website (please contact your F.A. Davis sales representative for access information): a complete Instructor's Guide, a test bank using three formats, an Interactive Teaching Tool presentation of the text illustrations, with related questions for students, podcasts of the chapter study outlines, and PowerPoint lecture outlines. 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.

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 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 health care 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—At the end of the chapter, this is a concise summary of the essentials in the chapter. You may find this outline useful as a quick review before an exam.

Review Questions—These are also at the end of the chapter. Your instructor may assign 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 refer you to the page(s) in the chapter on which the content needed to answer the question can be found.

For Further Thought—The heading tells you what these questions are for: thinking. Your instructor may use these for class discussion, and, if so, please do not ever be afraid to be mistaken. Contribute, raise your hand, 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. 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 has a question after the legend. These questions provide an ongoing quiz; try to answer each one as you come to it. 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 them easily. Your instructor may include all or some of these as required reading. These boxes are an introduction to pathophysiology.

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—Found at the end of the book, the glossary is your dictionary. All of the terms in bold type in the text, 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. 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 in this course and in your education.

Valerie C. Scanlon
Dobbs Ferry, New York

Tina Sanders
Castle Creek, New York

ACKNOWLEDGMENTS

Writing and illustrating are part of a book, yet never the whole, and we thank the editors and production staff of the F. A. Davis Company, especially:

- Lisa B. Houck, Publisher, Nursing
- Echo K. Gerhart, Content Project Manager
- Jean Rodenberger, Editor in Chief, Nursing
- Michael Bailey, Director of Production
- Bob Butler, Production Manager
- Daniel E. Domzalski, Illustration Coordinator
- Production Editors Chris Waller and Kelly Boutross, Tom Klonoski, Allison Repking, and everyone else at Graphic World who participated in this project
- Carolyn O'Brien, Illustration and Design Manager, for designing the layout and the cover
- Neil Kelly, Director of Sales, and all of the F. A. Davis sales representatives

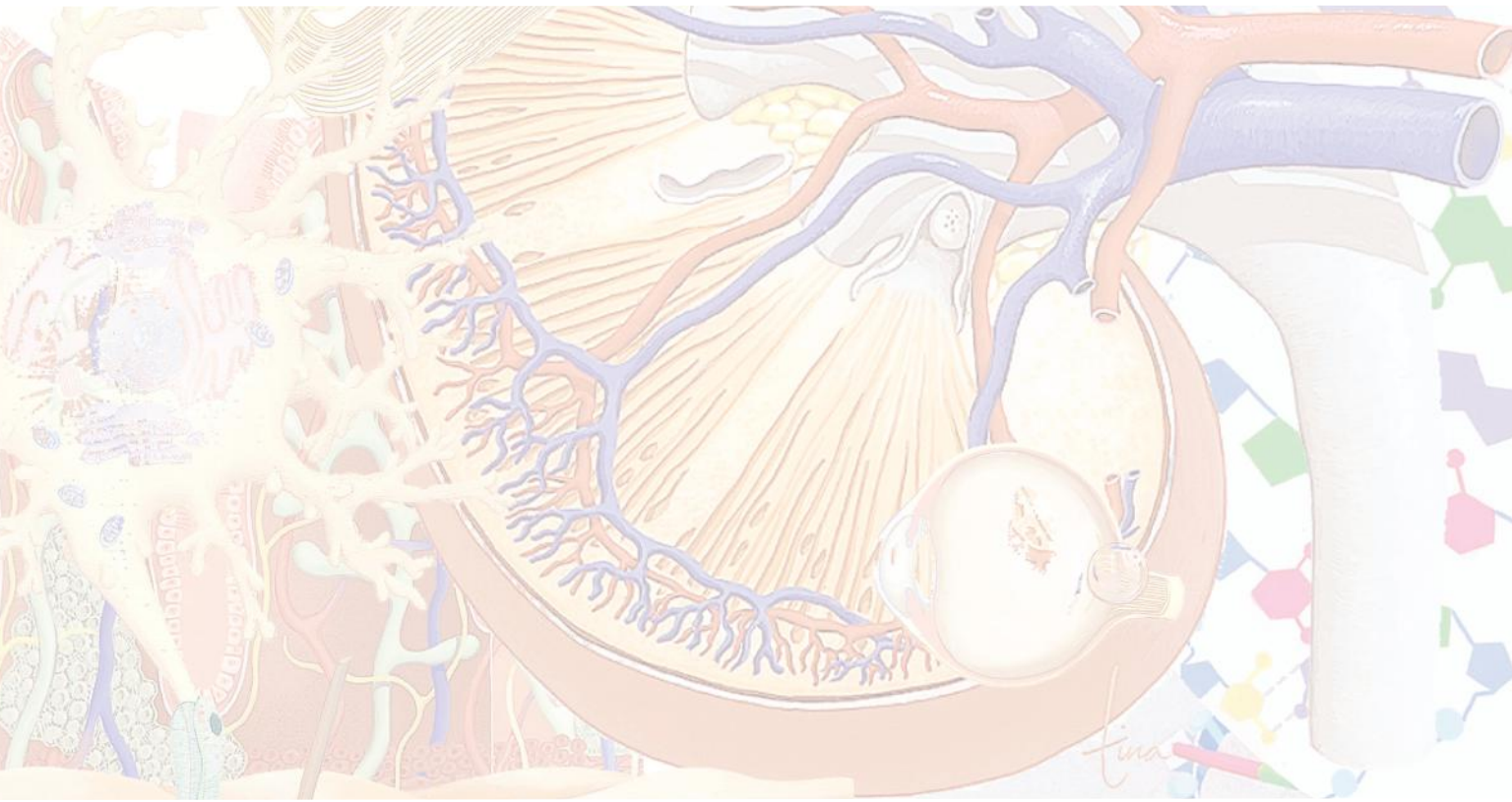
VCS

TS

CONTENTS

SEVENTH EDITION

ESSENTIALS OF ANATOMY AND PHYSIOLOGY



CHAPTER

Organization and General Plan 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 each.
- 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.

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)*
Microbiota *(MY-kroh-bye-**OH**-ta)*
Microbiome *(MY-kroh-**BYE**-ohm)*
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-**NOH**-sis)*
Disease *(di-**ZEEZ**)*
Magnetic resonance imaging (MRI) *(mag-**NET**-ik **REZ**-uh-nanse **IM**-ah-jing)*
Positron emission tomography (PET) *(**PAHZ**-i-tron e-**MISH**-un toh-**MAH**-grah-fee)*

CHAPTER OUTLINE

*Terms that appear in **bold type** in the chapter text are defined in the glossary, which begins on page 603.*

The human body is a precisely structured container of chemicals and 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 (the chemicals) 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 among anatomy, physiology, and pathophysiology.

The purpose of this text is to enable you to gain an understanding of anatomy and physiology with an 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. 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

Recall that the body is a container of 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) in hemoglobin, sodium (Na) in the salt sodium chloride that makes tears salty, and calcium (Ca) in the calcium salts that make bones hard. **Organic chemicals** are often very complex and always contain the elements carbon and hydrogen. In the 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**, and the human body consists of more than 200 different types of cells. Another way to think of the body is as a city of cells. Just as a large city has millions of people with many different jobs, the body contains trillions of cells that perform more than 200 jobs. Despite these different functions, human cells have certain structural 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. Just as in a city certain groups of individuals work together (in the fire department, for example) to keep the city functioning, groups of similar cells work together in the body. There are four groups of tissues:

Epithelial tissues—cover or line body surfaces; some are capable of producing secretions with specific functions.

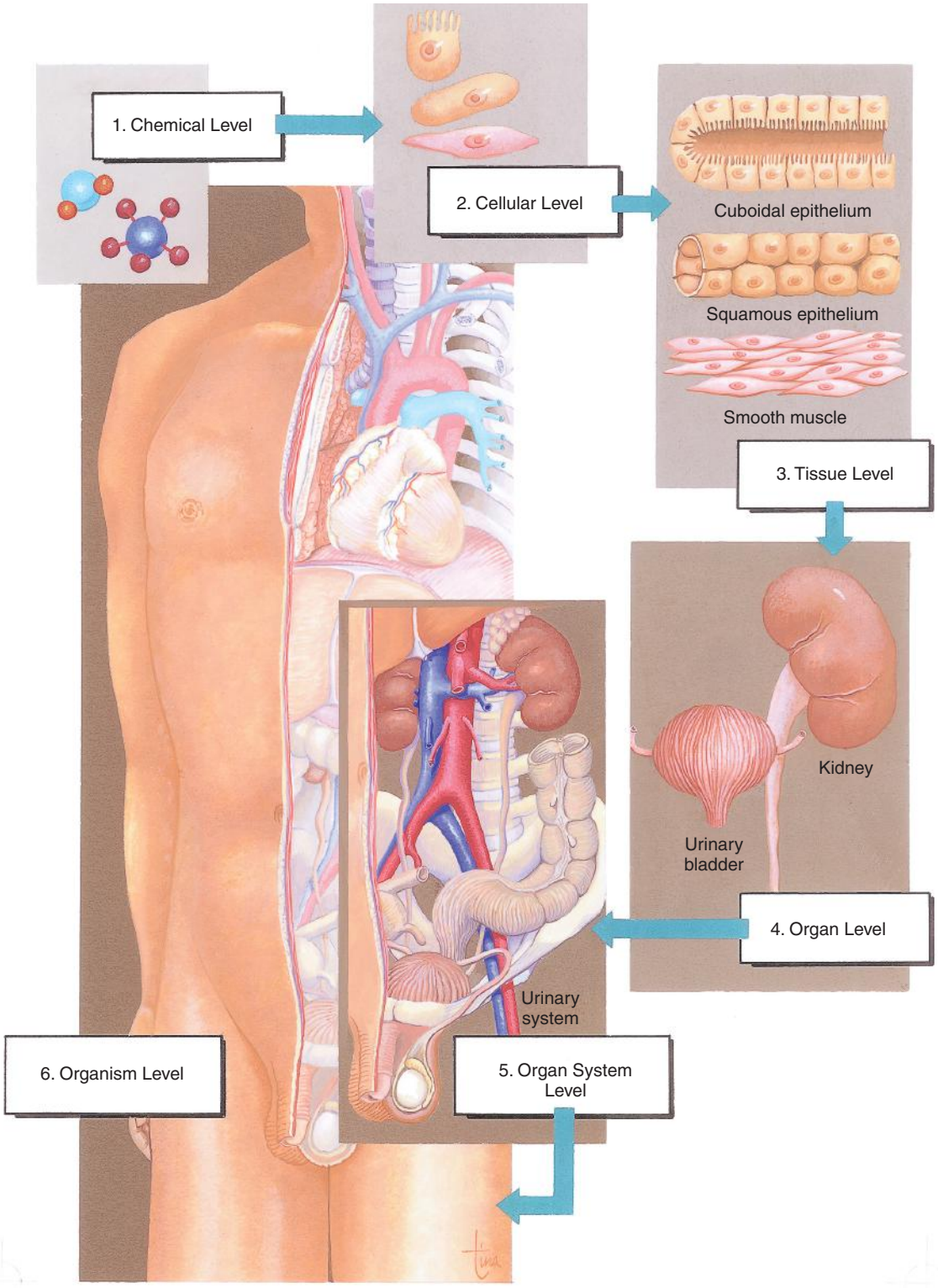


Figure 1–1 Levels of structural organization of the human body, depicted from the simplest (chemical) to the most complex (organism). The organ system shown here is the urinary system.

QUESTION: What other organ system seems to work directly with the urinary system?

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.

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—are 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 tissues—specialized to generate and transmit electrochemical impulses that regulate body functions. The brain and the 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, the lungs, and the 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, especially of proteins. 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. An organ may be considered a "cooperation of tissues," in which the whole is the anatomic sum of its parts, and much more than the physiologic sum. None of the tissues of the kidney can remove waste products from the blood by itself, but the functioning of all of the kidney tissues does so. Similarly, none of the tissues of the stomach can by itself begin the digestion of protein, but the stomach as a whole can (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, the digestive system, and the 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 all of the organ systems. Many of these are already familiar to you. Some organs are part of two organ systems; the pancreas, for example, is both a digestive organ and an endocrine organ, and the diaphragm is part of both the muscular system and the respiratory system. All of the organ systems make up an individual person, and all of them function together; that is, they are interdependent. For now, a few examples will give you an idea of the many interactions among the systems. All cells in the body require oxygen. The respiratory system obtains oxygen from the atmosphere, and the circulatory system distributes the oxygen. All cells need nutrients. The digestive system gets the nutrients, and the circulatory system distributes them. All cells produce waste products. The circulatory system collects the waste products, and the urinary system eliminates them from the blood. The balance of this text discusses each system and its interactions with other systems in more detail.

THE REST OF "US"

We are not alone. Every human being lives with an enormous population of bacteria and other microorganisms, our **microbiota**. It is estimated that the total bacteria that reside on us or inside us, with the most in the intestines, outnumber our own cells about 10 to 1. An older name for this population is **normal flora** (or resident flora, see Table 22–1 for their distribution), and different people have different proportions of the hundreds of species that make us their home. Each site on or inside the body that has bacteria is considered a small ecosystem called a **microbiome.** We have known for years that some intestinal bacteria produce vitamins that we absorb, especially vitamin K. We have also known that these bacteria, in their usual body site (surface of the skin, oral cavity, the vagina in women, among other microbiomes), help to prevent the growth of pathogens. This knowledge has been used lately to try to help those with antibiotic-resistant *Clostridium difficile* intestinal infections, and some people have been cured by "fecal transplants" (in capsule form) of intestinal bacteria from a healthy family member.

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 a blood type that is the same or compatible.

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 the corneas, the 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, liver, and skeletal muscle. Such implants may reduce or eliminate the need for human donors. Tissue engineering is also being used to create tracheas, arteries, urinary bladders, and heart valves.

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 or sections of arteries may be replaced by 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. A corneal implant is available for a person with age-related macular degeneration (see Chapter 9), in which central vision has been lost. The implant can enable the person to recognize faces and to read large-print books. Work is also progressing on devices that help damaged hearts pump blood more efficiently and on small, self-contained artificial hearts.

Although these new techniques and artificial parts have great promise, we must be realistic: They are very expensive and most will not become the standard of care or be in widespread use for many years.

Recent research suggests that by fermenting the food residues that we do not digest (often fiber, the complex carbohydrates of plants), the intestinal bacteria help nourish the epithelial cells that form the intestinal lining. Not only does this keep the lining intact and prevent leakage of intestinal contents into the tissues of the body, but it also helps suppress inflammation, which in excess can be damaging. Other researchers propose that our microbiota help the immune system to establish itself and contribute to the ability of our white blood cells to distinguish between "self" and "non-self." This is especially important for limiting the development of allergies (mistaken immune responses) and their potentially serious consequences such as asthma. Still other studies are investigating the contribution our microbiota make to weight loss or gain. This is all good but is not the whole story.

The presence of our microbiota has drawbacks as well. Not all bacterial products are beneficial to humans. Some, if absorbed, may be harmful, as is one (made from a chemical called carnitine found in red meat such as beef) that may contribute to heart disease. The total number of genes of all of these bacteria is estimated to be several million (in comparison, the genes of a human cell total about 22,000). Most of the bacterial products

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 and decides how to use it ■ Regulates body functions such as movement by means of electrochemical impulses	brain, spinal cord, 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, ovaries or testes, pancreas
Circulatory	■ Transports oxygen and nutrients to tissues and removes waste products	heart, blood, arteries, veins
Lymphatic	■ Returns tissue fluid to the blood ■ Destroys pathogens that enter the body and provides immunity	spleen, lymph nodes, thymus gland
Respiratory	■ Exchanges oxygen and carbon dioxide between the air and blood	lungs, trachea, larynx, diaphragm
Digestive	■ Changes food into 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.

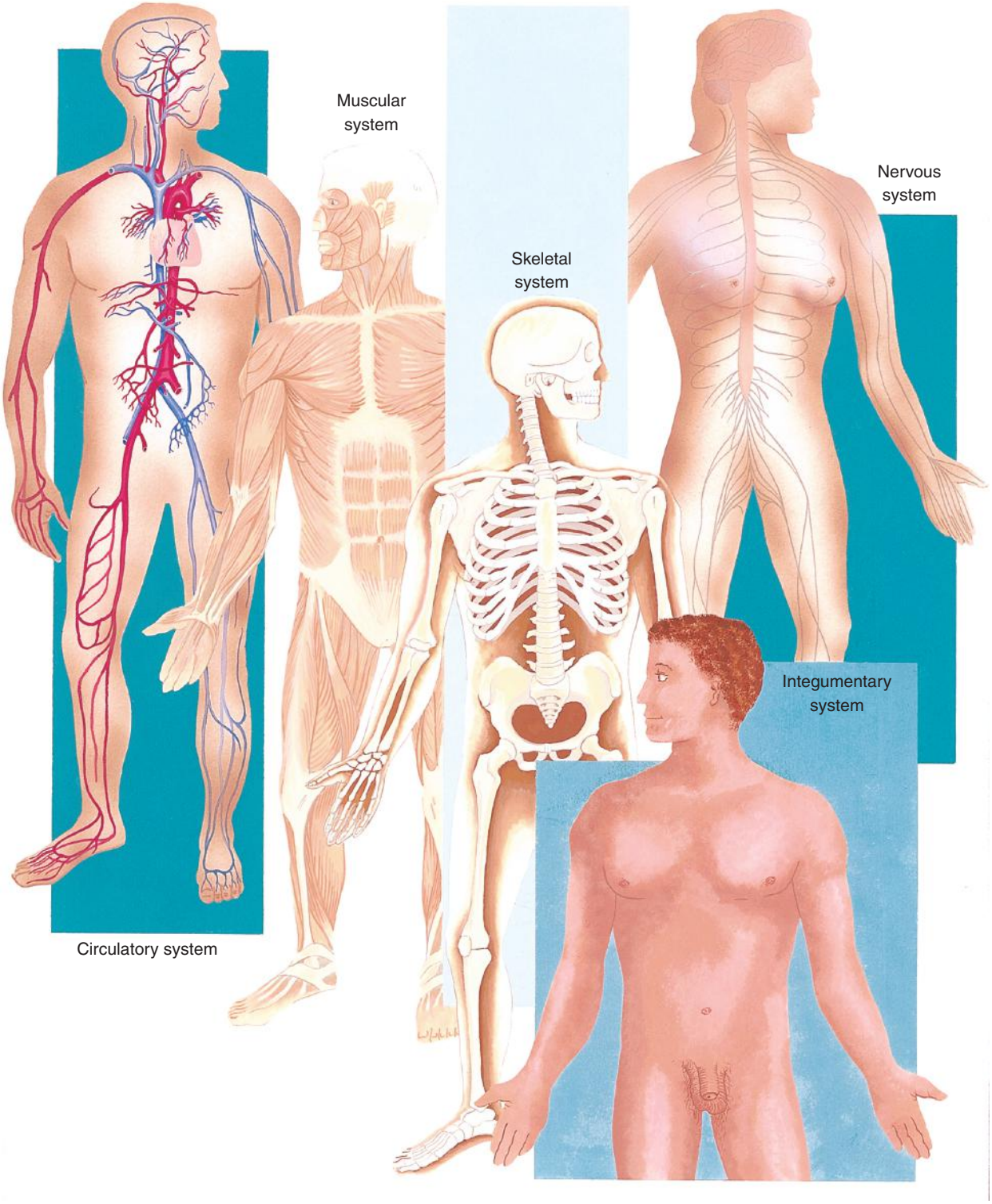


Figure 1–2 Organ systems. Compare the depiction of each system to its description in Table 1–1.

QUESTION: Name at least one organ shown in each system.

Continued