

# PRINCIPLES OF HUMAN ANATOMY

13<sup>TH</sup> EDITION

Gerard J. Tortora | Mark T. Nielsen



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Principles of

# HUMAN ANATOMY

13th Edition

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Bergen Community College

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University of Utah

**WILEY**

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# ABOUT THE AUTHORS



Courtesy of Heidi Chung

**Jerry Tortora** is Professor of Biology and former Biology Coordinator at Bergen Community College in Paramus, New Jersey, where he teaches human anatomy and physiology as well as microbiology. He received his bachelor's degree in biology from Fairleigh Dickinson University and his master's degree in science education from Montclair State College. He is a member of many professional organizations, including the Human Anatomy and Physiology Society (HAPS), the American Society of Microbiology (ASM), American Association for the Advancement of Science (AAAS), National Education Association (NEA), and the Metropolitan Association of College and University Biologists (MACUB).

Above all, Jerry is devoted to his students and their aspirations. In recognition of this commitment, Jerry was the recipient of MACUB's 1992 President's Memorial Award. In 1996, he received a National Institute for Staff and Organizational Development (NISOD) excellence award from the University of Texas and was selected to represent Bergen Community College in a campaign to increase awareness of the contributions of community colleges to higher education.

Jerry is the author of several best-selling science textbooks and laboratory manuals, a calling that often requires an additional 40 hours per week beyond his teaching responsibilities. Nevertheless, he still makes time for four or five weekly aerobic workouts that include biking and running. He also enjoys attending college basketball and professional hockey games and performances at the Metropolitan Opera House.

***To Reverend Dr. James F. Tortora, my brother, my friend, and my role model.***

*His life of dedication has inspired me in so many ways, both personally and professionally, and I honor him and pay tribute to him with this dedication. G.J.T.*



Courtesy of Gerard J. Tortora



Courtesy of Mark Nielsen

**Mark Nielsen** is a Professor in the Department of Biology at the University of Utah. For the past twenty-eight years he has taught anatomy, neuroanatomy, embryology, human dissection, comparative anatomy, and an anatomy teaching course to over 23,000 students. He developed the anatomy course for the physician assistant program at the University of Utah School of Medicine, where he taught for five years, and taught in the cadaver lab at the University of Utah School of Medicine. He developed the anatomy and physiology program for the Utah College of Massage Therapy, and his course materials are used by massage schools throughout the country. His graduate training is in comparative anatomy, and his anatomy expertise has a strong basis in dissection. He has prepared and participated in hundreds of dissections of both humans and other vertebrate animals. All his courses incorporate a cadaver-based component to the training with an outstanding exposure to cadaver anatomy. He is a member of the American Association of Anatomists (AAA), the Human Anatomy and Physiology Society (HAPS), and the Anatomical Society of Great Britain and Ireland (ASGBI).

Mark has a passion for teaching anatomy and sharing his knowledge with his students. In addition to the many students to whom he has taught anatomy, he has trained and served as a mentor for over 1,000 students who have worked in his anatomy laboratory as teaching assistants. His concern for students and his teaching excellence have been acknowledged through numerous awards. He received the prestigious Presidential Teaching Scholar Award at the University of Utah for excellence in teaching and was an initial recipient of the Beacons of Excellence Award for developing exceptional programs for student mentoring. He is a five-time recipient of the University of Utah Student Choice Award for Outstanding Teacher and Mentor, a two-time winner of the Outstanding Teacher in the Physician Assistant Program, recipient of the American Massage Therapy Association Jerome Perlinski Teacher of the Year Award, and a two-time recipient of Who's Who Among America's Teachers.

He enjoys sports, photography, good food, traveling, and exploring with his lovely wife and playing with his grandchildren.

***To my father and mother, the best mentors a son could ever have.***

*Thank you for your neverending support and love, and for teaching me the value of hard work. M.T.N.*



# PREFACE

***Principles of Human Anatomy***, thirteenth edition, is designed for introductory courses in human anatomy. The highly successful approach of previous editions—to provide students with an accurate, clearly written, and expertly illustrated presentation of the structure of the human body, to offer insights into the connections between structure and function, and to explore the practical and relevant applications of anatomical knowledge to everyday life and career development—has been enhanced in this edition by innovations designed to increase student motivation and success.

An anatomy course can be the gateway to a satisfying career in a host of health-related professions. It can also be incredibly challenging. We have designed the organization and flow of content within these pages based on our deep experience teaching anatomy and interacting with students over many years. We are cognizant of the fact that the teaching and learning environment has changed significantly to rely more heavily on the ability to access the rich content in this printed text in a variety of digital ways, anytime and anywhere. We are pleased that this 13<sup>th</sup> edition meets these changing standards and offers dynamic and engaging choices to make your experience in this course more rewarding and fruitful.

## *New for This Edition*

The thirteenth edition of ***Principles of Human Anatomy*** has been updated throughout, paying careful attention to include the most current terminology in use and including an enhanced glossary. The design has been refreshed to ensure that the content is clearly presented and easy to access. Clinical Connections that help students understand the relevance of anatomical structures and the functions they support by considering what happens when they don't work the way they should have been updated throughout and in some cases are now placed alongside related illustrations to strengthen these connections for students. The all-important illustrations that support this most visual of sciences have been scrutinized and revised as needed throughout. Nearly every chapter of the text has either a new or revised illustration or photograph.

We are most excited about the enhanced digital experience now available with the thirteenth edition of this text. **WileyPLUS** now includes a powerful new adaptive learning component called **ORION**. **WileyPLUS** with **ORION** allows students to take charge of their study time in ways they have not previously experienced and prepares them for more meaningful classroom and laboratory interactions. **Real Anatomy**, so popular with professors and students alike for its outstanding photography and deep possibilities for exploration of a human cadaver, has been updated and is now fully web-based and integrated into **WileyPLUS**. **WileyPLUS** itself has been refreshed with a new design that allows easier discoverability and access to the rich resources included, in addition to updated assessment questions throughout. New for the thirteenth edition is a digital alternative called **All Access Pack** for ***Principles of Human Anatomy***, 13e. This choice offers you a full etext to download and to keep, full access to **WileyPLUS** with **ORION**, and a Study Resource Guide to use as a basis for taking notes in class and studying later. It provides you with everything you need for your course, anytime, anywhere, on any device.



# TAKE A TOUR

The challenges of learning anatomy can be complex and time consuming. This textbook and **WileyPLUS** with **ORION** have been specifically designed to maximize your time studying by simplifying the choices you make in deciding what to study, how to study it, and in assessing your understanding of the content along the way.

## Chapter Beginnings and Ends

Each chapter is effectively bookended with stunning chapter introductions designed to grab students' interest and engage them in the topic at hand, and chapter summaries that not only highlight the important concepts of the chapter but point students to the media resources that will support greater understanding of those concepts.

## 23 THE RESPIRATORY SYSTEM

**INTRODUCTION** Have you ever swallowed something and had it go down the wrong tube, making you cough or choke uncontrollably? This uncomfortable (and sometimes embarrassing) situation occurs because the respiratory and digestive systems both arise from the embryonic gut tube and share the nose, mouth, and throat as a common initial pathway. While the majority of the gut tube gives rise to the digestive system (Chapter 24), the tube that will become the respiratory system forms a highly branched network of respiratory airways that terminate in the lungs. The respiratory tubes have the basic design fea-

### CHAPTER REVIEW AND RESOURCE SUMMARY

#### Review

#### 23.1 Respiratory System Anatomy

1. The respiratory system consists of the nose, pharynx, larynx, trachea, bronchi, and lungs. The respiratory system acts with the cardiovascular system to supply oxygen (O<sub>2</sub>) to and remove carbon dioxide (CO<sub>2</sub>) from the blood.
2. The external nose is made of cartilage and skin and is lined with a mucous membrane. Openings to the exterior are the external nares. The internal nose communicates with the paranasal sinuses and nasopharynx through the internal nares. The nasal cavity is divided by a nasal septum. The anterior portion of the cavity is called the nasal vestibule. The nose warms, moistens, and filters air and functions in olfaction and speech.
3. The pharynx (throat) is a muscular tube lined by a mucous membrane. The anatomical regions of the pharynx are the nasopharynx, oropharynx, and laryngopharynx. The nasopharynx functions in respiration. The oropharynx and laryngopharynx function both in respiration and digestion.
4. The larynx (voice box) is a passageway that connects the pharynx with the trachea. It contains the thyroid cartilage (Adam's apple), the epiglottis, which prevents food from entering the larynx; the cricoid cartilage, which connects the larynx and trachea; and the paired arytenoid, corniculate, and cuneiform cartilages. The vocal folds of the larynx produce sound as they vibrate; taut folds produce high pitches, and relaxed ones produce low pitches.
5. The trachea (windpipe) extends from the larynx to the main bronchi. It is composed of C-shaped rings of cartilage and smooth muscle and is lined with pseudostratified ciliated columnar epithelium.
6. The bronchial tree consists of the trachea, main bronchi, lobar bronchi, segmental bronchi, bronchioles, and terminal bronchioles. Walls of bronchi contain rings of cartilage; walls of bronchioles contain increasingly smaller plates of cartilage and increasing amounts of smooth muscle.
7. Lungs are paired organs in the thoracic cavity enclosed by the pleural membrane. The parietal pleura is the superficial layer that lines the thoracic cavity; the visceral pleura is the deep layer that covers the lungs. The right lung has three lobes separated by two fissures; the left lung has two lobes separated by one fissure, along with a depression, the cardiac notch.

sounds, and rids the body of small amounts of water and heat in exhaled air.

The branch of medicine that deals with the diagnosis and treatment of disease of the ears, nose, and throat (ENT) is called **otorhinolaryngology** (o'-tō-rī-nō-lar-in-GOL-ō-jē; *oto*=ear; *rhino*=nose; *laryngo*=voice box, *-logy*=study of). A **pulmonologist** (pul-mō-NOL-ō-gist; *pulmo*=lung) is a specialist in the diagnosis and treatment of diseases of the lungs. •

### WileyPLUS

#### Resource

Anatomy Overview - Overview of Respiratory Organs  
Anatomy Overview - Nasal Cavity and Pharynx  
Anatomy Overview - Respiratory Tissues  
Anatomy Overview - Respiratory Epithelium  
Figure 23.3 - Larynx  
Figure 23.7 - Relationship of the Pleural Membrane to the Lung  
Figure 23.11 - Structure of an Alveolus  
Exercise - Build an Airway  
Exercise - Concentrate on Respiratory Structures  
Concepts and Connections - Functional Anatomy of the Respiratory System

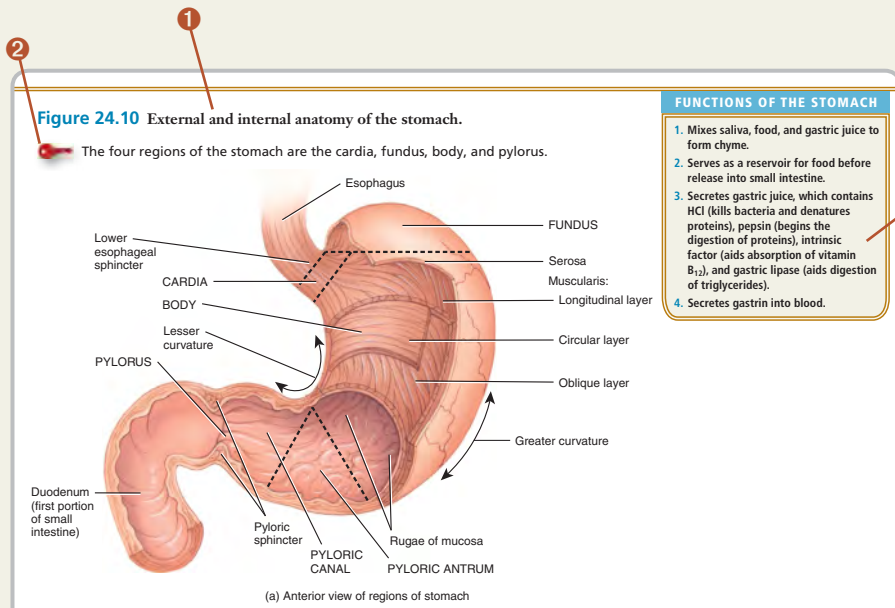


Did you ever wonder how smoking affects the respiratory system?

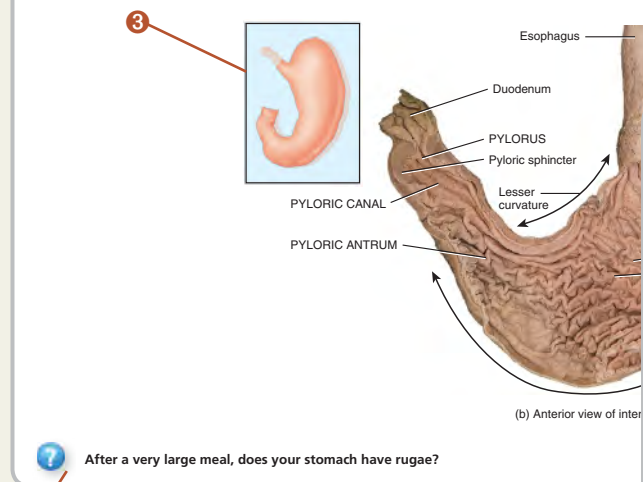
# Anatomy Is a Visual Science

Studying the figures in this book is as important as reading the narrative. The tools described here will help you understand the concepts being presented in any figure and assure you get the most out of the visuals.

- 1 **LEGEND** Read this first. It explains what the figure is about.
- 2 **KEY CONCEPT STATEMENT** Indicated by a “key” icon, this reveals a basic idea portrayed in the figure.
- 3 **ORIENTATION DIAGRAM** Added to many figures, this small diagram helps you understand the perspective from which you are viewing a particular piece of anatomical art.
- 4 **FIGURE QUESTIONS** Found at the bottom of each figure and accompanied by a “question mark” icon, these serve as a self-check to help you understand the material as you go along.
- 5 **FUNCTIONS BOXES** Included with selected figures, these provide brief summaries of the functions of the anatomical structure or system depicted.

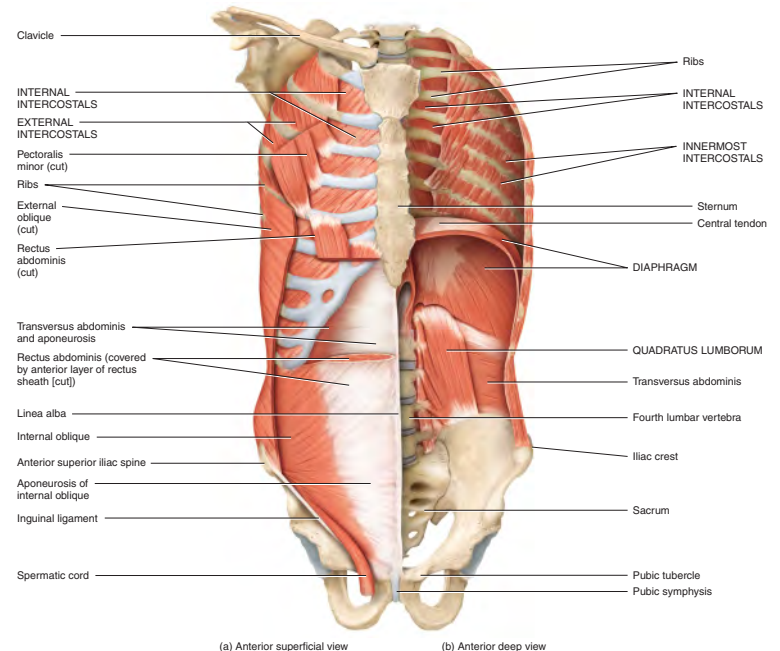


6 **MP3 DOWNLOADS** In each chapter you will find that several illustrations are marked with an icon. This indicates that an audio file, which narrates and discusses the important elements of that particular illustration, is available. You can access the downloads on the student companion website or within *WileyPLUS*.



**Figure 11.14** Muscles of the thorax that assist in breathing.

Openings in the diaphragm permit the passage of the aorta, esophagus, and inferior vena cava.



# Clinical Connections

It is easier to understand the relevance of anatomical structures and the functions they support by considering what happens when they don't work the way they should. The Clinical Connections, which appear throughout the text, present a variety of clinical perspectives related to the text discussion.



## CLINICAL CONNECTION | Rheumatism and Arthritis

**Rheumatism** (ROO-ma-tizm) is any painful disorder of the supporting structures of the body—bones, ligaments, tendons, or muscles—that is not caused by infection or injury. **Arthritis** is a form of rheumatism in which the joints are swollen, stiff, and painful. It afflicts about 45 million people in the United States, and is the leading cause of physical disability among adults over age 65. **Osteoarthritis (OA)** (os'-tē-ō-ar-THRĪ-tis) is a degenerative joint disease in which joint cartilage is gradually lost. It results from a combination of aging, obesity, irritation of the joints, muscle weakness, and wear and abrasion. Commonly known as "wear-and-tear" arthritis, osteoarthritis



(A) Gamma ray photograph of swollen joints (bright spots) due to RA



(B) Photograph of an individual with severe RA

is the most common type of arthritis and the most common reason for hip- and knee-replacement surgery. In **gout**, a form of arthritis, sodium urate crystals are deposited in the soft tissues of the joints. Gouty arthritis most often affects the joints of the feet, especially at the base of the big toe. The crystals irritate and erode the cartilage, causing inflammation, swelling, and acute pain.

**Rheumatoid arthritis (RA)** is an autoimmune disease in which the immune system of the body attacks its own tissues—in this case, its own cartilage and joint linings. RA is characterized by inflammation of the joint, which causes swelling, pain, and loss of function (Figures A and B). As noted above, this form of arthritis usually occurs bilaterally: If one wrist is affected, the other is also likely to be affected, although they are often not affected to the same degree.

The primary symptom of RA is inflammation of the synovial membrane. If untreated, the membrane thickens, and synovial fluid accumulates. The resulting pressure causes pain and tenderness. The membrane then produces an abnormal granulation tissue, called *pannus*, that adheres to the surface of the articular cartilage and sometimes erodes the cartilage completely. When the cartilage is destroyed, fibrous tissue joins the exposed bone ends. The fibrous tissue ossifies and fuses the joint so that it becomes immovable—the ultimate crippling effect of rheumatoid arthritis. The growth of the granulation tissue causes the distortion of the fingers that characterizes hands of RA sufferers. •

WileyPLUS offers you opportunities to take Clinical Connections even further with animated and interactive case studies that relate specifically to one body system

or another. Look for these under additional chapter resources as an interesting and engaging break from traditional study routines.

Contents Help Notes Browse Concepts Shows WWW Prev Next Home

Disruptions to Homeostasis. The Case of the Man with Opportunistic Infections.

### THE CASE OF THE MAN WITH OPPORTUNISTIC INFECTIONS

Stan, 32

**Presenting symptoms:**

- Fever
- Shortness of breath
- Persistent cough
- Chronic headaches
- Abdominal pain
- Diarrhea
- Weight loss
- Skin lesions on forehead and left arm

He admits to using drugs

Tests and indications Chemistry Cell Tissues Organs and systems Exercise Links

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# Exhibits Organize Complex Anatomy into Manageable Modules

Many topics in this text have been organized to bring together all the anatomical information into a simple-to-navigate content module. You will find Exhibits for bones, joints, skeletal muscles, nerves, blood vessels, and surface anatomy.

- 1 Objective to focus your study
- 2 Overview narrative of structure(s)
- 3 Table summarizing key features of structure(s)
- 4 Illustrations and photographs
- 5 Checkpoint question assesses your understanding
- 6 Clinical Connection provides relevance for learning the details

326 CHAPTER 11 • THE MUSCULAR SYSTEM

### EXHIBIT 11.C Muscles That Move the Mandible and Assist in Mastication and Speech (Figure 11.6)

**OBJECTIVE**

Describe the origin, insertion, action, and innervation of the muscles that move the mandible and assist in mastication and speech.

The muscles that move the mandible (lower jaw bone) at the *temporomandibular joint (TMJ)* are known as the *muscles of mastication* (chewing) (Figure 11.6). Of the four pairs of muscles involved in mastication, three are powerful closers of the jaw and account for the strength of the bite: **masseter**, **temporalis**, and **medial pterygoid**. Of these, the masseter is the strongest muscle of mastication. The medial and lateral pterygoid muscles assist in mastication by moving the mandible from side to side to help grind food. Additionally, the lateral pterygoids protract the mandible (thrust it forward). The masseter muscle has been removed in Figure 11.6 to illustrate the deeper pterygoid muscles; the masseter can be seen in Figure 11.4a-c. Note the enormous bulk of the temporalis and masseter muscles in Figure 11.4c, d compared to the smaller mass of the two pterygoid muscles.

**Figure 11.6** Muscles that move the mandible and assist in mastication and speech.

The muscles that move the mandible are also known as muscles of mastication.

(a) Right lateral superficial view

**CLINICAL CONNECTION Gravity and the Mandible**

As just noted, three of the four muscles of mastication close the mandible and only the lateral pterygoid opens the mouth. The force of **gravity on the mandible** offsets this imbalance. When the masseter, temporalis, and medial pterygoid muscles relax, the mandible drops. Now you know why the mouths of many persons, particularly the elderly, are open while they are asleep in a chair. In contrast, astronauts in zero gravity must work hard to open their mouths.

**Relating Muscles to Movements**

Arrange the muscles in this exhibit according to their actions on the mandible: (1) elevation, (2) depression, (3) retraction, (4) protraction, and (5) side-to-side movement. The same muscle may be mentioned more than once.

**CHECKPOINT**

9. What would happen if you lost tone in the masseter and temporalis muscles?

EXHIBIT 11.C 327

MUSCLE	ORIGIN	INSERTION	ACTION	INNERVATION
<b>Masseter</b> (MA-se-ter=chewer) (see Figure 11.4b, c)	Maxilla and zygomatic arch	Angle and ramus of mandible	Elevates mandible, as in closing mouth	Mandibular division of trigeminal (V) nerve
<b>Temporalis</b> (tem'pō-RĀ-lis; tempōr=time or temples)	Temporal bone	Coronoid process and ramus of mandible	Elevates and retracts mandible	Mandibular division of trigeminal (V) nerve
<b>Medial pterygoid</b> (TER-i-goyd; medial=close to midline; pterygoid=wing-like)	Medial surface of lateral portion of pterygoid process of sphenoid bone; maxilla	Angle and ramus of mandible	Elevates and protracts (protrudes) mandible and moves mandible from side to side	Mandibular division of trigeminal (V) nerve
<b>Lateral pterygoid</b> (TER-i-goyd; lateral=further from midline)	Greater wing and lateral surface of lateral portion of pterygoid process of sphenoid bone	Condyle of mandible; temporomandibular joint (TMJ)	Protracts mandible, depresses mandible as in opening mouth, and moves mandible from side to side	Mandibular division of trigeminal (V) nerve

(b) Right lateral deep view

7 Which is the strongest muscle of mastication?

## Chapter Resources Help You Focus and Review

Your book has a variety of special features that will make your time studying anatomy a more rewarding experience. These have been developed based on feedback from students—like you—who have used previous editions of the text. Their effectiveness is even further enhanced within *WileyPLUS*.

**Objectives** at the start of each section help you focus on what is important as you read. All of the content within *WileyPLUS* with ORION is tagged to these specific learning objectives so that you can organize your study or review what is still not clear in simple, more meaningful ways.

**Checkpoint** questions at the end of each section help you assess if you have absorbed what you have read.

**Mnemonics** are a memory aid that can be particularly helpful when learning specific anatomical features. Mnemonics are included throughout the text, some displayed in figures, tables, or Exhibits, and some included within the text discussion. We encourage you not only to use the mnemonics provided but also to create your own to help you learn the multitude of terms involved in your study of human anatomy.

**Key Medical Terms** at the end of chapters include selected terms dealing with both normal and pathological conditions.

**Critical Thinking Questions** are word problems that allow you to apply the concepts you have studied in the chapter to specific situations.

## Mastering the Language of Anatomy

The terminology in this edition is based on *Terminologia Anatomica*. Throughout the text we have included **Pronunciations** and, sometimes, **Word Roots** for many terms that may be new to you. These appear in parentheses immediately following the new words, and the pronunciations are repeated in the glossary at the back of the book. Look at the words carefully and say them out loud several times. Learning to pronounce a new word will help you remember it and make it a useful part of your medical vocabulary. Take a few minutes to read the pronunciation key, found at the beginning of the

Glossary at the end of this text (page G-1), so it will be familiar as you encounter new words.

To provide more assistance in learning the language of anatomy, a full **Glossary** of terms with phonetic pronunciations appears at the end of the book. The basic building blocks of medical terminology—**Combining Forms, Word Roots, Prefixes, and Suffixes**—are listed inside the back cover, as is a listing of **Eponyms**, traditional terms that include reference to a person's name, along with the current terminology.

# WileyPLUS *with* ORION

*WileyPLUS with ORION helps students learn by learning about them.*

ORION is a new addition to *WileyPLUS* that provides students with a personal, adaptive learning experience to help them build their proficiency on topics and use study time most efficiently.

*WileyPLUS with ORION* is great as:

- an adaptive **pre-lecture tool** that assesses your students' conceptual knowledge so they come to class better prepared,
- a **personalized study guide** that helps students understand both strengths and areas where they need to invest more time, especially in preparation for quizzes and exams.



**BEGIN**

Unique to ORION, students **begin** by taking a quick **diagnostic** for any chapter. This will determine each student's baseline proficiency on each topic in the chapter. Students see their individual diagnostic report to help them decide what to do next with the help of ORION's recommendations.



**PRACTICE**

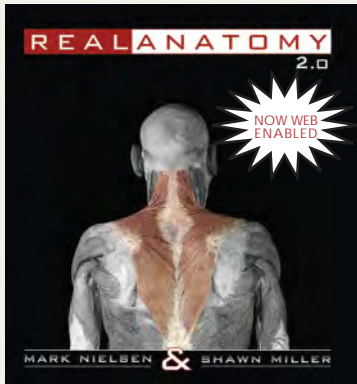
For each topic, students can either Study or Practice. **Study** directs the student to the specific topic they choose in *WileyPLUS*, where they can read from the e-textbook or use the variety of relevant resources available there. Students can also **practice**, using questions and feedback powered by ORION's adaptive learning engine. Based on the results of their diagnostic and ongoing practice, ORION will present students with questions appropriate for their current level of understanding and will continuously adapt to each student, helping them build their proficiency.



**MAINTAIN**

ORION includes a number of reports and ongoing recommendations for students to help them **maintain** their proficiency over time for each topic. Students can easily access ORION from multiple places within *WileyPLUS*. It does not require any additional registration, and there will not be any additional charge for students using this adaptive learning system.

# ADDITIONAL RESOURCES



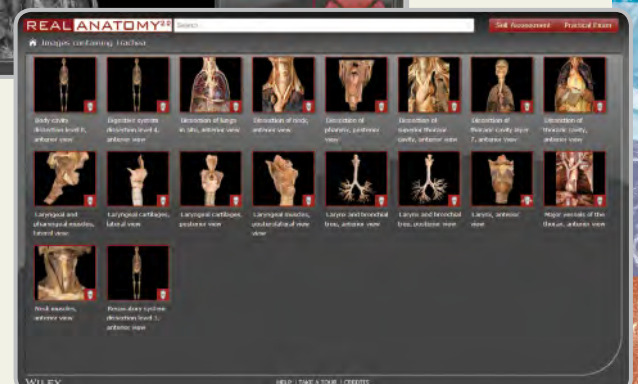
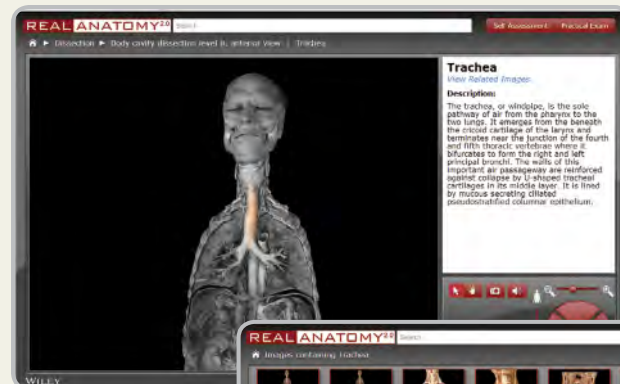
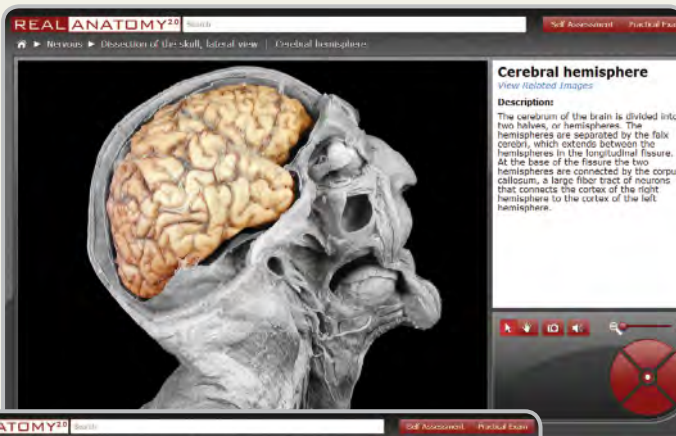
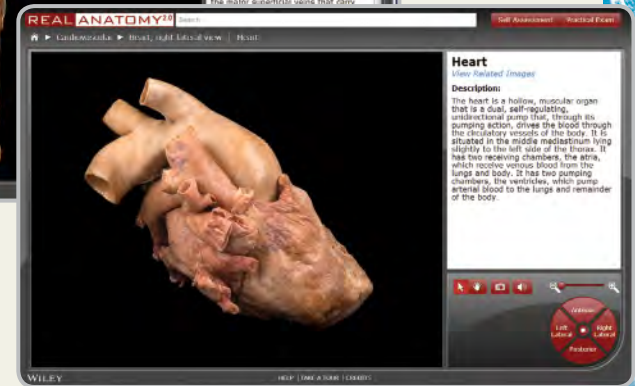
## Real Anatomy 2.0

Mark Nielsen and Shawn Miller, University of Utah

Real Anatomy is 3-D imaging software that allows you to dissect through multiple layers of a three-dimensional real human body to study and learn the anatomical structures of all body systems.

### NEW to Real Anatomy 2.0

- Now available on the Web, accessible by iPad and Android tablets.
- All possible highlight structures on an image are now accessible via a drop-down list as well as being searchable.



- Rotate the body as well as major organs to view the image from multiple perspectives.
- Use a built-in zoom feature to get a closer look at detail.
- A unique approach to highlighting and labeling structures does not obscure the real anatomy on view.

- New crumb trail navigation shows context of system, image, structure.
- Fully integrated into WileyPLUS with ORION.
- Dissect through up to 40 layers of the body and discover the relationships of the structures to the whole.



- Related Images provide multiple views of structures being studied.

- Snapshots can be saved of any image for use in PowerPoints, quizzes, or handouts.

- View histology micrographs at varied levels of magnification with the virtual microscope.

- Audio pronunciation of all labeled structures is readily available.



- Snapshots can be saved of any image for use in PowerPoints, quizzes, or handouts

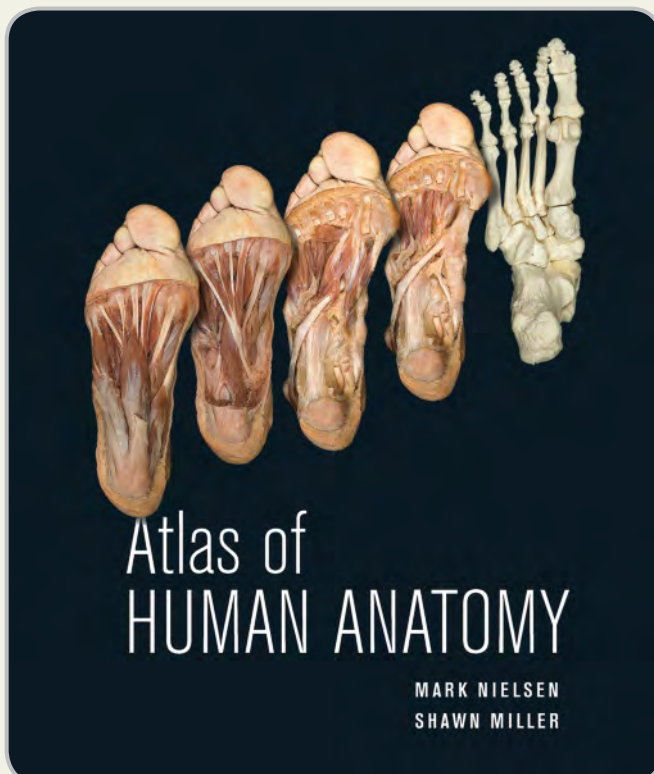


- Audio pronunciation of all labeled structures is readily available

# REAL ANATOMY

## *Photographic Atlas of Human Anatomy*, First Edition

Mark Nielsen and Shawn Miller, University of Utah



This beautiful atlas filled with outstanding photographs of meticulously executed dissections of the human body is a strong teaching and learning solution, not just a catalog of photographs. Organized around body systems, each chapter includes a narrative overview of the body system followed by detailed photographs that accurately and realistically represent the anatomical structures. Histology is included. *Photographic Atlas of Human Anatomy* will work well in your laboratories, as a study companion to your textbook, and as a print companion to the *Real Anatomy 2.0*.



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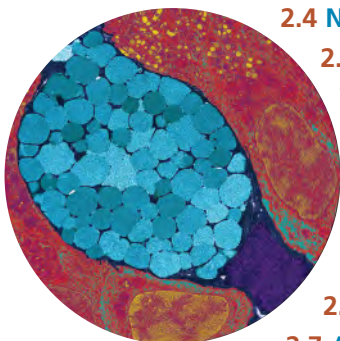
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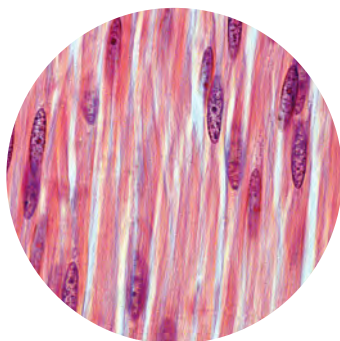
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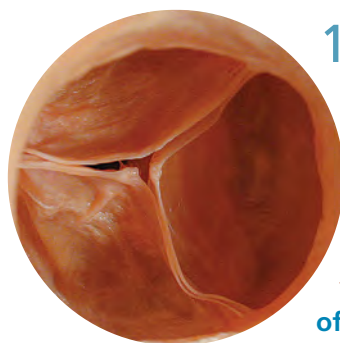
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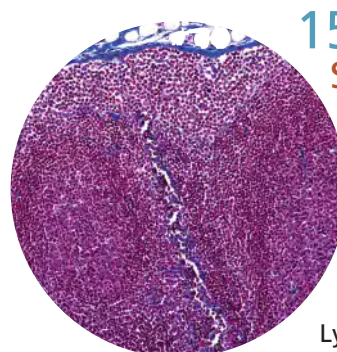
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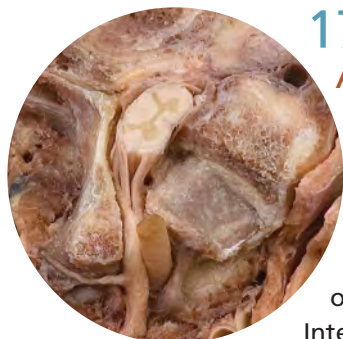
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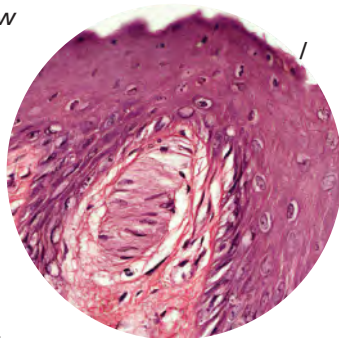
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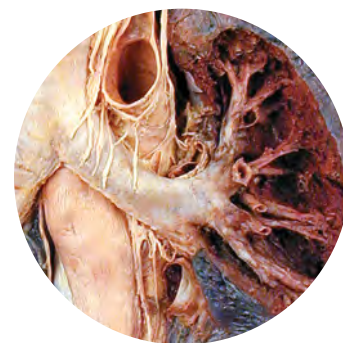
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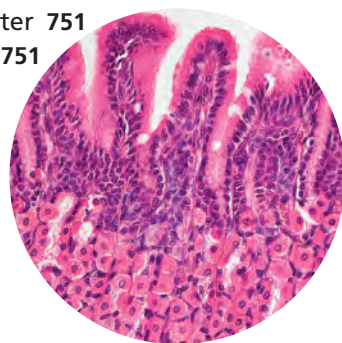
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# 1

# AN INTRODUCTION TO THE HUMAN BODY



**INTRODUCTION** You are about to begin a study of the human body to learn how it is organized and how it functions. In order to understand what happens when the body is injured, diseased, or placed under stress, you must know how it is put together and how its different parts work. Just as an auto mechanic must be familiar with the details of the structure and function of a car, health-care professionals and others who work in human performance and care professions must have intimate knowledge of the structures and functions of the human body. This knowledge can be one of your most effective tools. Much of what you study in this chapter will help you understand how anatomists visualize the body, and the basic anatomical vocabulary presented here will help you describe the body in a language common to both scientists and professionals. •



*Did you ever wonder  
why an autopsy  
is performed?*

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## 1.1 ANATOMY DEFINED

### OBJECTIVE

- Define anatomy and physiology, and name several branches of anatomy.

**Anatomy** (a-NAT-ō-mē; *ana-*=up; *-tomy*=process of cutting) is primarily the study of *structure* and the relationships among structures. It was first studied by **dissection** (dis-SEK-shun; *dis-*=apart; *-section*=act of cutting), the careful cutting apart of body structures to study their relationships. Today, a variety of imaging techniques also contribute to the advancement of anatomical knowledge. We will describe and compare some common imaging techniques in **Table 1.3**, which appears later in this chapter (see Section 1.8). The anatomy of the human body can be studied at various levels of structural organization, ranging from microscopic (visible only with the aid of a microscope) to macroscopic (visible without the use of a microscope). These levels and the different methods used to study them provide the basis for the branches of anatomy, several of which are described in **Table 1.1**.

Anatomy deals mostly with structures of the body. A related discipline, **physiology** (fiz'-e-OL-o-je; *physio-*=nature; *-logy*=study of), deals with *functions* of body parts—that is, how they work. Because function cannot be separated completely from

structure, you will learn how the structure of the body often reflects its functions. Some of the structure–function relationships are visibly obvious, such as the tight connections between the bones of the skull, which protect the brain. In contrast, the bones of the fingers are more loosely joined to permit movements such as playing an instrument, grasping a baseball bat, or retrieving a small object from the floor. The shape of the external ear assists in the collection and localization of sound waves, which facilitates hearing. Other relationships are not as visibly obvious; for example, the passageways that carry air into the lungs branch extensively when they reach the lungs. Tiny air sacs—about 300 million—cluster at the ends of the large number of airway branches. Similarly, the vessels carrying blood into the lungs branch extensively to form tiny tubes that surround the small air sacs. Because of these anatomical features, the total surface area within the lungs is about the size of a handball court. This large surface area is the key to the primary function of the lungs: the efficient exchange of oxygen and carbon dioxide between the air and the blood.

### CHECKPOINT

1. Which branches of anatomy would be used when dissecting a cadaver?
2. Give several examples of connections between structure and function in the human body.

TABLE 1.1

### Selected Branches of Anatomy

BRANCH	STUDY OF
<b>Embryology</b> (em'-brē-OL-ō-jē; <i>embry-</i> =embryo; <i>-logy</i> =study of)	In humans, the first eight weeks of development after fertilization of the egg
<b>Developmental biology</b>	The complete developmental history of an individual from fertilization to death
<b>Cell biology</b>	Cellular structure and function
<b>Histology</b> (his'-TOL-ō-jē; <i>hist-</i> =tissue)	Microscopic structure of tissues
<b>Sectional anatomy</b>	Internal structure and relationships of the body through the use of sections
<b>Gross anatomy</b>	Structures that can be examined without using a microscope
<b>Systemic anatomy</b>	Structure of specific systems of the body such as the nervous or respiratory systems
<b>Regional anatomy</b>	Specific regions of the body such as the head or chest
<b>Surface anatomy</b>	Surface markings of the body to understand the relationships of deep or internal anatomy through visualization and palpation (gentle touch)
<b>Imaging anatomy</b>	Body structures that can be visualized with x-rays, CT scans, MRI, and so on
<b>Pathological anatomy</b> (path'-ō-LOJ-i-kal; <i>path-</i> =disease)	Structural changes (from gross to microscopic) associated with disease

### CLINICAL CONNECTION | Noninvasive Diagnostic Techniques

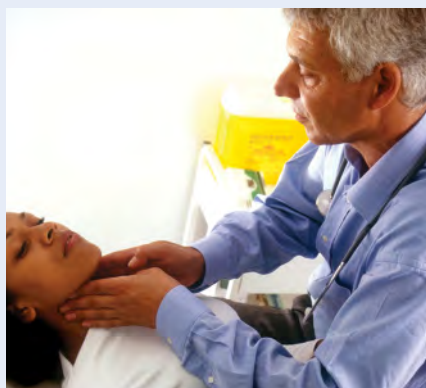


Several noninvasive diagnostic techniques are commonly used by health-care professionals and students to assess certain aspects of body structure and function. A **noninvasive diagnostic technique** is one that does not involve insertion of an instrument or device through the skin or into a body opening. In **inspection**, the first noninvasive diagnostic technique, the examiner observes the body for any changes that deviate from normal (Figure A). For example, a physician may examine the mouth cavity for evidence of disease. In **palpation** (pal-PĀ-shun; *palpa*-=to touch) the examiner feels body surfaces with the hands (Figure B). An example is palpating the neck to detect enlarged or tender lymph nodes. In **auscultation** (aus'-cul-TĀ-shun; *auscultā*-=to listen to) the examiner listens to body sounds to evaluate the functioning of certain organs, often using a stethoscope

to amplify the sounds (Figure C). An example is auscultation of the lungs during breathing to check for crackling sounds associated with abnormal fluid accumulation in the air spaces of the lungs. In **percussion** (pur-KUSH-un; *percus*-=to beat) the examiner taps on the body surface with the fingertips and listens to the resulting sound. Hollow cavities or spaces produce a different sound than solid organs do (Figure D). For example, percussion may reveal the abnormal presence of fluid in the lungs or air in the intestines. It is also used to reveal the size, consistency, and position of an underlying structure. An understanding of anatomy is important for the effective application of most of these techniques. Also, clinicians use these terms and others covered in this chapter to annotate their findings following a clinical examination. •



(A) Inspection of oral (mouth) cavity



(B) Palpation of lymph nodes in neck



(C) Auscultation of lungs



(D) Percussion of lungs

## 1.2 LEVELS OF BODY ORGANIZATION AND BODY SYSTEMS

### OBJECTIVES

- **Describe** the levels of structural organization that make up the human body.
- **Outline** the 11 systems of the human body, list the organs present in each, and explain their general functions.

The levels of organization of a language—letters of the alphabet, words, sentences, paragraphs, and so on—can be compared to the levels of organization of the human body. Your exploration of the human body will extend from some of the smallest body structures and their functions to the largest structure—an entire person. Organized from smallest to largest, six levels of organization will help you to understand anatomy: the chemical, cellular, tissue, organ, system, and organismal levels of organization (Figure 1.1).

- 1 The **chemical level**, which can be compared to the *letters of the alphabet*, includes **atoms**, the smallest units of matter that participate in chemical reactions, and **molecules**, two or more atoms joined together. Certain atoms, such as carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorus (P), and calcium (Ca), are essential for life. Two familiar molecules found in the body are deoxyribonucleic acid (DNA), the genetic material passed from one generation to the next, and glucose, commonly known as blood sugar.
- 2 At the **cellular level**, molecules combine to form cells, which can be compared to assembling letters into words. **Cells** are structures composed of chemicals and are the basic structural and functional units of an organism. Just as *words* are the

smallest building blocks of language, cells are the smallest living units in the human body. Among the many kinds of cells in your body are muscle cells, nerve cells, and blood cells. Figure 1.1 shows a smooth muscle cell, one of three types of muscle cells in the body. The cellular level of organization is the focus of Chapter 2.

- 3 The next level of structural organization is the **tissue level**. **Tissues** are groups of cells and the materials surrounding them that work together to perform a particular function, similar to the way words are put together to form *sentences*. There are just four basic types of tissue in your body: epithelial tissue, connective tissue, muscular tissue, and nervous tissue. *Epithelial tissue* covers body surfaces, lines hollow organs and cavities, and forms glands. *Connective tissue* connects, supports, and protects body organs while distributing blood vessels to other tissues. *Muscular tissue* contracts (shortens) to make body parts move and generates heat. *Nervous tissue* carries information from one part of the body to another. Chapter 3 describes the tissue level of organization in greater detail. Shown in Figure 1.1 is smooth muscle tissue, which consists of tightly packed smooth muscle cells.
- 4 At the **organ level**, different types of tissues are joined together. Similar to the relationship between sentences and *paragraphs*, **organs** are structures that are composed of two or more different types of tissues; they have specific functions and usually have recognizable shapes. Examples of organs are the stomach, heart, liver, lungs, and brain. Figure 1.1 shows how several tissues make up the stomach. The stomach's outer covering is a layer of epithelial and connective tissues that reduces friction when the stomach moves and rubs against other organs. Underneath these layers is a type of muscular tissue called *smooth muscle tissue*, which contracts to churn and mix food and

push it on to the next digestive organ, the small intestine. The innermost lining, the epithelial tissue layer, produces fluid and chemicals responsible for digestion in the stomach.

5 The next level of structural organization in the body is the **system level**, also called the **organ-system level**. A **system** (or *chapter* in our language analogy) consists of related organs (paragraphs) with a common function. An example is the digestive system, which breaks down and absorbs food. Its organs include the mouth, salivary glands, pharynx (throat), esophagus (tube that carries food from the throat to the stomach), stomach, small intestine, large intestine, liver, gallbladder, and pancreas. Sometimes an organ is part of more than one system. For example, the pancreas, which has multiple functions, is included in the digestive and endocrine systems.

6 The largest organizational level is the **organismal level**. An **organism** (OR-ga-nizm), any living individual, can be compared to a *book* in our analogy. All the parts of the human body functioning together constitute the total organism.

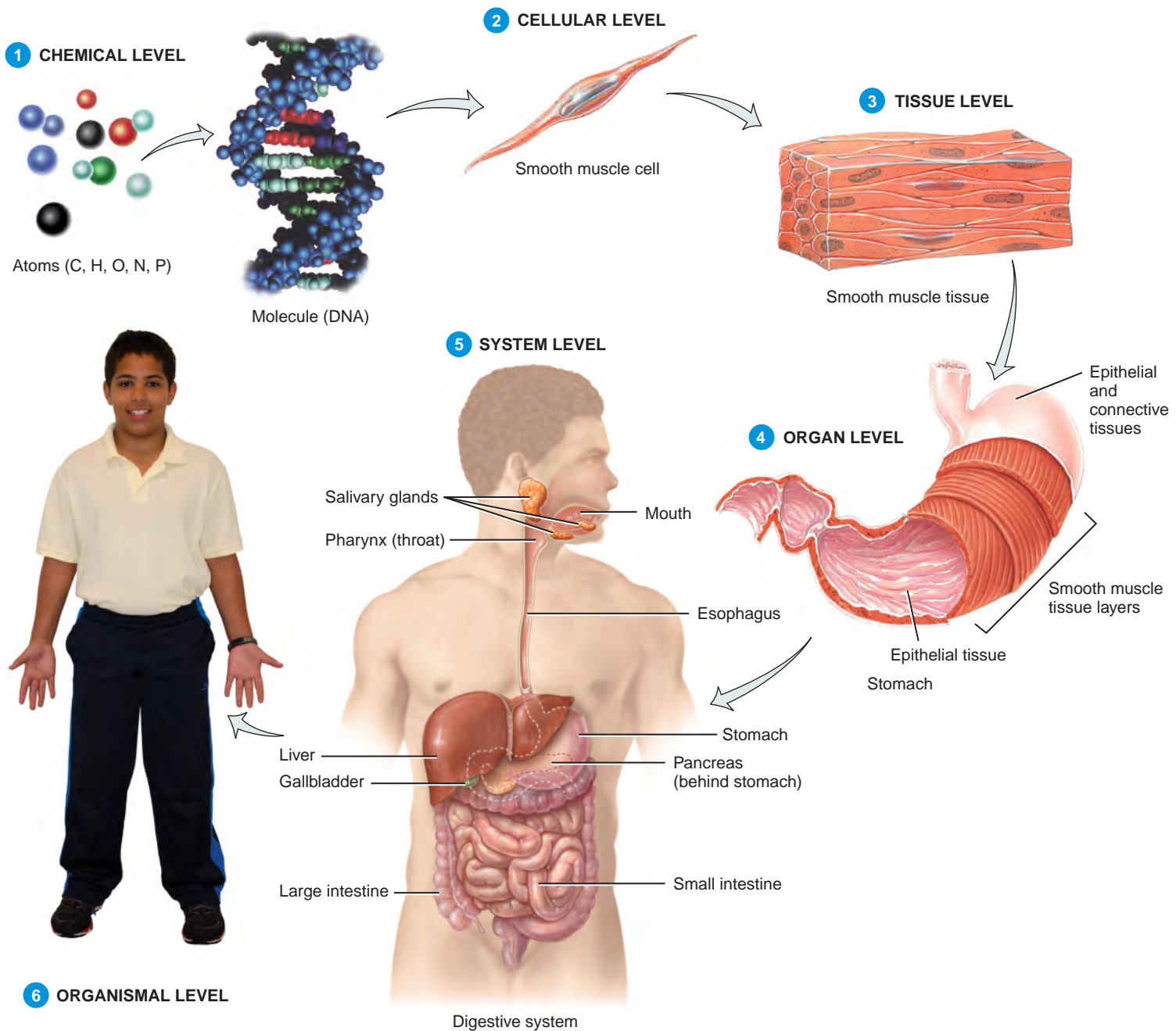
In the following chapters, you will study the anatomy and some physiology of the body systems. **Table 1.2** introduces the components and functions of these systems in the order they are discussed in the book.

**CHECKPOINT**

3. Define the following terms: atom, molecule, cell, tissue, organ, system, and organism.
4. Which body systems help eliminate wastes? (*Hint: Refer to Table 1.2.*)

**Figure 1.1** Levels of structural organization in the human body.

The levels of structural organization are chemical, cellular, tissue, organ, system, and organismal.

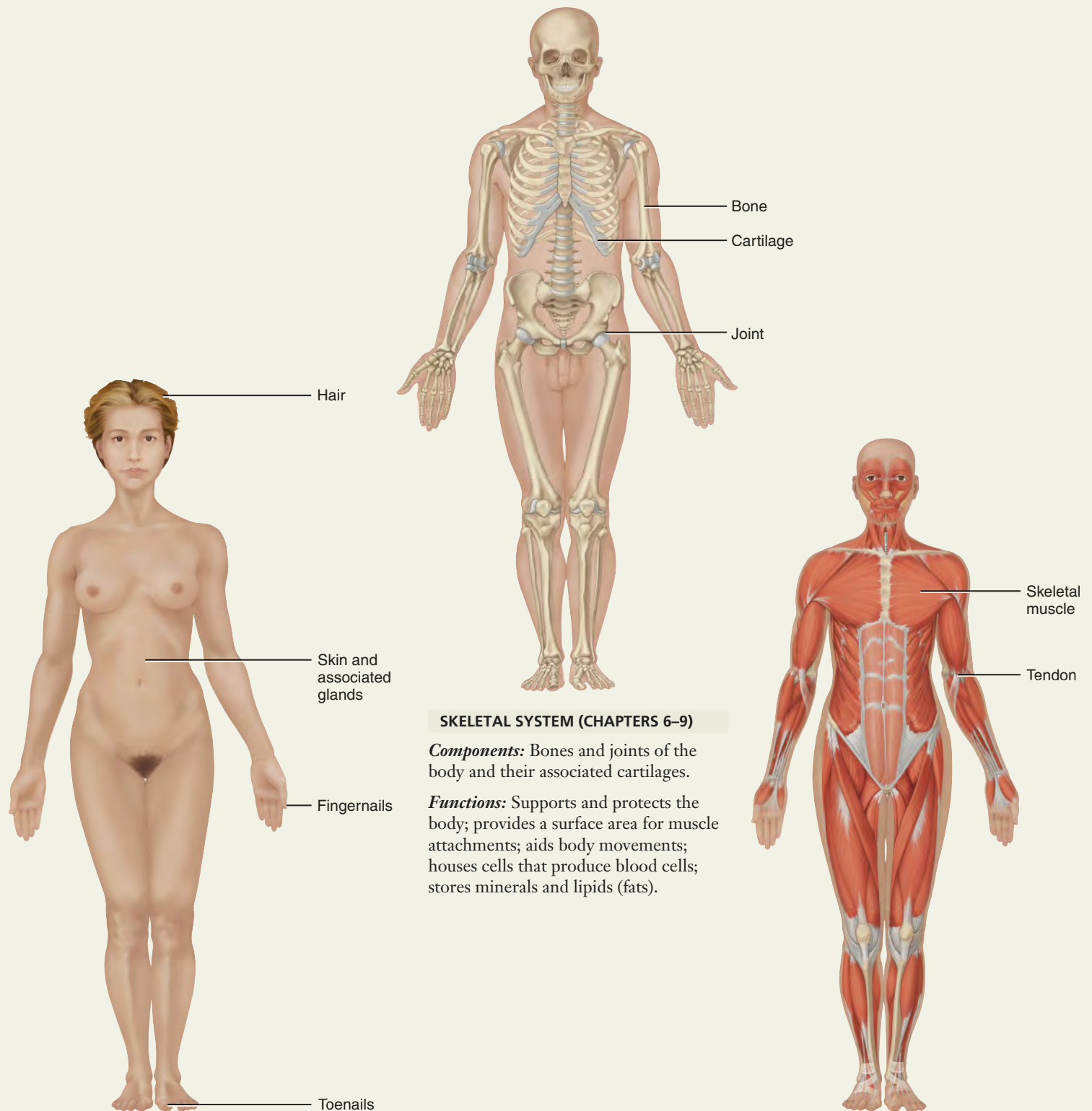


? Which level of structural organization is composed of two or more different types of tissues that work together to perform a specific function?



TABLE 1.2

## The Eleven Systems of the Human Body

**SKELETAL SYSTEM (CHAPTERS 6–9)**

**Components:** Bones and joints of the body and their associated cartilages.

**Functions:** Supports and protects the body; provides a surface area for muscle attachments; aids body movements; houses cells that produce blood cells; stores minerals and lipids (fats).

**INTEGUMENTARY SYSTEM (CHAPTER 5)**

**Components:** Skin, and structures associated with it, such as hair, fingernails and toenails, sweat glands, and oil glands and the subcutaneous layer.

**Functions:** Protects the body; helps regulate body temperature; eliminates some wastes; helps make vitamin D; and detects sensations such as touch, pain, warmth, and cold; stores fat and provides insulation.

**MUSCULAR SYSTEM (CHAPTERS 10, 11)**

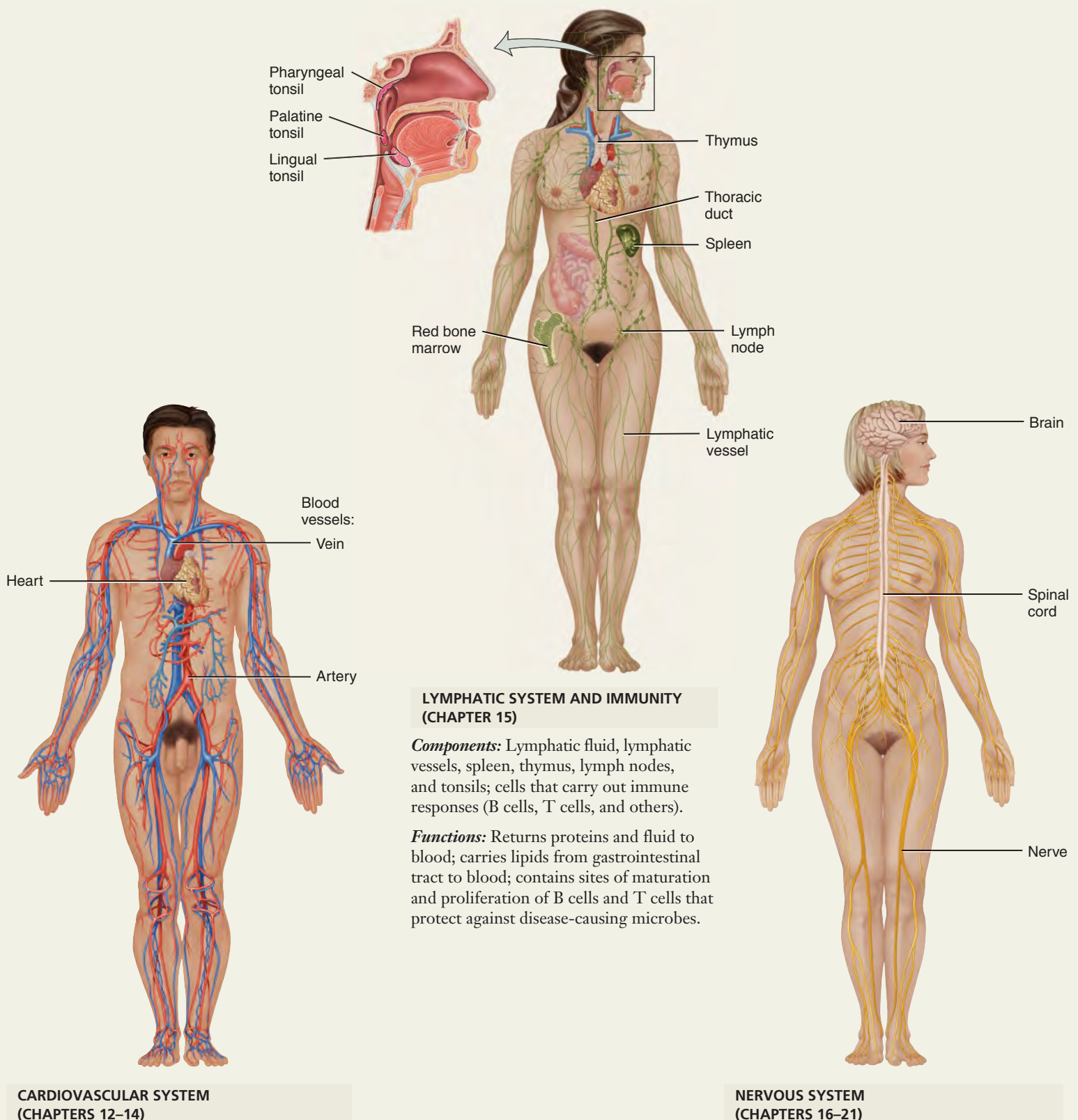
**Components:** Specifically refers to skeletal muscle tissue, which is muscle usually attached to bones (other muscle tissues include smooth and cardiac).

**Functions:** Participates in bringing about body movements, such as walking, maintains posture, and produces heat.

TABLE 1.2 CONTINUES

TABLE 1.2 CONTINUED

The Eleven Systems of the Human Body



**CARDIOVASCULAR SYSTEM (CHAPTERS 12–14)**

**Components:** Blood, heart, and blood vessels.  
**Functions:** Heart pumps blood through blood vessels; blood carries oxygen and nutrients to cells and carbon dioxide and wastes away from cells and helps regulate acid–base balance, temperature, and water content of body fluids; blood components help defend against disease and repair damaged blood vessels.

**LYMPHATIC SYSTEM AND IMMUNITY (CHAPTER 15)**

**Components:** Lymphatic fluid, lymphatic vessels, spleen, thymus, lymph nodes, and tonsils; cells that carry out immune responses (B cells, T cells, and others).  
**Functions:** Returns proteins and fluid to blood; carries lipids from gastrointestinal tract to blood; contains sites of maturation and proliferation of B cells and T cells that protect against disease-causing microbes.

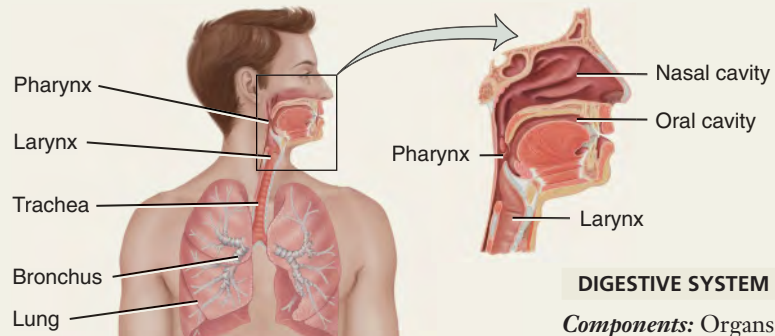
**NERVOUS SYSTEM (CHAPTERS 16–21)**

**Components:** Brain, spinal cord, nerves, and special sense organs, such as the eyes and ears.  
**Functions:** Generates action potentials (nerve impulses) to regulate body activities; detects changes in the body’s internal and external environments, interprets the changes, and responds by causing muscular contractions or glandular secretions.

**RESPIRATORY SYSTEM (CHAPTER 23)**

**Components:** Lungs and air passageways such as the pharynx (throat), larynx (voice box), trachea (windpipe), and bronchial tubes within the lungs.

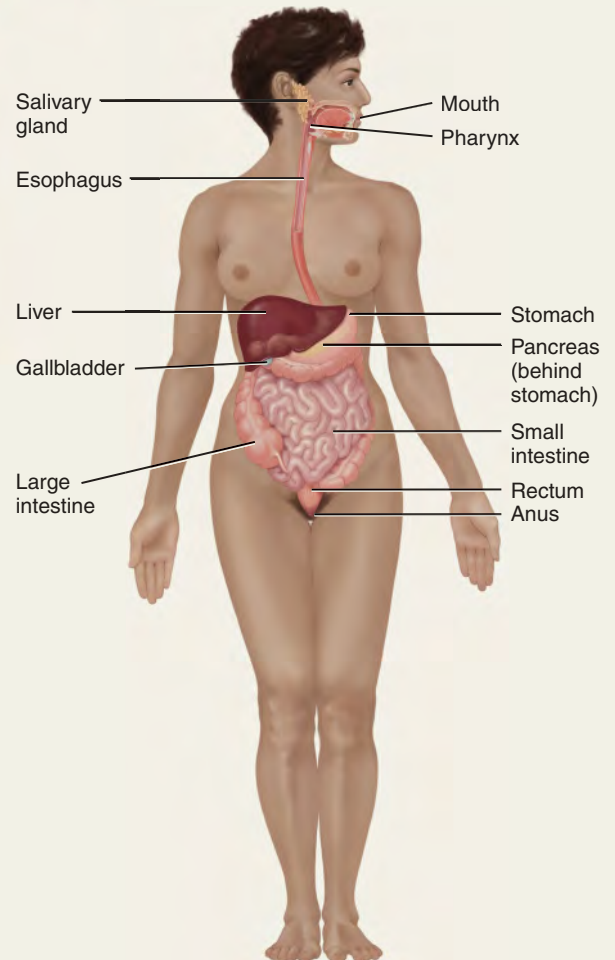
**Functions:** Transfers oxygen from inhaled air to blood and carbon dioxide from blood to exhaled air; helps regulate acid–base balance of body fluids; air flowing out of lungs through vocal cords produces sounds.



**DIGESTIVE SYSTEM (CHAPTER 24)**

**Components:** Organs of gastrointestinal tract—a long tube that includes the mouth, pharynx (throat), esophagus, stomach, small and large intestines, and anus; also includes accessory organs that assist in digestive processes, such as the salivary glands, liver, gallbladder, and pancreas.

**Functions:** Achieves physical and chemical breakdown of food; absorbs nutrients; eliminates solid wastes.



**ENDOCRINE SYSTEM (CHAPTER 22)**

**Components:** Hormone-producing glands (pineal gland, hypothalamus, pituitary gland, thymus, thyroid gland, parathyroid glands, adrenal glands, pancreas, ovaries, and testes) and hormone-producing cells in several other organs.

**Functions:** Regulates body activities by releasing hormones, which are chemical messengers transported in blood from an endocrine gland or tissue to a target organ.

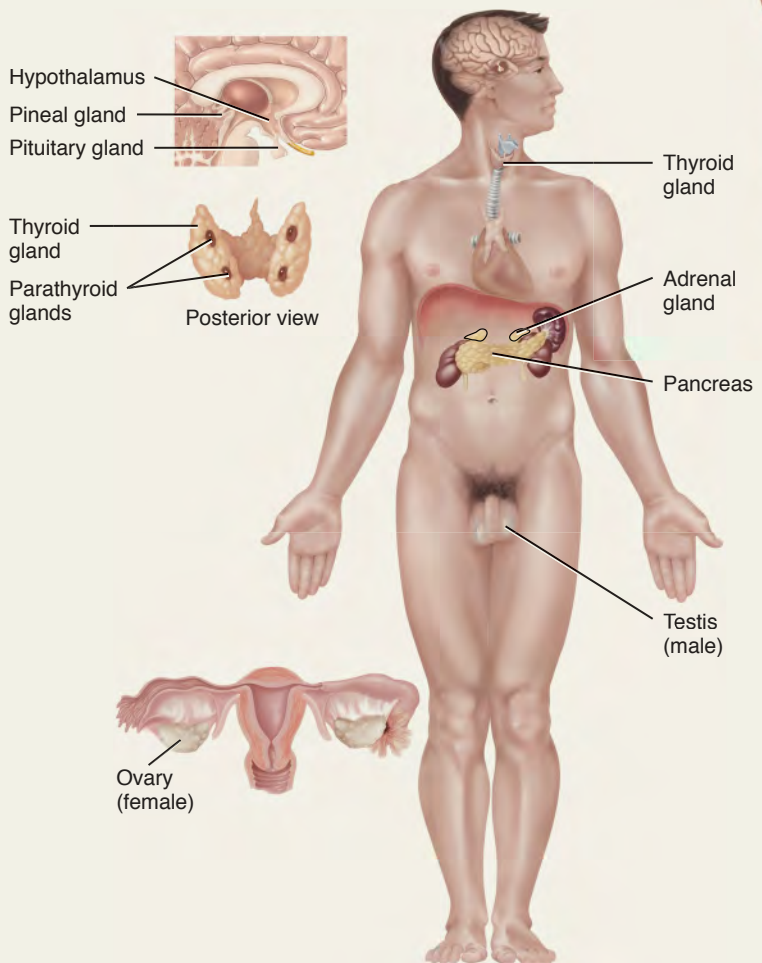
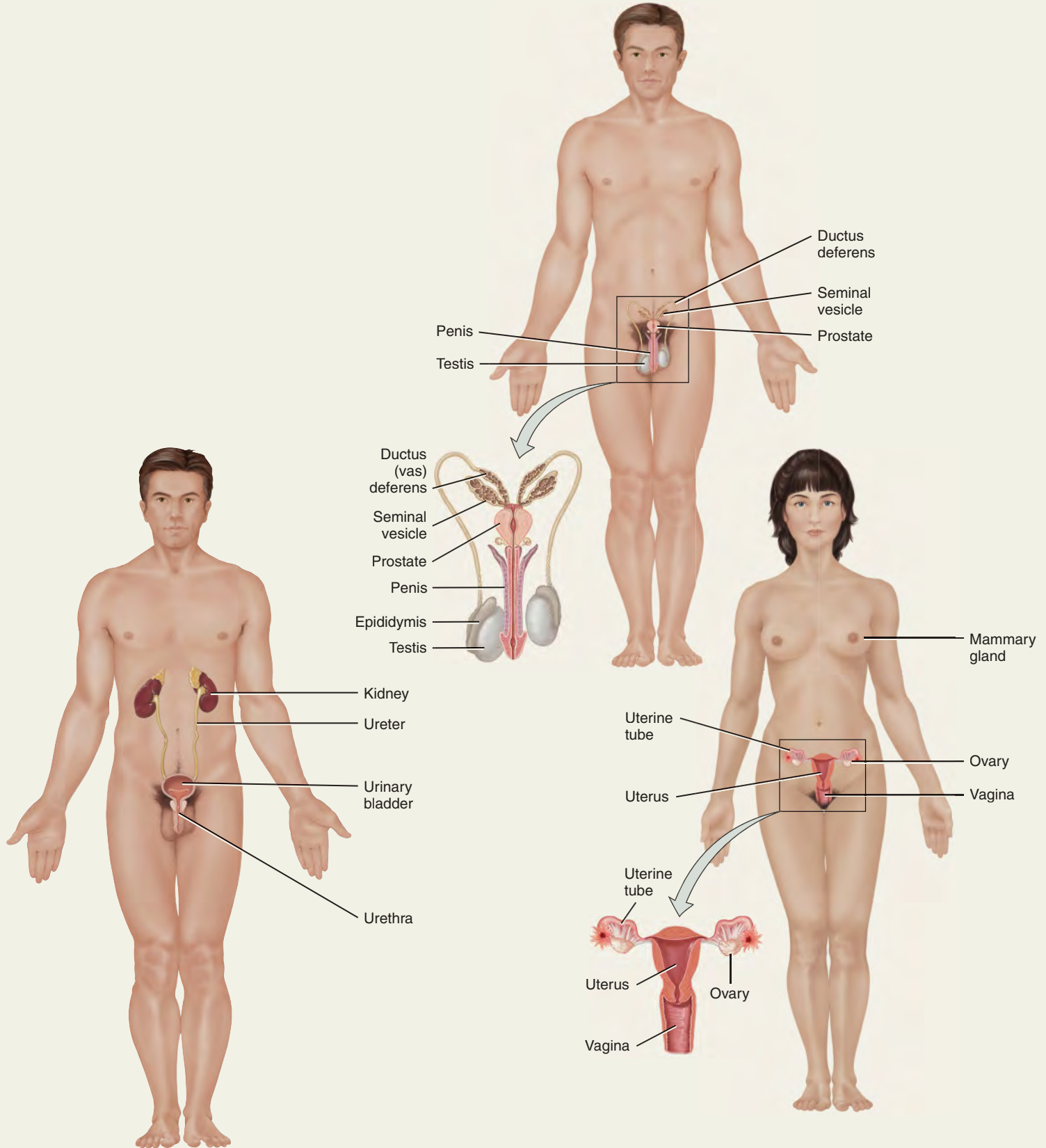


TABLE 1.2 CONTINUED

The Eleven Systems of the Human Body



URINARY SYSTEM (CHAPTER 25)

**Components:** Kidneys, ureters, urinary bladder, and urethra.

**Functions:** Produces, stores, and eliminates urine; eliminates wastes and regulates volume and chemical composition of blood; helps maintain the acid–base balance of body fluids; maintains body’s mineral balance; helps regulate production of red blood cells.

REPRODUCTIVE SYSTEMS (CHAPTER 26)

**Components:** Gonads (testes in males and ovaries in females) and associated organs (such as the uterine or fallopian tubes, uterus, and vagina in females and epididymides, seminal vesicles, prostate, ductus deferens, and penis in males).

**Functions:** Gonads produce gametes (sperm or oocytes) that unite to form a new organism; gonads also release hormones that regulate reproduction and other body processes; associated organs transport and store gametes; mammary glands produce milk.

## 1.3 LIFE PROCESSES

### OBJECTIVE

- Define the important life processes of humans.

All living organisms have certain characteristics that set them apart from nonliving things. The following are six important life processes of humans:

1. **Metabolism** (me-TAB-ō-lizm) is the sum of all the chemical processes that occur in the body. It includes the breakdown of large, complex molecules into smaller, simpler ones (catabolism) and the building up of complex molecules from smaller, simpler ones (anabolism). For example, food proteins are broken down into amino acids, building blocks that can then be used to build new proteins that make up muscles and bones.
2. **Responsiveness** is the body's ability to detect and respond to changes in its internal (inside the body) or external (outside the body) environment. Different cells in the body detect different sorts of changes and respond in characteristic ways. Nerve cells respond to changes in the environment by generating electrical signals, known as nerve impulses. Muscle cells respond to nerve impulses by contracting, which generates force to move body parts.
3. **Movement** includes motion of the whole body, individual organs, single cells, and even structures inside cells. For example, the coordinated action of several muscles and bones enables you to move your body from one place to another by walking or running. After you eat a meal that contains fats, your gallbladder (an organ) contracts and releases bile into the gastrointestinal tract to help digest them. When a body tissue is damaged or infected, certain white blood cells move from the bloodstream into the affected tissue to help clean up and repair the area. And inside individual cells, various cell structures move from one position to another to carry out their functions.
4. **Growth** is an increase in body size. It may be due to an increase in (1) the size of existing cells, (2) the number of cells, or (3) the amount of material surrounding cells.
5. **Differentiation** (dif'-er-en-shē-Ā-shun) is the process unspecialized cells go through to become specialized cells. Such precursor cells, which can divide and give rise to cells that undergo differentiation, are called *stem cells*. Specialized cells differ in structure and function from the unspecialized cells that gave rise to them. For example, specialized red blood cells and several types of white blood cells differentiate from the same unspecialized cells in red bone marrow. Similarly, a single fertilized human egg cell undergoes tremendous differentiation to develop into a unique individual who is similar to, yet quite different from, either of his or her parents.
6. **Reproduction** (rē-prō-DUK-shun) refers to the formation of new cells through cell division. The production of a new individual occurs through the fertilization of an ovum by a sperm cell to form a zygote, followed by repeated cell divisions and the differentiation of these cells.

Although not all of these processes occur in cells throughout the body all of the time, when any one of them ceases to occur properly, cell death may occur. When cell death is extensive and leads to organ failure, the result is death of the organism.

### CHECKPOINT

5. What types of movement can occur in the human body?

## 1.4 BASIC ANATOMICAL TERMINOLOGY

### OBJECTIVES

- Describe the orientation of the human body in the anatomical position.
- Relate the common names to the corresponding anatomical descriptive terms for various regions of the human body.
- Define the anatomical planes, the anatomical sections, and the directional terms used to describe the human body.

Scientists and health-care professionals use a common language of special terms when referring to body structures and their functions. The language of anatomy has precisely defined meanings that allow us to communicate clearly and unambiguously. For example, take the statement “The wrist is above the fingers.” This might be true if your upper limbs (described shortly) are at your sides. But if you held your hands up above your head, your fingers would be above your wrists. To prevent this kind of confusion, anatomists use a standard anatomical position and a special vocabulary for relating body parts to one another.

### Anatomical Position

In anatomy, the **anatomical position** (an'-a-TOM-i-kal) is the standard position of reference for the description of anatomical structures. In the anatomical position, the subject stands erect facing the observer, with the head level and the eyes facing directly forward. The lower limbs are parallel and the feet are flat on the floor and directed forward. The upper limbs are at the sides with the palms facing forward (Figure 1.2). With the body in the anatomical position, it is easier to visualize and understand its organization into various regions and describe relationships of various structures.

As just described, in the anatomical position, the body is upright. There are two terms used to describe a reclining body. If the body is lying face down, it is in the **prone** position. If the body is lying face up, it is in the **supine** position.

### Regional Names

The human body is divided into several major regions that can be identified externally. These are the head, neck, trunk, upper limbs, and lower limbs. The **head** consists of the skull and face. The *skull* encloses and protects the brain, while the *face* is the front portion of the head that includes the eyes, nose, mouth, forehead, cheeks, and chin. The **neck**, a modified portion of the trunk, supports the head and attaches it to the remainder of the trunk. The **trunk** consists of the *neck*, *thorax*, *abdomen*, and *pelvis*. Each **upper limb (extremity)** is attached to the trunk and consists of the *shoulder*, *armpit*, *arm* (portion of the limb from the shoulder to the elbow), *forearm* (portion of the limb from the elbow to the wrist), *wrist*, and *hand*. Each **lower limb (extremity)** is also attached to the trunk and consists of the *buttock*, *thigh* (portion of the limb from the buttock to the knee), *leg* (portion of the limb from the knee to the ankle), *ankle*, and *foot*. The **groin** is the area on the front surface of the body marked by a crease on each side, where the trunk attaches to the thighs. Understanding the precise meaning of arm and forearm in the upper limb and thigh and leg in the lower limb is very important when reading or describing a clinical assessment.