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Preface

I first started writing lab procedures for my students 14 years ago in response to frustration my students and I were feeling with the anatomy and physiology lab and the accompanying lab manual. My students wanted—and needed—focused activities, clear objectives and explanations, and exercises that enabled them to appreciate the often-missed "big picture" of A&P. None of the available lab manuals provided this, so I was left with no choice but to write my own lab procedures. The results of my efforts were well worth it, as my students were engaged and active the entire lab period. Their lab and class grades improved.

In 2003, I met with David Ferguson, now the president of Morton Publishing Company, and he offered me a dream opportunity: to share my exercises with students and instructors throughout the country. The result of that meeting was the text *Exercises for the Anatomy and Physiology Laboratory*, a simple black-and-white manual with focused activities. My goal with this book was to solve the teaching problems in the A&P lab and to enhance the experience for my colleagues and our students.

Exercises was enthusiastically received, suggesting that we had indeed provided instructors and students something that they had been needing. We were so encouraged that we set out to produce an expanded, full-color version of the exercises that included more explanations, new activities, a complete art program, and new pedagogy. This book became *Exploring Anatomy and Physiology in the Laboratory*, or EAPL. Like its predecessor, it was warmly received.

Over the lifespan of *EAPL*, we received a great deal of wonderfully helpful feedback from our adopters. Some of the most frequent feedback that we received was that professors liked the book, but it was too difficult to customize for a pure anatomy course. So, from that feedback, *Exploring Anatomy in the Laboratory (EAL)* was born. With this new book, we kept many of the same great features that made *EAPL* so popular but customized the procedures and text for a pure anatomy course.

Exploring Anatomy in the Laboratory includes the following features:

- **Pre-Lab Exercises.** The pre-lab exercises are a feature from *EAPL* that have been customized to focus more on anatomy. Each unit opens with a list of key terms that students should define before coming to lab. Additionally, the pre-lab exercises of most units feature labeling and coloring exercises for anatomical structures. The pre-lab exercises allow this text to function as both a laboratory manual and a study guide.

- **Organized Anatomy and Model Inventories.** Two other features that were incorporated into this text from *EAPL* are the organized anatomical lists and the model inventories. In each unit, the anatomical structures are organized in a way that provides a centralized list for students that is easy for instructors customize based upon preference. The list of terms matches the order in which they are presented in the text discussion so students have a more intuitive reference in their book if they need help.

  Each anatomy list is followed by a Model Inventory, in which students assign descriptive names to their anatomical models and then list the structures that they are able to locate on the model. This helps students to focus more on the anatomy and to engage more parts of their brains as they examine, pronounce, and write down the names of the anatomical structures.

- **Drawing Activities and Tracing Exercises.** One of the more popular features from *EAPL* is the tracing exercises, and these were carried over to *EAL*. In tracing exercises, students trace the pathway of a certain substance (e.g., a molecule of glucose or an erythrocyte) throughout the body to develop a "big-picture" view of anatomy. In addition, brand new drawing activities were added just for *EAL*. We have seen recently at meetings of the Human Anatomy and Physiology Society how drawing activities can improve retention of anatomy dramatically, so we added these activities to most units.

- **Expanded Anatomy Art Program.** We expanded significantly upon the existing art program of *EAPL* to include more anatomy-specific art. More views, structures, and sections were added so that anatomy students can get a better overall understanding of the human body.

- **End-of-Unit Quizzes with Critical Thinking Questions.** We carried over the Check Your Recall and Check Your Understanding end-of-unit quizzes from *EAPL* and customized them for an anatomy course. The Check Your Understanding questions have always been popular, as they ask students to apply the material they have just learned and use higher-order thinking to solve problems.
- **Hints and Tips Boxes.** Students nearly always have difficulty with certain topics in anatomy. For these topics students can refer to a boxed feature called Hints and Tips. These boxes are scattered throughout the text to help students tackle these particularly difficult topics in the lab.
- **Affordability.** Last, but not least, this new text has been produced to maintain one of the most important goals of Morton Publishing Company: affordability. Textbooks are expensive, and the last thing the average student needs is to purchase a lab manual that is one hundred dollars or more. This text is unique in that it provides high-quality material priced with student budgets in mind.

We hope that *Exploring Anatomy in the Laboratory* meets—and even exceeds—your expectations for a customized anatomy manual. Please share your feedback with us about ways we can continue to improve this text so that it provides an optimal learning experience for your students.

—Erin Amerman

Acknowledgments

Although it is my name on the cover of this text, textbooks are never a solo effort. Many people were integral to the production and development of this book, and I would like to take this brief opportunity to express my gratitude.

First and foremost I would like to thank my family, particularly my daughter Elise, my mother Cathy, and my husband Chris. Without your unwavering support, none of my textbooks would have been possible. And to Elise, thank you especially for being patient with me being behind my computer screen so often. (Although now that you're a tween, you're probably actually grateful to have me out of your hair.) Also, I can't forget my animals: My cats unfailingly managed to be completely in the way of whatever I was doing, and my dogs always contributed to phone meetings by barking and howling in the background.

Next I would like to extend my gratitude to the talented book team with whom I was fortunate enough to work: Joanne Saliger, who expertly designed and produced the book as she always does; Sarah Thomas, who skillfully copyedited the text and coordinated the expansion of the art program in Exploring Anatomy in the Laboratory; Marta Martins, who coordinated everything as the acquisitions editor, and who did so in Portuguese, French, and English; the team at Imagineering, who provided the beautiful illustrations; Trina Lambert, who proofread the text; Carolyn Acheson, who provided indexing services; and John Crawley, Michael Leboffe, and Justin Moore, who allowed me to use several of their excellent photos and photomicrographs. I truly appreciate all of your hard work and generosity.

I would also like to thank the following reviewers for their valuable suggestions that helped to shape the contents of this book: Diana M. Coffman, Lincoln Land Community College; Angela Corbin, Nicholls State University; Dr. Cassy Cozine, University of Saint Mary; Molli Crenshaw, Texas Christian University; Kathryn A. Durham, R.N., Ph.D., Lorain County Community College; Jill E. Feinstein, Richland Community College; Nancy E. Fitzgerald, M.D., Alvin Community College; Carol Haspel, Ph.D., Laguardia Community College; Stephanie Ann Havemann, Ph.D., Alvin Community College; Elizabeth Hodgson, York College of Pennsylvania; Steven Leadon, Durham Technical Community College; Eddie Lunsford, Southwestern Community Colege; Dr. Shawn Macauley, Muskegon Community College; Darren Mattone, Muskegon Community College; John David Matula, Alvin Community College; Justin Moore, American River College; Tommy D. Morgan, Alvin Community College; Michele Robichaux, Nicholls State University; Deanne Roopnarine, Nova Southeastern University; Amy Fenech Sandy, Columbus Technical College in Columbus, GA; Lori Smith, American River College; Valory Thatcher, Mt. Hood Community College; and Cathy Whiting, Gainesville State College.

The acknowledgements would be incomplete without thanking Doug Morton, who has kindly provided me with another opportunity to publish with his company. And finally, I extend a special thank you to President David Ferguson for his support, patience, friendship, Broncos games, and willingness to go hiking with me to look for snakes even if he is unwilling to actually touch a snake himself.

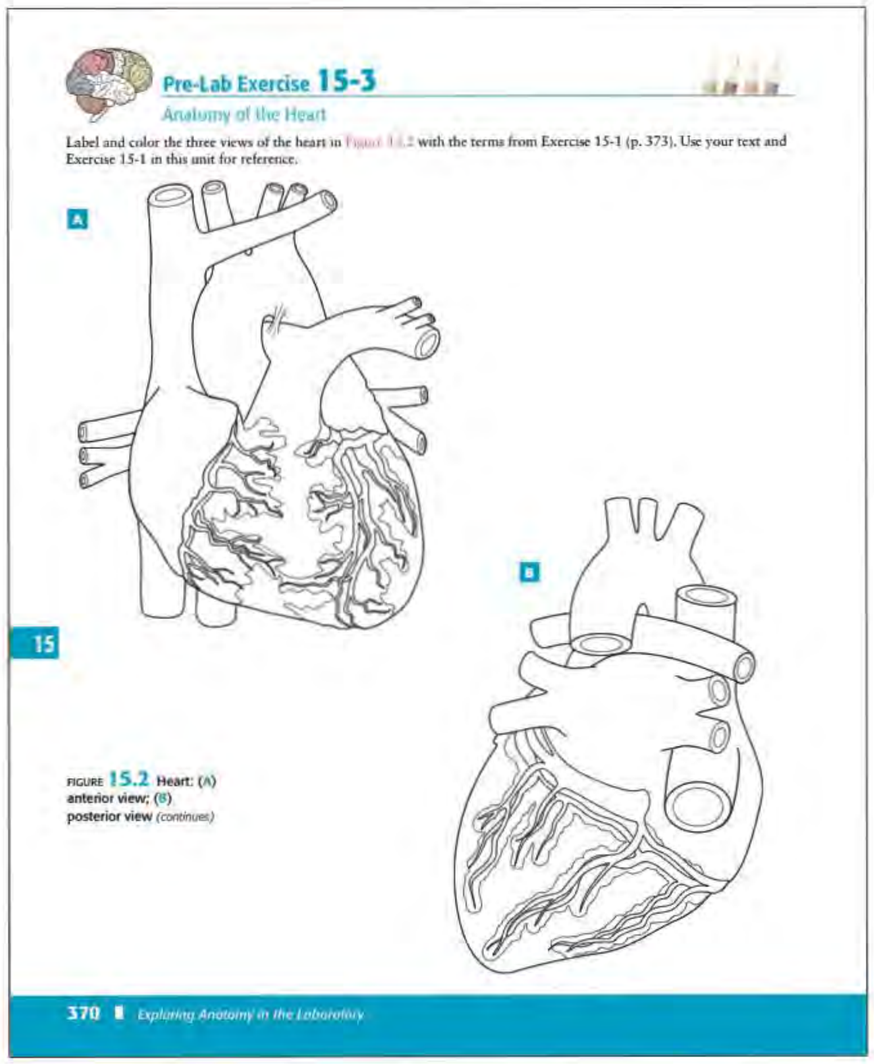
About the Author

Erin C. Amerman has been involved in anatomy and physiology education for more than 15 years as an author and professor, most recently at Florida State College at Jacksonville in Jacksonville, Florida. She received a B.S. in Cellular and Molecular Biology from the University of West Florida and a doctorate in Podiatric Medicine from Des Moines University. *Exploring Anatomy in the Laboratory* is her fourth book with Morton Publishing.

Be Prepared

OBJECTIVES set learning goals to prepare students for what they are expected to know after completing the lab. They also aid in the review of material.

PRE-LAB EXERCISES encourage students to actively prepare for the lab by defining key terms, doing labeling and coloring exercises to learn anatomical structures, and reviewing vital material from previous units, saving instructors from having to spend excessive time reviewing material from the lecture. These exercises can be completed using information available in the lab manual and will help students move through the lab more effectively. By asking students to draw their own leader lines and write out definitions, the pre-lab exercises are designed to help students retain information and build a deeper understanding of the content.



Pre-Lab Exercise 15-3

Anatomy of the Heart

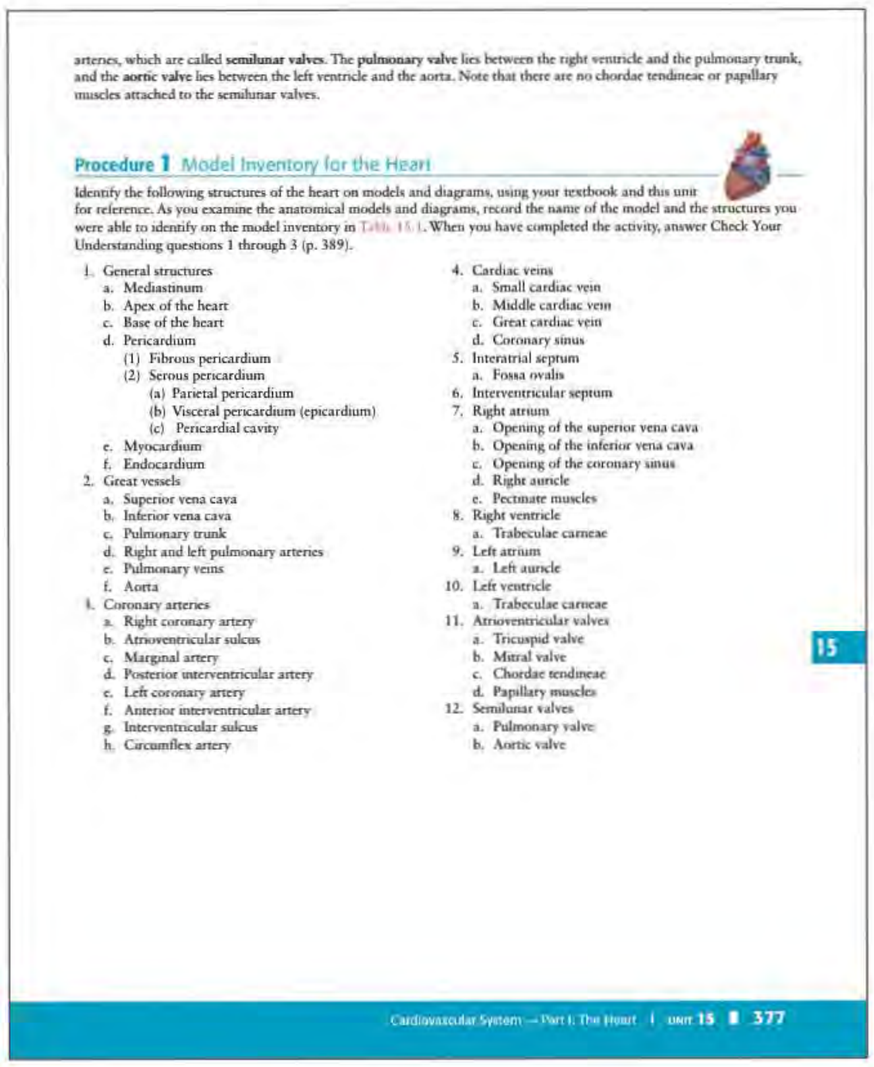
Label and color the three views of the heart in Figure 15.2 with the terms from Exercise 15-1 (p. 373). Use your text and Exercise 15-1 in this unit for reference.

A

B

FIGURE 15.2 Heart: (A) anterior view; (B) posterior view *(continues)*

370 ▮ Exploring Anatomy in the Laboratory



arteries, which are called **semilunar valves**. The **pulmonary valve** lies between the right ventricle and the pulmonary trunk, and the **aortic valve** lies between the left ventricle and the aorta. Note that there are no chordae tendineae or papillary muscles attached to the semilunar valves.

Procedure 1 Model Inventory for the Heart

Identify the following structures of the heart on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 15.1. When you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 389).

1. General structures
   a. Mediastinum
   b. Apex of the heart
   c. Base of the heart
   d. Pericardium
      (1) Fibrous pericardium
      (2) Serous pericardium
         (a) Parietal pericardium
         (b) Visceral pericardium (epicardium)
         (c) Pericardial cavity
   e. Myocardium
   f. Endocardium
2. Great vessels
   a. Superior vena cava
   b. Inferior vena cava
   c. Pulmonary trunk
   d. Right and left pulmonary arteries
   e. Pulmonary veins
   f. Aorta
3. Coronary arteries
   a. Right coronary artery
   b. Atrioventricular sulcus
   c. Marginal artery
   d. Posterior interventricular artery
   e. Left coronary artery
   f. Anterior interventricular artery
   g. Interventricular sulcus
   h. Circumflex artery
4. Cardiac veins
   a. Small cardiac vein
   b. Middle cardiac vein
   c. Great cardiac vein
   d. Coronary sinus
5. Interatrial septum
   a. Fossa ovalis
6. Interventricular septum
7. Right atrium
   a. Opening of the superior vena cava
   b. Opening of the inferior vena cava
   c. Opening of the coronary sinus
   d. Right auricle
   e. Pectinate muscles
8. Right ventricle
   a. Trabeculae carneae
9. Left atrium
   a. Left auricle
10. Left ventricle
    a. Trabeculae carneae
11. Atrioventricular valves
    a. Tricuspid valve
    b. Mitral valve
    c. Chordae tendineae
    d. Papillary muscles
12. Semilunar valves
    a. Pulmonary valve
    b. Aortic valve

Cardiovascular System — Part I: The Heart ▮ UNIT 15 ▮ 377

Be Organized

MODEL INVENTORIES provide organized and easily referenced lists of anatomical structures that students are responsible for identifying. These lists help students catalog the specimens they see in the lab. The emphasis on examination, description, pronunciation, and writing the names of anatomical structures encourages students to be actively involved in the learning process and allows them to better retain the material.

Be Active

FOCUSED ACTIVITIES are the guiding philosophy of this lab manual. Students learn best when they are actively engaged in the laboratory. In this manual, students are asked to be active by describing, labeling, writing, coloring, and drawing. Each activity has been designed to align with the material covered in a one-semester course.

Finding the coronary vessels tends to be difficult because the superficial surface of the heart is covered with adipose tissue. To see the coronary vessels, carefully dissect the adipose tissue.

2 Locate the superior vena cava. Insert scissors or a scalpel into the superior vena cava and cut down into the right atrium. Before moving on to step 3, note the structure of the tricuspid valve, and draw it in the space provided. How many flaps do you see? What is the function of this valve?

3 Once the right atrium is exposed, continue the cut down into the right ventricle, which is shown in Figure 15.9. Structures to locate at this time include the

a. tricuspid valve,
b. chordae tendineae,
c. papillary muscles,
d. myocardium, and
e. endocardium (shiny layer on the inside of the heart).

4 Insert the scissors into the pulmonary trunk. Note the structure of the pulmonary valve, and draw it in the space provided. How does it differ structurally from the tricuspid valve? What is the function of this valve?

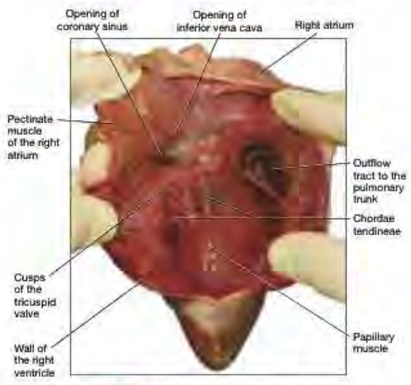


FIGURE 15.9 Right ventricle of a sheep heart.

5 Insert the scissors into a pulmonary vein. Cut down into the left atrium. Note the structure of the mitral valve, and draw it below. What is the function of this valve? How does its structure differ from that of the pulmonary and tricuspid valves?

6 Continue the cut into the left ventricle. Note the thickness of the left ventricle, as shown in Figure 15.10. How does it compare with the thickness of the right ventricle? Why is there a difference?

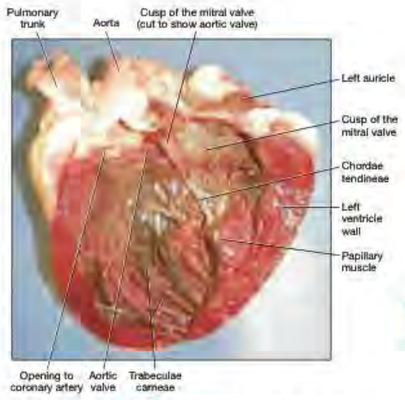


FIGURE 15.10 Left ventricle of a sheep heart.

7 Insert the scissors into the aorta. Extend the cut until you can see the aortic valve. Draw the aortic valve in the space provided. Is it structurally more similar to the pulmonary valve or the mitral valve? What is the function of this valve?

TRACING EXERCISES ask students to write step-by-step, turn-by-turn directions to follow substances (blood cells, food molecules, waste by-products, electrical events) through the human body, then trace the substances' path on a "map" of the body. These exercises allow students to see the big picture of how the body systems interact and to understand the relationship between structure and function.

8 Your instructor may wish you to identify other structures on the heart. List any additional structures in the space provided.

Procedure 4 Tracing Blood through the Heart

Use water-soluble markers and a laminated outline of the heart to trace the pathway of blood as it flows through the heart and pulmonary circulation. Use a blue marker to indicate areas that contain deoxygenated blood and a red marker to indicate areas that contain oxygenated blood. If no laminated outline is available, use Figure 15.11. When you have completed the activity, answer Check Your Understanding question 5 (p. 390).

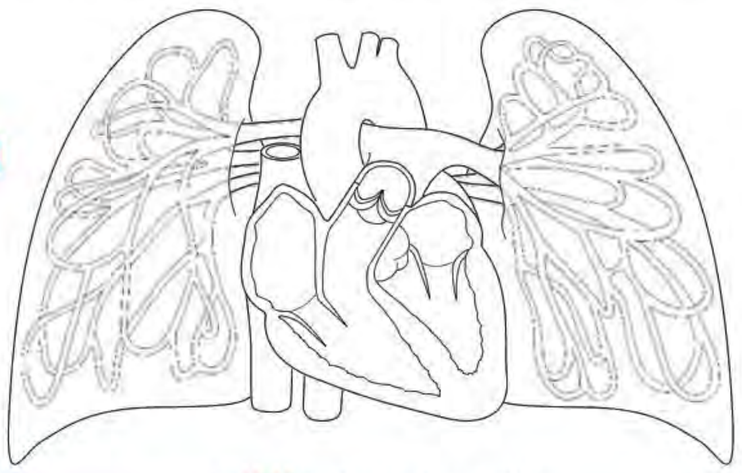


FIGURE 15.11 Heart, lungs, and pulmonary circulation.

Be Focused

ILLUSTRATIONS and **PHOTOGRAPHS** in *Exploring Anatomy in the Laboratory* were specifically designed for use in the laboratory setting. The clear photographs and photomicrographs, coupled with carefully drawn illustrations, provide a detailed view of anatomical structures to improve student retention of the material and to aid in the understanding of important concepts.

The atria receive blood from the body's largest veins, and the ventricles eject blood into the body's largest arteries. These large blood vessels are known as the **great vessels**, and they include the following:

1. **Superior and inferior venae cavae.** The **superior vena cava** (VEE-nah KAY-vah) is a large vein that in general drains deoxygenated blood from structures above the diaphragm, while the **inferior vena cava** drains structures below the diaphragm. Both empty into the right atrium. These veins drain a group of blood vessels collectively called the **systemic circuit**, in which gases and nutrients are exchanged between the blood and the tissues outside of the lungs.
2. **Pulmonary trunk.** The **pulmonary trunk** is a large artery that branches from the right ventricle. Shortly after it forms, it splits into **right** and **left pulmonary arteries**, which deliver deoxygenated blood to the lungs through a series of vessels collectively called the **pulmonary circuit**. Within the pulmonary circuit, gases are exchanged, and the blood becomes oxygenated.
3. **Pulmonary veins.** The **pulmonary veins** bring oxygenated blood back from the pulmonary circuit and deliver it to the left atrium. There are generally four pulmonary veins.
4. **Aorta.** The large **aorta** (ay-OHR-tah) is an artery that stems from the left ventricle, after which it branches repeatedly to deliver oxygenated blood to the systemic circuit.

HINTS & TIPS

Red or Blue?

On anatomical models, vessels that carry oxygenated blood are red, whereas those that carry deoxygenated blood are blue. Systemic arteries carry oxygenated blood to the body's cells and so are red on anatomical models. Systemic veins, on the other hand, carry deoxygenated blood back to the right atrium and so are blue. But be sure to remember that the reverse is true in the pulmonary circuit: The pulmonary arteries carry deoxygenated blood to the lungs and the pulmonary veins carry oxygenated blood to the heart. So, in the pulmonary circuit, the arteries are blue and the veins are red.

The other set of blood vessels visible on the external surface of the heart are the vessels collectively called the **coronary circulation** (KOHR-oh-nehr-ee). The **coronary arteries** branch off the base of the aorta and bring oxygenated blood to the cells of the myocardium, and they are drained by a set of **cardiac veins**. The first coronary artery, the **right coronary artery**, travels in a groove between the atria and ventricles called the right **atrioventricular sulcus** (ay-tree-oh-ven-TRIK-yoo-lur). It branches into the **marginal artery**, which serves the lateral part of the right atrium and right ventricle, and the **posterior interventricular artery**, which serves the posterior heart. The other coronary artery is the **left coronary artery**, which branches shortly after it forms into the **anterior interventricular artery** (also known as the **left anterior descending artery**), which travels along a groove between the right and left ventricles called **interventricular sulcus** to supply the anterior heart. Its second branch is the **circumflex artery** (SIR-kum-flex), which travels in the left atrioventricular sulcus to supply the left atrium and posterior left ventricle. When a coronary artery is blocked, the reduced blood flow to the myocardium can result in hypoxic injury and death to the tissue, a condition termed **myocardial infarction** (commonly called a heart attack).

The anatomy of the cardiac veins often varies from person to person, but the following three main veins generally are present:

1. **small cardiac vein,** which drains the inferolateral heart,
2. **middle cardiac vein,** which drains the posterior heart, and
3. **great cardiac vein,** which drains most of the left side of the heart.

All three veins drain into the large **coronary sinus** located on the posterior right atrium. The coronary sinus drains into the right atrium.

On a dissection of the heart, as shown in Figure 15.6, we can see that the atria and ventricles are divided by muscular walls called *septa*. In between the atria is a thin wall called the **interatrial septum** (in-ter-AY-tree-ul). This wall has a small dent in it called the **fossa ovalis**, which is a remnant of a hole that was present during fetal life called the *foramen ovale*. The much thicker **interventricular septum** separates the two ventricles. The heart's four chambers include the:

1. **Right atrium.** The **right atrium** (AY-tree-um) is the superior right chamber. It receives deoxygenated blood from the body's main veins—the **superior vena cava**, the **inferior vena cava**, and the **coronary sinus**—the openings for which we find on the right atrium's posterior side. Externally, it has a large pouch called the **right auricle** (OHR-ik-ul) that allows the right atrium to expand and fill with more blood. Internally, the anterior surface of the right atrium is rough due to muscular ridges called **pectinate muscles** (PEK-tin-et).

EXERCISES

The **cardiovascular system** transports oxygen, nutrients, wastes, other solutes, and cells throughout the body. In this unit we begin our exploration of the cardiovascular system with the pump that drives it—the heart. The heart is a remarkable organ, tirelessly beating more than 100,000 times per day to pump more than 8,000 liters of blood around the body. In this unit we examine the anatomy of this remarkable organ, including the blood flow through the heart and the histology of cardiac muscle.

Exercise 15-1

Anatomy of the Heart

MATERIALS

- ❑ Heart models
- ❑ Preserved heart
- ❑ Dissection equipment
- ❑ Dissection tray
- ❑ Blue and red water-soluble marking pens
- ❑ Laminated outline of the heart and lungs
- ❑ Colored pencils

The heart is located in the mediastinum and is on average about the size of a fist (Figure 15.5). Its **apex** is its pointy inferior tip, and its **base** is its flattened posterior side. As you can see in Figure 15.4, the heart is surrounded by a double-layered membrane called the **pericardium** (pehr-ee-KAR-dee-um). The outermost layer of the pericardium, called the **fibrous pericardium**, anchors the heart to surrounding structures. It is made of dense irregular collagenous connective tissue that is not very distensible, which helps to prevent the heart from overfilling. The inner layer, called the **serous pericardium**, is itself composed of two layers. The outer portion, called the **parietal pericardium**, is functionally fused to the fibrous pericardium. The parietal pericardium folds over on itself to attach to the heart muscle and form the inner portion called the **visceral pericardium**, also known as the **epicardium**. Between the parietal and visceral layers we find a thin layer of serous fluid that occupies a narrow potential space called the **pericardial cavity**. The fluid within the pericardial cavity helps the heart to beat without friction.

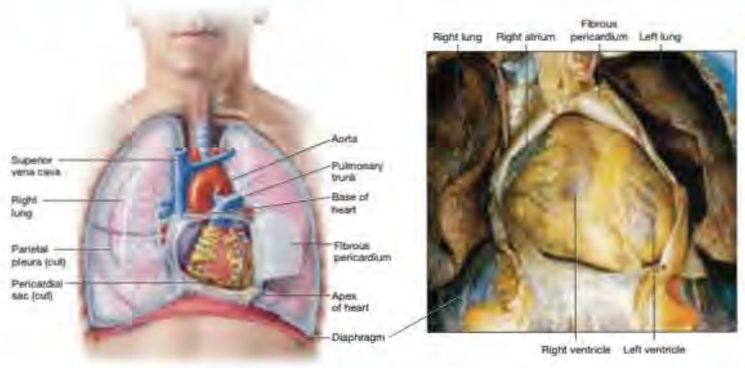


FIGURE 15.3 Thoracic cavity.

HINTS & TIPS sidebars appear throughout the book to help students navigate some of the more difficult topics in A&P.

Be Sure

UNIT QUIZZES consist of labeling, fill-in-the-blank, multiple choice, and sequencing questions that test students' ability to retain the material they completed in the lab. These sheets can be used as graded lab quizzes and/or to check attendance in the lab.

Name: _____

Section _____ Date _____

UNIT 15 REVIEW

Check Your Recall

1 Label the following parts of the heart on Figure 15.13.

- ❑ Anterior interventricular artery
- ❑ Aorta
- ❑ Circumflex artery
- ❑ Inferior vena cava
- ❑ Pulmonary trunk
- ❑ Pulmonary veins
- ❑ Right coronary artery
- ❑ Superior vena cava

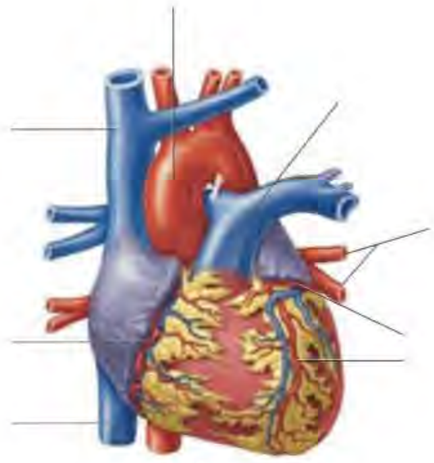


FIGURE 15.13 Heart, anterior view.

Be Aware

Textbooks are expensive, and the last thing a student needs is to spend too much for a lab manual. Morton Publishing is committed to providing high-quality products at reasonable prices.

It is our sincere hope that *Exploring Anatomy in the Laboratory* will provide you with the tools necessary for a productive and interesting laboratory experience. *We welcome all comments and suggestions for future editions of this book. Please feel free to contact us at* eapl@morton-pub.com or visit us at www.morton-pub.com.

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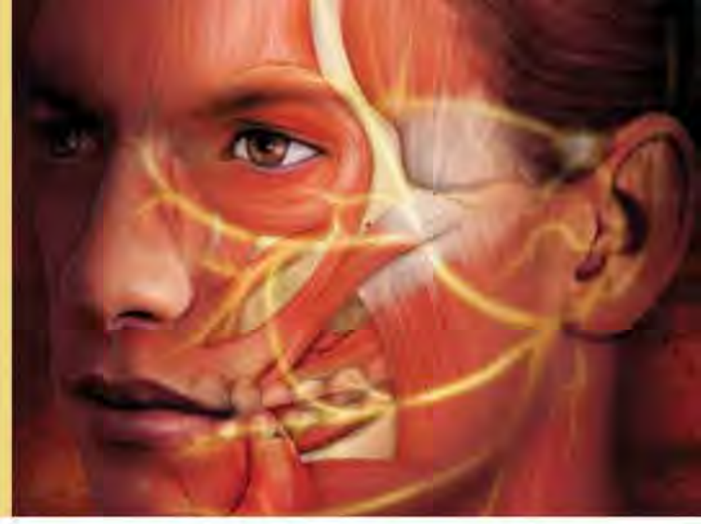


Note: Accented syllables are capitalized; for example "a-NAT-oh-mee and fiz-ee-AHL-oh-jee."

abdominal (ab-DAH-min-nul)
abducens (ab-DOO-senz)
acetabulum (ah-seh-TAB-yoo-lum)
acetylcholine (ah-SEE-til-koh-leen)
acinar (AY-sin-ahr)
acromial (ah-KROH-mee-ul)
acromioclavicular (ah-KROH-mee-oh-clah-VIK-yoo-lur)
acromion (ah-KROH-mee-ahn)
adenohypophysis (ad-en-oh-hy-POF-ih-sis)
adipocytes (AD-ih-poh-syt'z)
adrenocorticotropic (ah-dree-noh-kohr-tih-koh-TROH-pik)
adventitia (ad-ven-TISH-uh)
agglutination (ah-gloo-tin-AY-shun)
albuginea (al-byoo-JIN-ee-uh)
aldosterone (al-DAHS-tur-ohn)
alveolar (al-vee-OH-lahr)
alveoli (al-vee-OH-lye)
amphiarthroses (am-fee-ahr-THROH-seez)
antebrachial (an-tee-BRAY-kee-ul)
antecubital (an-tee-KYU-bih-tul)
antidiuretic (an-ty-dy-yoo-RET-ik)
aorta (ay-OHR-tah)
arachnoid mater (ah-RAK-noyd MAH-tur)
arcuate (ARK-yoo-it)
areola (aehr-ee-OH-lah)
aganulocytes (AY-gran-yoo-loh-syt'z)
arrector pili (ah-REK-tohr PIL-eye)
arytenoid (ah-RIT-eh-noyd)
atrioventricular (ay-tree-oh-ven-TRIK-yoo-lur)
atrium (AY-tree-um)
auricle (OHR-ih-kul)
axillary (AX-il-ehr-ee)
axon (AX-ahn)
azygos (ay-ZY-gus)
baroreceptor (BEHR-oh-ree-sep-tohr)
basal lamina (BAY-zul LAM-in-uh)
basale (bah-SAH-lay)
basophils (BAY-soh-filz)
biceps brachii (BY-seps BRAY-kee-eye)
brachial (BRAY-kee-uhl)
brachialis (bray-kee-AL-iss)
brachiocephalic (bray-kee-oh-seh-FAL-ik)
brachioradialis (bray-kee-oh-ray-dee-AL-iss)
bronchi (BRONG-kye)
bronchial (BRONG-kee-uhl)
bronchioles (BRONG-kee-ohlz)
bronchomediastinal (brongk-oh-mee-dee-ah-STYN-uhl)
buccal (BYOO-kul)
bulbourethral (bul-boh-yoo-REETH-ruhl)
bursae (BURR-see)
calcaneal (kal-KAY-nee-uhl)
calcitonin (kal-sih-TOH-nin)
calvaria (kal-VEHR-ee-uh)
calyces (KAY-lih-seez)
canaliculi (kan-ah-LIK-yoo-lee)
canines (KAY-nynz)
capitulum (kah-PIT-yoo-lum)
carina (kar-EYE-nah)
carneae (kar-NEE-ee)
carotid (kah-RAWT-id)
carpals (KAR-pulz)
carpi radialis (KARP-eye RAY-dee-al-iss)
carpi ulnaris (KARP-eye ul-NEHR-iss)
cauda equina (KOW-dah eh-KWY-nah)
cecum (SEE-kum)
celiac (SEEL-ee-ak)
centrioles (SEN-tree-ohlz)
centromere (SEN-troh-meer)
centrosome (SEN-troh-sohm)
cephalic (sef-AL-ik)
cerebellum (sehr-eh-BELL-um)
cerebrospinal (seh-ree-broh-SPY-nul)
cerebrum (seh-REE-brum)
cervical (SIR-vih-kul)
cervicis (SIR-vih-sis)
chiasma (ky-AZ-mah)
chonchae (KAHN-kee)
chondrocytes (KAHN-droh-syt'z)
chordae tendineae (KOHRD-ee tin-din-EE-ee)
choroid (KOHR-oyd)
chromatin (KROH-mah-tin)
chromosomes (KROH-moh-sohmz)
cilia (SILL-ee-uh)
ciliary body (sill-ee-AER-ee)
circumflex (SIR-kum-flex)
cisterna chyli (sis-TER-nah KY-lee)
cisternae (sis-TER-nee)
clitoris (KLIT-uhr-is)
coccyx (KAHX-iks)
cochlea (KOHK-lee-ah)
colloid (KAWL-oyd)
conchae (KAHN-kee)
conjunctiva (kon-junk-TY-vah)
conus medullaris (KOHN-us med-yoo-LEHR-us)
coracoid (KOHR-ah-koyd)
cornea (KOHR-nee-ah)
corneum (KOHR-nee-um)

corniculate (kor-NIK-yoo-layt)
coroid (KOHR-oyd)
coronal (koh-ROH-nul)
coronary (KOHR-oh-nehr-ee)
corpora cavernosa (kohr-POHR-ah kah-ver-NOH-sah)
corpus callosum (KOHR-pus kal-OH-sum)
corpus luteum (KOHR-pus LOO-tee-um)
corpus spongiosum (KOHR-pus spun-jee-OH-sum)
cranial (KRAY-nee-ul)
cremaster (kreh-MASS-ter)
cricoid (KRY-koyd)
cricothyroid (kry-koh-THY-royd)
cricothyroidotomy (kry-koh-thy-royd-AH-toh-mee)
crista galli (KRIS-tah GAHL-ee)
cruciate (KROO-shee-iht)
crural (KROO-rul)
cubital (KYOO-bit-uhl)
cuneiform (kyoo-NEE-ih-form)
cystic (SIS-tik)
cytokinesis (sy-toh-kin-EE-sis)
cytoplasm (SY-toh-plaz-m)
cytosol (SY-toh-sahl)
deciduous (dih-SIJ-oo-us)
dendrites (DEN-drytz)
denticulate ligaments (den-TIK-yoo-lit)
detrusor (dee-TROO-sohr)
diaphragm (DY-uh-fram)
diaphysis (dy-AEH-fih-sis)
diarthroses (dy-ar-THROH-seez)
diencephalon (dy-en-SEF-ah-lahn)
digital (DIJ-it-ul)
dorsalis pedis (dohr-SAL-is PEE-dis)
ductus deferens (DUK-tuss DEF-er-ahnz)
duodenum (doo-AH-den-um)
dura (DOO-rah MAH-ter)
endolymph (EN-doh-limf)
endometrium (en-doh-MEE-tree-um)
endomysium (en-doh-MY-see-um)
endoneurium (en-doh-NOOR-ee-um)
endoplasmic reticulum (en-doh-PLAZ-mik reh-TIK-yoo-lum)
endosteum (en-DAH-stee-um)
ependymal (eh-PEN-dih-mul)
epicardium (ep-ee-KAR-dee-um)
epicondyles (ep-ee-KAHN-dylz)
epididymis (ep-ih-DID-ih-miss)
epidural (ep-ih-DOO-rul)
epiglottis (ep-ih-GLAH-tiss)
epimysium (ep-ee-MY-see-um)
epineurium (ep-ih-NOOR-ee-um)
epiphyseal (eh-PIF-ih-seez-ul)
epiphysis (eh-PIF-ih-seez)
epiploic (ep-ih-PLOH-ik)
epithalamus (ep-ih-THAL-ih-mus)
epithelial (ep-ih-THEE-lee-uhl)
eponychium (ep-oh-NIK-ee-um)
erector spinae (eh-REK-tohr SPY-nee)
erythrocytes (eh-RITH-roh-syt'z)
erythropoietin (eh-rith-roh-POY-ee-tin)
esophagus (eh-SOF-ah-gus)
falciform (FALL-sih-form)
falx cerebelli (FALS sehr-eh-BELL-ee)
falx cerebri (FALS seh-REE-bree)
fascia (FASH-ah)
fascicles (FASS-ih-kullz)
faciculata (fah-SIK-yoo-lah-tah)
femoral (FEM-oh-rul)
fibroblasts (FY-broh-blastz)
fibula (FIB-yoo-lah)
fibularis (fib-yoo-LEHR-iss)
filum terminale (FY-lum ter-mee-NAL-ay)
fimbriae (FIM-bree-ay)
flagella (flah-JEL-uh)
fovea capitis (FOH-vee-ah CAP-ih-tiss)
fovea centralis (FOH-vee-uh sin-TRAL-iss)
frontal (FRUHN-tul)
funiculi (fun-IK-yoo-lye)
ganglia (GAYNG-lee-uh)
gastrocnemius (gas-trawk-NEE-mee-us)
gingivae (JIN-jih-vay)
glomerulosa (glom-ehr-yoo-LOH-sah)
glomerulus (gloh-MEHR-yoo-lus)
glossopharyngeal (glah-soh-fehr-IN-jee-ul)
glucagon (GLOO-kah-gawn)
glucocorticoids (GLOO-koh-kort-ih-koydz)
gluteal (GLOO-tee-ul)
glycoproteins (GLY-koh-proh-teenz)
Golgi (GOHL-jee)
gracilis (grah-SILL-iss)
granulosum (gran-yoo-LOH-sum)
gyri (JY-ree)
haustra (HAW-struh)
hemoglobin (HEE-moh-glohb-in)
hemolysis (heem-AH-lih-sis)
hepatopancreatic ampulla (heh-PAH-toh-payn-kree-at-ik am-POOL-ah)
hilum (HY-lum)
humerus (HYOO-mur-us)
hyaline (HY-ah-lin)
hypothalamus (hy-poh-THAL-uh-muss)
hypophyseal (hy-PAW-fih-see-ul)
ileocecal (ill-ee-oh-SEE-kul)
ileum (ILL-ee-um)
iliac (ILL-ee-ak)
iliocostalis (ill-ee-oh-kawst-AL-iss)
iliopsoas (ill-ee-oh-SOH-uhs)
ilium (ILL-ee-um)
incus (ING-kus)
infraspinatus (in-frah-spin-AY-tus)
infundibulum (in-fun-DIB-yoo-lum)
inguinal (IN-gwih-nul)
integumentary (in-TEG-yoo-MEN-tuh-ree)
intercalated (in-TER-kah-layt-ed)
intertrochanteric (in-ter-troh-kan-TEHR-ik)
intertubercular sulcus (in-ter-too-BUR-kyoo-lur SUL-kuss)
ischium (ISS-kee-um)
islets (EYE-lets)
jejunum (jeh-JOO-num)
jugular (JUG-yoo-lur)
juxtaglomerular (jux-tah-gloh-MEHR-yoo-lur)
keratinocytes (kehr-ah-TIN-oh-syt'z)

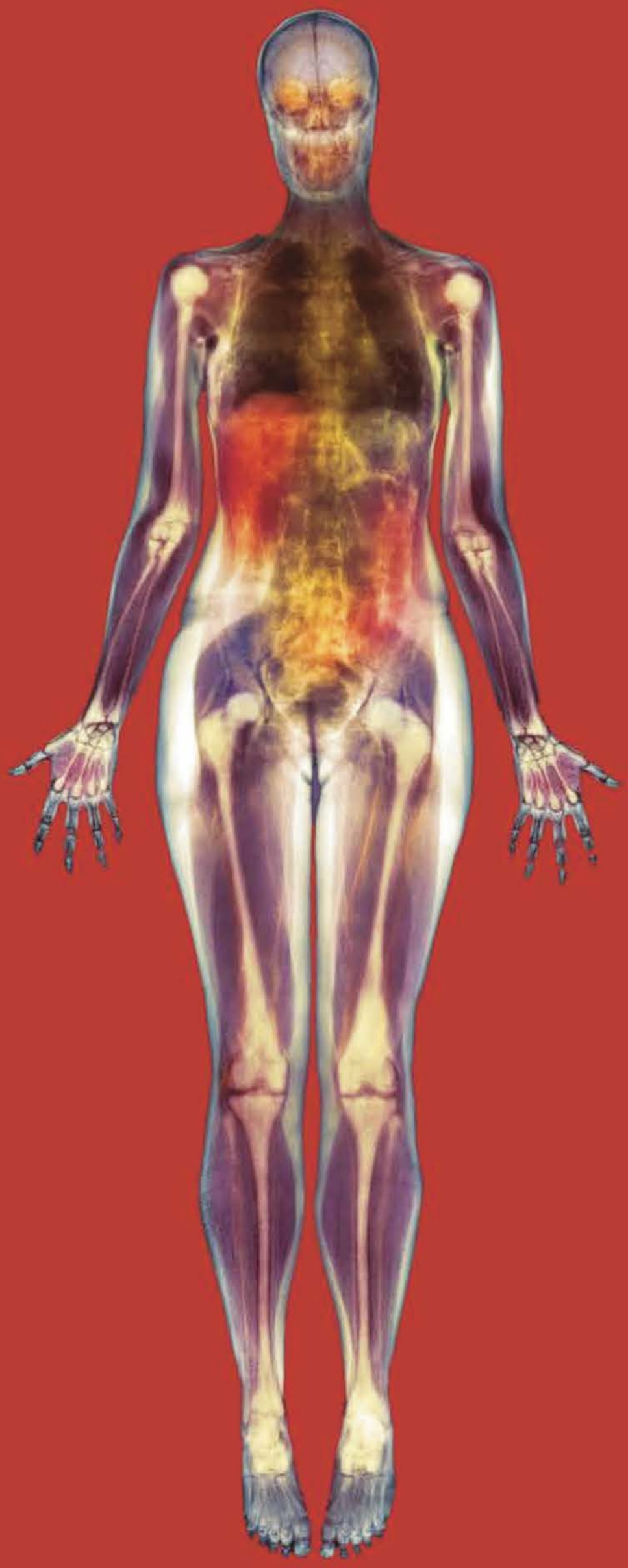
labia (LAY-bee-ah)
lacerum (LAS-er-um)
lacrimal (LAK-rih-mul)
lacrimal caruncle (LAK-rih-mul kar-UN-kul)
lacteal (LAK-teel)
lacunae (lah-KOO-nee)
lambdoid (LAM-doyd)
lamellae (lah-MELL-ee)
laryngopharynx (lah-RING-oh-fehr-inks)
larynx (LEHR-inks)
latissimus dorsi (lah-TISS-ih-muss DOHR-sye)
leukocytes (LOO-koh-syt'z)
linea aspera (LIN-ee-ah ASS-per-ah)
lingual (LING-yoo-uhl)
longissimus (lawn-JISS-ih-muss)
lucidum (LOO-sid-um)
lumbar (LUHM-bahr)
lunula (LOON-yoo-luh)
luteinizing (LOO-tee-in-aye-zing)
lymph (LIMF)
lymphocytes (LIMF-oh-syt'z)
lysosomes (LY-soh-zohmz)
macula densa (MAK-yoo-lah-DEN-sah)
macula lutea (MAK-yoo-lah LOO-tee-ah)
malleolus (mal-ee-OH-lus)
malleus (MAL-ee-us)
mammary (MAM-uh-ree)
manubrium (mah-NOO-bree-um)
maxillae (mak-SILL-ee)
mediastinum (mee-dee-ass-TY-num)
medius (MEE-dee-us)
medulla oblongata (meh-DOOL-uh ahb-lahn-GAH-tuh)
meiosis (my-OH-sis)
melanin (MEL-uh-nin)
melanocytes (mel-AN-oh-syt'z)
melatonin (mel-uh-TOH-nin)
meninges (meh-NIN-jeez)
menisci (men-ISS-kee)
mental (MEN-tul)
mesenchyme (MES-en-ky'm)
mesentery (MEZ-en-tehr-ee)
metopic (met-AHP-ik)
microglial (my-kroh-GLEE-ul)
microvilli (my-kroh-VIL-eye)
micturition (mik-chur-ISH-un)
mineralocorticoids (min-er-al-oh-KORT-ih-koydz)
mitochondria (my-toh-KAHN-dree-ah)
mitosis (my-TOH-sis)
mitral (MY-trul)
monocytes (MAHN-oh-syt'z)
mons pubis (MAHNS PYOO-biss)
musculocutaneous (musk-yoo-loh-kyoo-TAY-nee-us)
myelin (MY-lin)
myocardium (MY-oh-kar-dee-um)
myocytes (MY-oh-syt'z)
myofibrils (my-oh-FY-brillz)
myometrium (MY-oh-mee-tree-um)
myosin (MY-oh-sin)
nasal (NAY-zul)
nasopharynx (NAYZ-oh-fehr-inks)
nephrons (NEF-rahnz)
neurilemma (noor-ih-LEM-ah)
neuroglial (noor-oh-GLEE-uhl)
neurohypophysis (noor-oh-hy-POF-ih-sis)
neurons (NOOR-ahnz)
neutrophils (NOO-troh-filz)
nuchal (NOO-kul)
nucleolus (noo-klee-OH-lus)
nucleus (NOO-klee-us)
obturator (AHB-too-ray-tohr)
occipital (ahk-SIP-ih-tul)
ocular (AWK-yoo-lur)
oculomotor (ahk-yoo-loh-MOH-tohr)
olecranon (oh-LEK-rah-nahn)
oligodendrocytes (oh-lig-oh-DEN-droh-syt'z)
omentum (oh-MEN-tum)
oocytes (OH-oh-syt'z)
oogenesis (OH-oh-gen-eh-sis)
oogonia (oh-oh-GOH-nee-ah)
oral (OH-rul)
orbicularis oculi (ohr-bik-yoo-LEHR-iss AWK-yoo-lye)
orbital (OHR-bit-ul)
organelles (ohr-gan-ELLZ)
oropharynx (OHR-oh-fehr-inks)
osseous (AHS-see-us)
osteoblashs (AH-stee-oh-blasts)
osteoclasts (AH-stee-oh-klasts)
osteocytes (AH-stee-oh-syt'z)
osteogenic (ah-stee-oh-JEN-ik)
osteons (AH-stee-ahnz)
otic (OH-tik)
oxytocin (awks-ee-TOH-sin)
palate (PAL-it)
palatine (PAL-ah-teen)
palmar (PAHL-mur)
palpebrae (pal-PEE-bray)
pancreas (PAYN-kree-iss)
papillae (pah-PILL-ee)
parietal (pah-RY-eh-tul)
parotid (pah-ROT-id)
patella (puh-TEL-uh)
patellar (puh-TEL-ur)
pectinate (PEK-tin-et)
pectineus (pek-TIN-ee-uhs)
pelvic (PEL-vik)
pericardial (pehr-ee-KAR-dee-ul)
pericardium (pehr-ee-KAR-dee-um)
perilymph (PEHR-ee-limf)
perimetrium (pehr-ee-MEE-tree-um)
perimysium (pehr-ee-MY-see-um)
perineurium (pehr-ee-NOOR-ee-um)
periodontal ligament (pehr-ee-oh-DAHN-tuhl)
periosteum (pehr-ee-AH-stee-um)
peristalsis (pehr-ih-STAHL-sis)
peritoneal (pehr-ih-toh-NEE-ul)
Peroxisomes (per-AWKS-ih-zohms)
pharyngotympanic (fah-ring-oh-tim-PAN-ik)
pharynx (FEHR-inks)
phospholipid (FAHS-foh-lip-id)
phrenic (FREN-ik)

pia mater (PEE-ah MAH-tur)
pineal (pin-EE-ul)
pituitary (pih-TOO-ih-tehr-ee)
plantar (PLAN-tahr)
pleural (PLOO-ruhl)
pneumothorax (noo-moh-THOHR-ax)
podocytes (POH-doh-syt'z)
popliteal (pop-lih-TEEL)
porta hepatis (POR-tuh heh-PAH-tis)
prostate (PRAH-stayt)
pseudostratified (SOO-doh-strat-ih-fy'd)
pterygoid (TEHR-ih-goyd)
pubic (PYOO-bik)
pubis (PYOO-bis)
pudendal nerve (poo-DEN-dal)
pylorus (py-LOHR-us)
rami (RAY-mee)
Ranvier (rahn-vee-ay)
renal (REE-nul)
rete testis (REE-tee TES-tis)
retina (RET-in-ah)
retroperitoneal (reh-troh-per-ih-toh-NEE-ul)
ribosomes (RY-boh-zohmz)
rugae (ROO-ghee)
saccule (SAK-yool)
sacroiliac (say-kroh-ILL-ee-ak)
sacrum (SAY-krum)
sagittal (SAJ-ih-tul)
saphenous (SAF-en-us)
sarcolemma (sar-koh-LEM-uh)
sarcomere (SAR-koh-meer)
sarcoplasm (SAHR-koh-plazm)
sarcoplasmic reticulum (SAR-koh-plaz-mik reh-TIK-yoo-lum)
sartorius (sar-TOHR-ee-us)
scapula (SCAP-yoo-lah)
scapular (SKAP-yoo-lur)
sciatic (sy-AEH-tik)
sclera (SKLEHR-ah)
sebaceous (seh-BAY-shuhs)
sebum (SEE-bum)
sella turcica (SELL-uh TUR-sih-kah)
semimembranosus (sem-eye-mem-brah-NOH-sus)
seminiferous (sem-ih-NIF-er-us)
semitendinosus (sem-eye-ten-din-OH-sus)
seromucous (seer-oh-MYOO-kuss)
serous (SEER-us)
serratus anterior muscle (ser-AY-tus)
soleus (SOHL-ee-us)
spermatogenesis (sper-mat-oh-JEN-ih-sis)
spermatogonia (sper-mat-oh-GOH-nee-ah)
sphenoid (SFEE-noyd)
spinae (SPY-nee)
spinalis muscles (spy-NAL-iss)
spinosum (spin-OH-sum)
spirometer (spy-RAH-met-ur)
splenius capitis (SPLEN-ee-us CAP-it-us)
squamous (SKWAY-mus)
stapes (STAY-peez)
sternal (STUR-nul)
sternocleidomastoid (stern-oh-kly-doh-MASS-toyd)
subclavian (sub-KLAY-vee-in)
sublingual (sub-LING-gwul)
subscabularis (sub-skap-yoo-LEHR-us)
sulci (SUL-kee)
supracondylar (soo-prah-KAHN-dah-lar)
supraspinatus (soo-prah-spin-AY-tus)
sural (SOO-rul)
sutural (SOO-tchur-ul)
sutures (SOO-tchurz)
symphysis (SIM-fih-sis)
synarthroses (sin-ar-THROH-seez)
synovial (sih-NOH-vee-ul)
taeniae coli (TEE-nee-ee KOHL-eye)
talus (TAY-luss)
tarsals (TAHR-sulz)
telodendria (tee-loh-DEN-dree-uh)
telophase (TEL-oh-phayz)
teres (THER-eez)
thalamus (THAL-uh-muss)
thoracic (thoh-RASS-ik)
thympoietin (thy-moh-poh-EE-tin)
vctibia (TIB-ee-ah)
tibialis (tib-ee-AL-is)
trabeculae (trah-BIK-yoo-lee)
trachea (TRAY-kee-uh)
transversus (tranz-VUR-suss)
trapezius (trah-PEE-zee-uhs)
trigone (TRY-gohn)
triiodothyronine (try-eye-oh-doh-THY-roh-neen)
trochanter (TROH-kan-tur)
trochlea (TROH-klee-uh)
trochlear (TROH-klee-ur)
tropomyosin (trohp-oh-MY-oh-sin)
troponin (troh-POH-nin)
tympanic (tim-PAN-ik)
umbilical (um-BIL-ih-kul)
ureteral (yoo-REE-ter-ul)
ureters (YOOR-eh-terz)
urethra (yoo-REETH-rah)
uterosacral (yoot-er-oh-SAY-krul)
utricle (YOO-trih-kul)
uvea (YOO-vee-uh)
uvula (YOO-vyoo-luh)
vagus (VAY-gus)
vena cava (VEE-nuh KAY-vuh)
vermis (VER-miss)
vertebral (vur-TEE-brul)
vestibulocochlear (ves-tib-yoo-loh-KOHK-lee-ur)
villi (VILL-eye)
visceral (VISS-er-ul)
vitreous (VIT-ree-us)
xiphoid (ZY-foyd)

Contents

Introduction to Anatomical Terms

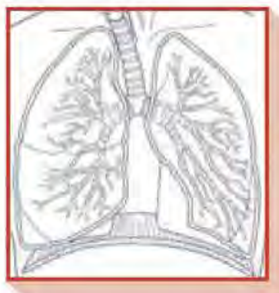
1



OBJECTIVES

Once you have completed this unit, you should be able to:

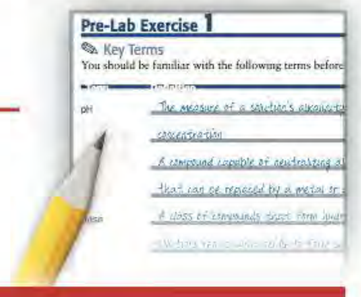
1. Demonstrate and describe anatomical position.
2. Apply directional terms to descriptions of body parts.
3. Use regional terms to describe locations on the body.
4. Locate and describe the divisions of the major body cavities and the membranes lining each cavity.
5. Demonstrate and describe anatomical planes of section.
6. Identify the organ systems, their functions, and the major organs in each system.



Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 1-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Directional Terms

Anterior (ventral) _____

Posterior (dorsal) _____

Superior (cranial) _____

Inferior (caudal) _____

Proximal _____

Distal _____

Superficial _____

Deep _____

Body Cavities and Membranes

Posterior body cavity _____

_____

Anterior body cavity _____

_____

Serous membrane _____

_____

Planes of Section

Sagittal plane _____

_____

Frontal (coronal) plane _____

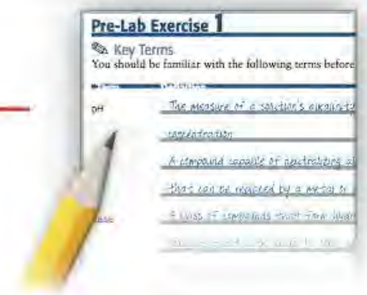
_____

Transverse plane _____

_____

Name _____ Section _____ Date _____

Pre-Lab Exercise 1-2



Organ Systems

The body has 11 organ systems, each of which contains certain organs, and each with a specific subset of functions. Note that some organs are part of more than one system.

Here you will identify the 11 organ systems, their major organ(s), and the basic function(s) of each system (Table 1.1). Use your textbook and Exercise 1-6 from this unit for reference.

TABLE 1.1 Organ Systems

Organ System	Major Organs	Organ System Functions
Integumentary system		
Skeletal system		
Muscular system		
Nervous system		
Cardiovascular system		

(continues)

TABLE **1.1** Organ Systems *(cont.)*

Organ System	Major Organs	Organ System Functions
Respiratory system		
Lymphatic system		
Urinary system		
Digestive system		
Endocrine system		
Reproductive system		

EXERCISES

1

The bullet entered the right posterior scapular region, 3 centimeters lateral to the vertebral region, 4 centimeters inferior to the cervical region, and penetrated deep to the muscle and bone, but superficial to the parietal pleura . . .

Would you believe that by the end of this unit, you will be able to translate the above sentence and also locate the hypothetical wound? Unit 1 introduces you to the world and language of **anatomy**, the study and science of the structure of the human body. Like learning any new language, this may seem overwhelming at first. The key to success is repetition and application: The more you use the terms, the easier it will be for them to become part of your normal vocabulary.

From the terminology we will move on to the organization of the body into body cavities and organ systems. Once you have completed this unit, return to the above sentence, and challenge yourself to locate the precise position of the bullet wound on an anatomical model.

Exercise 1-1

Anatomical Position

In the study of the human body, most specimens are presented in a standard position called **anatomical position**. In anatomical position the specimen is presented facing forward, with the toes pointing forward, the feet shoulder-width apart, and the palms facing outward, as shown in Figure 1.1. This presentation of anatomical specimens creates a standard point of reference that facilitates communication among scientists and healthcare professionals.

Procedure 1 Demonstrating Anatomical Position

Have your lab partner stand in a normal, relaxed way, then adjust their position so it matches anatomical position.

When you have completed this exercise, answer Check Your Understanding question 1 (p. 27).

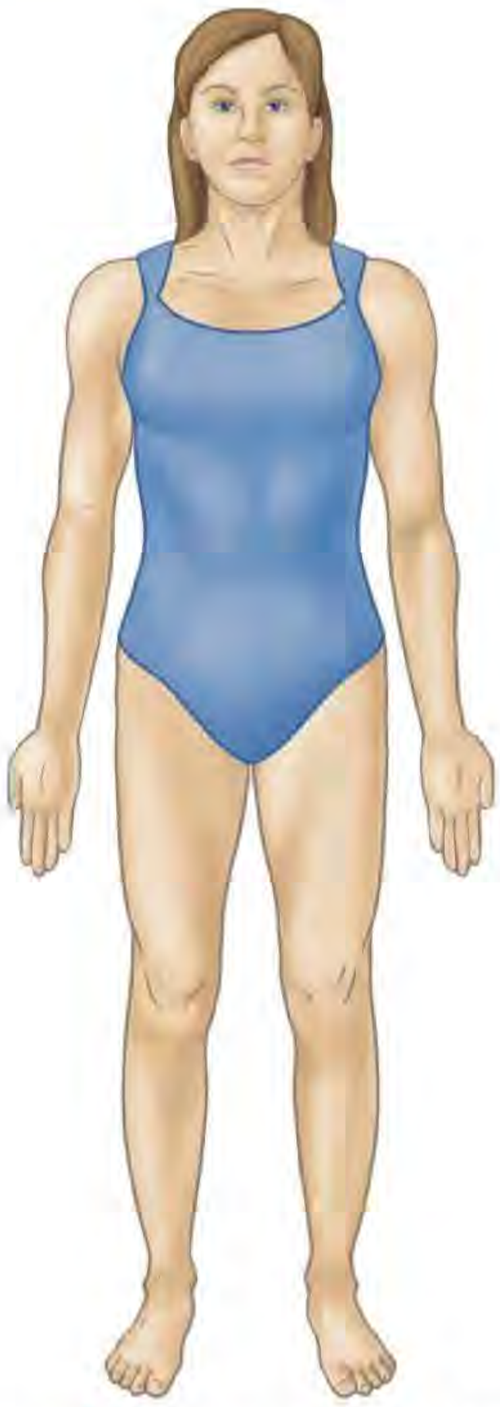


FIGURE **1.1** Anatomical position.

Exercise 1-2

Directional Terms

Another method that makes communication easier and less prone to errors is to use **directional terms** to define the location of body parts and body markings. For example, when describing a wound on the chest, we could say:

- The wound is near the middle and top of the chest; or
- The wound is on the right anterior thoracic region, 4 centimeters lateral to the sternum, and 3 centimeters inferior to the acromial region.

The second option is precise and allows the reader to exactly locate the wound. Remember that these descriptions are referring to a figure in anatomical position.

Review the definitions of the directional terms that you completed in Pre-Lab Exercise 1-1 and that are illustrated in Figure 1.2. Use these terms to fill in the correct directional term in the following practice procedure.

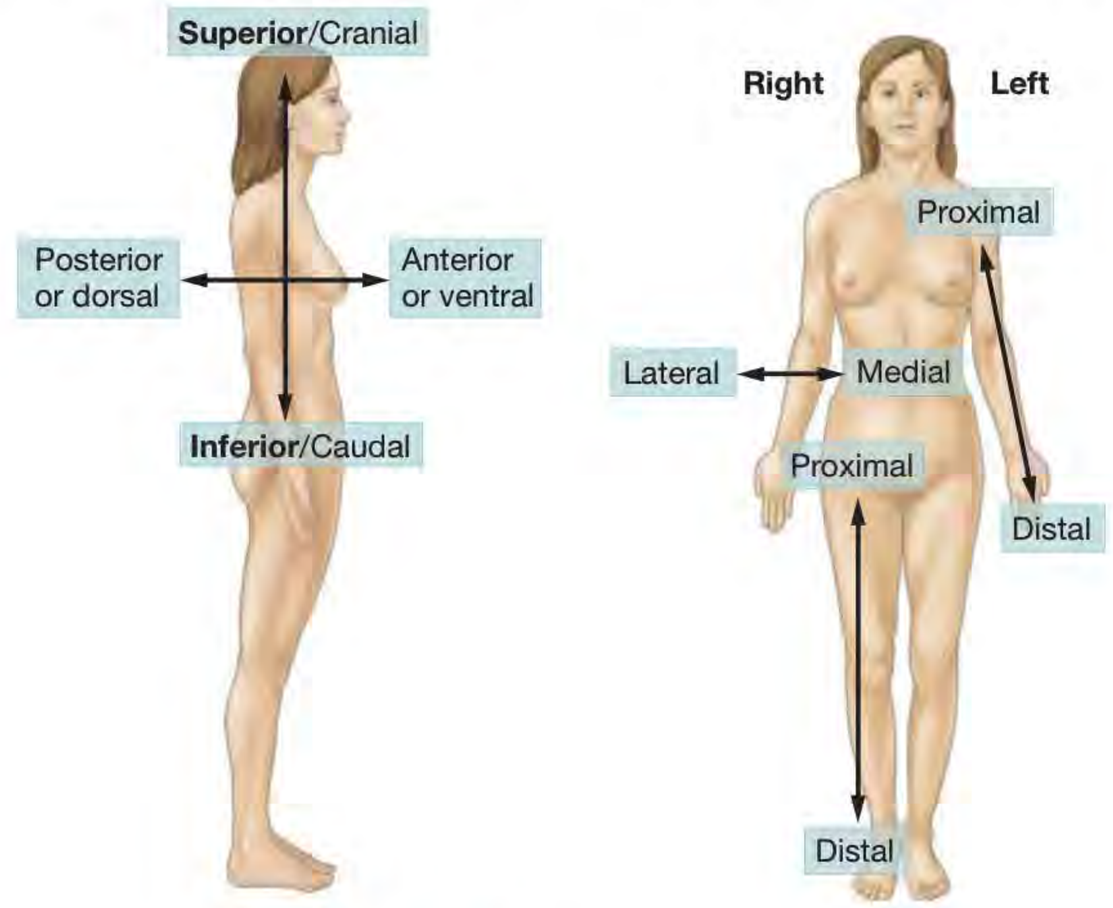


FIGURE **1.2** Directional terms.

Procedure 1 Directional Terms

Fill in the correct directional term for each of the following items. Note that in some cases, more than one directional term may apply.

The elbow is _____ to the wrist.

The chin is _____ to the nose.

The shoulder is _____ to the sternum (breastbone).

The forehead is _____ to the mouth.

The skin is _____ to the muscle.

The spine is _____ to the esophagus.

The nose is _____ to the cheek.

The spine is on the _____ side of the body.

The arm is _____ to the torso.

The knee is _____ to the hip.

Exercise 1-3

Regional Terms

MATERIALS

- ❑ Laminated outline of the human body
- ❑ Water-soluble marking pens

You may have noticed in the previous exercise that we said *thoracic region* and *acromial region* instead of using generic words such as "chest" and "shoulder." These more specific words are known as **regional terms**, and their use is another standard practice to make descriptions as specific as possible and to reduce the potential for errors in communication. For example, the "shoulder" could consist of quite a large area, whereas the "acromial region" refers to one specific location.

The following regional terms, illustrated in Figure 1.3, are among the more common terms you will encounter in your study of anatomy. Note that most of these terms are adjectives rather than nouns. This means that the term is not complete unless it is paired with the term "region." For example, we cannot say, "The wound is in the antebrachial;" we instead must say, "The wound is in the antebrachial *region*."

The following list may look daunting, but you are probably familiar with several of the terms already. For example, you likely know the locations of the "oral," "nasal," and "abdominal" regions. Watch for other terms that you may know.

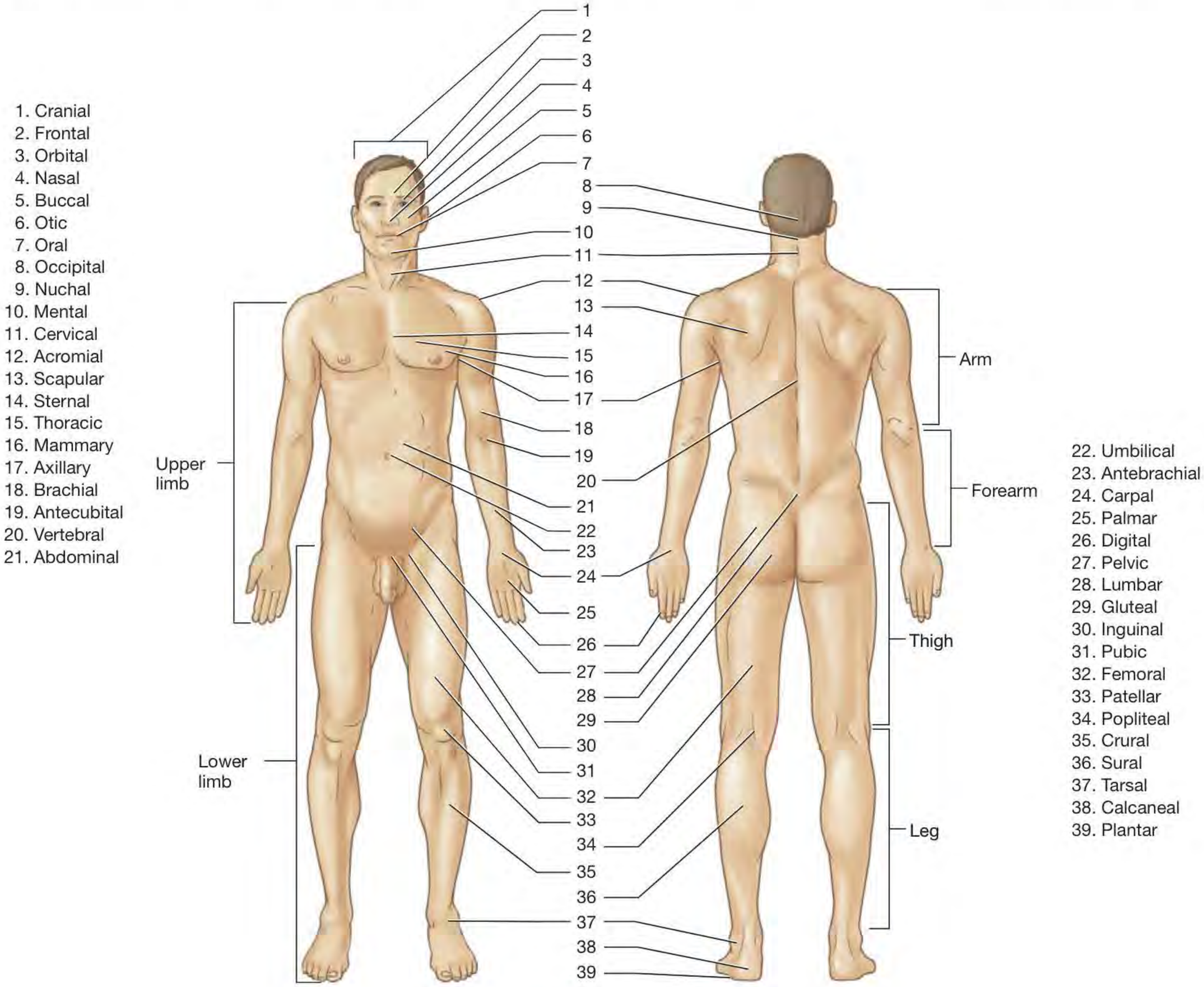


FIGURE 1.3 Regional terms.

1

Procedure 1 Labeling Body Regions

Use water-soluble markers to locate and label each of the following regions on laminated outlines of the human body. If outlines are unavailable, label the regions on Figure 1.4. When you have completed this exercise, answer Check Your Understanding questions 2 through 4 (pp. 27–29).

Adjectives

- ❑ Abdominal (**ab-DAH-min-nul**)
- ❑ Acromial (**ah-KROH-mee-ul**)
- ❑ Antebrachial (**an-tee-BRAY-kee-ul**)
- ❑ Antecubital (**an-tee-KYU-bih-tul**)
- ❑ Axillary (**AX-il-ehr-ee**)
- ❑ Brachial (**BRAY-kee-uhl**)
- ❑ Buccal (**BYOO-kul**)
- ❑ Calcaneal (**kal-KAY-nee-ul**)
- ❑ Carpal (**KAR-pul**)
- ❑ Cephalic (**sef-AL-ik**)
- ❑ Cervical (**SIR-vih-kul**)
- ❑ Cranial (**KRAY-nee-ul**)
- ❑ Crural (**KROO-rul**)
- ❑ Digital (**DIJ-it-ul**)
- ❑ Femoral (**FEM-oh-rul**)
- ❑ Frontal (**FRUHN-tul**)
- ❑ Gluteal (**GLOO-tee-ul**)
- ❑ Inguinal (**IN-gwih-nul**)
- ❑ Lumbar (**LUHM-bahr**)
- ❑ Mammary (**MAM-uh-ree**)
- ❑ Mental (**MEN-tul**)
- ❑ Nasal (**NAY-zul**)
- ❑ Occipital (**aks-SIP-ih-tul**)
- ❑ Oral (**OH-rul**)
- ❑ Orbital (**OHR-bit-ul**)
- ❑ Otic (**OH-tik**)
- ❑ Palmar (**PAHL-mur**)
- ❑ Patellar (**pah-TEL-ur**)
- ❑ Pelvic (**PEL-vik**)
- ❑ Plantar (**PLAN-tahr**)
- ❑ Popliteal (**pop-lih-TEEL**)
- ❑ Pubic (**PYOO-bik**)
- ❑ Scapular (**SKAP-yoo-lur**)
- ❑ Sternal (**STUR-nul**)
- ❑ Sural (**SOO-rul**)
- ❑ Tarsal (**TAR-sul**)
- ❑ Thoracic (**thoh-RASS-ik**)
- ❑ Umbilical (**um-BIL-ih-kul**)
- ❑ Vertebral (**vur-TEE-brul**)

Nouns

- ❑ Arm
- ❑ Forearm
- ❑ Leg
- ❑ Lower limb
- ❑ Thigh
- ❑ Upper limb

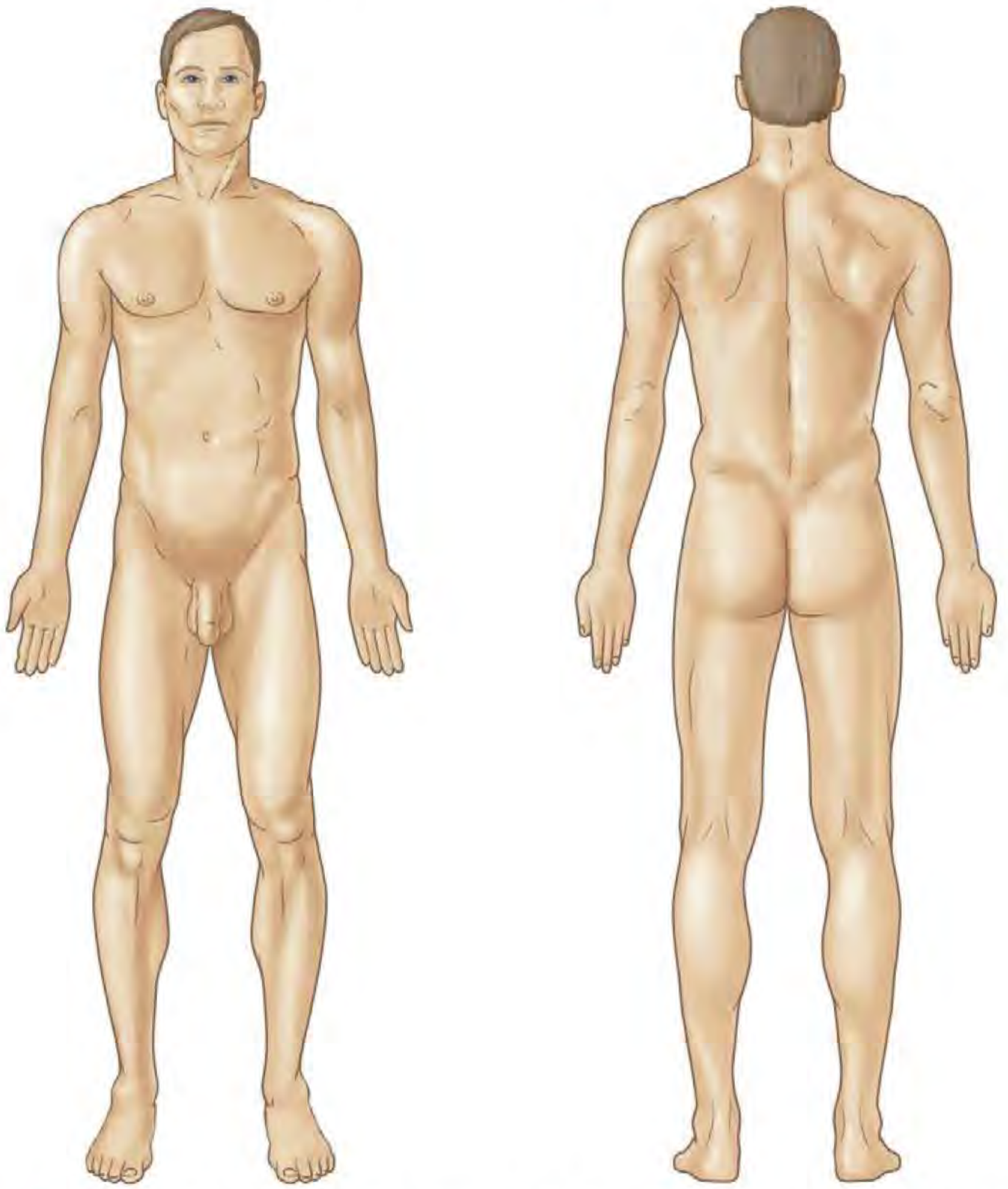


FIGURE **1.4** Anterior and posterior views of the human body in anatomical position.

Exercise 1-4

Body Cavities and Membranes

MATERIALS

- ❑ Human torso models
- ❑ Fetal pigs (or other preserved small mammals)
- ❑ Dissection kits/dissection trays

The body is divided into several fluid-filled cavities, each of which contains specific organs. In this exercise you will identify the body cavities and the organs contained within each cavity.

As you can see in Figure 1.5, there are two major body cavities, each of which is subdivided into smaller cavities, as follows:

1. **Posterior (dorsal) body cavity.** As implied by its name, the **posterior body cavity** is largely on the posterior, or dorsal, side of the body. It contains two smaller cavities:
   a. **Cranial cavity.** The **cranial cavity** is the area encased by the skull. It contains the brain and the special sense organs such as the eyes and the organs for hearing.
   b. **Vertebral** (or **spinal**) **cavity.** The **vertebral cavity** is the area encased by the vertebrae. It contains the spinal cord.
2. **Anterior (ventral) body cavity.** The **anterior body cavity** is largely on the anterior, or ventral, side of the body. It has two main divisions: the **thoracic cavity** (thoh-RASS-ik), which is superior to the diaphragm, and the **abdominopelvic cavity** (ab-dom-ih-noh-PEL-vik), which is inferior to the diaphragm. Within the thoracic and abdominopelvic cavities are smaller subcavities, several of which are formed by thin sheets of tissue called **serous membranes** (SEER-us). Cells of these membranes produce a thin, watery fluid called **serous fluid** that lubricates organs so they move within the

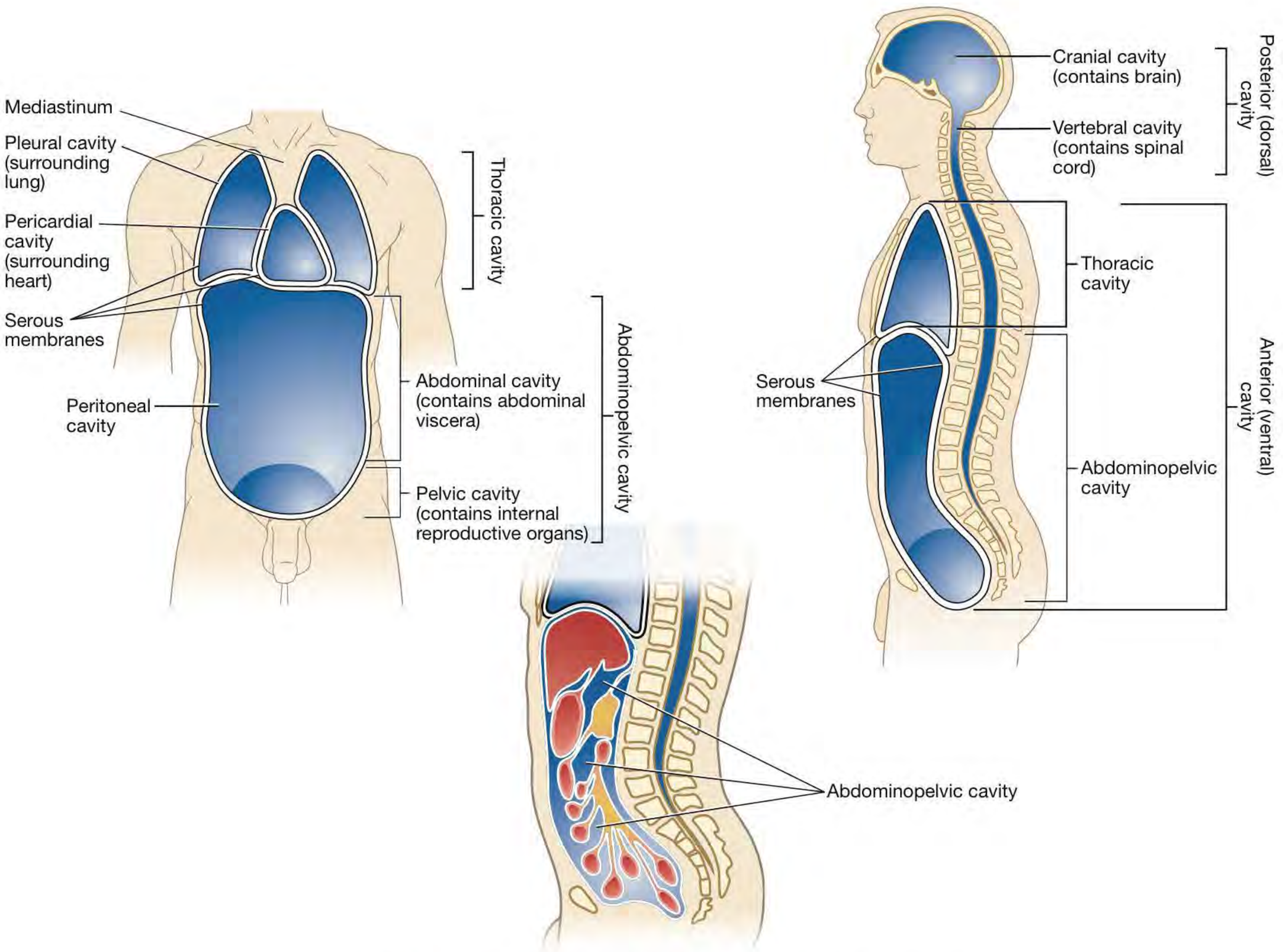


FIGURE 1.5 Anterior and lateral views of the body cavities.

cavity with little friction. Serous membranes are composed of two layers: an outer **parietal layer** (pah-RY-eh-tul), which is attached to the surrounding structures, and an inner **visceral layer** (VISS-er-ul), which is attached to the organ or organs of the ventral cavity. Between the parietal and visceral layers is a thin potential space that contains serous fluid. This potential space is also referred to as a cavity. The following are the divisions of the anterior cavity:

a. **Thoracic cavity.** The **thoracic cavity** encompasses the area encased by the ribs. We find the following smaller cavities within the thoracic cavity:
   (1) **Pleural cavities.** Each **pleural cavity** (PLOO-rul) surrounds one of the lungs. The pleural cavities are located between two serous membranes called the **pleural membranes.** The **parietal pleura** is attached to the body wall, and the **visceral pleura** is attached to the surface of the lung.
   (2) **Mediastinum.** The area between the pleural cavities, called the **mediastinum** (meh-dee-ass-TY-num), contains the great vessels, the esophagus, the trachea and bronchi, and other structures. It houses another set of serous membranes that form the **pericardial cavity** (pehr-ee-KAR-dee-ul), which surrounds the heart. The pericardial cavity is between the **pericardial membranes;** the **parietal pericardium** is attached to surrounding structures, and the inner **visceral pericardium** is attached to the heart muscle.

b. **Abdominopelvic cavity.** The **abdominopelvic cavity** encompasses the area inferior to the diaphragm and extends into the bony pelvis. It contains the **peritoneal membranes** (pehr-ih-toh-NEE-ul); the **parietal peritoneum** is attached to the body wall and surrounding structures, and the inner **visceral peritoneum** is attached to the surface of many of the organs in the cavity. Between these two layers of peritoneal membranes we find the **peritoneal cavity.** Note that some organs are posterior to the **peritoneal cavity;** such organs are said to be **retroperitoneal** (reh-troh-pehr-ih-toh-NEE-ul). The abdominopelvic cavity is divided into two smaller cavities:
   (1) **Abdominal cavity.** The area superior to the bony pelvis, called the **abdominal cavity,** houses many of the organs of the digestive, lymphatic, and urinary systems.
   (2) **Pelvic cavity.** The cavity housed within the bony pelvis, the **pelvic cavity,** contains certain organs of the reproductive system as well as certain organs of the digestive and urinary systems.

We often divide the abdominopelvic cavity into four quadrants: the right upper, right lower, left upper, and left lower quadrants. We can also divide the abdominopelvic cavity into nine regions based on a series of lines drawn over the surface of the abdomen. The regions are listed and labeled in Figure 1.6.

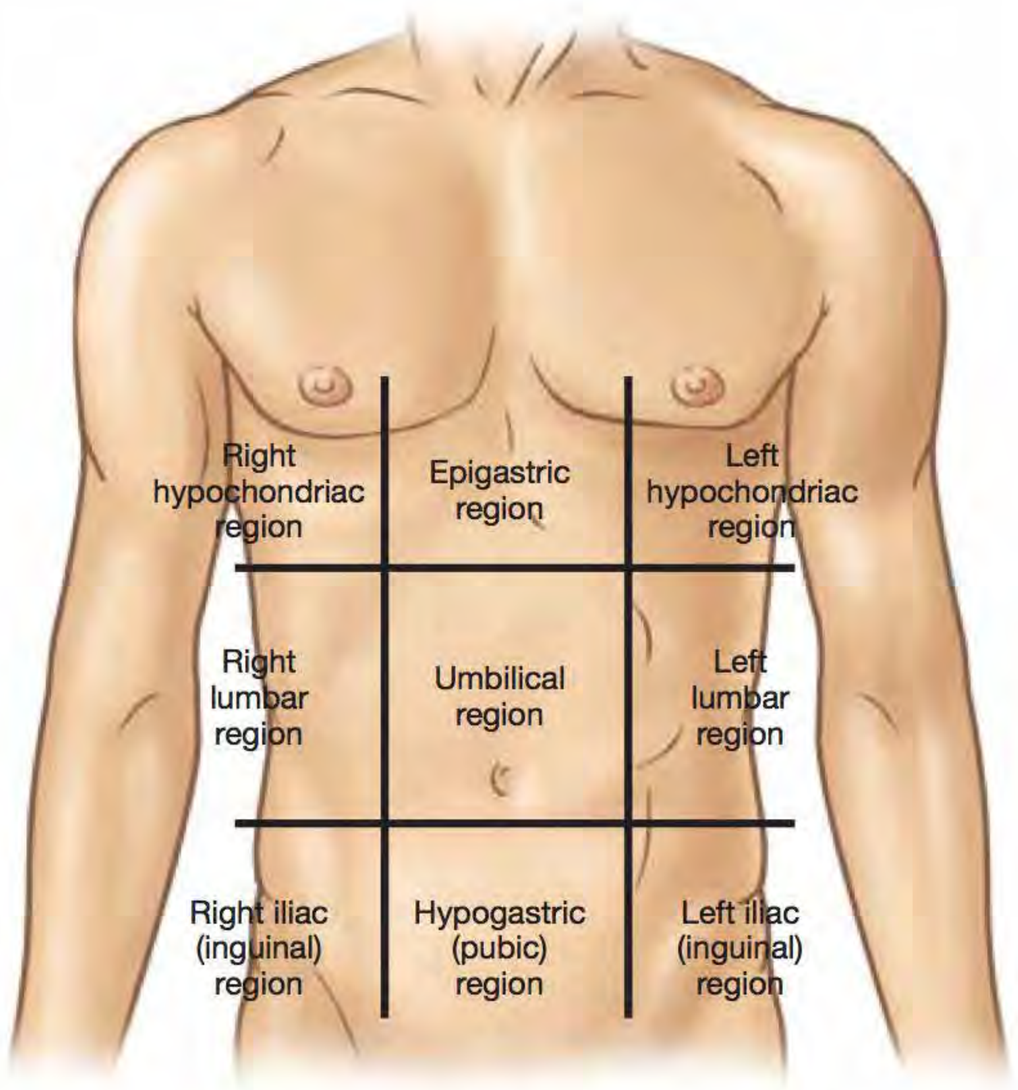


FIGURE **1.6** Regions of the abdominopelvic cavity.

Procedure 1 Body Cavities

In this procedure you will use a human torso model or a preserved small mammal such as a fetal pig, a cat, or a rat to examine the body cavities. If you are using a preserved small mammal, you may use the following procedure to open the body cavities. *Note that you will not open the animal fully in this procedure to preserve structures for future dissections.*

1. Place the animal on a dissecting tray with its dorsal (back) side facing you. Use your scalpel to make a shallow, cross-shaped incision. Make the first incision through the skin along the nape of the neck. Make the second incision from the anterior part of the skull down along the animal's midline to about 4 inches inferior to the first incision. Ensure that your incisions are shallow so you do not damage structures deep to the skin. List the organs you are able to see in Table 1.2.
2. Gently peel back the skin using a blunt dissection probe, and note the appearance of the skin and the exposed muscles, bones, and joints. If your instructor wants you to expose the brain and spinal cord, use either a scalpel or a saw to carefully cut through the skull and a section of the vertebral column.
3. When you have finished your examination of the animal's dorsal side, close the skin, and wrap the area with wet towels soaked with a preservative solution.
4. Flip the animal over, and place it in the dissecting tray with its ventral side facing you. Use a scalpel to make a shallow incision along the animal's midline from the superior neck down to its groin. Make a second incision across the animal's chest and a third incision across the animal's abdomen.
5. Using a blunt dissection probe, peel back the skin of the abdomen carefully to expose the abdominopelvic cavity, and examine its contents.
6. Gently peel back the skin of the chest and neck incisions. Use scissors or a scalpel to carefully cut through the sternum, expose the thoracic cavity, and examine its contents.

When you have opened your preserved small mammal or human torso model, locate and identify each cavity, and do the following:

1. List the organs you are able to see in Table 1.2. See Figures 1.7 and 1.8 for reference.
2. Mark each region of the abdominopelvic cavity with a pin or marking tape (if working with a torso model). Note which organs are visible in each region.

TABLE **1.2** Body Cavities and Regions of the Abdominopelvic Cavity

Cavity	Organ(s)
Posterior Cavity	
1. Cranial cavity	
2. Vertebral cavity	
Anterior Cavity	
1. Thoracic cavity	
a. Pleural cavities	
b. Mediastinum	
(1) Pericardial cavity	
2. Abdominopelvic cavity	
a. Subdivisions	
(1) Abdominal cavity	
(2) Pelvic cavity	
b. Regions	
(1) Right hypochondriac region	
(2) Epigastric region	
(3) Left hypochondriac region	
(4) Right lumbar region	
(5) Umbilical region	
(6) Left lumbar region	
(7) Right iliac region	
(8) Hypogastric region	
(9) Left iliac region	

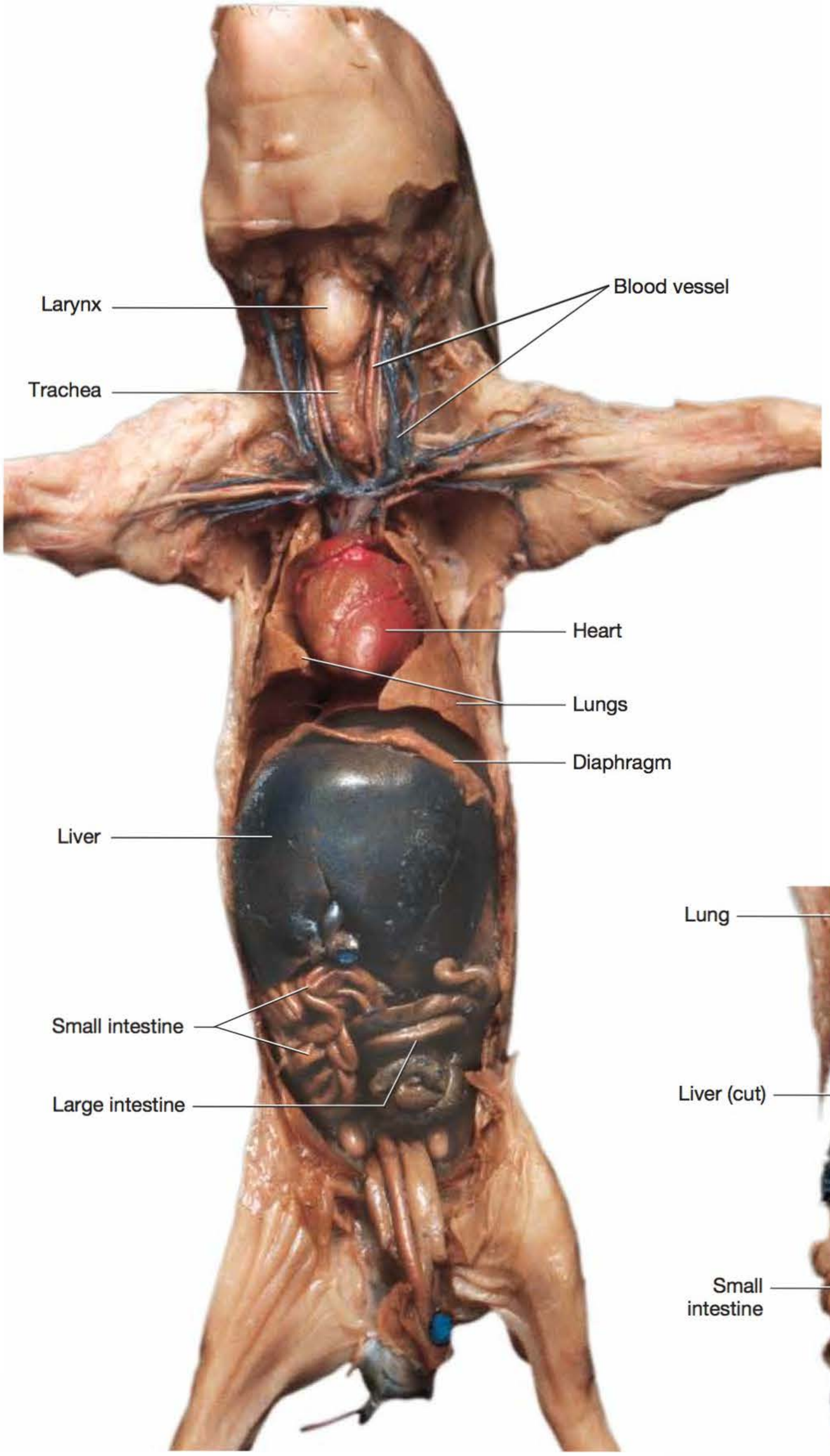


FIGURE **1.7** Ventral view of the fetal pig.

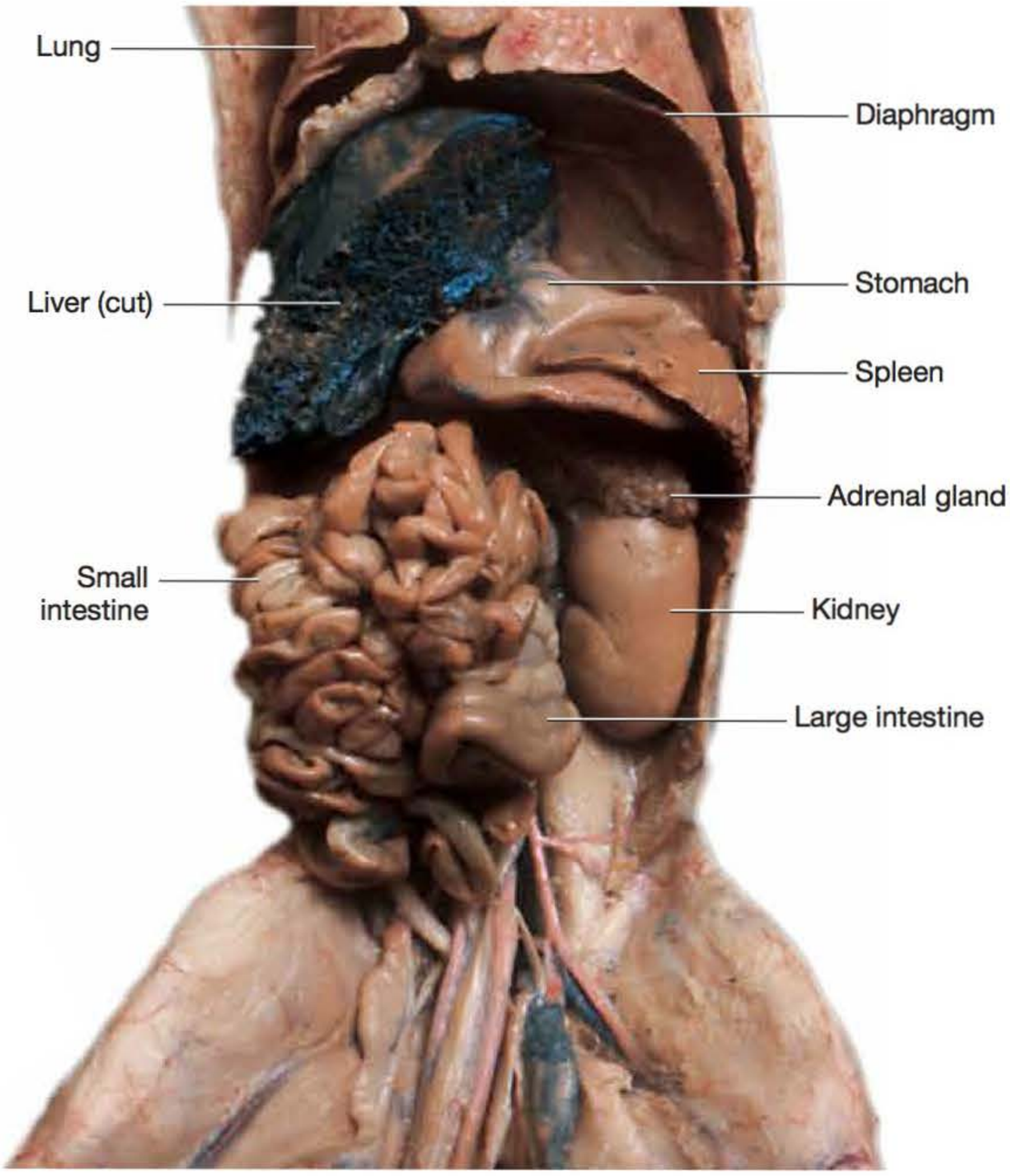


FIGURE **1.8** Abdominopelvic cavity of the fetal pig.

Procedure 2 Serous Membranes

Part A

Serous membranes are best examined on a preserved specimen such as a fetal pig, because their structure is difficult to appreciate on a model. As you dissect the fetal pig or other small mammal, look for the serous membranes listed in Table 1.3. Take care not to tear the fragile membranes, which consist of just a few layers of cells. As you identify each membrane, record in the table where you found the membrane and the structure to which the membrane is attached (the lungs, heart, abdominal wall, etc.).

TABLE **1.3** Serous Membranes

Membrane	Cavity	Structure
Parietal pleura		
Visceral pleura		
Parietal pericardium		
Visceral pericardium		
Parietal peritoneum		
Visceral peritoneum		

Part B

Draw in the body cavities on your laminated outlines of the human body or Figure 1.9. Label the serous membranes surrounding the cavity where applicable.

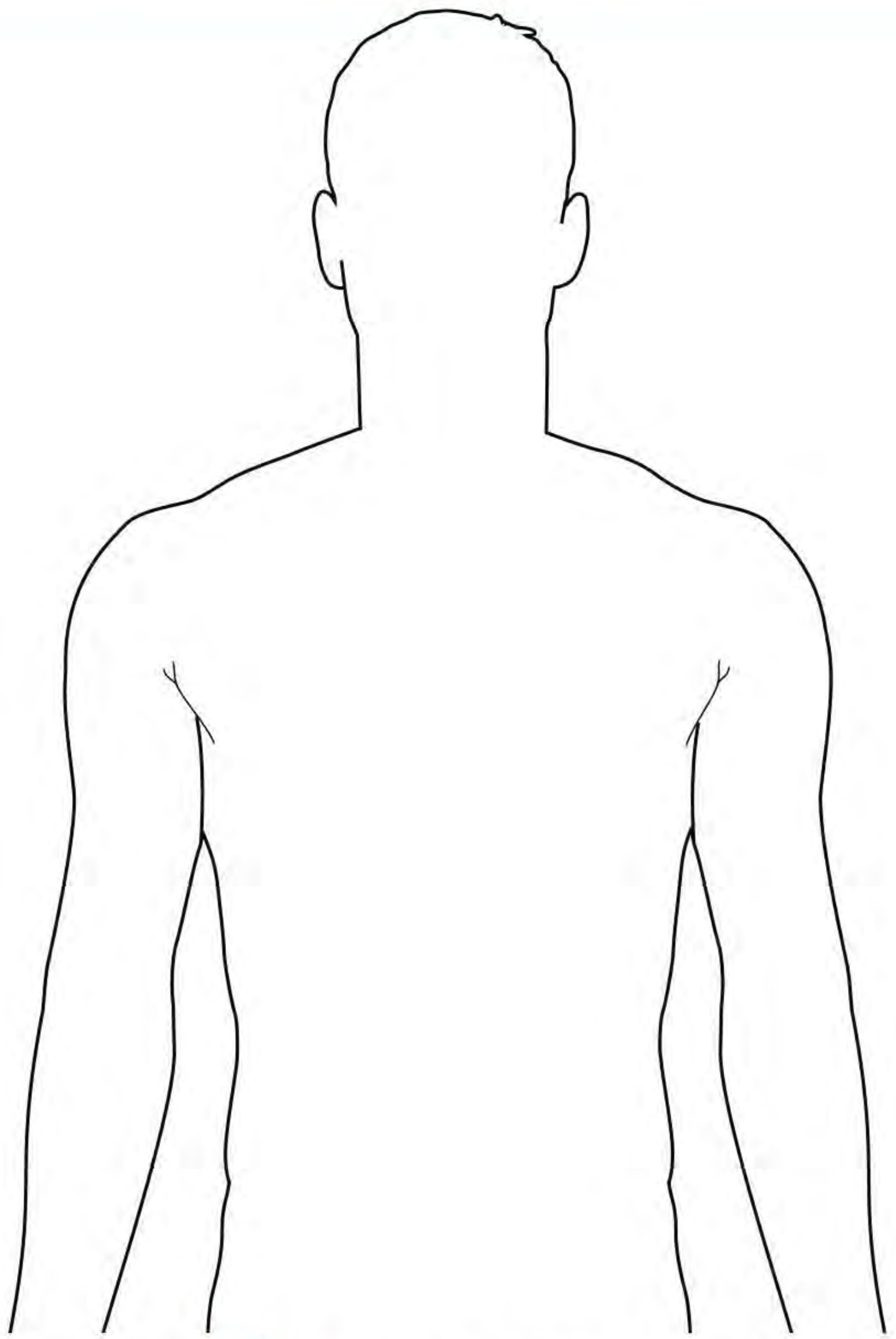


FIGURE **1.9** Anterior view of the human torso.

Procedure 3 Applications of Terms, Cavities, and Membranes

Remember this from the unit opener?

The bullet entered the right posterior scapular region, 3 centimeters lateral to the vertebral region, 4 centimeters inferior to the cervical region, and penetrated deep to the muscle and bone, but superficial to the parietal pleura . . .

Now it's your turn to combine the different anatomical terms you have used to describe a "bullet wound." Assume that you are acting as coroner, and you have a victim with three gunshot wounds. In this scenario your victim will be your fetal pig or a human torso model that your instructor has "shot." For each "bullet wound," describe the location of the wound using at least three directional terms and as many regional terms as possible, following this example. As coroner, you have to be as specific as possible, and don't forget to keep your patient in anatomical position.

Shot **1**	
Shot **2**	
Shot **3**	

Exercise 1-5

Planes of Section

MATERIALS

- ❑ Various anatomical models demonstrating planes of section
- ❑ Modeling clay
- ❑ Knife or scalpel

Often in anatomy, we need to obtain different views of the internal structure of an organ or a body cavity. These views are obtained by making an **anatomical section** along a specific plane. The commonly used planes of section, shown in Figures 1.10 and 1.11, are as follows:

1. **Sagittal plane.** A section along the **sagittal plane** (SAJ-ih-tul) divides the specimen into right and left parts. The sagittal section has two variations:
   a. **Midsagittal sections** divide the specimen into equal right and left halves.
   b. **Parasagittal sections** divide the specimen into unequal right and left parts.
2. **Frontal plane.** The **frontal plane,** also known as the **coronal plane** (koh-ROH-nul), divides the specimen into an anterior (front) part and a posterior (back) part.
3. **Transverse plane.** The **transverse plane,** also known as a **cross section** or the **horizontal plane,** divides the specimen into a superior (or proximal) part and an inferior (or distal) part.
4. **Oblique section.** An **oblique section** cuts at an angle and is intended to allow examination of structures difficult to see with standard angles. Note that an oblique section is not illustrated in Figure 1.10.

Note that although there is only a single midsagittal plane, there are a near infinite number of possible parasagittal, frontal, transverse, and oblique planes. In your study of anatomy, you will see many different examples of these planes of section.

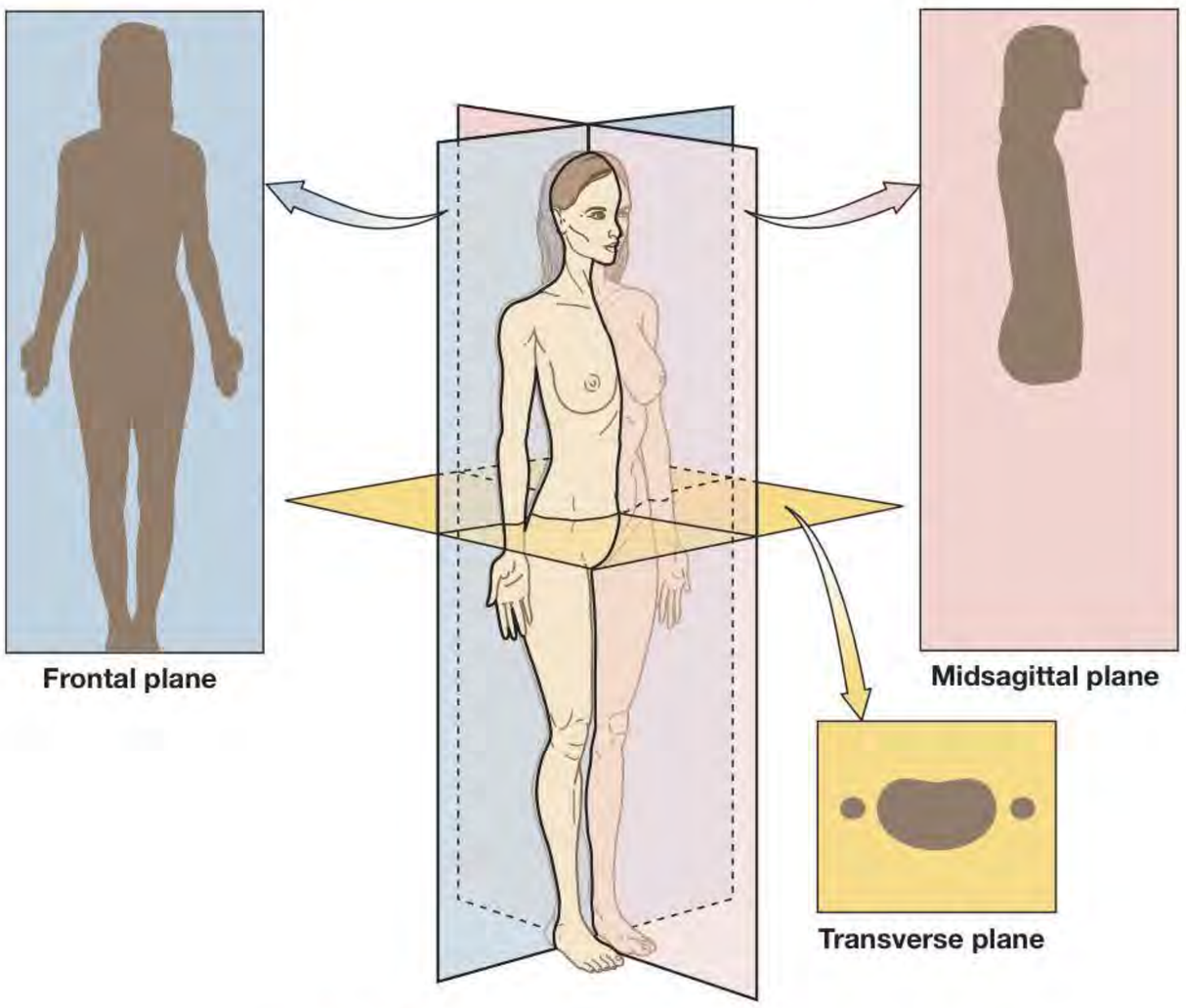


FIGURE **1.10** Anatomical planes of section.

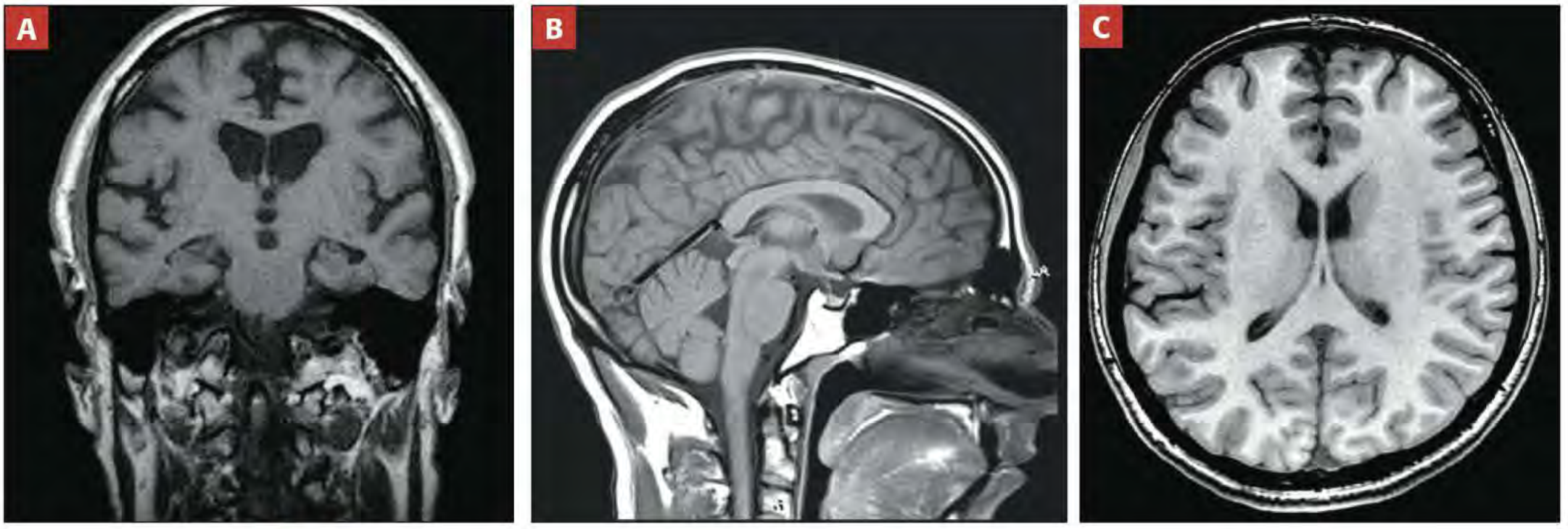


FIGURE **1.11** Planes of anatomical section visible on computed tomography scans of the brain: (**A**) frontal section; (**B**) midsagittal section; (**C**) transverse section.

Procedure 1 Sectioning Along Anatomical Planes

Use a scalpel to cut a ball of modeling clay in each of following anatomical planes. Before you make your cuts, mold your clay into the shape of a head and draw eyes on the head to denote anterior and posterior sides. Use Figures 1.10 and 1.11 for reference. When you have completed this exercise, answer Check Your Understanding questions 5 and 6 (p. 30).

1. Sagittal
   a. Midsagittal
   b. Parasagittal
2. Frontal
3. Transverse
4. Oblique

Procedure 2 Identifying Examples of Anatomical Planes of Section

Identify at least two examples of each plane of section listed in Table 1.4 on anatomical models that your instructor provides. In addition, list the organs that are visible in the section.

TABLE **1.4** Anatomical Models and Planes of Section

Examples of Midsagittal and/or Parasagittal Sections	
Model Name or Description	Organ(s) Visible
1.	
2.	
Examples of Frontal Sections	
Model Name or Description	Organ(s) Visible
1.	
2.	
Examples of Transverse Sections	
Model Name or Description	Organ(s) Visible
1.	
2.	

Exercise 1-6

Organs and Organ Systems

MATERIALS

- ❑ Human torso models
- ❑ Fetal pigs (or other preserved small mammals)
- ❑ Dissection kits/dissection trays

The human body has 11 organ systems, each with specific organs and functions (Figure 1.12). In this exercise you will examine the organ systems and identify their major organs.

Procedure 1 Organs

Identify the following organs on your preserved mammal specimen or human torso models. Check off each organ as you identify it, and record the organ system to which it belongs in Table 1.5. Remember that some organs may function in more than one system.

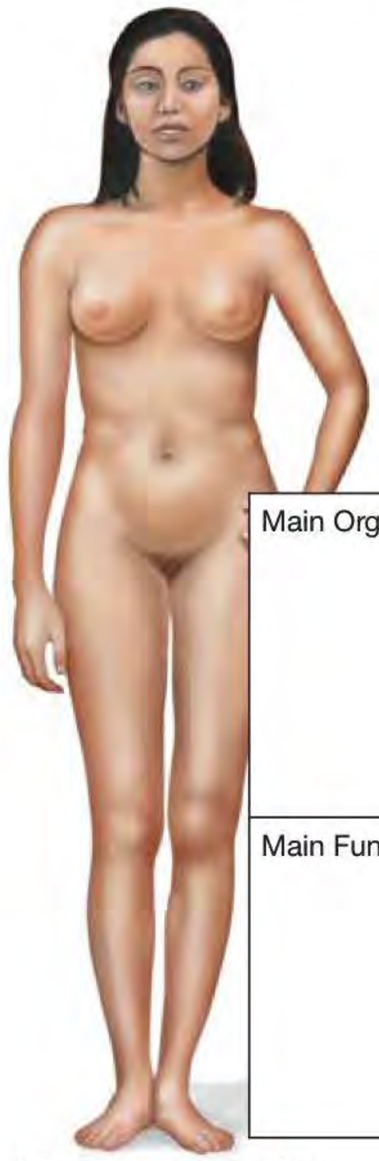
- ❑ Adrenal glands
- ❑ Blood vessels
- ❑ Bones
- ❑ Brain
- ❑ Esophagus
- ❑ Gallbladder
- ❑ Heart
- ❑ Intestines
- ❑ Joints
- ❑ Kidneys
- ❑ Larynx
- ❑ Liver
- ❑ Lungs
- ❑ Pancreas
- ❑ Skeletal muscles
- ❑ Skin
- ❑ Spinal cord
- ❑ Spleen
- ❑ Stomach
- ❑ Testes (male) or ovaries (female)
- ❑ Thymus
- ❑ Thyroid gland
- ❑ Trachea
- ❑ Urinary bladder

TABLE **1.5** Organs and Organ Systems

Organ System	Major Organ(s)
Integumentary system	
Skeletal system	
Muscular system	
Nervous system	
Cardiovascular system	
Lymphatic system	
Respiratory system	
Digestive system	
Urinary system	
Endocrine system	
Reproductive system	

Procedure 2 Organ Systems

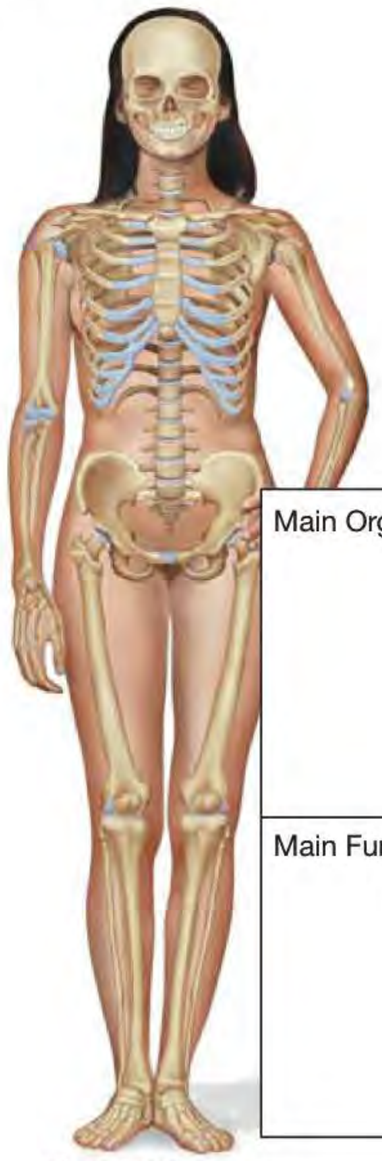
The body's organ systems are illustrated in Figure 1.12. Fill in the blanks next to each organ system to identify the major organs shown and principal functions of each system. When you have completed this exercise, answer Check Your Understanding question 7 (p. 30).



Main Organs:

Main Functions:

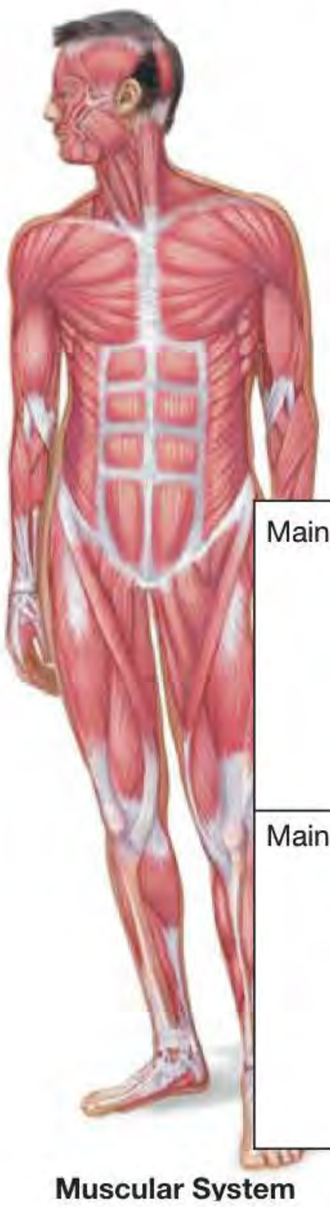
Integumentary System



Main Organs:

Main Functions:

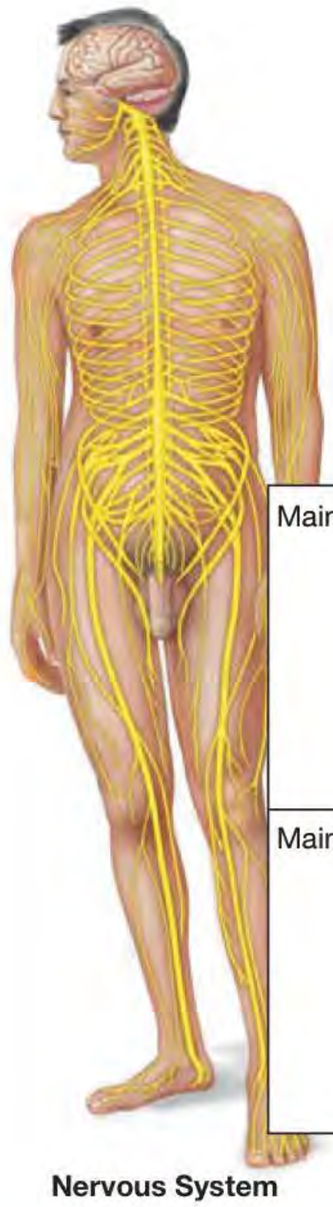
Skeletal System



Main Organs:

Main Functions:

Muscular System

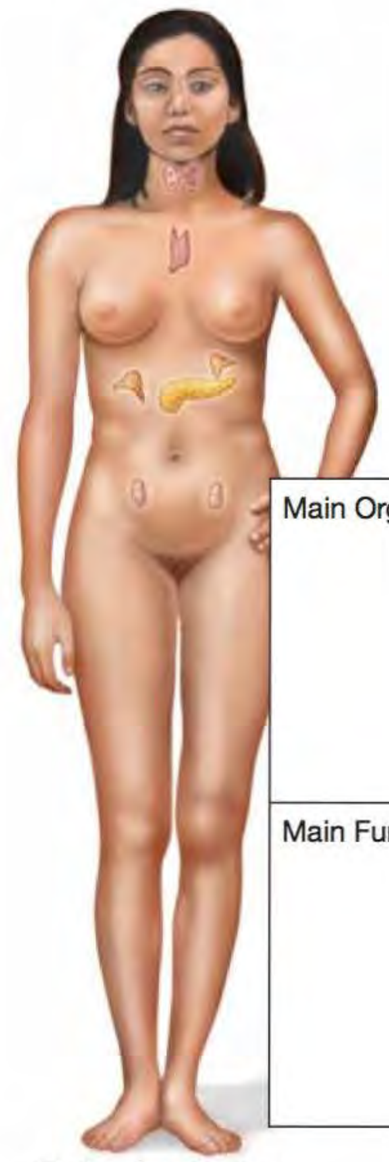


Main Organs:

Main Functions:

Nervous System

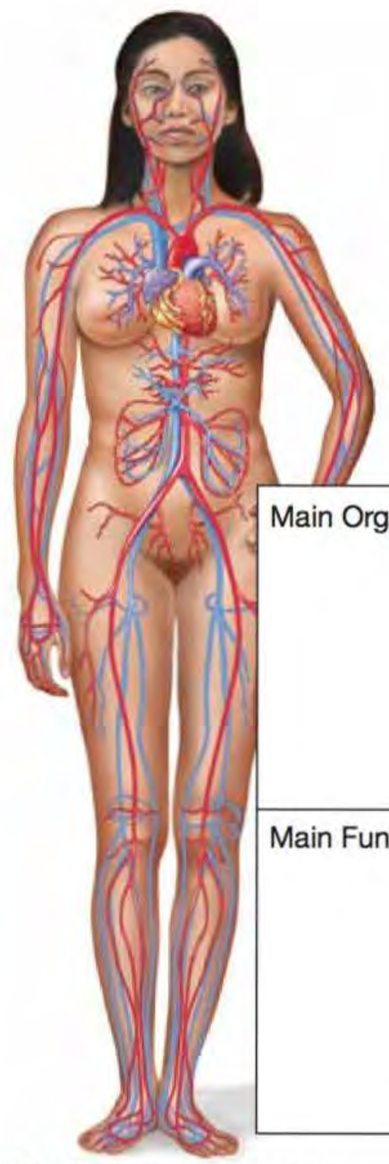
FIGURE **1.12** Organ systems of the body *(continues)*



Main Organs:

Main Functions:

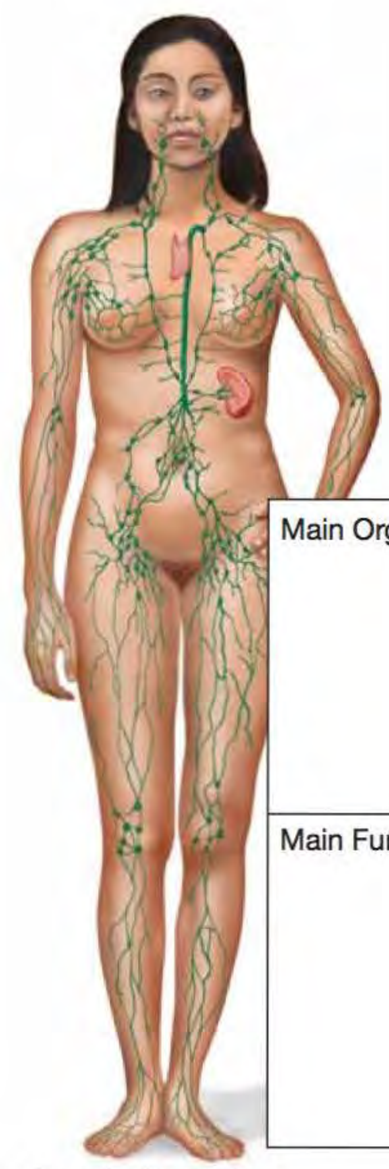
Endocrine System



Main Organs:

Main Functions:

Cardiovascular System



Main Organs:

Main Functions:

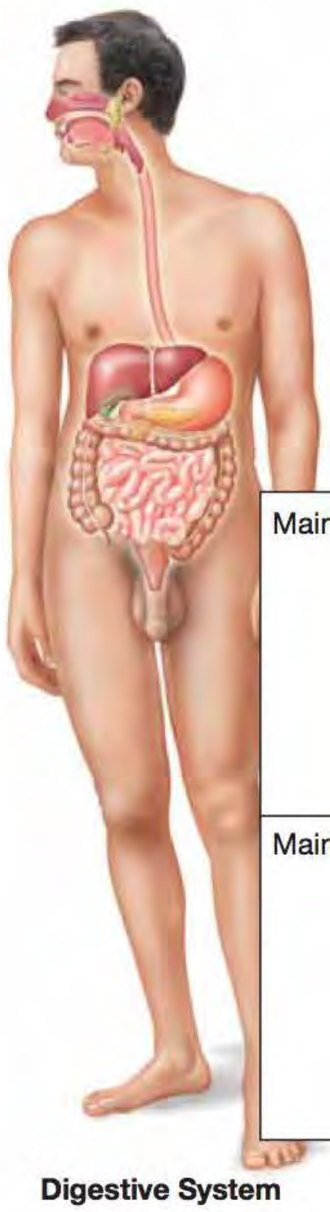
Lymphatic System

Main Organs:

Main Functions:

Respiratory System

FIGURE **1.12** *(cont.)* **Organ systems of the body** *(continues)*



Main Organs:

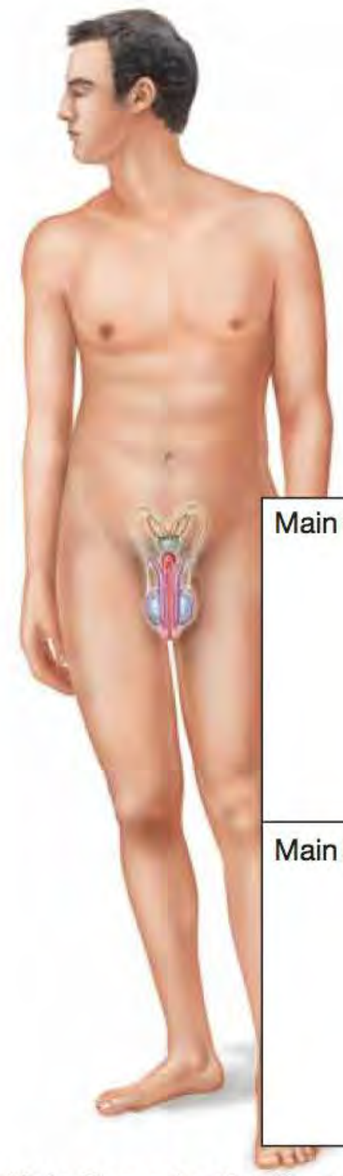
Main Functions:

Digestive System

Main Organs:

Main Functions:

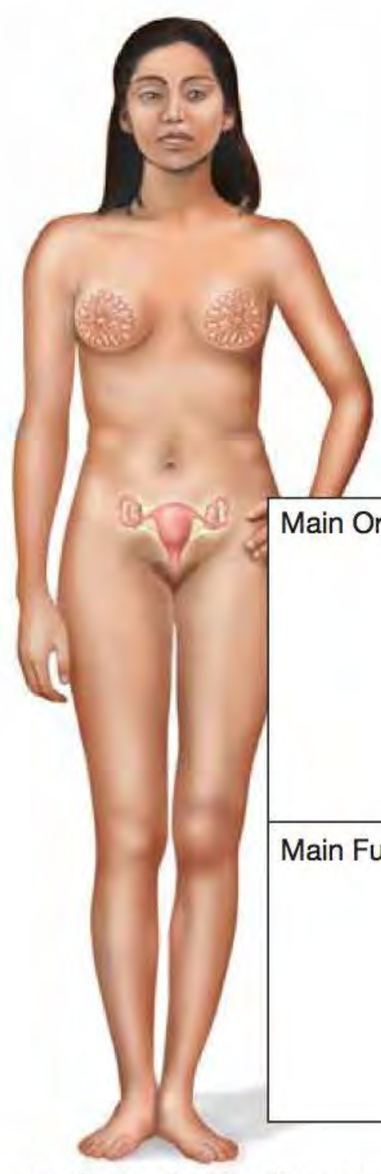
Urinary System



Main Organs:

Main Functions:

Male Reproductive System



Main Organs:

Main Functions:

Female Reproductive System

FIGURE **1.12** *(cont.)* **Organ systems of the body.**

Name _____

Section _____ Date _____

Check Your Recall

1 **Which of the following best describes anatomical position?**

a. Body facing forward, toes pointing forward, palms facing backward
b. Body, toes, and palms facing backward
c. Body facing forward, arms at the sides, palms facing outward
d. Body facing backward and palms facing outward

2 ***Matching:*** **Match the directional term with its correct definition.**

_____ Distal
_____ Lateral
_____ Anterior
_____ Proximal
_____ Inferior
_____ Deep
_____ Superficial
_____ Posterior
_____ Medial
_____ Superior

A. Away from the surface/toward the body's interior
B. Toward the back of the body
C. Closer to the point of origin (e.g., of a limb)
D. Away from the body's midline
E. Toward the head
F. Farther from the point of origin (e.g., of a limb)
G. Toward the body's midline
H. Away from the head/toward the tail
I. Toward the front of the body
J. Toward the surface/skin

3 **Which of the following is an incorrect use of a directional term?**

a. The ankle is inferior to the knee.
b. The sternum is superior to the abdomen.
c. The bone is deep to the muscle.
d. The mouth is medial to the ears.

4 **Label the following anatomical regions on Figure 1.13.**

- ❑ Brachial region
- ❑ Carpal region
- ❑ Cervical region
- ❑ Digital region
- ❑ Forearm
- ❑ Inguinal region
- ❑ Leg
- ❑ Lumbar region
- ❑ Orbital region
- ❑ Otic region
- ❑ Sternal region
- ❑ Upper limb

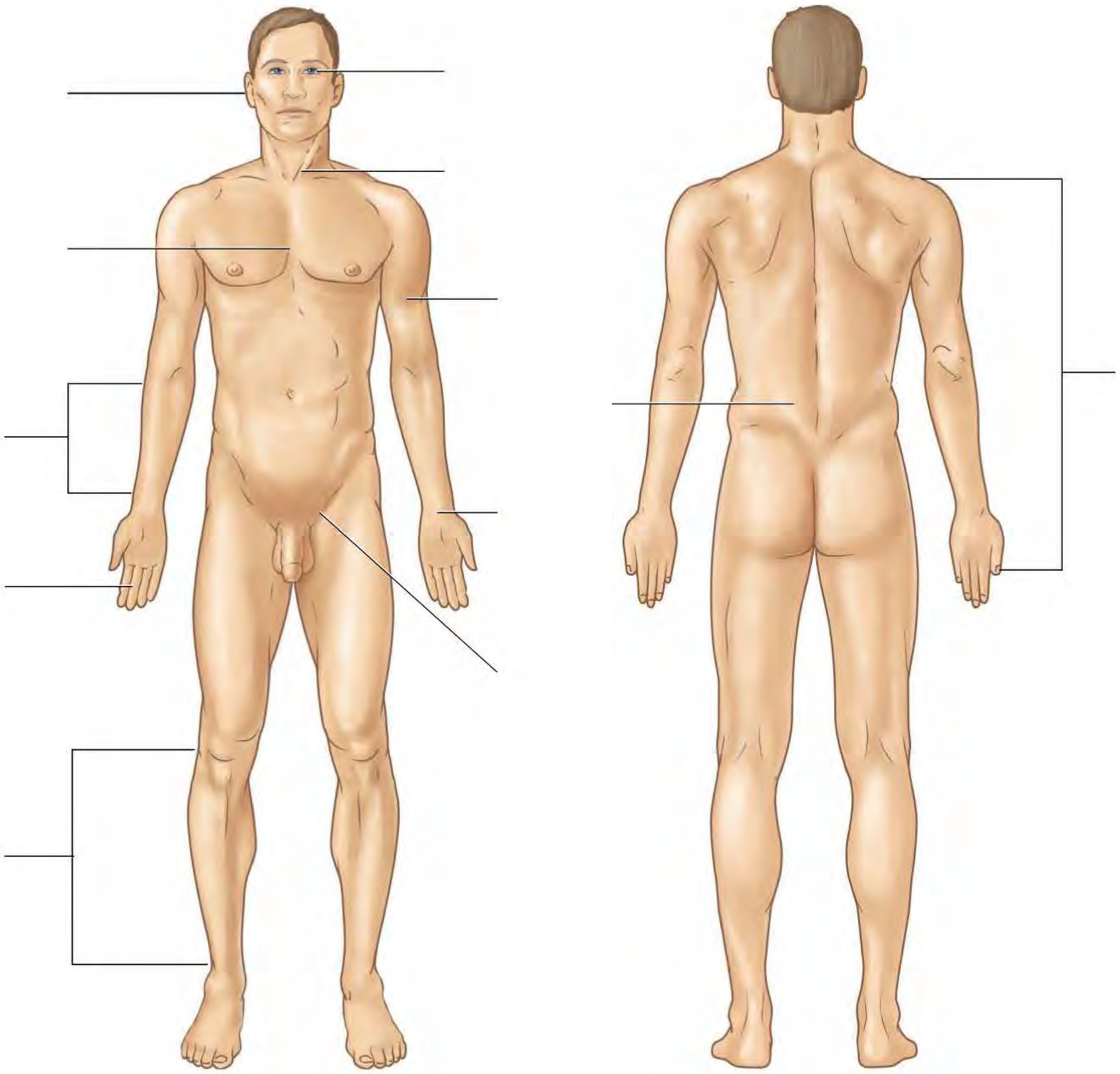


FIGURE **1.13** Anterior and posterior views of the body.

5 **Anatomical position and specific directional and regional terms are used in anatomy to**

a. standardize units of measure.
b. provide a standard that facilitates communication and decreases the chances for errors.
c. provide a standard that is used to develop drug delivery systems.
d. make students' lives difficult.

Name _____

Section _____ Date _____

UNIT 1

6 **Label the following body cavities on Figure 1.14, and indicate with an asterisk (*) which cavities are surrounded by serous membranes.**

- ❑ Abdominal cavity
- ❑ Abdominopelvic cavity
- ❑ Cranial cavity
- ❑ Posterior body cavity
- ❑ Mediastinum
- ❑ Pelvic cavity
- ❑ Pericardial cavity
- ❑ Peritoneal cavity
- ❑ Pleural cavity
- ❑ Thoracic cavity
- ❑ Anterior body cavity
- ❑ Vertebral cavity

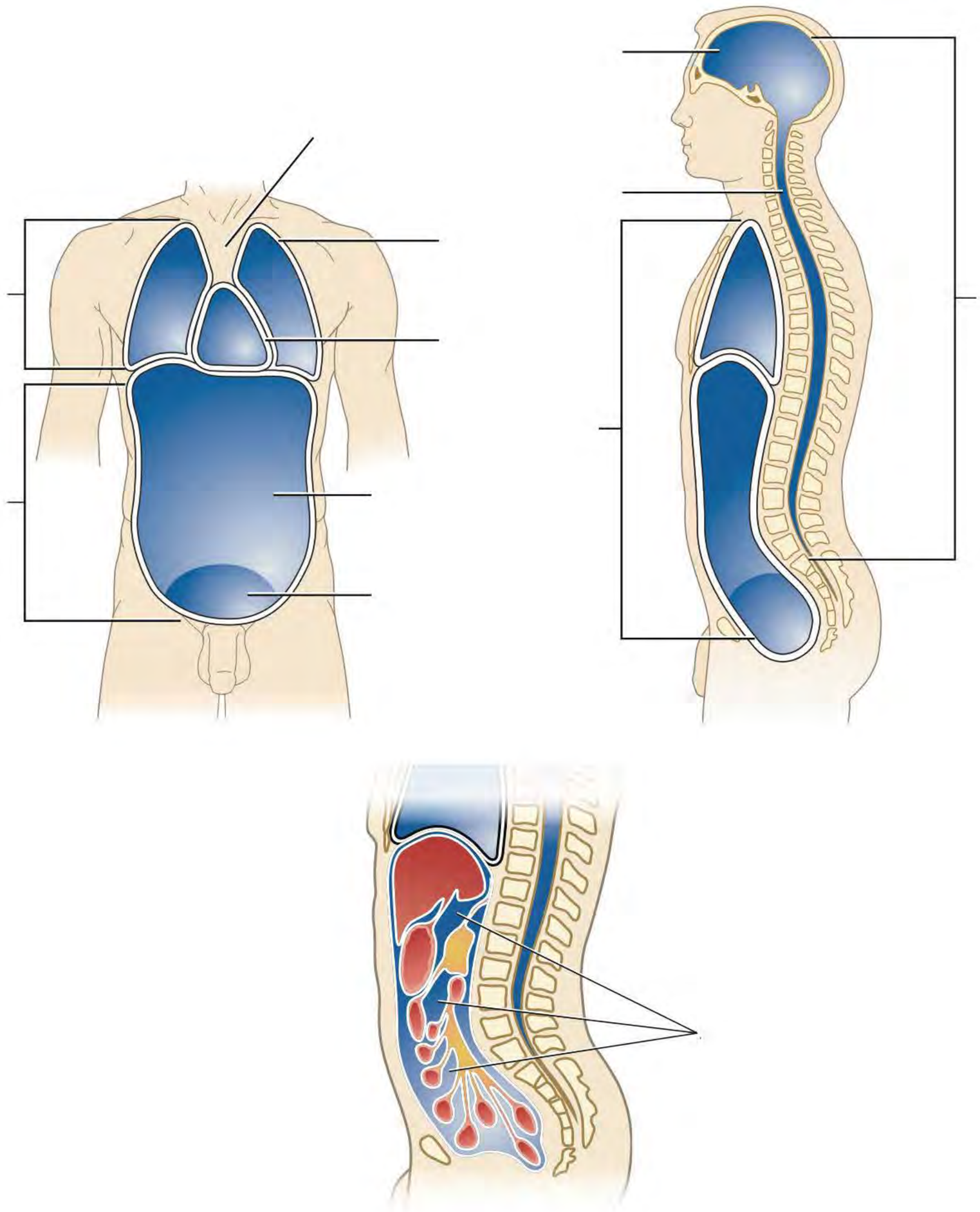


FIGURE **1.14** Anterior and lateral views of the body cavities.

7 *Fill in the blanks:* A serous membrane secretes _____, which _____ the organs in certain _____ body cavities.

8 Define the following planes of section.

a Midsagittal plane _____

_____

b Parasagittal plane _____

_____

c Frontal plane _____

_____

d Transverse plane _____

_____

e Oblique plane _____

_____

9 The following organs belong to the _____ system: esophagus, gallbladder, liver.

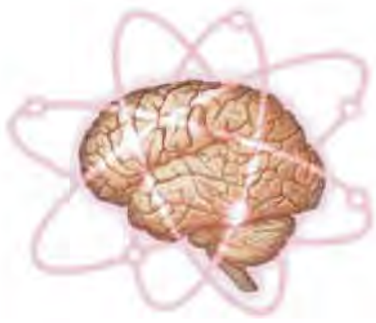
a. integumentary
b. reproductive
c. lymphatic
d. digestive

10 The following organs belong to the _____ system: pancreas, thyroid gland, adrenal glands.

a. endocrine
b. urinary
c. lymphatic
d. cardiovascular

Name _____

Section _____ Date _____



UNIT 1 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Figure 1.15 is not in anatomical position. List all of the deviations from anatomical position.

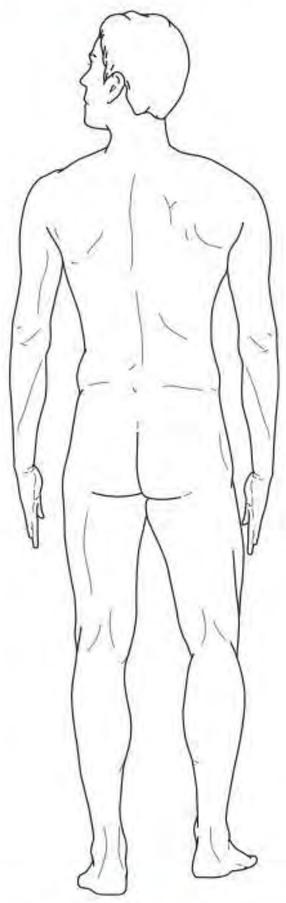


FIGURE **1.15** Figure not in anatomical position.

2 Locate the following wounds, and mark them on the body in Figure 1.16.

a The wound is located in the left inferior, posterior lumbar region. It is 5 centimeters superior to the gluteal region and 3 centimeters lateral to the vertebral region.

b The wound is located on the right anterior, medial crural region, 10 centimeters proximal to the tarsal region.

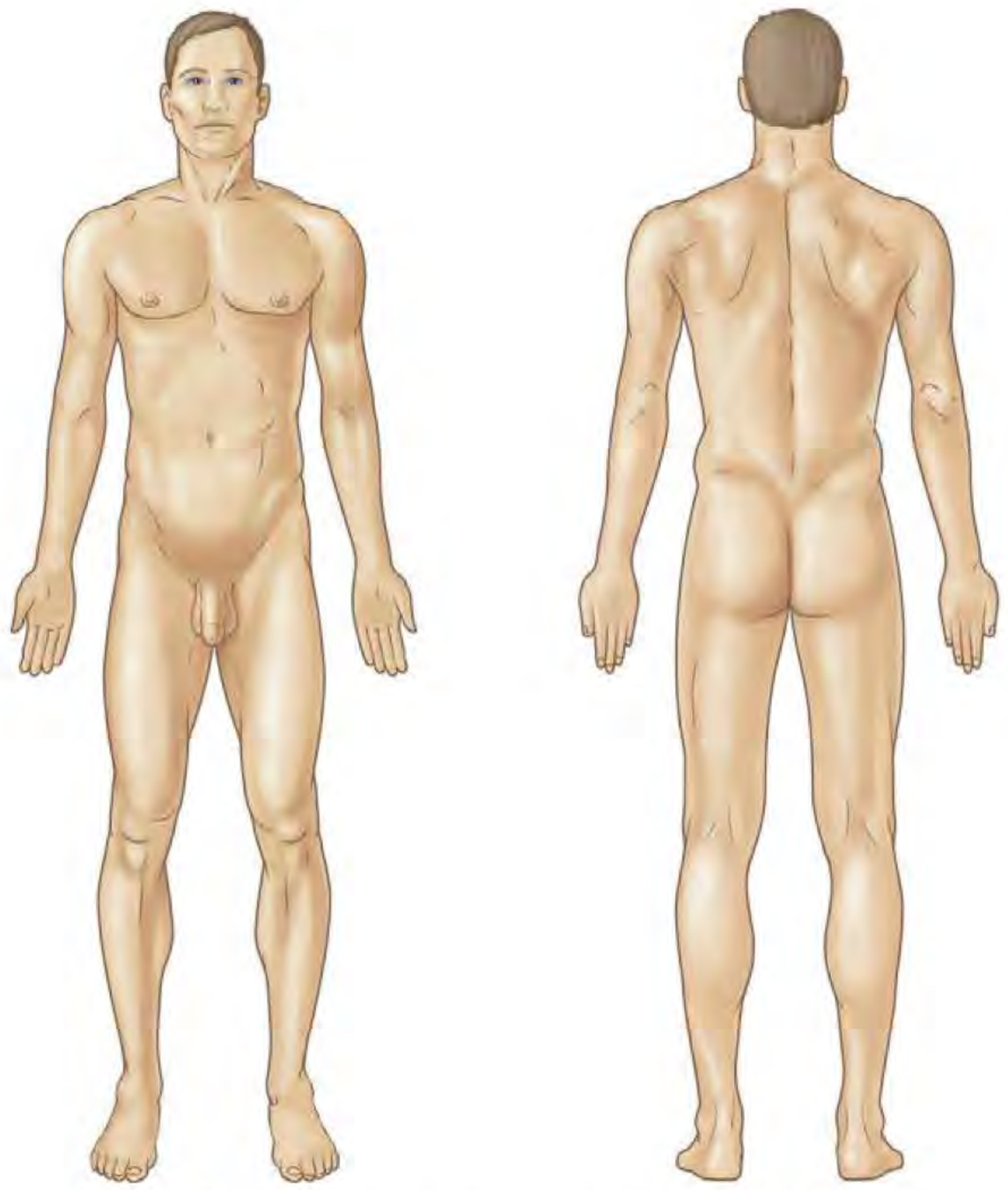


FIGURE **1.16** Anterior and posterior views of the body.

3 **You are reading a surgeon's operative report. During the course of the surgery, she made several incisions. Your job is to read her operative report and determine where the incisions were made. Draw and label the incisions on Figure 1.17.**

a The first incision was made in the right anterior cervical region, 3 centimeters lateral to the trachea. The cut extended vertically in an inferior direction, beginning 2 centimeters inferior to the mental region and ending 3 centimeters superior to the thoracic region.

b The second incision began in the left anterior axillary region and extended medially to the sternal region. At the sternal region the cut turned inferiorly and ended 4 centimeters superior to the umbilical region.

c The third incision was made in the left posterior scapular region. The cut was extended medially to 2 centimeters lateral to the vertebral region, where it turned superiorly and ended one centimeter inferior to the cervical region.

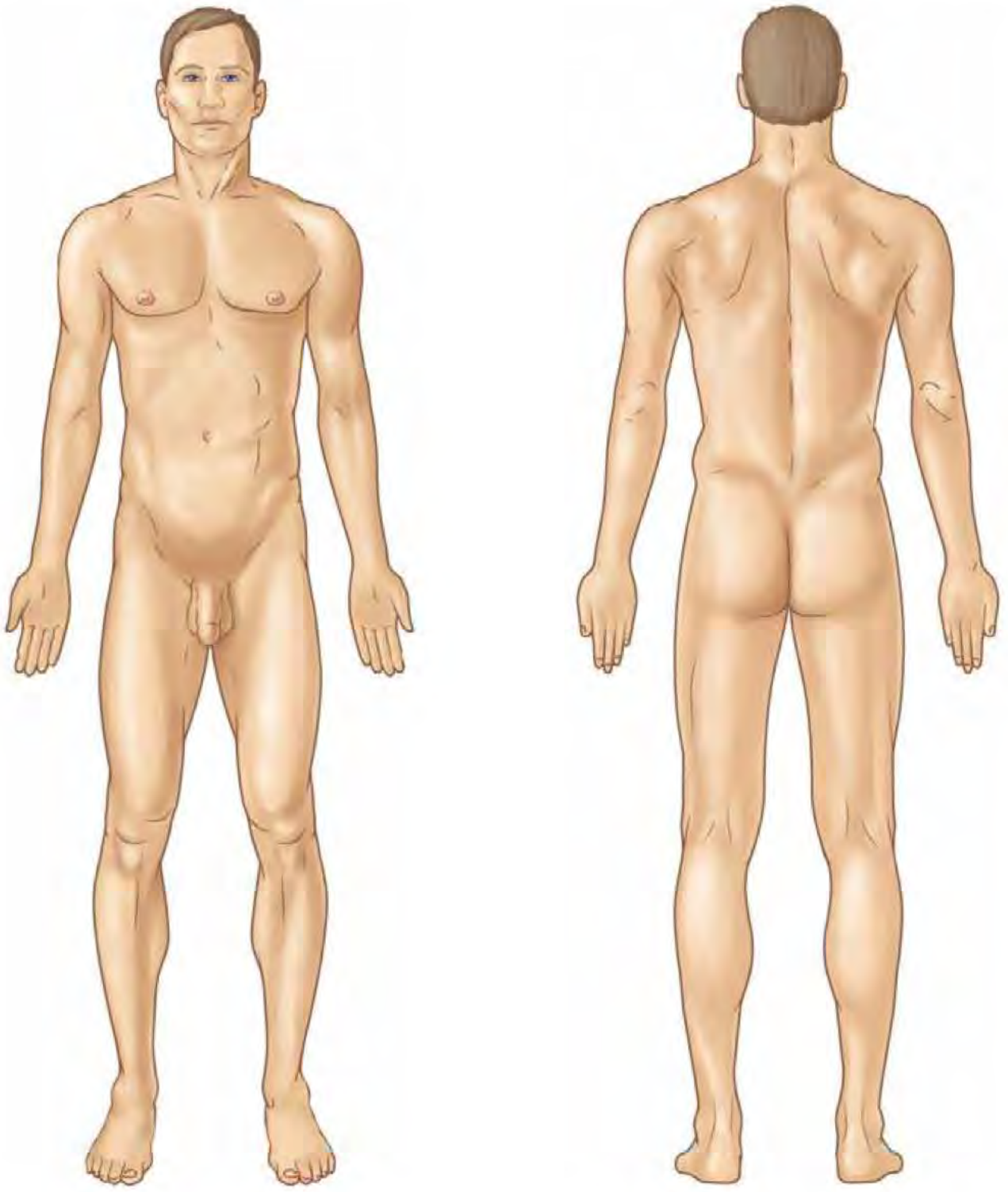


FIGURE **1.17** Anterior and posterior views of the body.

Name _____

Section _____ Date _____

4 Describe the location of the wounds on Figure 1.18 using at least three correct regional and directional terms.

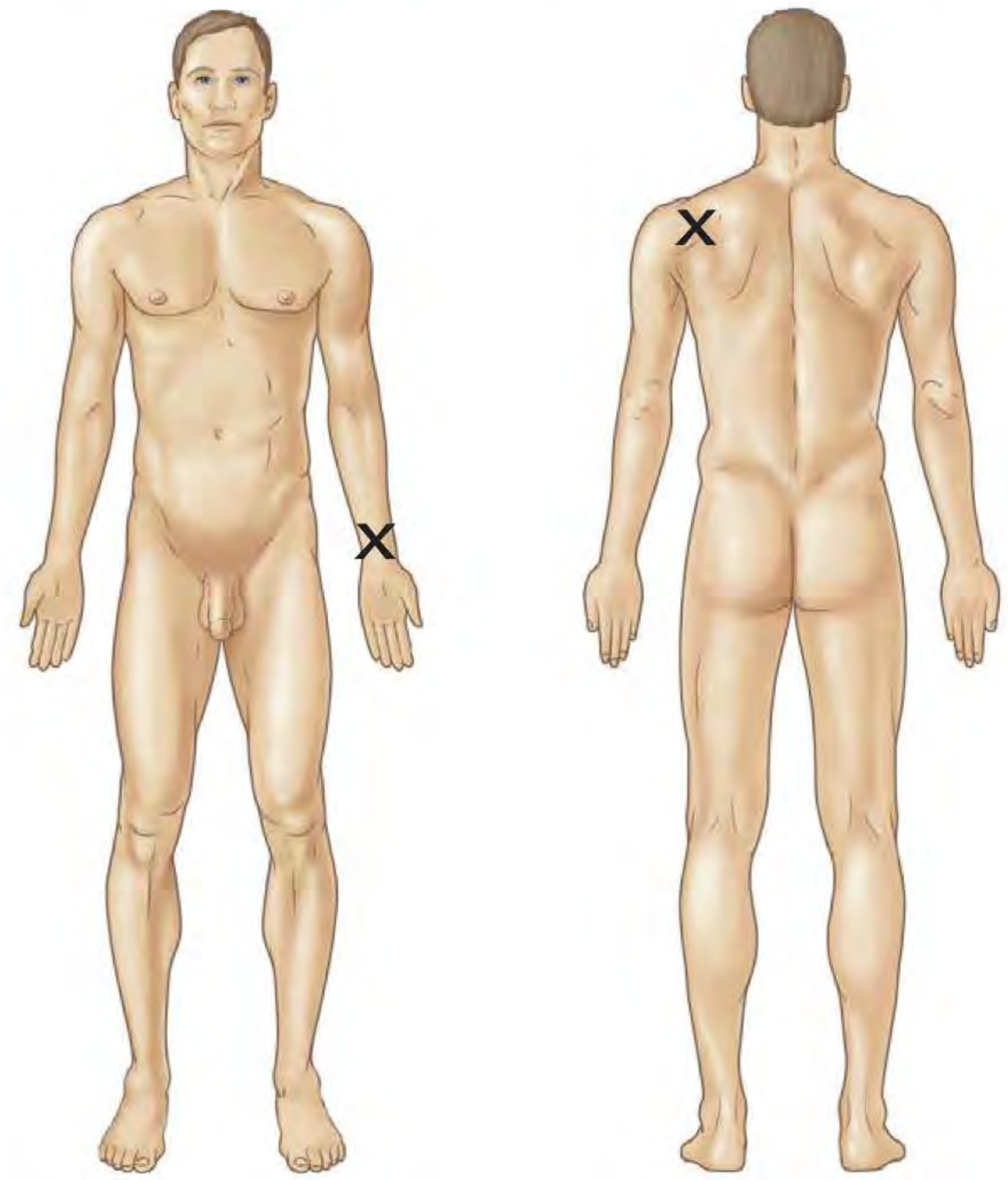


FIGURE **1.18** Anterior and posterior views of the body.

a _____

_____

_____

_____

b _____

_____

_____

_____

5 What may be some real-world applications of anatomical sections? (*Hint:* Think of the medical field.)

6 Which anatomical section(s) would provide a view of the internal anatomy of both kidneys?

7 The type of anatomy we are studying in this lab manual is called systemic anatomy, which means that we cover the organs related to a specific organ system. Some, however, choose to study anatomy from a regional point of view (e.g., the abdominal region or the thoracic region). **Find at least two organ systems that contain organs in different regions of the body, and state where the organs are located in the body.**

> ***Example:*** The nervous system has organs in the cranial cavity (the brain), the spinal cavity (the spinal cord), the thoracic and abdominopelvic cavities (spinal and cranial nerves), and the upper and lower limbs (spinal nerves).

Introduction to the Microscope

2

OBJECTIVES

Once you have completed this unit, you should be able to:

1. Identify the major parts of the microscope.
2. Define the magnification of high, medium, and low power.
3. Demonstrate proper use of the microscope.
4. Practice focusing on low, medium, and high power.
5. Define depth of focus.

2

EXERCISES

Working with the microscope and slides seems to be one of the least favorite tasks of anatomy students. But with a bit of help, a fair amount of patience, and a lot of practice, the use of microscopes becomes progressively easier with each unit.

Exercise 2-1

Introduction to the Microscope

MATERIALS

- ❑ Light microscopes with three objective lenses
- ❑ Introductory slides (letter "e" and three colored threads)

The microscopes that you will use in this lab are called light microscopes (Figure 2.1). This type of microscope shines light through the specimens to illuminate them, and the light is refracted through objective lenses to magnify the image. Light microscopes have the following components:

- **Ocular lens.** The **ocular lens** (AWK-yoo-lur) is the lens through which you look to examine the slide. The microscope may have one

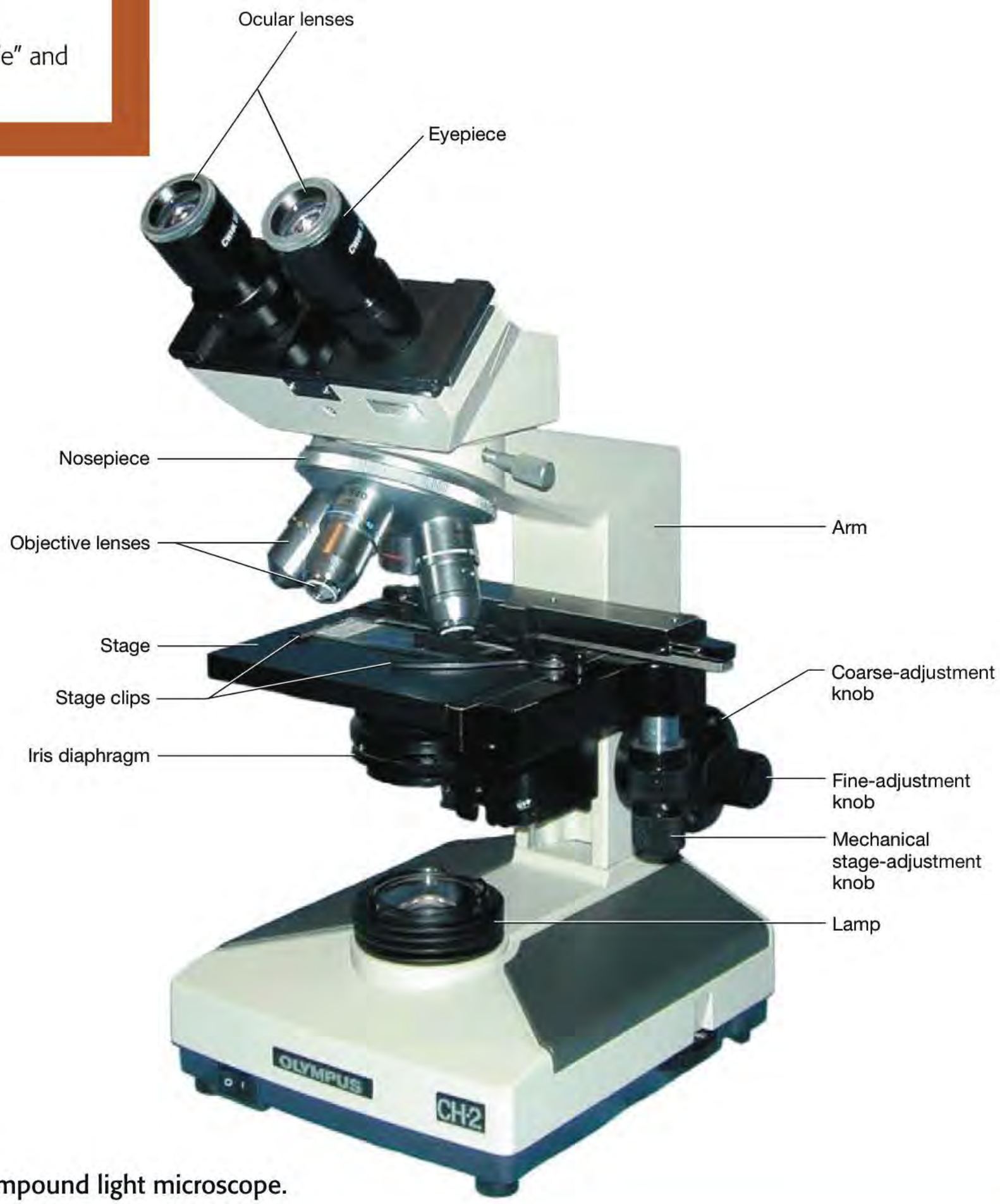


FIGURE **2.1** Compound light microscope.

ocular lens (a **monocular** microscope) or two ocular lenses (a **binocular** microscope). Many ocular lenses have pointers that can be moved by rotating the black **eyepiece**. The area of the slide visible when you look into the ocular is known as the **field of view**.

- **Objective lenses.** The **objective lenses** are lenses with various powers of magnification. Most microscopes have low (4×), medium (10×), and high (40×) power objective lenses. Note that sometimes the 4× objective is referred to as the *scan objective*. On such microscopes, the 10× objective is actually called the *low*-power objective. The objective lenses are attached to the **nosepiece**, which allows the operator to switch between objectives. Certain microscopes have a higher power objective (100×), called the **oil immersion lens**, which requires that a drop of oil be placed between the slide and objective lens. Without this drop of oil, you will not be able to focus the image.
- **Stage.** The **stage** is the surface on which the slide sits. It typically has *stage clips* to hold the slide in place. The stage on many microscopes is moveable using the mechanical stage adjustment knob. Others require you to move the slide manually.
- **Arm.** The **arm** supports the body of the microscope and typically houses the adjustment knobs.
- **Coarse adjustment knob.** The large knob on the side of the arm is the **coarse adjustment knob**. Turning it moves the stage up and down to change the distance of the stage from the objective lenses. It allows gross focusing of the image.
- **Fine adjustment knob.** The smaller knob underneath the coarse adjustment knob is the **fine adjustment knob**. Turning it allows fine-tuning of the image's focus.
- **Lamp.** The **lamp**, also called the *illuminator*, provides the light source. It rests on the *base* of the microscope.
- **Iris diaphragm.** On the underside of the stage is an adjustable wheel called the **iris diaphragm** that controls the amount of light allowed to pass through the slide. The iris diaphragm is important to check when you are focusing on an image, as too much light will wash the image out, and too little light will make it harder to see details.

Check Your Recall

1 ***Matching:*** **Match the following terms with the correct definition from the column.**

____ Ocular lens
____ Iris diaphragm
____ Arm
____ Objective lens
____ Coarse adjustment knob
____ Stage
____ Fine adjustment knob
____ Lamp

A. The surface on which the slide sits
B. The microscope's light source
C. Allows fine tuning of the focus
D. The lens through which you look to view the slide
E. Supports the body of the microscope
F. Controls the amount of light that passes through the slide
G. Moves the stage up and down; provides gross focusing
H. Lenses of various powers of magnification

2 ***Fill in the blank:*** **Magnification of the ocular lens is usually** _____.

3 **The lens that provides 100× magnification is the**

a. low power lens.
b. medium power lens.
c. high power lens.
d. oil immersion lens.

Procedure 1 Magnification

2

Light is refracted through two lenses to obtain magnification—the ocular lens and the objective lens. Magnification of the ocular lens is usually 10×. This means that if you were to view a slide with only the ocular lens, the image would be magnified 10 times. Magnification of the objectives lenses varies, but typically is 4× for low power, 10× for medium power, and 40× for high power. (To verify that this is the case for your microscope, look at the side of the objective lens, which usually is labeled with its magnification.) Remember that oil immersion provides even greater magnification at 100×. When calculating the total magnification, you must multiply the magnification of the ocular lens (10) by the power of the objective lens.

Fill in Table 2.1 to determine total magnification at each of the different objective lenses on your microscope. Remember that the magnification of the objective lens is usually printed on the side of the lens itself.

TABLE **2.1** Total Magnification at Each Power

Magnification of Ocular Lens	Power	Magnification of Objective Lens	Total Magnification
	Low		
	Medium		
	High		
	Oil Immersion		

As I'm certain your professor will tell you, microscopes are expensive! Care must be taken to ensure that the microscopes stay in good working condition. Taking proper care of microscopes makes the histology sections of your labs run more smoothly, and also ensures that you stay on your lab instructor's good side. Keeping that in mind, following are some general guidelines for handling the microscopes:

- Use two hands to support the microscope when carrying it—one hand to hold the arm and the other hand to support the base.
- Gather up the cord so it does not dangle off the lab table after you have plugged in the microscope. This will help to prevent people from tripping over loose cords.
- Clean the lenses with lens paper only. Do not use paper towels or cloth to clean a lens, because this will scratch its surface.
- Make sure the lowest power objective is in place before you begin. This will prevent you from cracking the slide and possibly the lens.
- Get the image in focus on low power, then switch to higher power and adjust with the fine adjustment knob. Be careful not to use the coarse adjustment knob with the high power objective in place, because you could break the slide and damage the lens.
- When you are finished with the microscope, turn the nosepiece to the lowest power objective, and remove the slide. Be sure to clean off the objective if you used oil, because oil left on the objective tends to harden. Turn off the power to the microscope, and unplug it. This will decrease the chances of a blown bulb or fuse next time the microscope is used. Before putting the microscope away, wrap the electrical cord around the base, and cover it with a dust cover.

If you follow these general guidelines, you can rest assured that the microscopes (and your grade) will not suffer any harm.

Check Your Recall

4 **Before you begin, you should make sure that**

a. the objective lens is switched to the highest-power magnification.
b. the lamp is turned to its full brightness.
c. the ocular lens is switched to the highest-power magnification.
d. the objective lens is switched to the lowest-power magnification.

5 **How should you carry the microscope?**

6 **What should you use to clean the lenses?**

7 **What should you do if your slide looks dramatically different from the slide in your lab manual?**

8 **If you are having trouble making out details on your slide, what can you do?**

a. Adjust the focus with the fine adjustment knob.
b. Reduce the amount of light with the iris diaphragm.
c. Both a and b.
d. Neither a nor b.

HINTS & TIPS

How to Approach Microscopy

2

Before you try to focus the microscope, read the following hints and tips to make it easier.

- **Always start on low power.** You are *supposed* to start on low power anyway, to avoid damaging the objective lenses. Sometimes, though, students forget, and jump straight to medium or high power. This risks damaging the lenses and also makes it harder on you. Bear in mind that most slides will have more than one histological or cellular structure on each slide. Starting on low power allows you to scroll through a large area of the slide, and then focus in on the desired part of the section.
- **Beware of too much light.** It is easy to wash out the specimen with too much light. If you are having difficulty making out details, first adjust the focus with the fine adjustment knob. If this doesn't help, use the iris diaphragm to reduce the amount of light illuminating the specimen. This will increase the contrast and allow you to observe more details. It also helps to reduce headaches and eyestrain.
- **Keep both eyes open.** It is tempting to close one eye when looking through a monocular microscope. Admittedly, keeping both eyes open isn't easy at first, but it helps to reduce eyestrain and headaches.
- **Compare your specimen to the photos in your lab manual.** Although the slides you are examining will not necessarily be identical to the photos in this book, they should be similar in appearance. Generally speaking, if you are looking at something that is vastly different from what is in this book, you probably should move the slide around a bit or change to a different power objective to find the correct tissue or cell type on the slide. Other good sources for micrographs include atlases, your textbook, and images on the Internet.
- **Remember that the slides aren't perfect.** Not all slides will clearly demonstrate what you need to see. Some aren't stained adequately or properly. Some are sectioned at a funny angle. Some don't contain all of the tissue or cell types you need to see. What should you do about this? See the next hint for the answer.
- **Look at more than one slide of each specimen.** This will help you in the face of subpar slides and also will assist you overall in gaining a better understanding of the specimens you are examining.
- **Draw what you see.** Although you may tend to resist drawing, even the most basic picture is helpful for two reasons. First, it allows you to engage more parts of your brain in the learning process. The more areas of your brain engaged, the better are the chances you will retain the information. Also, drawing is helpful in that you actually have to look at the specimen long enough to draw it.
- **Have patience!** It really does get easier. Don't get frustrated, and don't give up. By the end of the semester, you may come to appreciate the microscope and the fascinating world it reveals.

Procedure 2 Focusing the Microscope

Now that we know how to handle the microscope properly, let's practice using it. We will start with a simple slide: an image of a newsprint letter "e."

1 Obtain a slide of the letter "e."

2 Examine the letter "e" slide macroscopically (with the naked eye) before placing it on the stage. How is the "e" oriented on the slide? Is it right side up, upside down, backward, etc.?

3 Switch the nosepiece to the low power objective, place the slide on the stage, and secure it with the stage clips. Move the slide using the stage adjustment knob until the "e" is in your field of view.

4 Use the coarse adjustment knob to bring the slide into focus slowly. Once it is grossly in focus, use the fine adjustment knob to sharpen the focus. Note that you might need to adjust the iris diaphragm to allow more light to pass through the specimen, as the newsprint is relatively thick. How is the "e" oriented in the field of view? Is it different from the way it was when you examined it in item 2?

5 Move the nosepiece to medium power. You should only have to adjust the focus with the fine adjustment knob; no adjustment of the coarse focus should be necessary.

6 Once you have examined the slide on medium power, move the nosepiece to high power. Again, focus only with the fine adjustment knob.

Wasn't that easy?

Check Your Recall

9 What are the steps you should use to focus the image on the slide?

Procedure 3 Depth of Field

2

At times you will look at a slide and see something brown or black and kind of neat-looking with interesting swirls and specks. What is this fascinating discovery you've made? It's dirt on top of the slide. This happens because people tend to focus the objective on the first thing they can make out, which usually is the top of the coverslip on the slide, and this has a tendency to be dirty.

These "dirt discoveries" can be avoided by appreciating what is known as **depth of field**. Also called the *depth of focus*, the depth of field is the thickness of a specimen that is in sharp focus. Thicker specimens will require you to focus up and down to look at all levels of the specimen. This takes practice and skill. Let's get some practice doing this. Here we will use a slide that has three differently-colored threads stacked on top of one another.

1. Obtain a slide with three colored threads. The threads are located on the slide at varying depths, and you will have to focus on each thread individually.
2. Examine the slide macroscopically prior to putting it on the stage.
3. Switch the nosepiece to the low power objective, place the slide on the stage, and secure it with the stage clips. Move the slide using the stage adjustment knob until the threads are in your field of view.
4. Use the coarse adjustment knob to get the slide into focus on low power.
5. Switch to medium power, and use the fine adjustment knob to sharpen the focus. Which thread(s) is(are) in focus?
6. Move the objective up and down slowly with the coarse adjustment knob, focusing on each individual thread. Determine which color thread is on the bottom, in the middle, and on the top, and write the color order here:

Bottom _____

Middle _____

Top _____

Check Your Recall

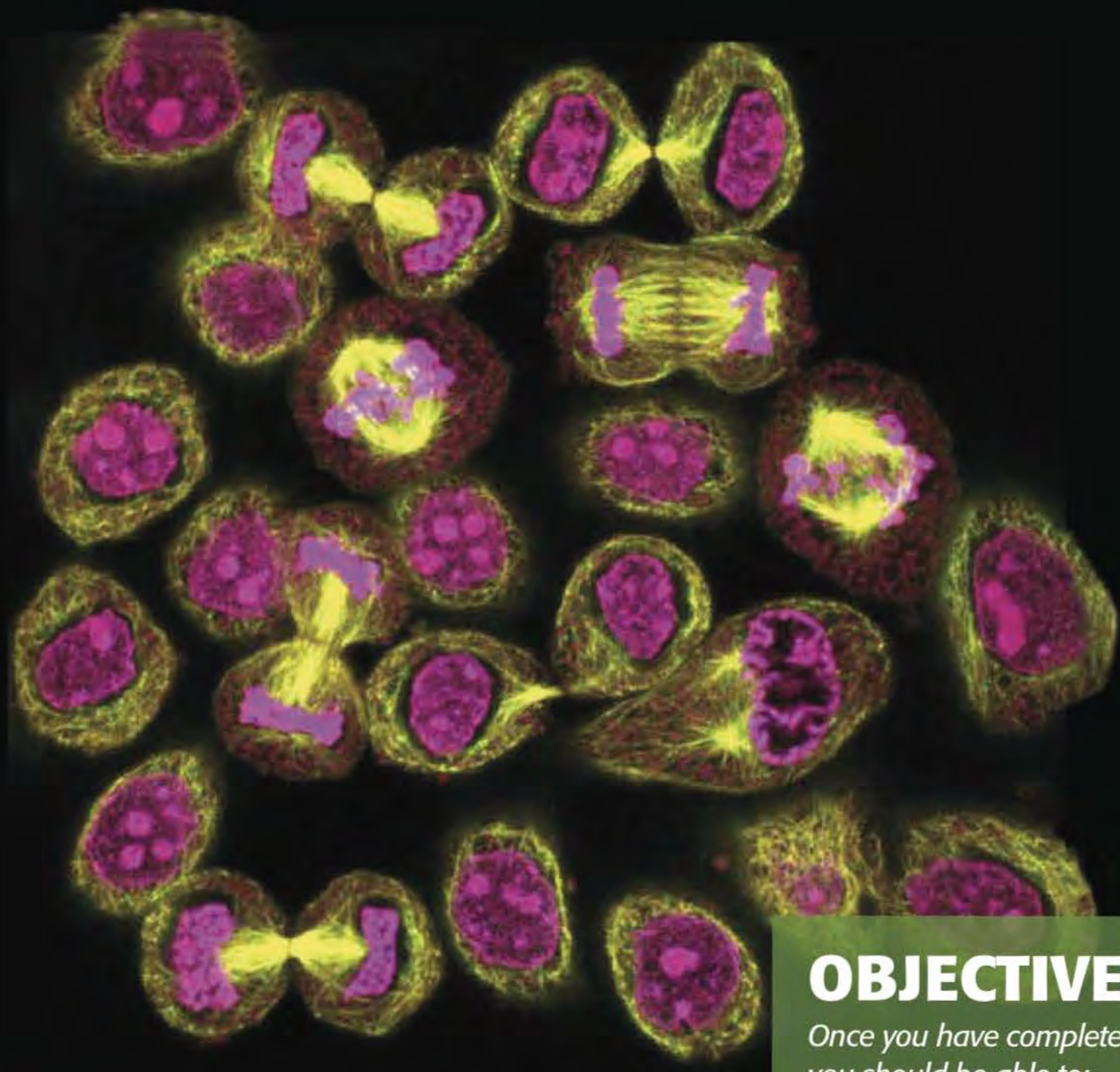
10 What is the depth of field?

_____

_____

Cytology

3



OBJECTIVES

Once you have completed this unit, you should be able to:

1. Identify parts of the cell and organelles.
2. Prepare and observe a sample of cells.
3. Identify the stages of the cell cycle and mitosis.

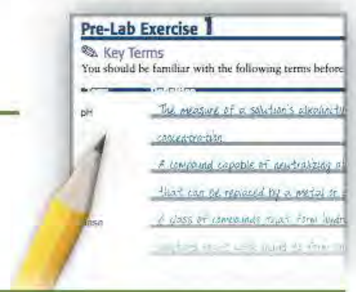
Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.

3

Pre-Lab Exercise 3-1



✎ Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition
Cell Structures and Organelles	
Plasma membrane	
Cytoplasm	
Nucleus	
Mitochondrion	
Ribosome	
Peroxisome	
Smooth endoplasmic reticulum	
Rough endoplasmic reticulum	
Golgi apparatus (or complex)	
Lysosome	
Centrosome	
Cilia	

Name _____ Section _____ Date _____

Flagella _____

_____

Vesicle _____

_____

Cell Cycle and Mitosis

Cell cycle _____

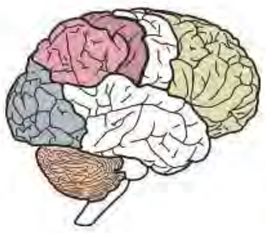
_____

Interphase _____

_____

Mitosis _____

_____



Pre-Lab Exercise 3-2

The Plasma Membrane

3 Label and color the parts of the plasma membrane in Figure 3.1 with the terms from Exercise 3-1 (p. 45). Use your text and Exercise 3-1 in this unit for reference.

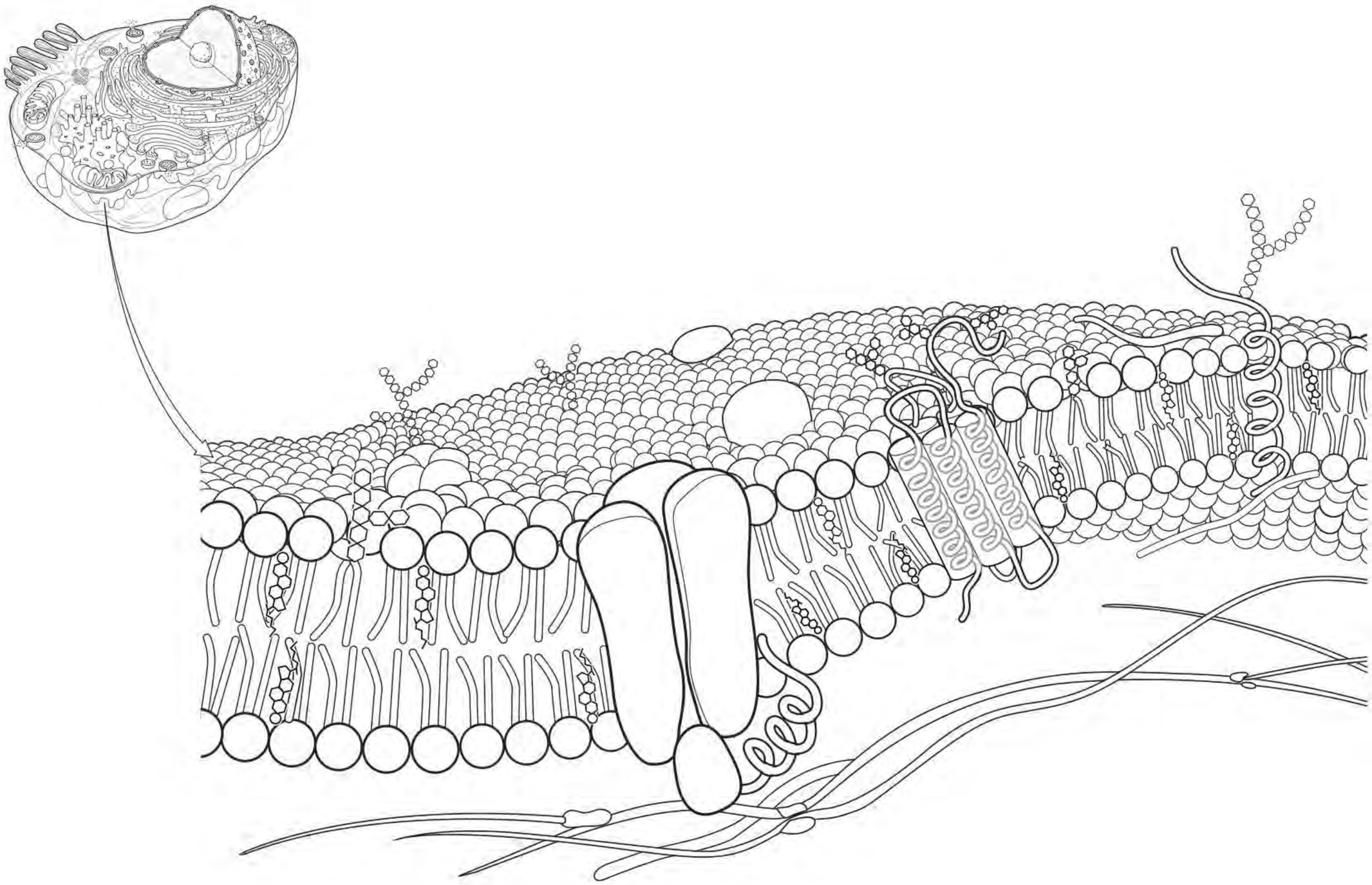
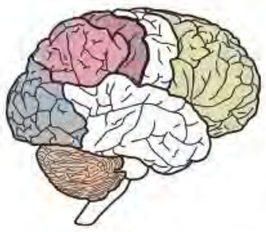


FIGURE **3.1** Plasma membrane.

Name _____ Section _____ Date _____



Pre-Lab Exercise 3-3

The Parts of the Cell

Label and color the parts of the cell in Figure 3.2 with the terms from Exercise 3-1 (p. 45). Note that you may not see all structures in this diagram. Use your text and Exercise 3-1 in this unit for reference.

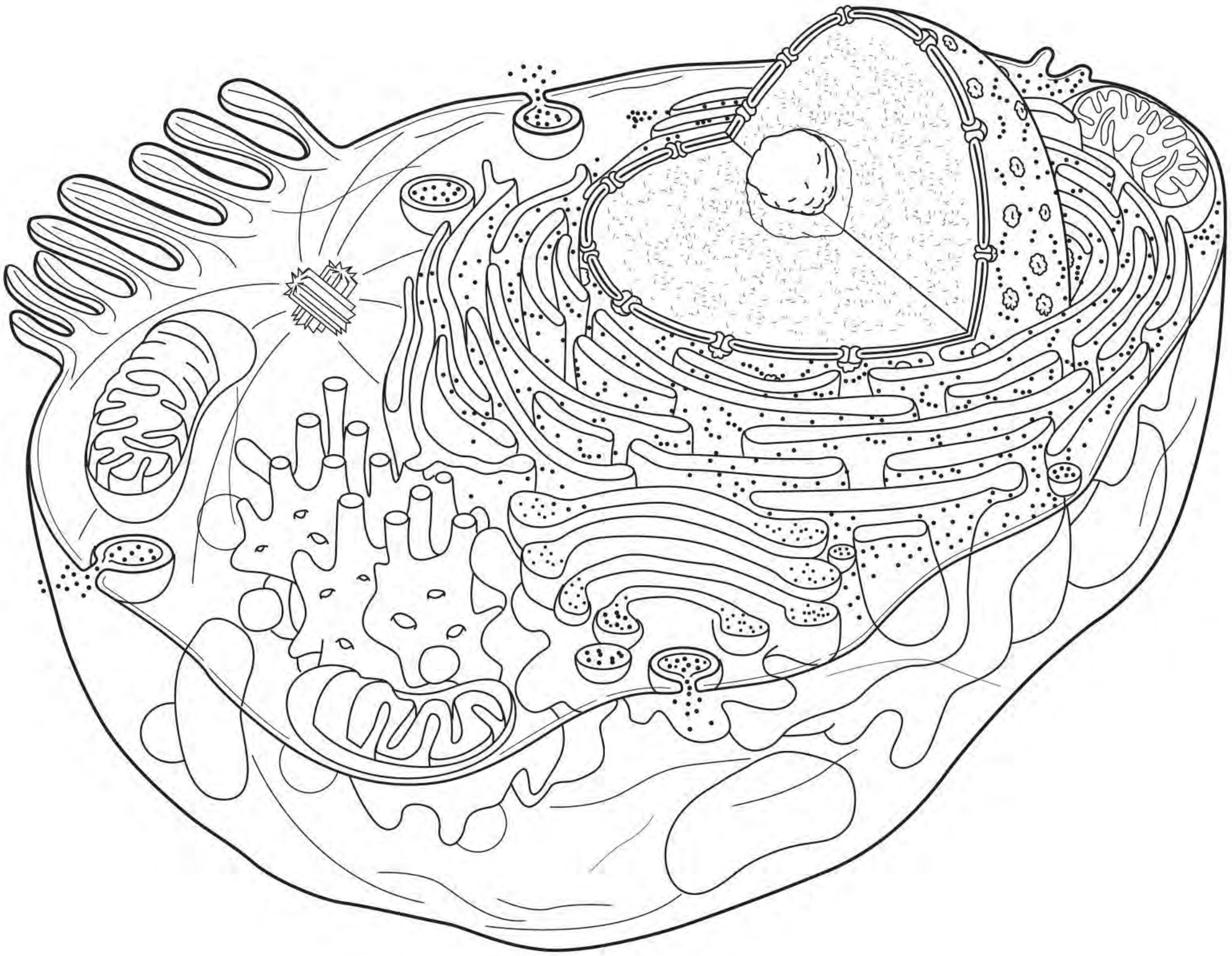


FIGURE 3.2 Generalized cell.

Pre-Lab Exercise 3-4

The Cell Cycle

Use your text and lab manual to answer the following questions about the cell cycle and mitosis.

1 Describe the following stages of the cell cycle.

a G1 _____

_____

_____

b S _____

_____

_____

c G2 _____

_____

_____

d M _____

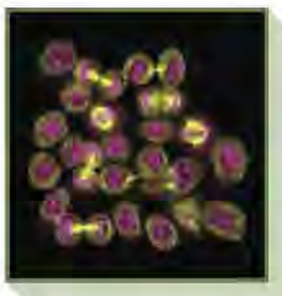
_____

_____

2 Describe the events occurring in the cell in each of the phases of mitosis in Table 3.1.

TABLE **3.1** Stages of Mitosis

Stage of Mitosis	Events Taking Place in the Cell	Cell Appearance
Prophase		
Metaphase		
Anaphase		
Telophase		



EXERCISES

Before we examine organs and systems, we need to start with a simpler level of organization: the **cell**, the smallest unit of life. This unit introduces you to the cell, its structures, and how the cell reproduces itself via the process of cell division.

Note that this is the first unit in which you will use a *Model Inventory*—something you will use throughout this lab manual. In this inventory you will list the anatomical models or diagrams that you use in lab—if the model is not named, make up a descriptive name for it. You will then record in a table the structures you are able to locate on each model. This is particularly helpful for study purposes, as it allows you to return to the proper models to locate specific structures.

In this unit you will also do your first "Time to Draw" exercise, in which you sketch and label one of your anatomical models. Studies have shown that drawing structures helps you form a mental map of what you've learned and leads to better retention. If you're hesitant to draw, remember that your drawings don't have to be works of art—they are simply sketches to represent the anatomy of the specimens that you examine.

Exercise 3-1

Organelles and Cell Structures

MATERIALS

- ❑ Cell models and diagrams
- ❑ 5 colors of modeling clay
- ❑ Fetal pigs or other preserved small mammals
- ❑ Wooden applicator sticks
- ❑ Methylene blue dye
- ❑ Glass slide (blank)
- ❑ Distilled water
- ❑ Coverslip
- ❑ Light microscope
- ❑ Cell slides (with red blood cells, skeletal muscle, and sperm cells)
- ❑ Colored pencils

Most cells in the body are composed of three basic parts—the plasma membrane, the cytoplasm, and the nucleus.

1. **Plasma membrane.** The **plasma membrane** is the outer boundary of the cell (Figure 3.3). As you can see in Figure 3.3, it is composed of a **phospholipid bilayer** (FAHS-foh-lip-id). Notice that the two rows of phospholipids are aligned so that their fatty acid tails face one another and their polar phosphate heads face the water-containing fluids inside and outside of the cell. There are multiple components interspersed throughout the phospholipid bilayer, including **integral proteins, peripheral proteins, cholesterol, glycoproteins** (GLY-koh-proh-teenz), and **glycolipids**. It is a dynamic, fluid structure that acts as a selectively permeable barrier, meaning that it only allows certain solutes to pass into or out of the cell. In parts of the body where rapid absorption is necessary, the plasma membrane is folded into projections called **microvilli** (my-kroh-VIL-eye), which increase its surface area.

2. **Cytoplasm.** The **cytoplasm** (SY-toh-plaz-m) is the material inside the cell. It consists of three parts: **cytosol** (SY-toh-sahl), the **cytoskeleton**, and **organelles** (ohr-gan-ELLZ; Figure 3.4).

   a. **Cytosol** is the fluid portion of the cytoplasm and contains water, solutes, enzymes, and other proteins.

   b. The **cytoskeleton** is a collection of protein filaments including **microtubules, actin filaments**, and **intermediate filaments**. Together, these filaments support the cell, function in cell movement, and move substances within the cell. In addition, microtubules form the core of motile extensions from the cell called **cilia** (SILL-ee-uh) and **flagella** (flah-JEL-uh). Cilia are small, hairlike extensions that beat rhythmically together to propel substances past the cell. Flagella are single extensions that propel the cell itself (sperm cells are the only flagellated cells in the human body).

   c. **Organelles** are specialized cellular compartments that carry out a variety of functions. The organelles we cover in this unit include the following:

      - **Ribosomes.** The small, granular **ribosomes** (RY-boh-zohmz) are composed of two subunits. Some ribosomes float freely in the cytosol, whereas others are bound to the membrane of another organelle or the nucleus. They are one of the few organelles that are not surrounded by a membrane. Ribosomes are the sites of protein synthesis in the cell.

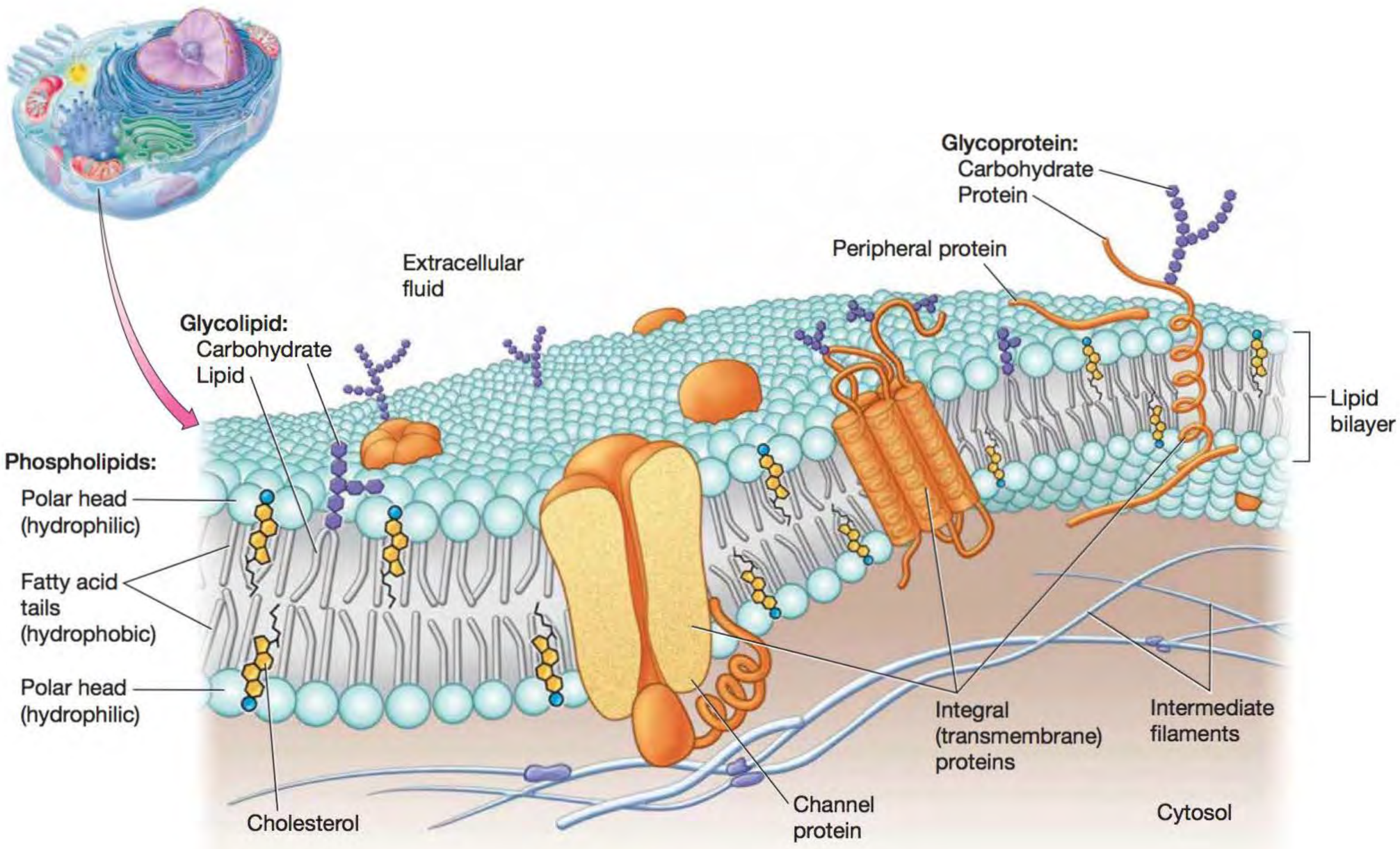


FIGURE **3.3** Plasma membrane.

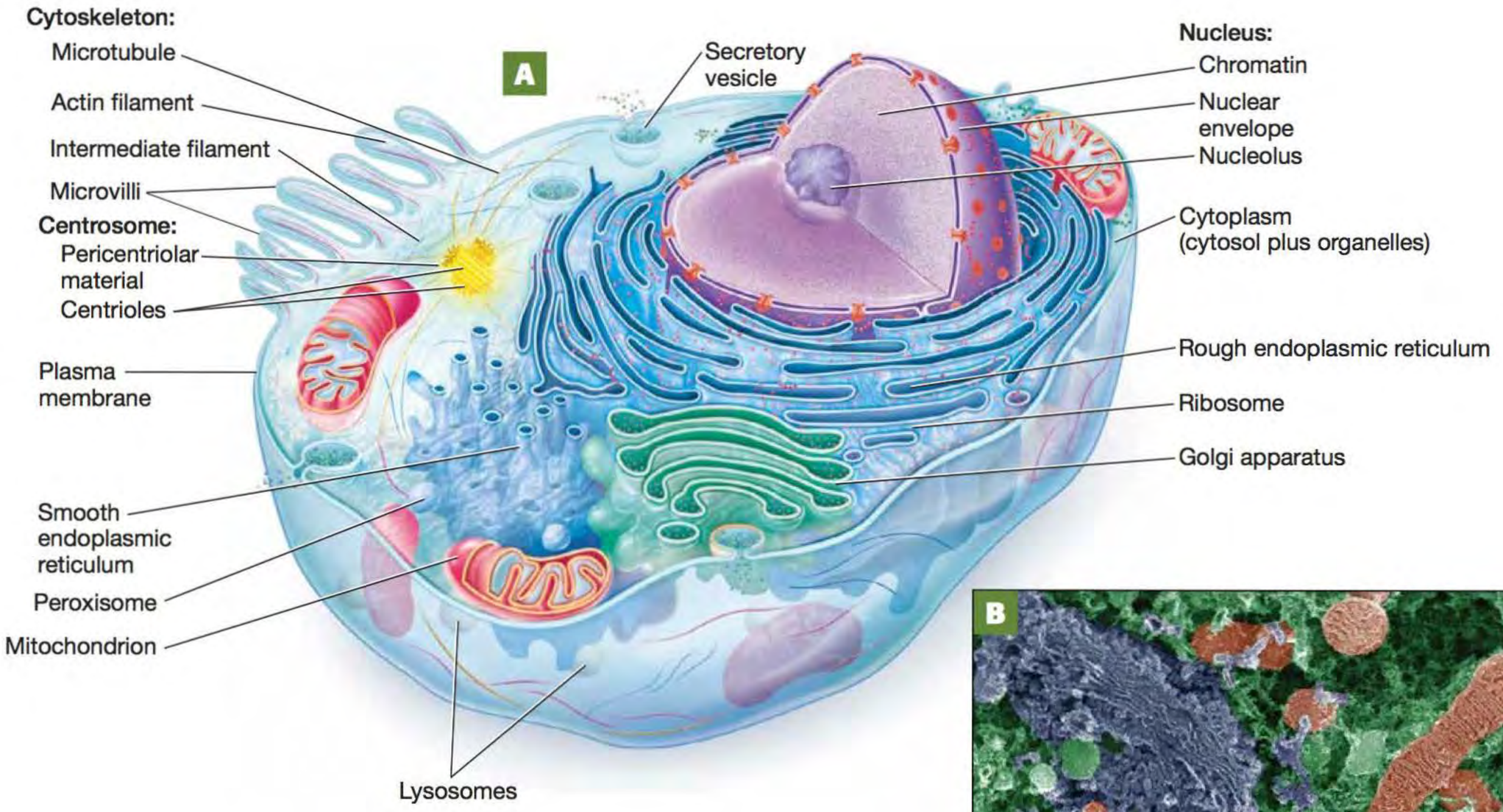


FIGURE **3.4** (A) Generalized cell, sectional view; (B) cellular organelles, SEM.

- **Peroxisomes.** The small, vesicular organelles known as **peroxisomes** (per-AWKS-ih-zohmz) are small, round membrane-bounded sacs. They contain enzymes that catalyze reactions to detoxify chemicals produced by cellular reactions, metabolize fatty acids, and synthesize certain phospholipids.
- **Mitochondria.** The bean-shaped **mitochondria** (my-toh-KAHN-dree-ah) produce the bulk of the cell's ATP (energy). Notice in Figure 3.5 that they are surrounded by a double plasma membrane that encloses a central space called the **matrix.** Within the matrix we find numerous enzymes and mitochondrial DNA.
- **Endoplasmic reticulum.** The series of membrane-enclosed sacs known as the **endoplasmic reticulum** (en-doh-PLAZ-mik reh-TIK-yoo-lum) may be of two types: **rough endoplasmic reticulum,** or **RER,** which has ribosomes on its surface, and **smooth endoplasmic reticulum,** or **SER,** which lacks ribosomes. The RER functions in protein synthesis and modifies proteins that the ribosomes have made. The SER has multiple functions, including lipid synthesis and detoxification reactions.

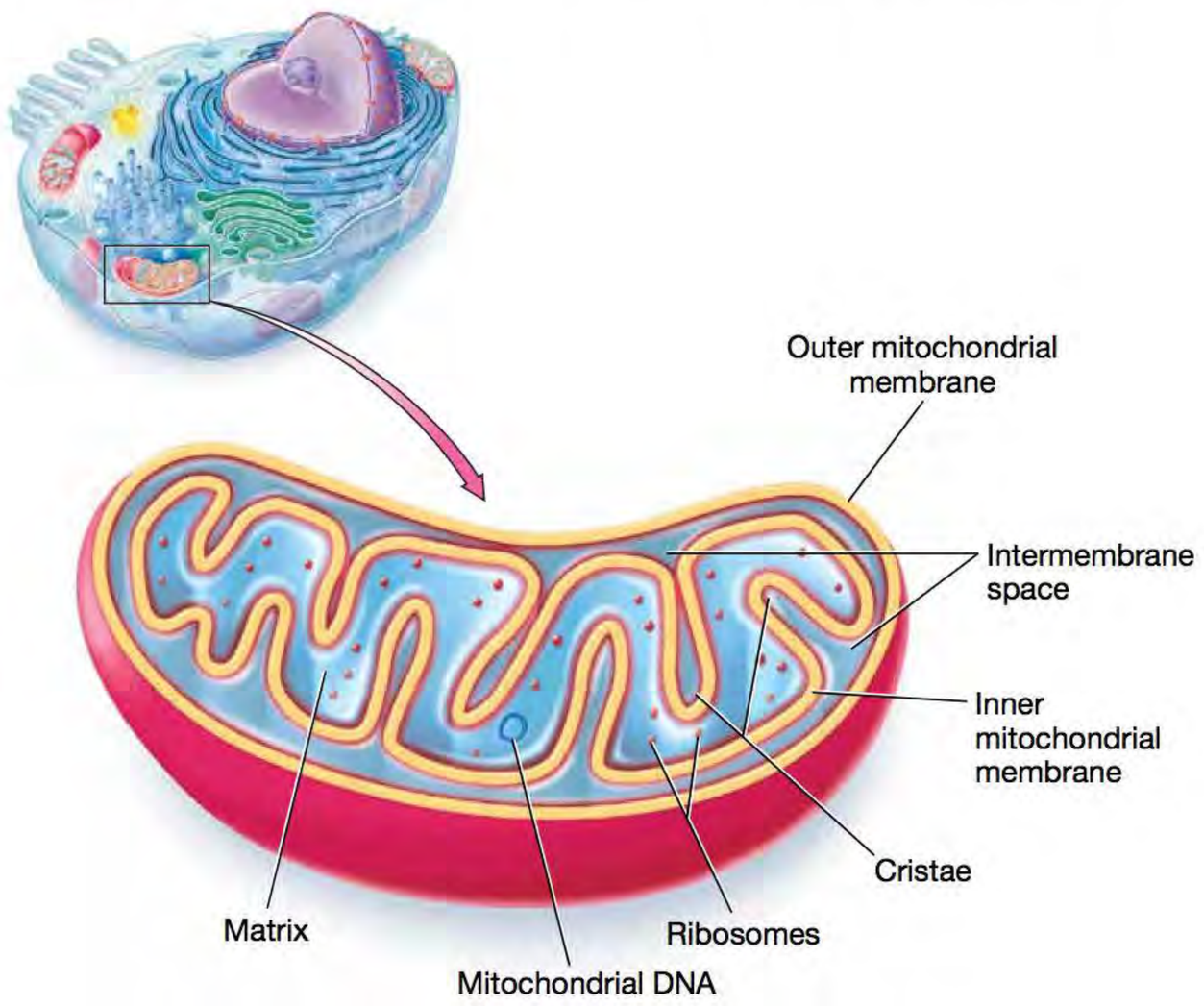


Figure 3.5 Mitochondrion.

- **Golgi apparatus.** The **Golgi apparatus** (GOHL-jee) is a stack of flattened sacs near the RER. Its membrane-enclosed sacs receive vesicles from the RER and other places in the cell and process, modify, and sort the products within the vesicles.
- **Lysosomes. Lysosomes** (LY-soh-zohmz) are membrane-bounded sacs filled with digestive enzymes that catalyze reactions that digest particles brought into the cell, old and worn-out organelles, and even the cell itself.
- **Centrioles. Centrioles** (SEN-tree-ohlz) are paired organelles composed primarily of microtubules that are located in the central area of the cell called the **centrosome** (SEN-troh-sohm). They appear to be microtubule organizing centers and are important in facilitating the assembly and disassembly of microtubules.

3. **Nucleus.** The third component in nearly all cells is a specialized organelle called the **nucleus** (NOO-klee-us). The nucleus is the cell's biosynthetic center that directs the synthesis of all of the body's proteins, as well as certain nucleic acids. The nucleus is surrounded by a double membrane called the **nuclear envelope,** which contains holes called **nuclear pores.** Within the nucleus we find **chromatin** (KROH-mah-tin), a ball-like mass of tightly coiled DNA and proteins; RNA; and a dark-staining region called the **nucleolus** (noo-klee-OH-lus). The nucleolus contains a type of RNA called **ribosomal RNA** and is the "birthplace" of ribosomes.

Note that the cell shown in Figure 3.4 is a **generalized cell** that contains each organelle in average numbers. Most cells in the body don't look like this and instead are specialized so their structure follows their functions. For example, the cells of the liver contain a large amount of smooth endoplasmic reticulum, and immune cells (phagocytes) house many lysosomes.

Procedure 1 Model Inventory for the Cell

Identify the following structures of the cell on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures that you were able to identify on the model inventory in Table 3.2. When you have completed this activity, answer Check Your Understanding questions 1 and 2 (p. 59).

1. Plasma membrane
   a. Phospholipid bilayer
   b. Integral proteins
   c. Peripheral proteins
   d. Carbohydrates
   e. Microvilli
2. Cytoskeleton
   a. Microtubules
   b. Actin filaments
   c. Intermediate filaments
   d. Cilia
   e. Flagella
3. Cytoplasmic organelles
   a. Ribosomes
   b. Peroxisomes
   c. Mitochondria
   d. Rough endoplasmic reticulum
   e. Smooth endoplasmic reticulum
   f. Golgi apparatus
   g. Lysosomes
   h. Centrioles
4. Nucleus
   a. Nuclear membrane
   b. Nuclear pores
   c. Chromatin
   d. Nucleolus

TABLE **3.2** Cellular Structures Model Inventory

Model/Diagram	Structures Identified

Procedure 2 Time to Draw

In the space below, draw, color, and label one of the cell models that you examined. In addition, write the function of each organelle that you label.

Procedure 3 Building a Plasma Membrane

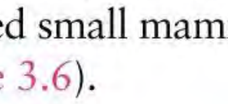
In this exercise, you will build a model of the plasma membrane with modeling clay. Refer to Figure 3.3 (p. 46) for assistance. Use the following color code to build your model:

- Phosphate heads: blue
- Fatty acid tails: yellow
- Integral proteins: red
- Peripheral proteins: green
- Carbohydrates: orange

Procedure 4 Preparing a Cell Sample

Now let's attempt to identify some organelles and cell structures on an actual cell. You will obtain a sample of cells from the mouth (either your own or from a preserved small mammal), and then stain the cells with methylene blue so that certain cellular structures are visible (Figure 3.6).

1. Obtain a blank slide and a coverslip.
2. Clean the slide with lens paper.
3. Swab the inside of your cheek with a sterile wooden applicator stick. As an alternative, swab the inside cheek of a fetal pig or other preserved small mammal. Do not get large chunks of tissue on the swab, or individual cells will not be visible.
4. Wipe the swab with the cheek cells on the blank slide. If you are using your own cheek cells, dispose of the swab in a biohazard bag.
5. Place one drop of methylene blue dye onto the slide. Wait 1 minute.
6. Rinse the dye off the slide with distilled water and pat dry. The blue dye should be barely visible on the slide. If you see large areas of blue, rinse the slide again, or get a new sample of cheek cells.
7. Place a coverslip over the stained area, and place the slide on the stage of a microscope. Focus the image grossly on low power, then switch to the high power objective lens to find individual cells (use oil immersion if available).



Safety Note

Safety glasses and gloves are required!
Methylene blue stains hands and clothes readily.

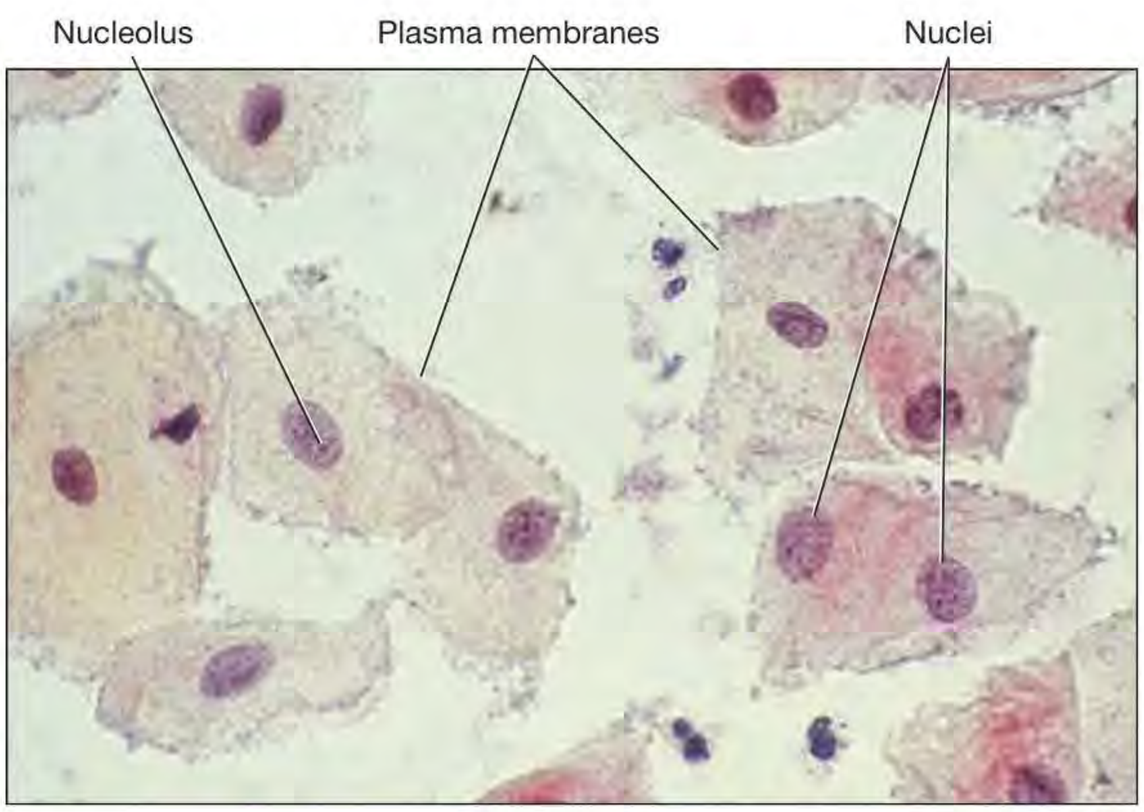
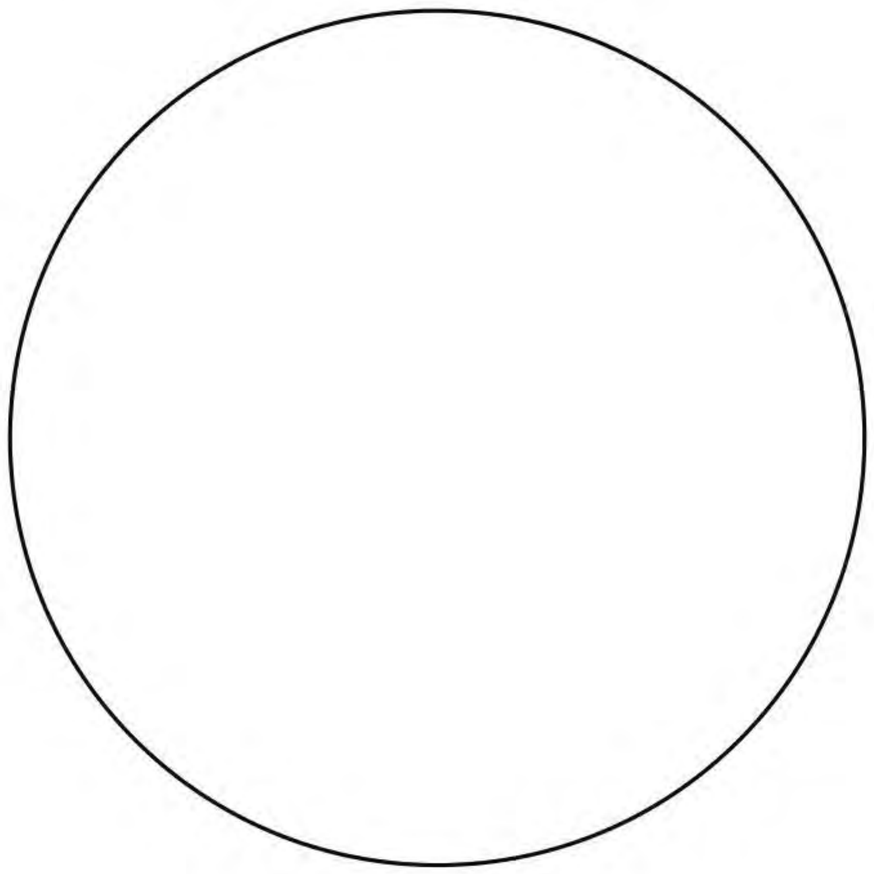


FIGURE **3.6** Cell sample stained with methylene blue.

8 Draw an individual cell, and label all cell structures and organelles that you can identify.



HINTS & TIPS

How to Draw Useful Micrograph Diagrams

You don't need to be a great artist to draw useful micrograph diagrams. Following are some tips for producing effective drawings that can help you learn the material and study for practical exams.

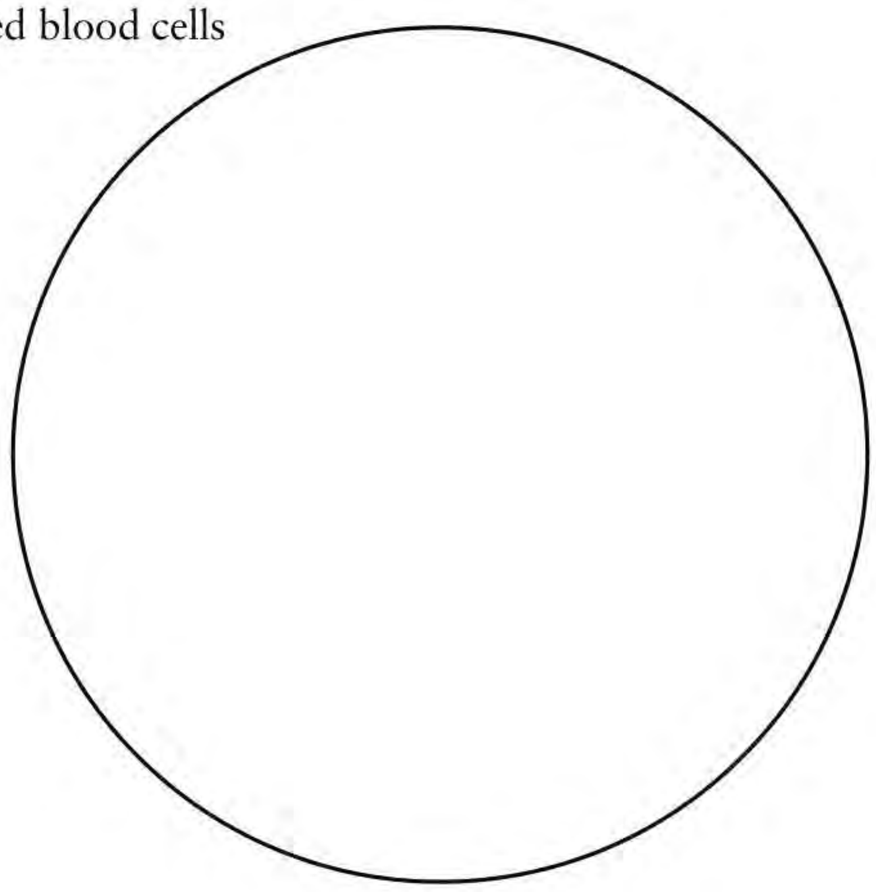
- First look at a diagram of the cell or tissue in question in this book or your textbook to get oriented and get an idea of what you should look for in the field of view.
- Make note of the image's magnification. As always, start on low power, then advance to higher-powered objectives as needed. You should aim for a magnification about the same as the magnification in the diagram.
- Reproduce as closely as possible what you see in the field of view using a pencil. This doesn't have to be a work of art, but you should take care to draw the shape of the cells, the way the cells are organized, and the components of the extracellular matrix. You may draw in the circles in this manual or on a piece of white paper for larger diagrams.
- Add color to your drawing with colored pencils using the slide as a guide. Color is a critical component, particularly for study purposes. Some slides will have uniquely colored stains or staining patterns, and studying the colored images can prove quite helpful. In addition, the slides that your lab uses might have different stains than the images in your book. In these cases, it is useful to have a drawing with those specific stain colors.
- The final step is to label your drawing. Use your lab manual, textbook, and other resources as a guide to ensure that your labels are accurate.

Don't make the mistake of thinking that you can take a shortcut of just drawing what's in your lab manual or book instead of what's under the microscope. The slides usually don't look exactly like what you see in your books, and it's the microscope slides that will be on your exams. Drawing the microscope slides will be far more useful for your studying and your grade.

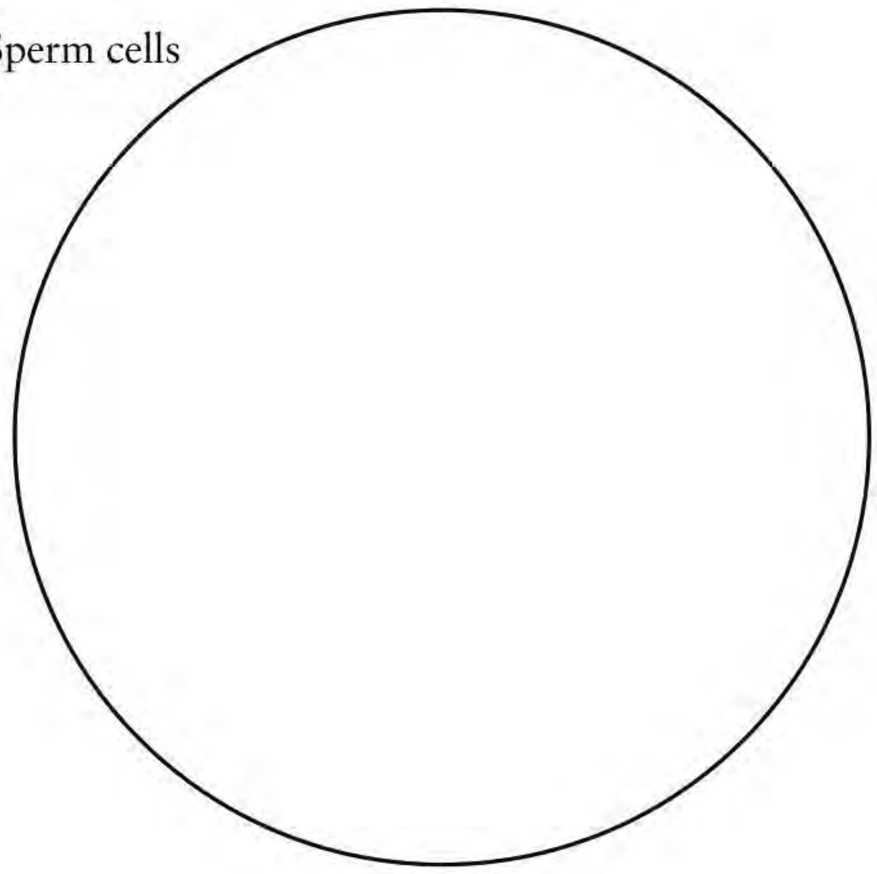
Procedure 5 Examining Cellular Diversity with Microscopy

The structure of different cell types can vary drastically. Cells differ not only in size and shape but also in the types and prevalence of organelles in the cell. In this activity you will examine prepared microscope slides of red blood cells, sperm cells, and skeletal muscle cells. Use the techniques you learned in Unit 2: Begin your observation on low power, and advance to high power for each slide. Note that sperm cells can be difficult to find, so an oil-immersion lens is helpful to find the tiny cells. Draw, color, and label the cellular structures and organelles that you see on each slide. You may wish to look at Figure 4.8 (p. 76) for red blood cells, Figure 4.9A (p. 83) for skeletal muscle, and Figure 22.14 (p. 560) for sperm cells. When you have completed this activity, answer Check Your Understanding question 3 (p. 59).

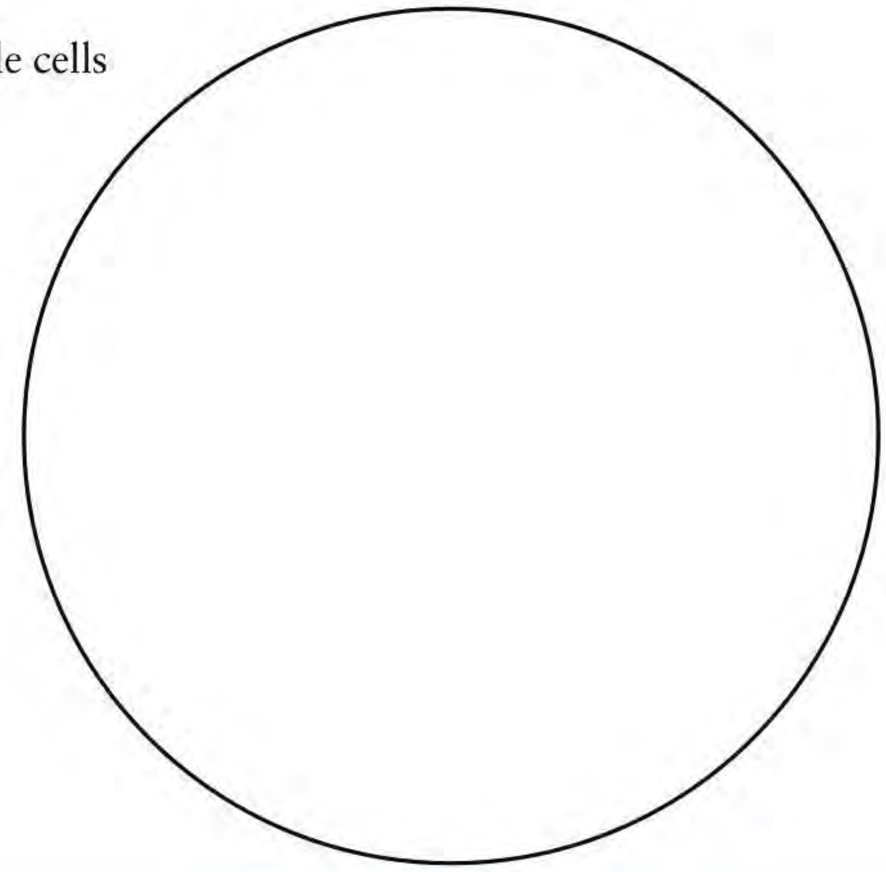
1 Red blood cells



2 Sperm cells



3 Skeletal muscle cells



Exercise 3-2

Mitosis and the Cell Cycle

MATERIALS

- ❑ Cell models or diagrams
- ❑ Mitosis models
- ❑ Mitosis slides
- ❑ Light microscope
- ❑ Colored pencils

Each daughter cell has the same exact genetic and structural characteristics as the original cell. The portions of the cycle from G1–G2, when the cell is not dividing, are collectively called **interphase**. Note that some cells are *amitotic*, meaning that they do not divide by mitosis. Such cells are said to be in phase G_0 of the cell cycle.

Mitosis proceeds in the four general stages shown in Figure 3.8.

Most cells go through a continual cycle of growth and replication called the **cell cycle**. The cell cycle consists of four phases (Figure 3.7):

1. **G1**, or the initial growth phase,
2. **S phase**, during which the DNA is replicated,
3. **G2**, the second growth phase, and
4. **M phase** or **mitosis** (my-TOH-sis), during which the cell divides its organelles, cytosol, and replicated DNA among two identical **daughter cells**.

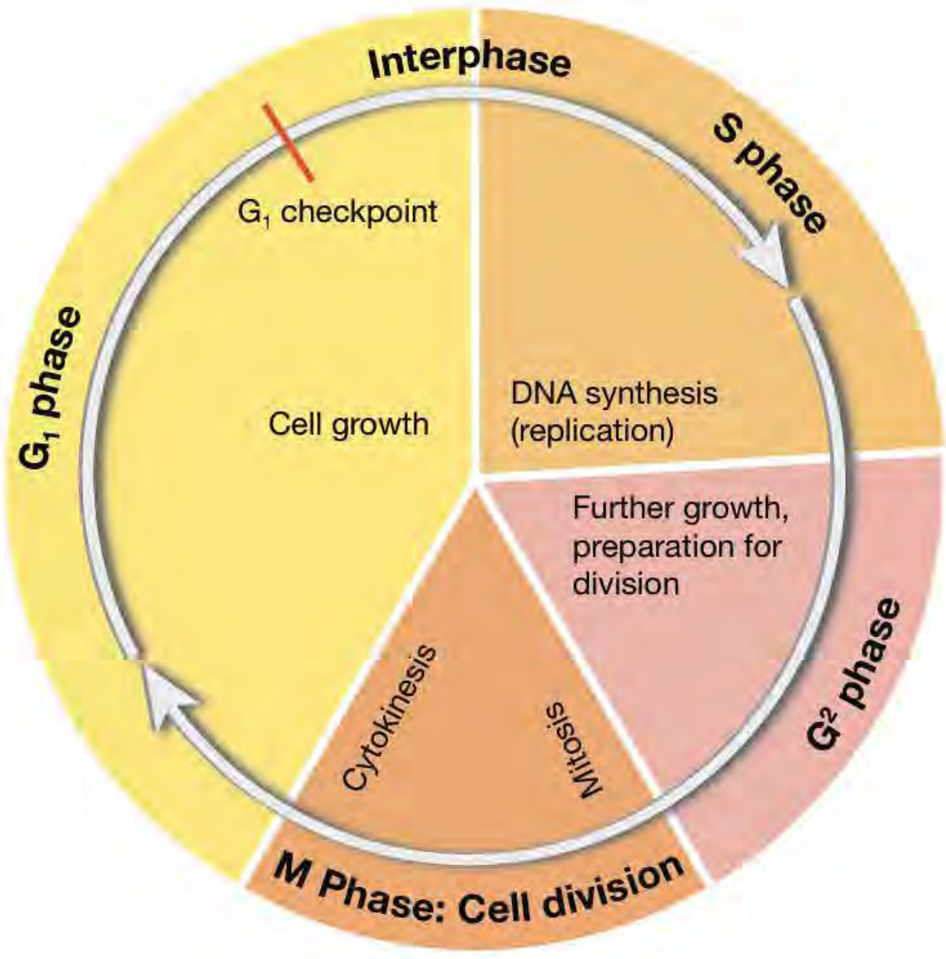


FIGURE **3.7** The cell cycle.

1. **Prophase**. During **prophase**, the nuclear membrane starts to degenerate, and the DNA condenses so individual **chromosomes** (KROH-moh-sohmz) are visible. Human cells have 23 pairs of **homologous chromosomes:** one set from the mother, and one set from the father. After the DNA is replicated, each homologous chromosome exists in a set called **sister chromatids**. Also during this stage, we see a structure called the **mitotic spindle** organizing around the centrioles, which begin migrating to the opposite poles of the cell.
2. **Metaphase**. In **metaphase** we see the chromosomes line up along the central portion of the cell. Microtubules called **spindle fibers** emanate from the each side of the mitotic spindle and attach to a structure called the **centromere** (SEN-troh-meer) that joins each pair of sister chromatids.
3. **Anaphase**. During **anaphase** we see the spindle fibers shorten, which pulls the sister chromatids toward the opposite poles of the cell. In addition, a process called **cytokinesis** (sy-toh-kin-EE-sis) begins, during which the cytoplasm is divided up among the two forming cells.
4. **Telophase**. In the final phase of mitosis, **telophase** (TEL-oh-phayz), a divot forms between the two cells called a **cleavage furrow** (Figure 3.9). As the cleavage furrow progressively narrows, the cell is pinched into two identical daughter cells. In addition, during this stage the nuclear membranes begin to reassemble, the mitotic spindle becomes less visible, and cytokinesis is completed.

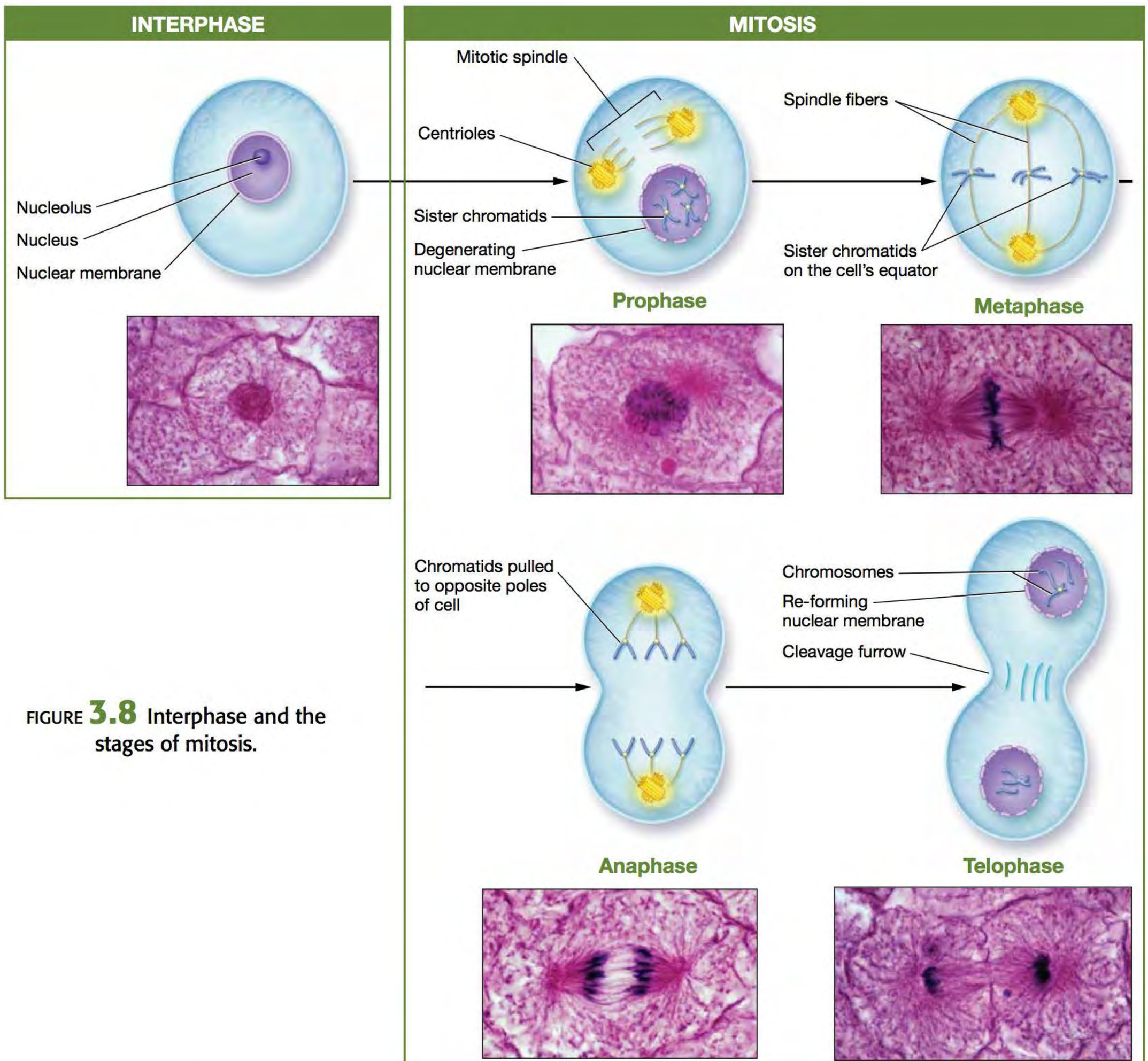


FIGURE **3.8** Interphase and the stages of mitosis.

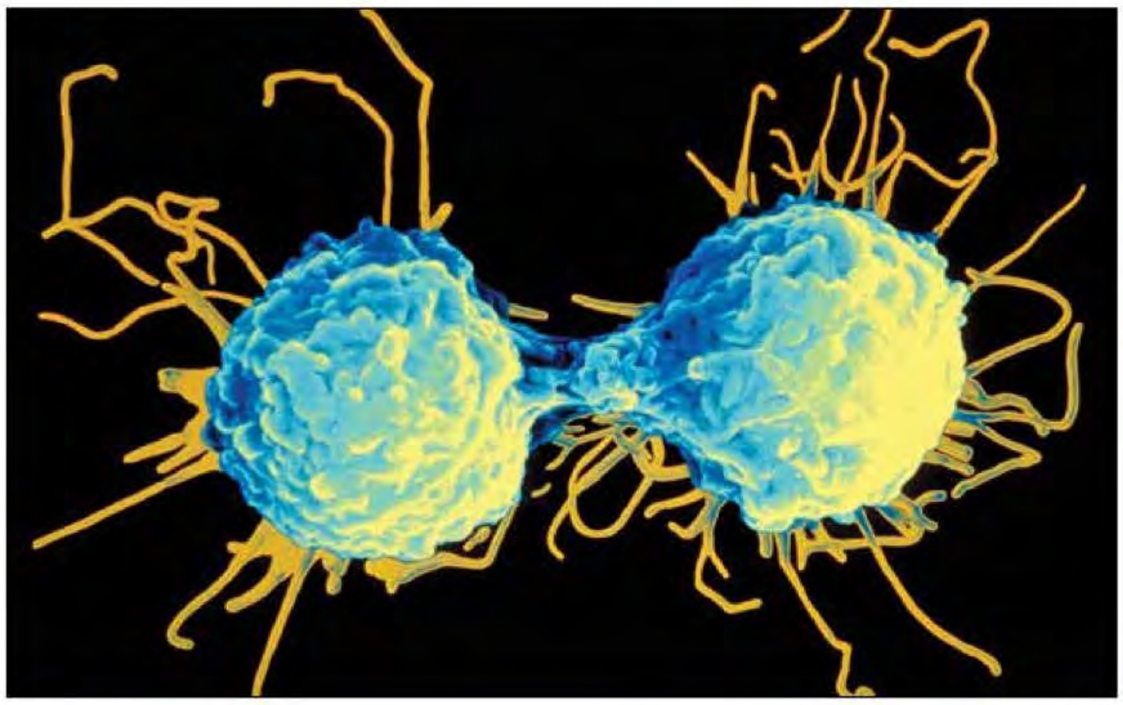


FIGURE **3.9** White blood cell in telophase of mitosis.

Procedure 1 Identify Structures of Cell Division

Identify the following structures associated with mitosis on cell models and diagrams.

1. Mitotic spindle
   a. Centrioles
   b. Microtubules (spindle fibers)
2. Nucleus
   a. Nucleolus
   b. Nuclear membrane
3. Chromosomes
   a. Sister chromatids
   b. Centromere

Procedure 2 Model Mitosis

Arrange models of the cell cycle and mitosis in the proper order. As an alternative, build a set of cell cycle models with modeling clay, and arrange them in the proper order of the cycle.

1. Interphase
2. Mitosis
   a. Prophase
   b. Metaphase
   c. Anaphase
   d. Telophase

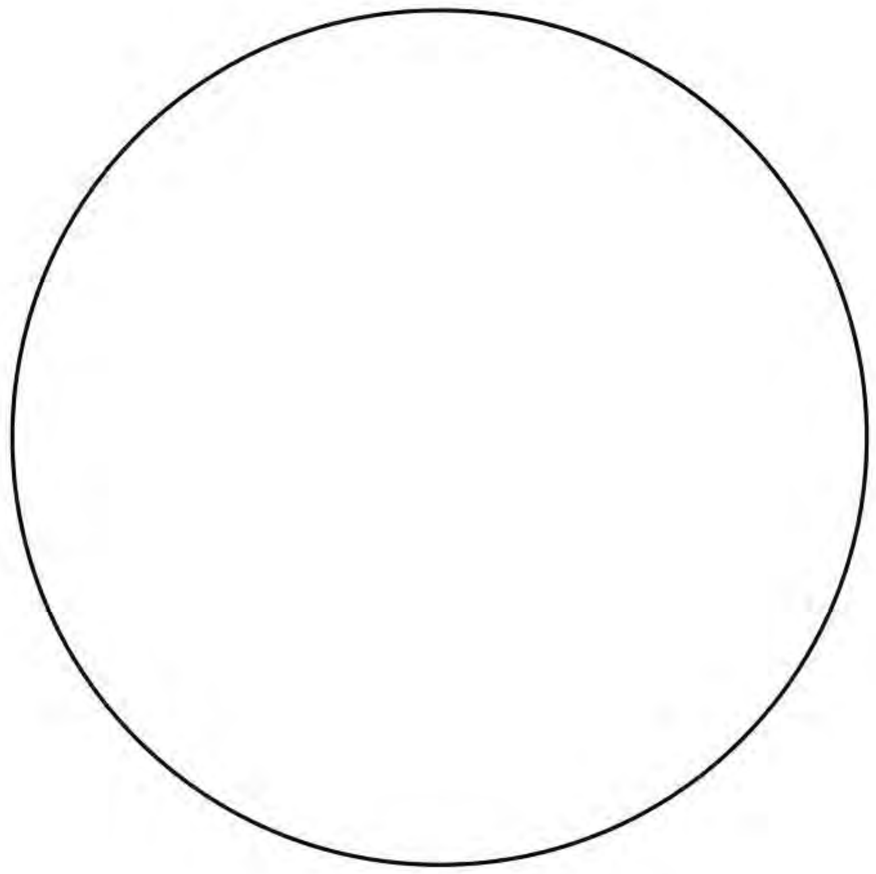
Procedure 3 Microscopy of the Cell Cycle

Examine the five phases of the cell cycle on prepared whitefish mitosis slides using the highest-power objective. Note that every stage of the cell cycle may not be visible on one single slide, so you may have to use more than one slide. Note also that most of the cells you see will be in interphase.

Draw and describe what the cell looks like during each phase of the cell cycle, and label your drawing with as many of the structures of cell division (see p. 53) as you can see in each cell. Use your Pre-Lab Exercises and Figure 3.8 for reference. When you have completed the activities, answer Check Your Understanding questions 4 and 5 (pp. 59–60).

1 Interphase

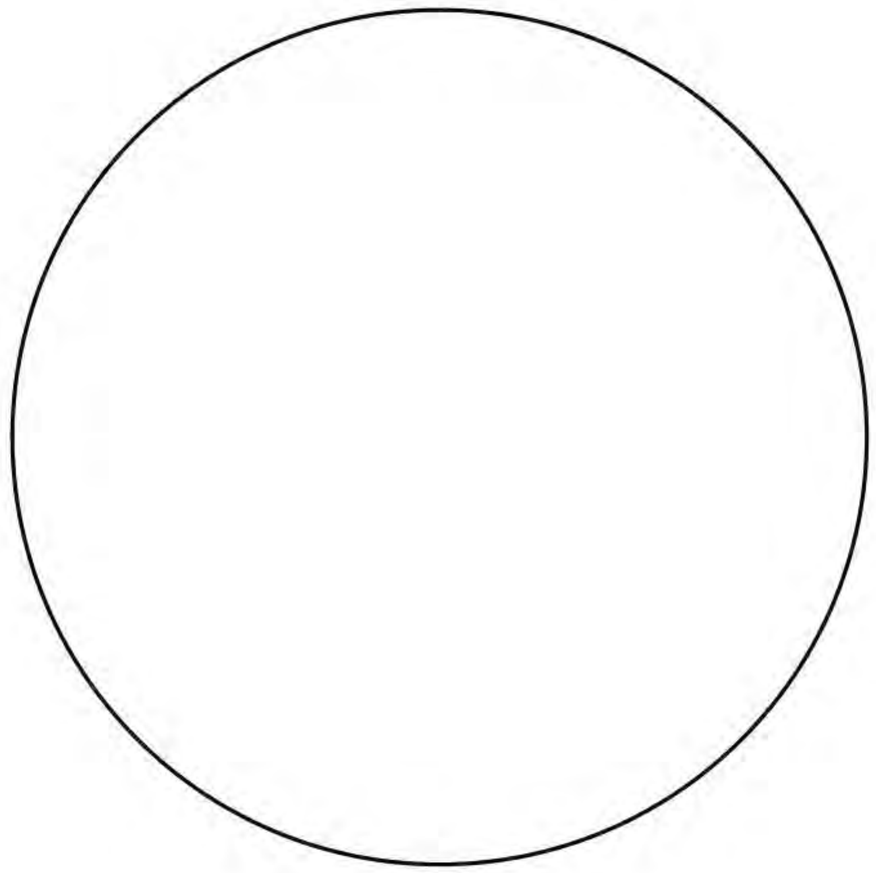
Description:



2 Mitosis

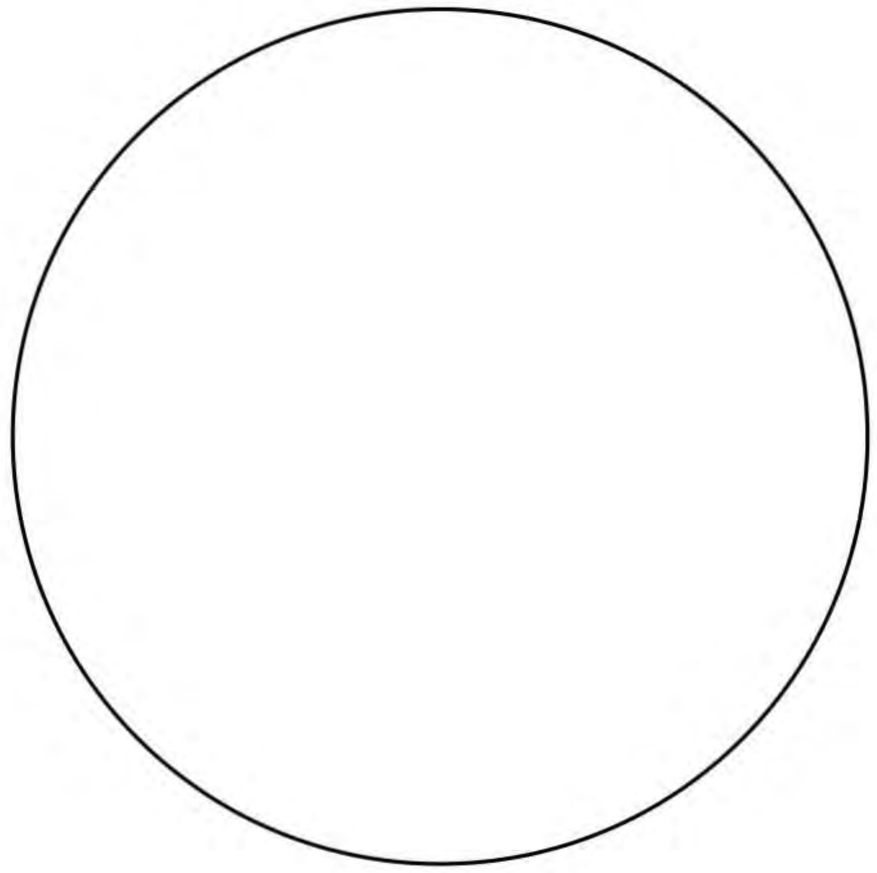
a Prophase

Description:



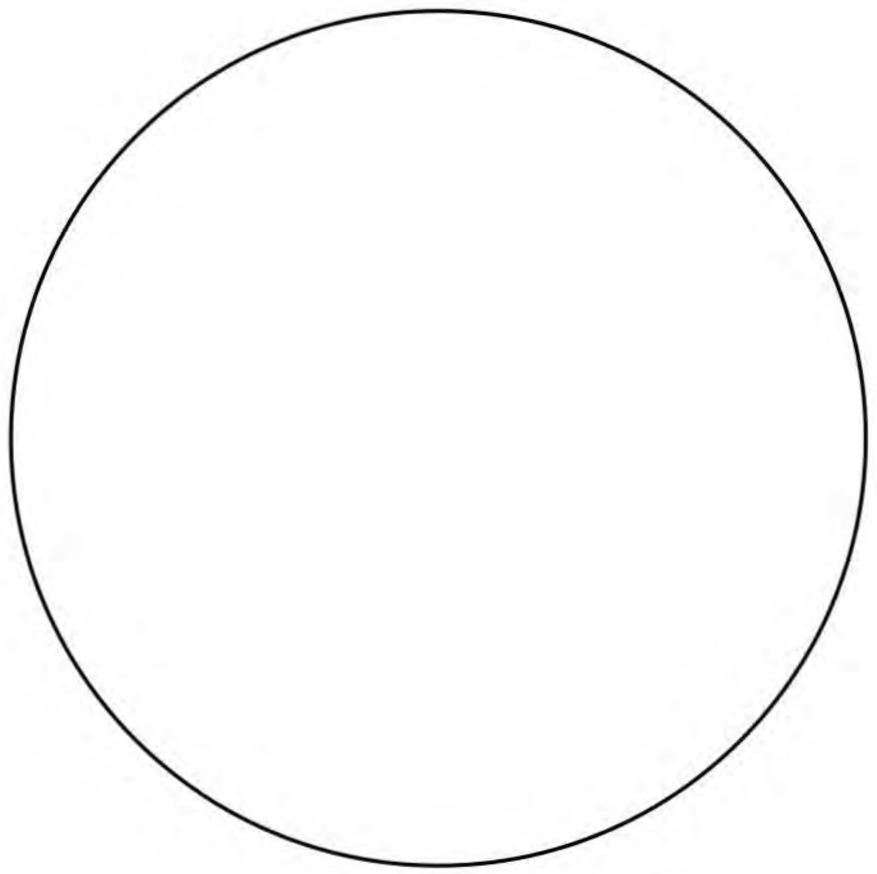
b Metaphase

Description:



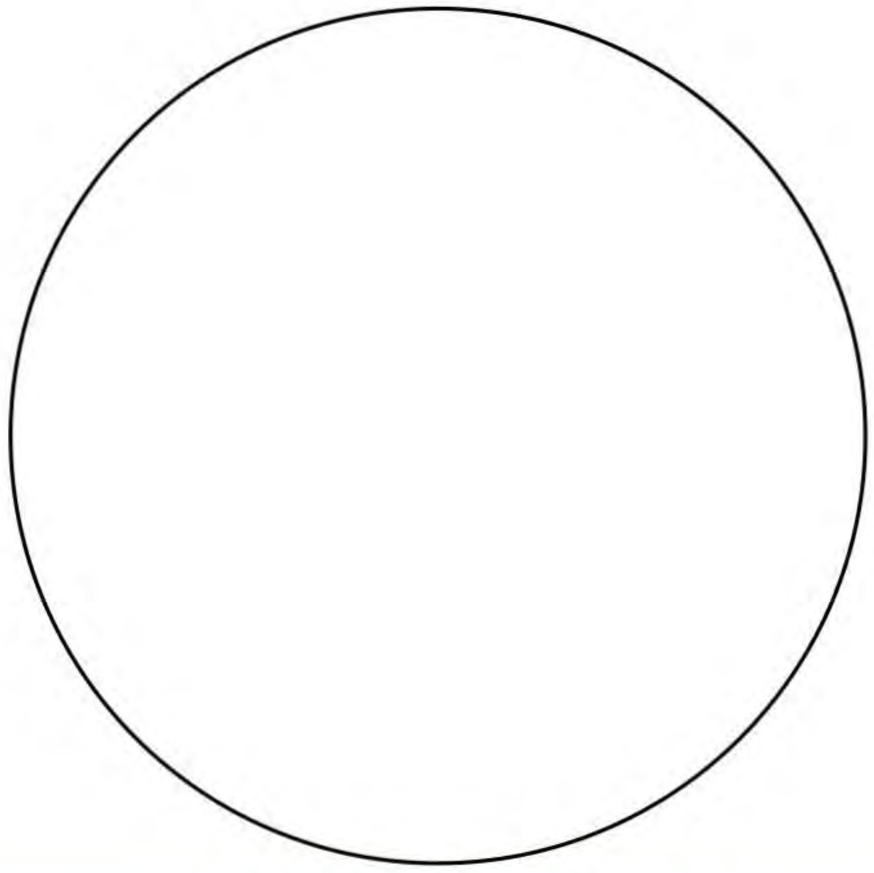
c Anaphase

Description:



d Telophase

Description:



Name _____

Section _____ Date _____

UNIT 3

REVIEW

Check Your Recall

1 **Label the following parts of the cell on Figure 3.10.**

- ❑ Chromatin
- ❑ Golgi apparatus
- ❑ Microvillus
- ❑ Mitochondrion
- ❑ Nuclear envelope
- ❑ Nucleolus
- ❑ Plasma membrane
- ❑ Rough endoplasmic reticulum
- ❑ Smooth endoplasmic reticulum

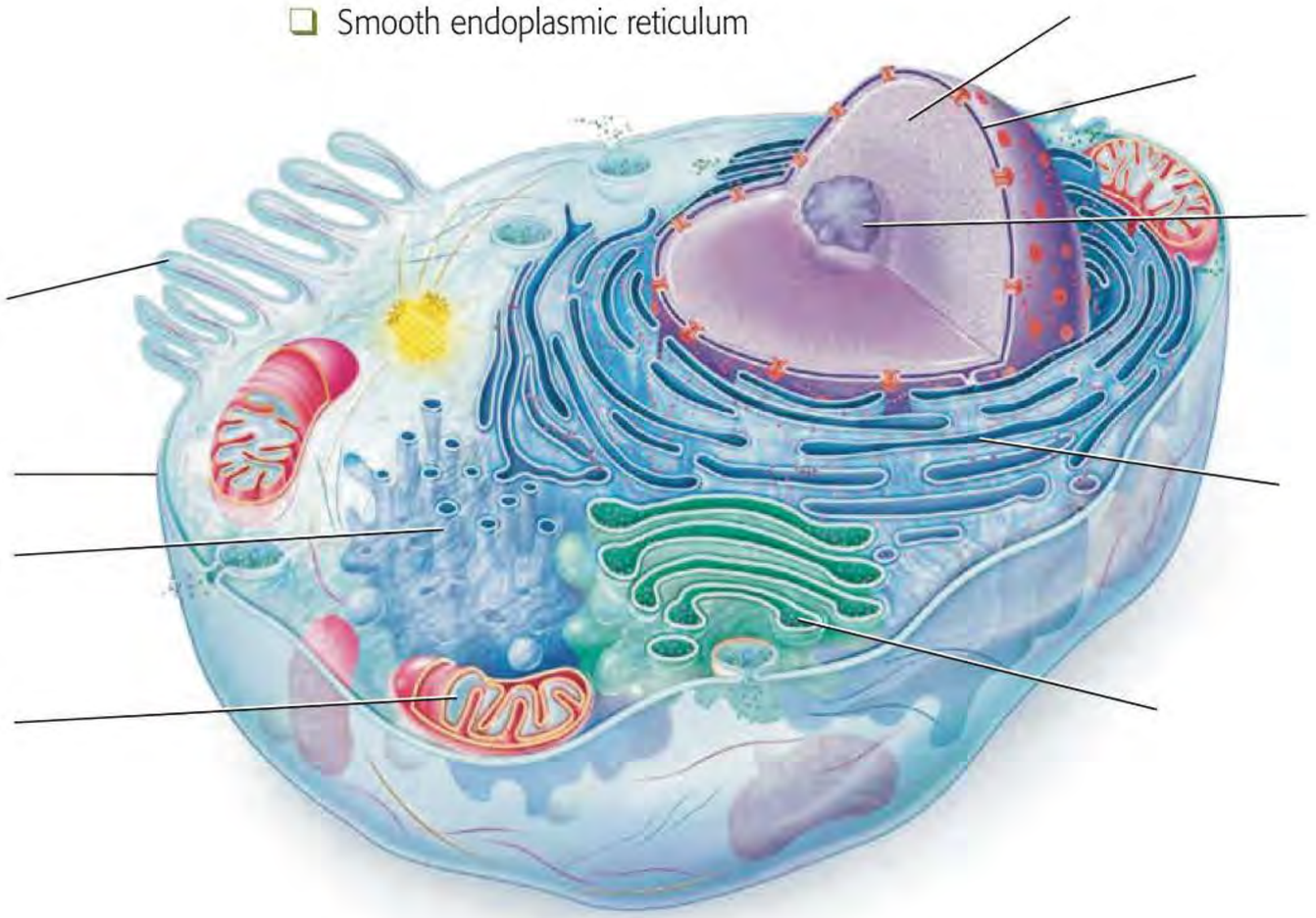


FIGURE **3.10** Generalized cell.

2 **Which of the following is not a component of the plasma membrane?**

a. Cholesterol
b. Glycolipids
c. Phospholipids
d. Nucleic acids

3 **How do phospholipids line up in the plasma membrane?**

_____

_____

4 **Which of the following is not a basic component of most cells?**

a. Microvilli
b. Plasma membrane
c. Nucleus
d. Cytoplasm

5 ***Matching:*** **Match the following organelles and cell structures with the correct definitions.**

_____ Plasma membrane	A. Biosynthetic center of the cell
_____ Smooth ER	B. Produce(s) the bulk of the cell's ATP
_____ Mitochondria	C. Contain(s) digestive enzymes
_____ Ribosomes	D. Stack of flattened sacs that modifies and sorts proteins
_____ Rough ER	E. Composed of a phospholipid bilayer
_____ Nucleus	F. Series of membrane-enclosed sacs with ribosomes on the surface
_____ Nucleolus	G. Cytoskeletal filament found in cilia and flagella
_____ Lysosome	H. Series of membrane-enclosed sacs that detoxify substances and synthesize lipids
_____ Microtubule	I. The cell's "ribosome factory"
_____ Golgi apparatus	J. Granular organelles that are the sites of protein synthesis

6 **During which portion of the cell cycle does DNA replication take place?**

a. G1
b. S phase
c. G2
d. M phase

7 **What takes place during cytokinesis?**

8 **Label the stages of mitosis and the cell cycle on Figure 3.11.**

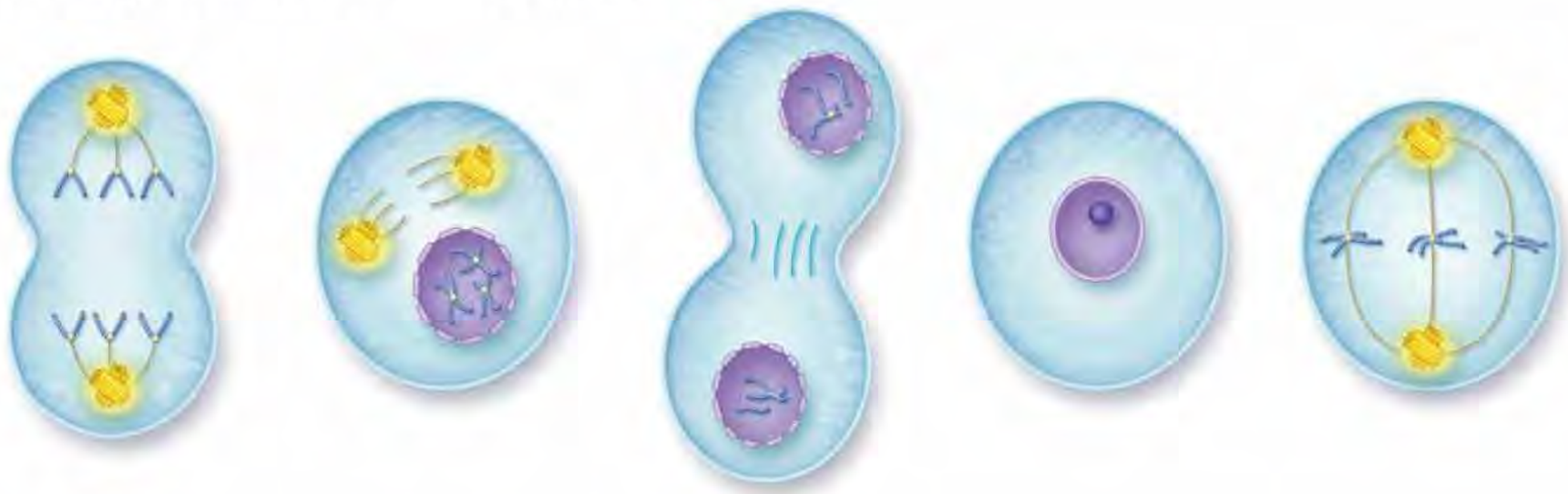


FIGURE **3.11** Stages of the cell cycle and mitosis.

9 **Which of the following is *not* a phase of mitosis?**

a. Prophase
b. Telophase
c. Interphase
d. Anaphase

10 **What is the function of the mitotic spindle and spindle fibers during mitosis?**

Name _____

Section _____ Date _____

REVIEW 3

Check Your Understanding

Critical Thinking and Application Questions

1 Mitochondria contain their own DNA, which encodes 13 proteins. Defects on the mitochondrial DNA can be passed down maternally, leading to a group of diseases called *mitochondrial cytopathies*. What sort of functional defects would you expect to see in cells with diseased mitochondria?

2 Another group of diseases that affect a specific organelle are the *lysosomal storage diseases*. What potential problems could be caused by defective lysosomes?

3 Which cell type that you observed lacks a nucleus? What functions would this cell be unable to carry out?

4 Predict locations in the body where cell populations would undergo rapid mitosis. Why would you expect frequent cell division in these locations?

5 Many anticancer drugs inhibit the formation of the mitotic spindle. What effect will this have on cell division? Why?

3

4 Histology

OBJECTIVES

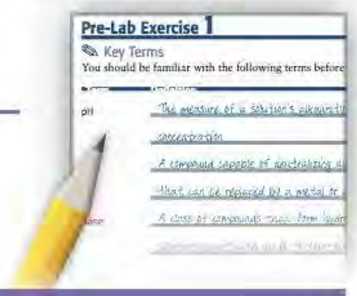
Once you have completed this unit, you should be able to:

1. Identify epithelial tissues by number of layers, cell shape, and specializations.
2. Identify and describe connective tissues.
3. Identify and describe muscle and nervous tissues.
4. Relate tissue structure to tissue function, and describe how organs are formed from two or more tissue types.
5. Give examples of organs where each tissue type is found.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 4-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Epithelial Tissue

Simple epithelial tissue _____

Stratified epithelial tissue _____

Pseudostratified epithelial tissue _____

Squamous cell _____

Cuboidal cell _____

Columnar cell _____

Basement membrane _____

Connective Tissue

Ground substance _____

Collagen fiber _____

Elastic fiber _____

Reticular fiber _____

Loose connective tissue

Dense connective tissue

4

Cartilage

Bone

Blood

Muscle Tissue

Striated

Skeletal muscle tissue

Cardiac muscle tissue

Smooth muscle tissue

Nervous Tissue

Neuron

Neuroglial cell

EXERCISES

The histology labs can be some of the more intimidating and frustrating labs for beginning anatomy students. The subjects are somewhat abstract and unfamiliar and require use of a complicated tool—the microscope. The best way to approach this subject is to be systematic, and let your lab manual walk you through it step-by-step. If you get confused, don't despair. With the help of this book, your lab instructor, and a little patience, you can do it! Before you begin, you may wish to review the "Hints and Tips" boxes on p. 69 and p. 77.

The exercises in this unit introduce you to the four basic types of tissue: **epithelial tissue** (ep-ih-THEE-lee-uhl), **connective tissue, muscle tissue,** and **nervous tissue** (Figure 4.1). All four of these tissue types have two main components: cells, which are specialized for each tissue type, and the **extracellular matrix** (ECM), which is the material around the tissue's cells that is largely produced by the cells themselves.

ECM consists of two components: ground substance and protein fibers. **Ground substance** is a gelatinous material that contains water, ions, nutrients, large polysaccharides, and glycoproteins. It enables the tissue to resist compression. **Protein fibers** are found within the ground substance. There are three types of protein fibers found within tissues:

1. **Collagen fibers** are composed of the thick protein **collagen,** which gives a tissue tensile strength (i.e., the ability to resist stretching forces).
2. **Elastic fibers** are composed of the protein **elastin,** which makes a tissue distensible, or able to be stretched and to return to its original shape and size.
3. **Reticular fibers** are thin fibers made of a special type of collagen protein. They interweave to form networks that support blood vessels, nerves, and other structures.

Let's now begin our exploration of this fascinating level of organization.

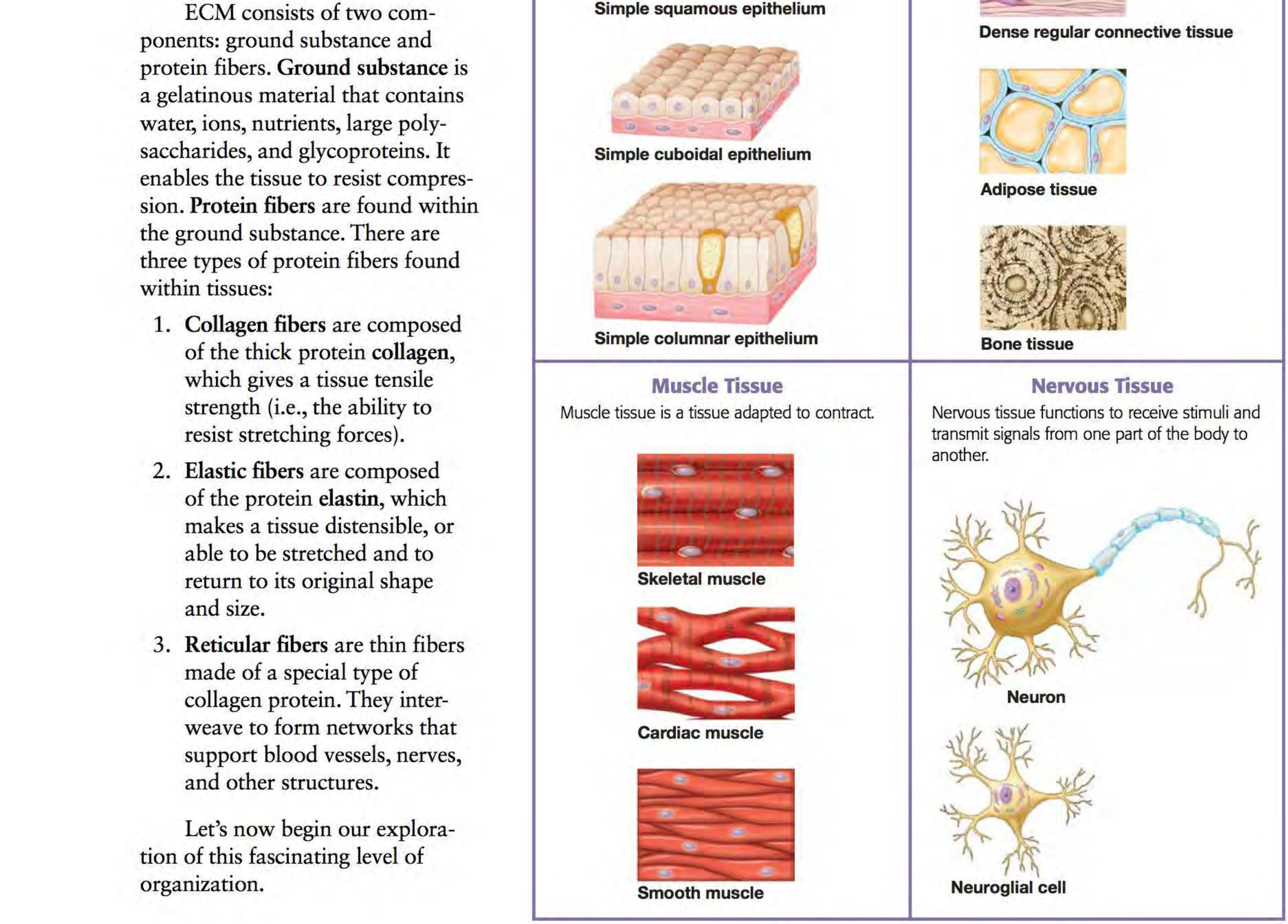


FIGURE **4.1** The four different types of tissue.

Exercise 4-1

Epithelial Tissue

MATERIALS

- ❑ Epithelial tissue slides
- ❑ Light microscope
- ❑ Colored pencils

Epithelial tissues are our covering and lining tissues. They are found covering body surfaces, lining body passageways, lining body cavities, and forming glands. Epithelia predominantly contain cells called **epithelial cells**, and their ECM is limited mostly to the space underneath the cells in a layer called the **basal lamina** (BAY-zul LAM-in-uh). The basal lamina adheres to another layer of ECM produced by the connective tissues deep to the epithelium (known as the *lamina reticularis*). Together, these two structures are called the **basement membrane**.

Epithelial tissues are all **avascular**; they have no blood vessels to supply them directly and rely on oxygen and nutrients that diffuse up from deeper tissues. For this reason, epithelial tissues can be only a certain number of cell layers in thickness. If they are too thick, oxygen and nutrients will not reach the more superficial cells and they will die.

The many types of epithelia are classified according to the number of layers of cells as either **simple epithelia**, which have only one layer of cells, or **stratified epithelia**, which have two or more cell layers. Epithelia are also classified by the predominant cell shape as **squamous** (SKWAY-muss) or flat, **cuboidal**, or **columnar**. These two criteria give us the following classes (see Figure 4.2):

1. **Simple epithelia:**
   a. **Simple squamous epithelium. Simple squamous epithelium**, shown in Figure 4.2A, consists of a single layer of flat cells with a flattened nucleus. We often find simple squamous epithelium in places where substances have to cross the epithelium quickly, such as the air sacs of the lungs.
   b. **Simple cuboidal epithelium**. Note in Figure 4.2B that the cells of **simple cuboidal epithelium** are about as wide as they are tall, with a spherical, central nucleus. Simple cuboidal epithelium is found lining glands such as the thyroid gland, certain respiratory passages, and in the kidneys.
   c. **Simple columnar epithelium**. The cells of **simple columnar epithelium**, shown in Figure 4.2C, are taller than they are wide, with spherical nuclei generally located near the base of the cell. These cells line certain respiratory passages, much of the digestive tract, and the genitourinary tract. The apical plasma membranes of simple columnar epithelial cells often contain cilia or are folded into microvilli.
   d. **Pseudostratified ciliated columnar epithelium. Pseudostratified** (SOO-doh-strat-ih-fy'd) **epithelium**, seen in Figure 4.2D, has the appearance of having many layers but actually has only one layer of cells (*pseudo* = false). This type of epithelium usually has cilia, and the cell shape is always columnar. It is found lining the nasal cavity and much of the respiratory tract.

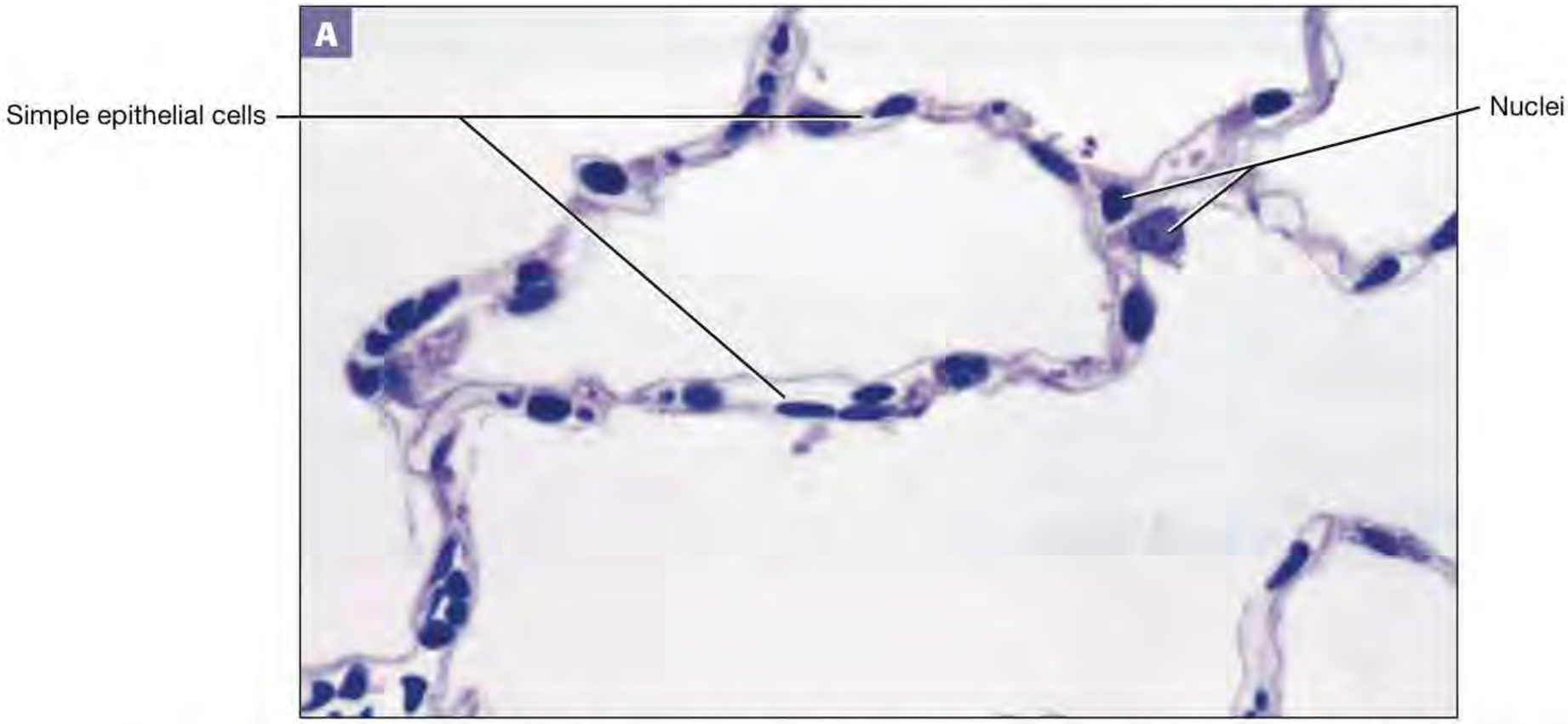


FIGURE **4.2** Simple epithelial tissues: (A) simple squamous epithelium from the lungs *(continues)*

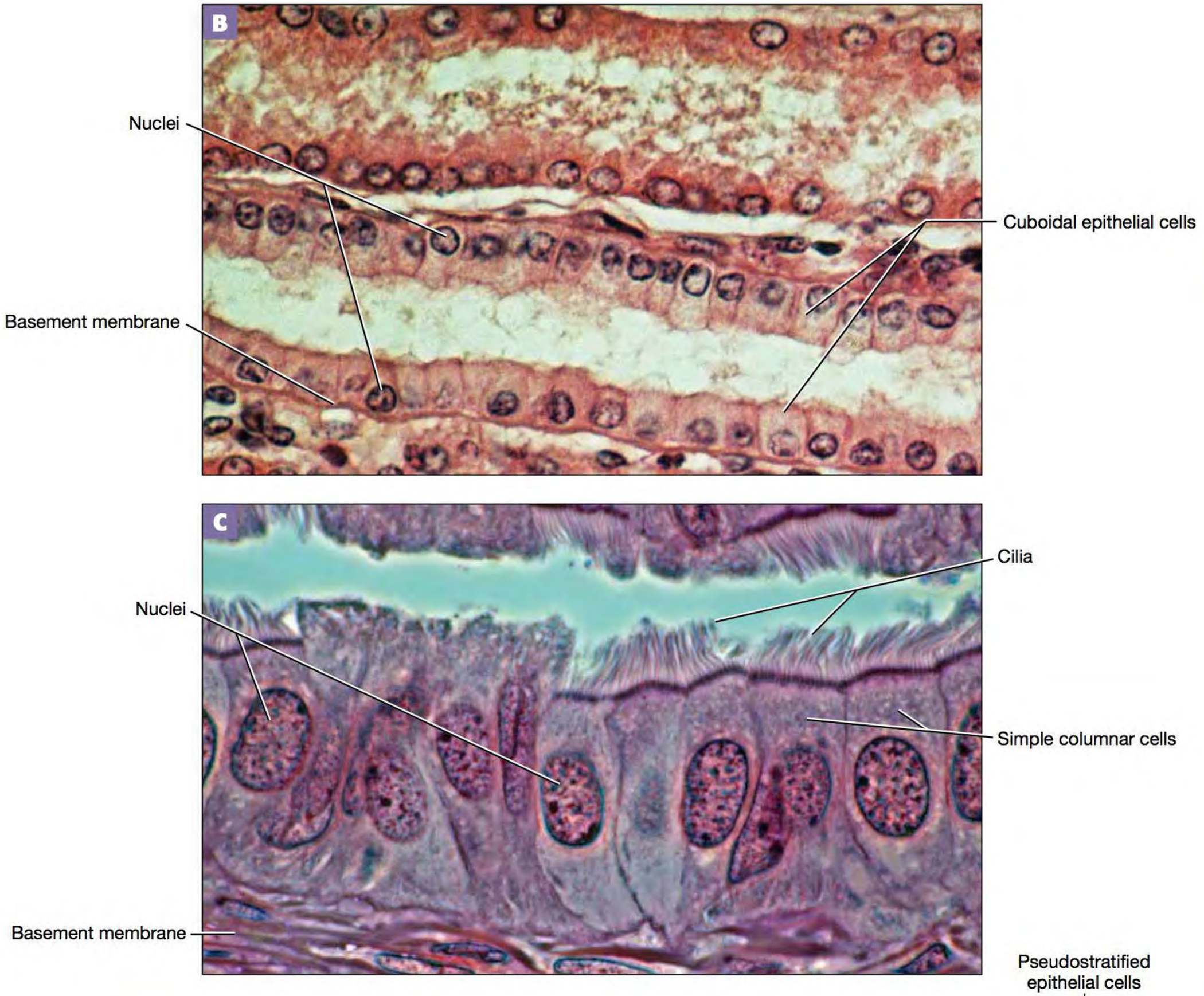


FIGURE **4.2** Simple epithelial tissues *(cont.)*: (**B**) simple cuboidal epithelium from the kidney; (**C**) simple ciliated columnar epithelium from the uterine tube; (**D**) pseudostratified ciliated columnar epithelium from the trachea (light micrograph and scanning electron micrograph, respectively).

2. **Stratified epithelia:**
   a. **Stratified squamous epithelium.** This type of epithelium consists of many layers of flattened cells and has two variants. The first, shown in Figure 4.3A, is **stratified squamous keratinized epithelium,** which consists of epithelial cells called **keratinocytes** (kehr-ah-TIN-oh-syt′z) that produce the hard protein **keratin.** Note in the figure that the more superficial cells are dead and are filled with purplish keratin. This is because they are too far away from the blood supply in the deeper tissues and, as a result, they harden and die. Stratified squamous keratinized epithelial cells resist mechanical stresses and, accordingly, are found in the outer layer of the skin where the body is subject to multiple environmental stresses.

      Stratified squamous nonkeratinized epithelium (Figure 4.3B) contains no keratin and is located in places subject to lesser degrees of mechanical stress, such as the oral cavity, the pharynx (throat), the anus, and the vagina. This type of epithelium is not as thick and, as a result, the superficial cells are alive and much different in appearance than those of keratinized epithelium.

   b. **Stratified cuboidal epithelium** and **stratified columnar epithelium.** Both of these types of epithelium are rare in the human body (Figure 4.3C shows stratified cuboidal epithelium only) and are found lining the ducts of certain glands.

   c. **Transitional epithelium. Transitional epithelium,** shown in Figure 4.3D, is stratified but is not classified by its shape because its cells can change shape. Typically, the apical or surface cells are dome-shaped, but when the tissue is stretched, they flatten and are squamous in appearance. Transitional epithelium is found lining the urinary bladder and ureters.

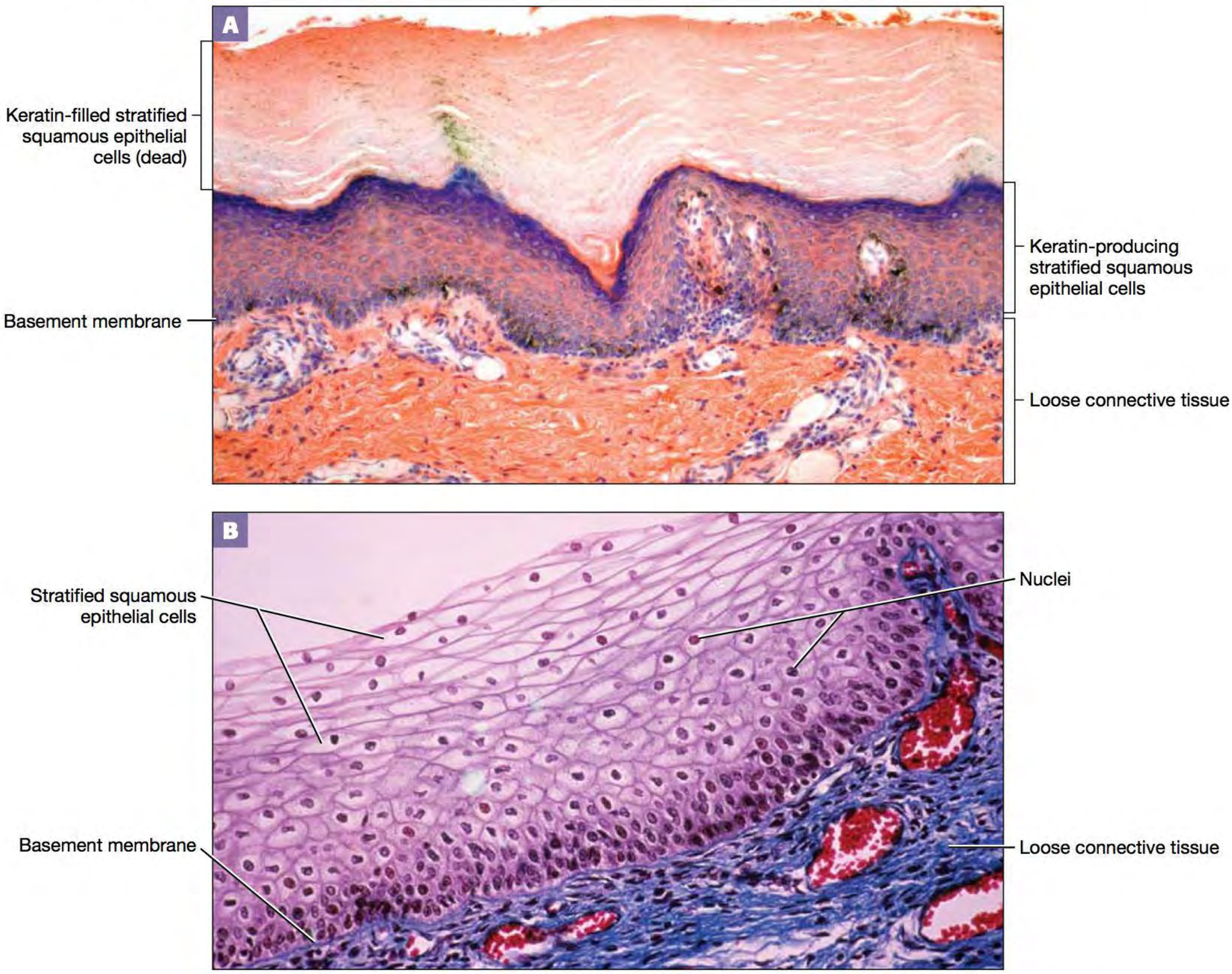


FIGURE **4.3** Stratified epithelial tissues: (A) stratified squamous keratinized epithelium from the skin; (B) stratified squamous nonkeratinized epithelium from the vagina *(continues)*

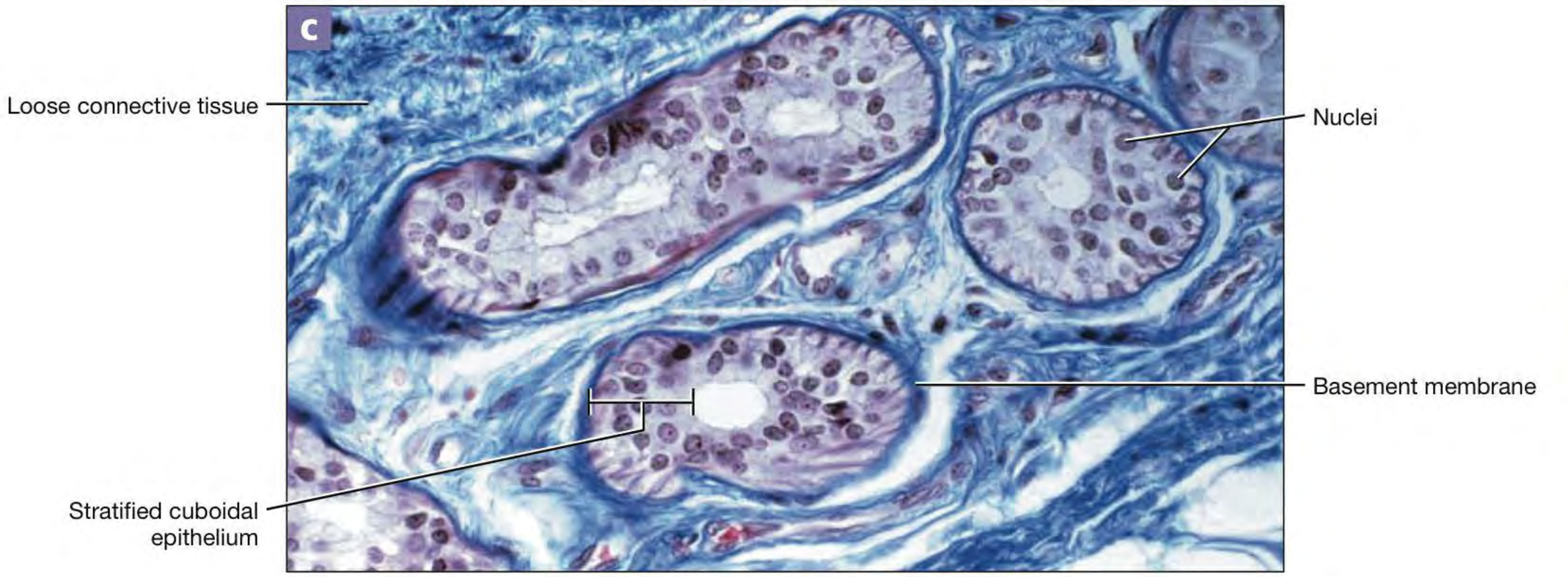


FIGURE **4.3** Stratified epithelial tissues *(cont.)*: (**C**) stratified cuboidal epithelium from a sweat gland; (**D**) transitional epithelium from the urinary bladder.

HINTS & TIPS

How to Approach Epithelium

Before you start, remember how to approach any slide: First examine the slide with the naked eye, then begin on low power and scan the slide, and advance progressively to higher power to see details. Use the figures in this manual as a guide—if your slide looks nothing like the tissue in the figure, scroll around the slide, and keep looking. But don't rely completely on the figures here, because the slides that your lab uses may be prepared with different stains or from different tissues.

Also, remember that when you are looking at any slide, you are seeing two things only: cells and ECM. First identify the cells, which are easy to identify by their dark purple-staining nuclei. Everything around the cell, be it purple straight lines, pink wavy lines, or light purple gel, is just ECM. If you keep this in mind, you can use the cell appearance, distribution, and ECM composition to determine what type of tissue you are seeing. A few simple facts can help you distinguish epithelial tissues from other tissues:

- Epithelial tissues are all avascular, so you won't see any blood vessels in epithelium.
- Epithelial tissues are typically on the outer edge of the slide. Keep in mind that most slides have several tissues in each section. To find the epithelial tissue, scroll to one end of the slide or the other.
- Epithelial tissues consist mostly of cells. Look for cells that are tightly packed together with only a thin layer of ECM underneath the cells.

Procedure 1 Microscopy of Epithelial Tissues

Examine prepared slides of the following epithelial tissues. Use colored pencils to draw what you see under the microscope, and label your drawings with the terms from Figures 4.2 and 4.3. Then (a) describe what you see, and (b) give examples of locations in the body where this tissue is found.

1 Simple squamous epithelium

a _____

_____

b _____

_____

2 Simple cuboidal epithelium

a _____

_____

b _____

_____

3 Simple columnar epithelium

a _____

_____

b _____

_____

4 Pseudostratified ciliated columnar epithelium

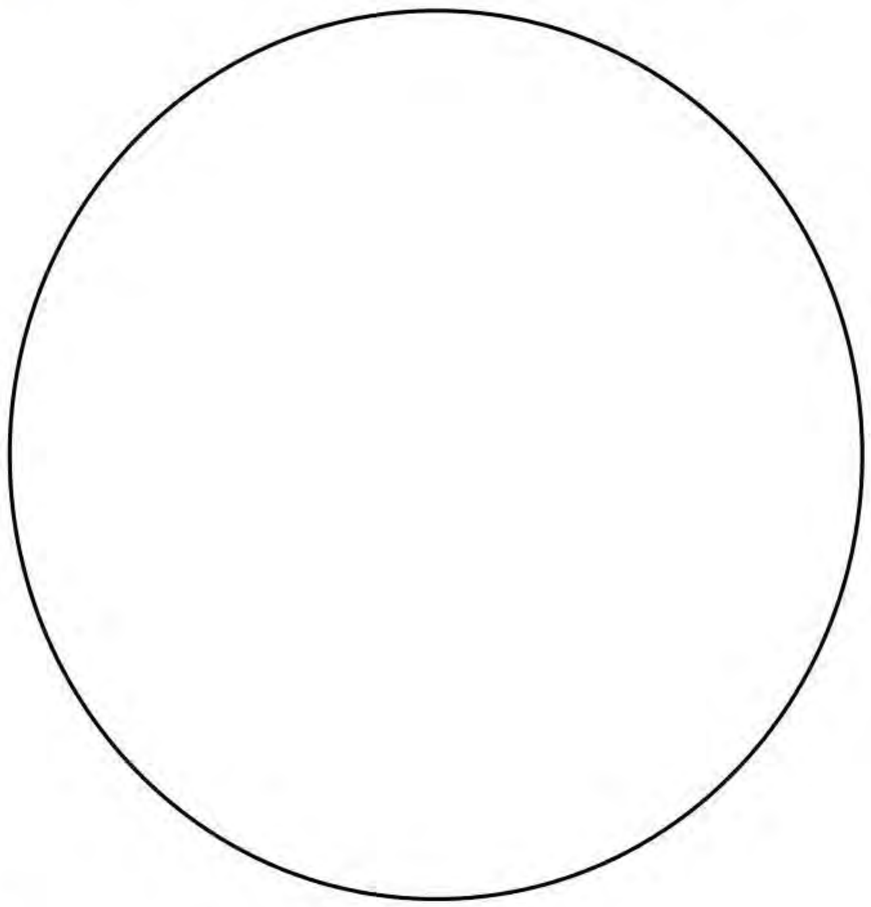
a _____

_____

b _____

_____

5 Stratified squamous keratinized epithelium



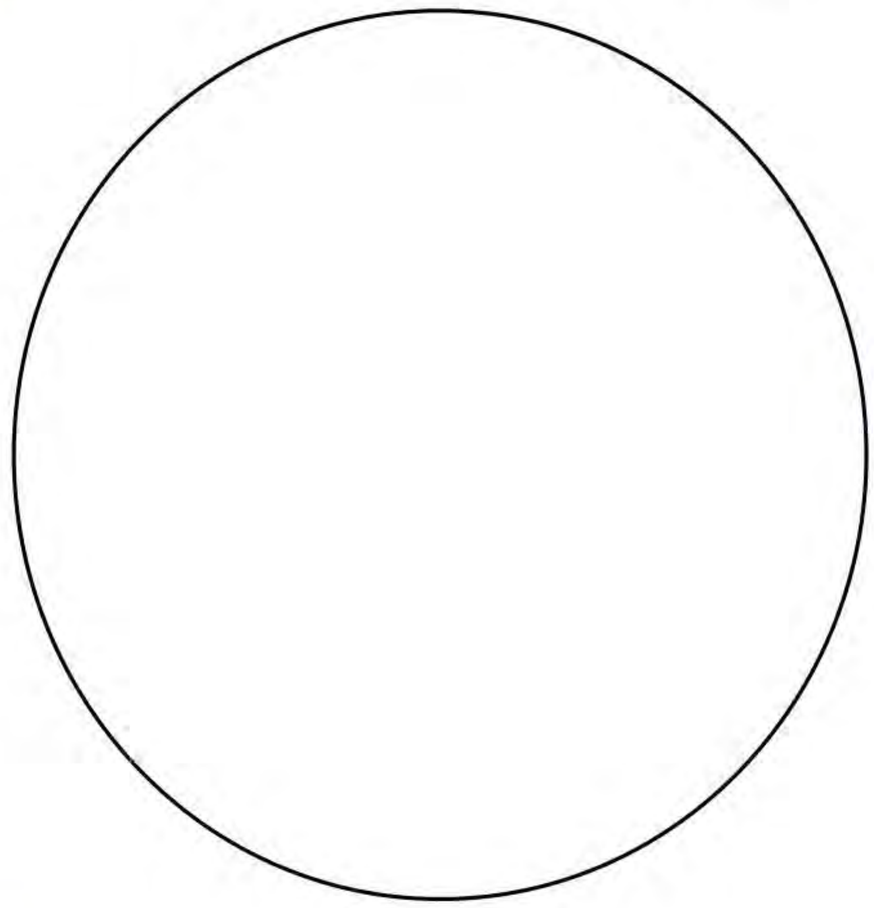
a _____

_____

b _____

_____

6 Stratified squamous nonkeratinized epithelium



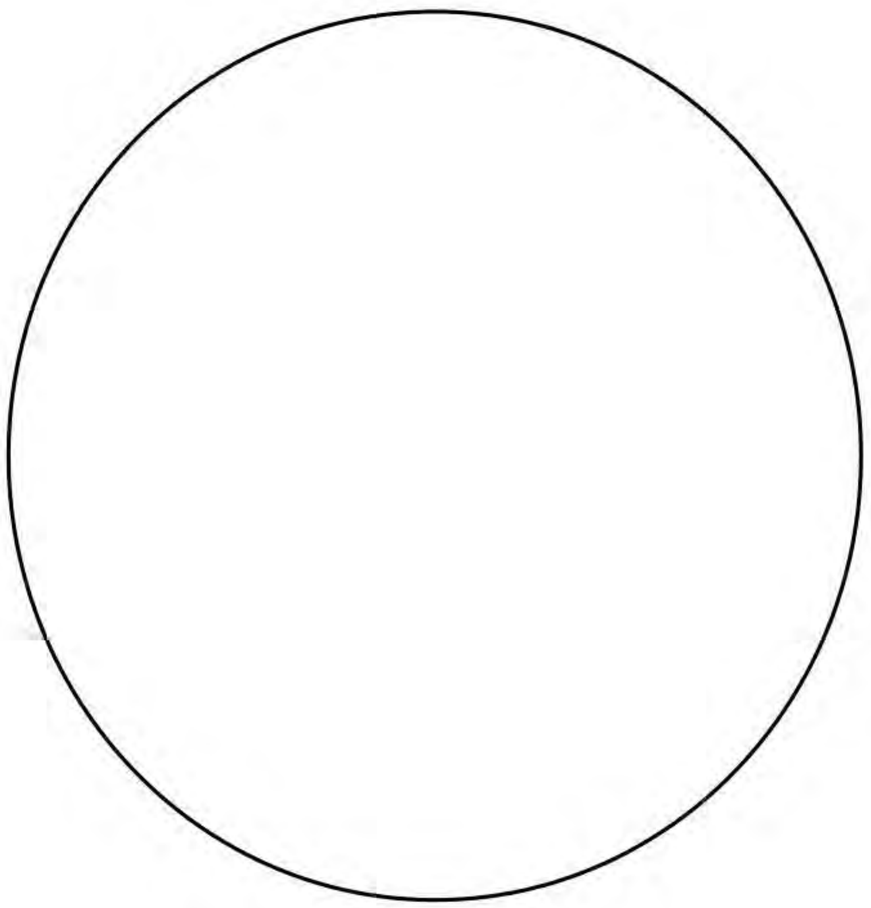
a _____

_____

b _____

_____

7 Stratified cuboidal epithelium



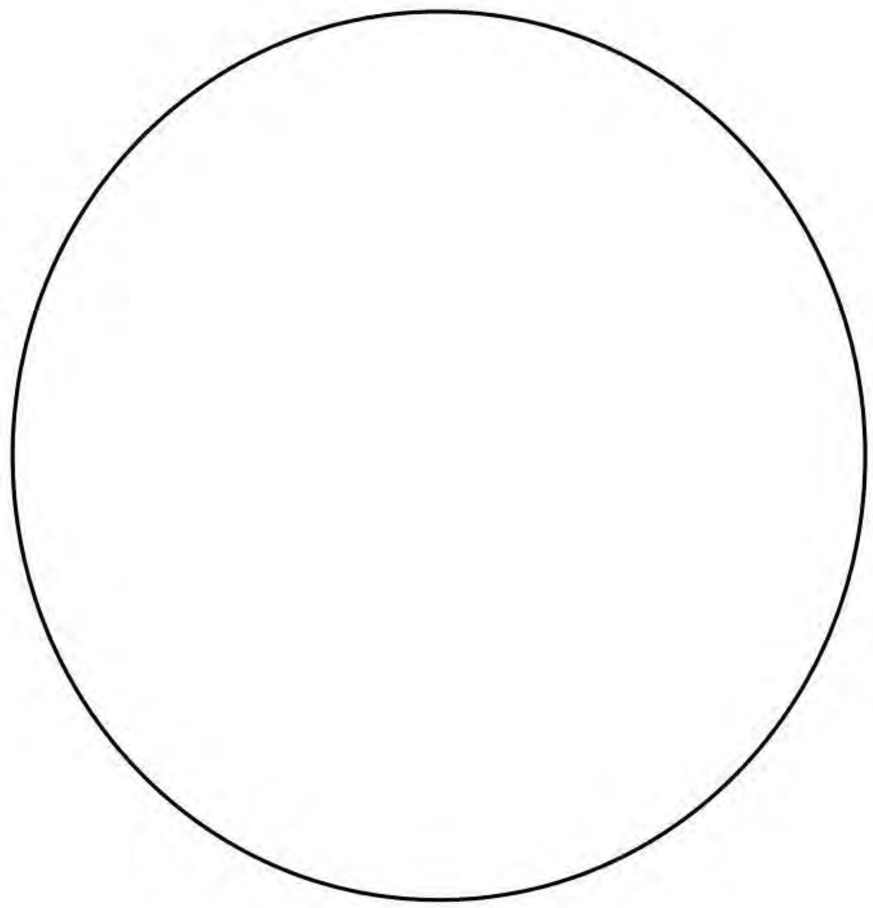
a _____

_____

b _____

_____

8 Transitional epithelium



a _____

_____

b _____

_____

Exercise 4-2

Connective Tissue

MATERIALS

- ❑ Connective tissue slides
- ❑ Light microscope
- ❑ Colored pencils

Connective tissues are found throughout the body. They have a variety of functions, most of which serve to *connect*, as their name implies (blood is an exception). All connective tissues stem from a common embryonic tissue called **mesenchyme** (MES-en-ky'm). Connective tissues are distinguished easily from epithelial tissues by the prominence of their extracellular matrices. Typically, connective tissues contain few cells and have an extensive ECM.

The four general types of connective tissue (CT) are as follows:

1. **Connective tissue proper. Connective tissue proper,** the most widely distributed class of connective tissue in the body, consists of scattered cells called **fibroblasts** (FY-broh-blastz) that secrete an extensive ECM filled with many types of protein fibers. This tissue is highly vascular with an extensive blood supply. The subclasses of CT proper include the following:

- **Loose (areolar) CT.** You can see in Figure 4.4A that the primary element in **loose CT** is ground substance, which gives it a "loose" appearance on a slide. All three types of protein fibers are scattered in loose CT ground substance. Loose CT is found as part of the basement membrane and in the walls of hollow organs.
- **Reticular CT.** As you can guess by the name, **reticular CT** consists of many reticular fibers produced by cells called **reticular cells** (Figure 4.4B). It is located in the spleen and lymph nodes, where the fine reticular fibers interweave to form "nets" that trap pathogens and foreign cells. Reticular CT also is located around blood vessels and nerves, where it forms supportive networks.
- **Adipose tissue.** Notice in Figure 4.4C that **adipose tissue** (fat tissue) has a much different appearance than the other types of CT proper. It consists of mostly huge cells called **adipocytes** (AD-ih-poh-syt'z) with collagen fibers in the ECM. Each adipocyte contains a large lipid droplet that occupies most of its cytoplasm. The nucleus and other organelles are barely visible, because they are pushed to the periphery of the cell against the plasma membrane. Adipose tissue is distributed widely throughout the body under the skin and around organs.
- **Dense regular collagenous CT.** The difference between loose and dense CT is obvious in Figure 4.5A. **Dense regular collagenous CT** consists primarily of collagen fibers arranged in parallel bundles with little ground substance and few cells. It is exceptionally strong and makes up structures that require tensile strength in a single plane, such as tendons and ligaments.
- **Dense irregular collagenous CT.** Like dense regular collagenous CT, **dense irregular collagenous CT** consists of bundles of collagen fibers. Notice in Figure 4.5B, however, that these collagen bundles are arranged in an irregular,

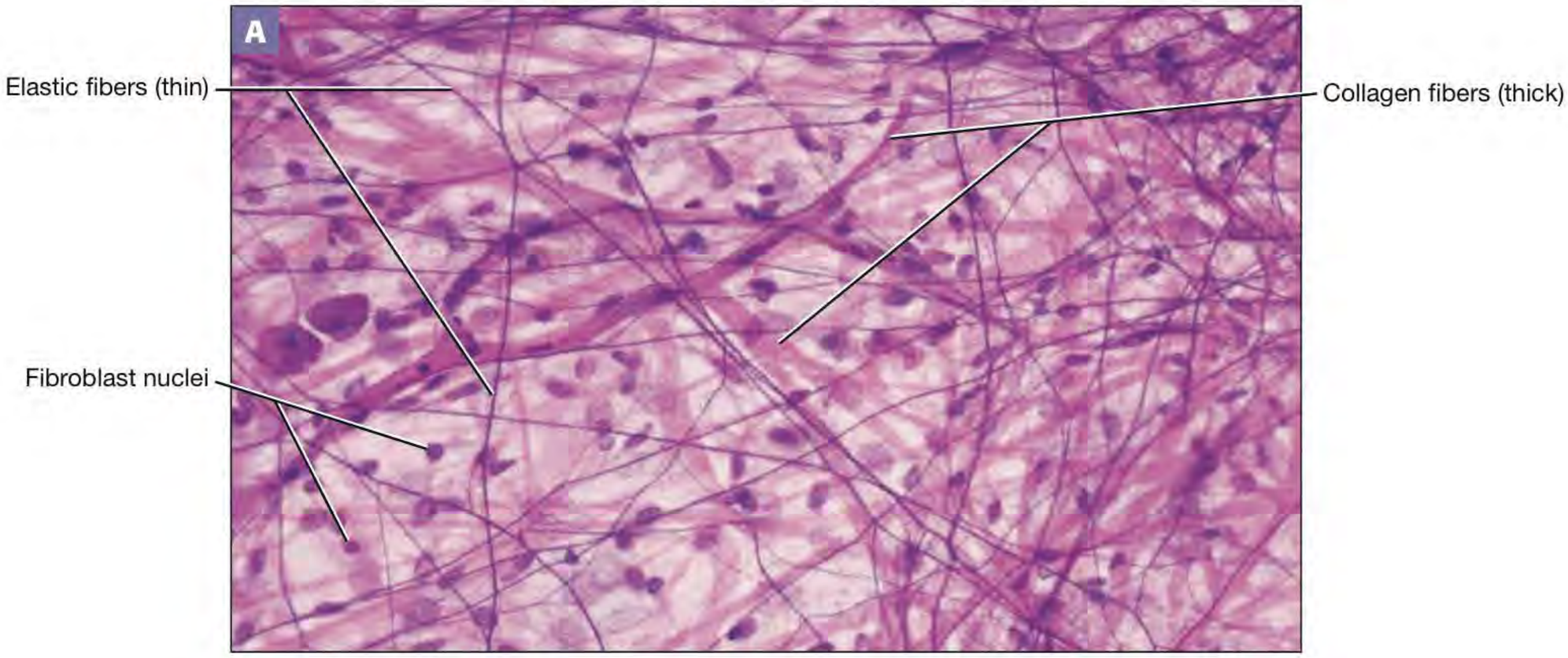
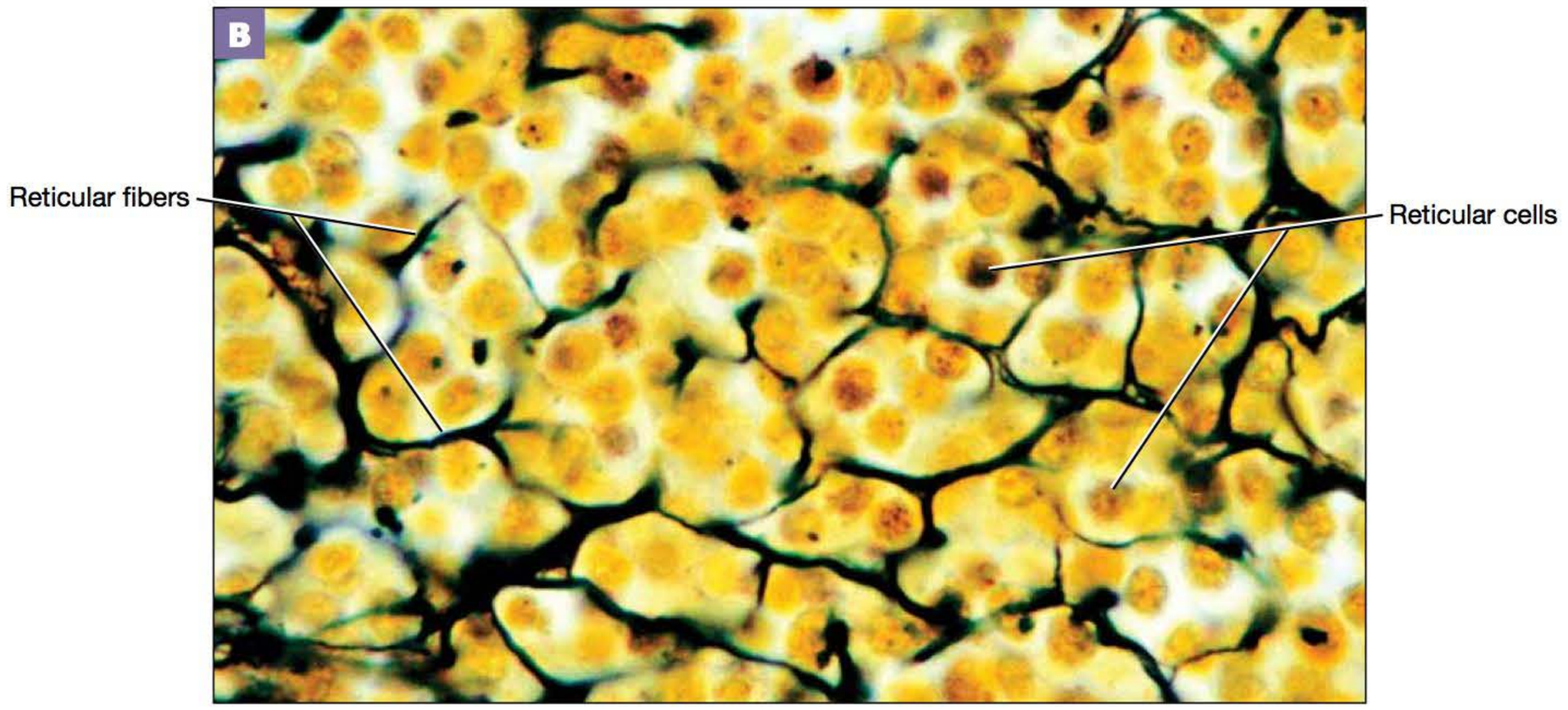


FIGURE **4.4** Loose connective tissues: (**A**) loose (areolar) CT *(continues)*



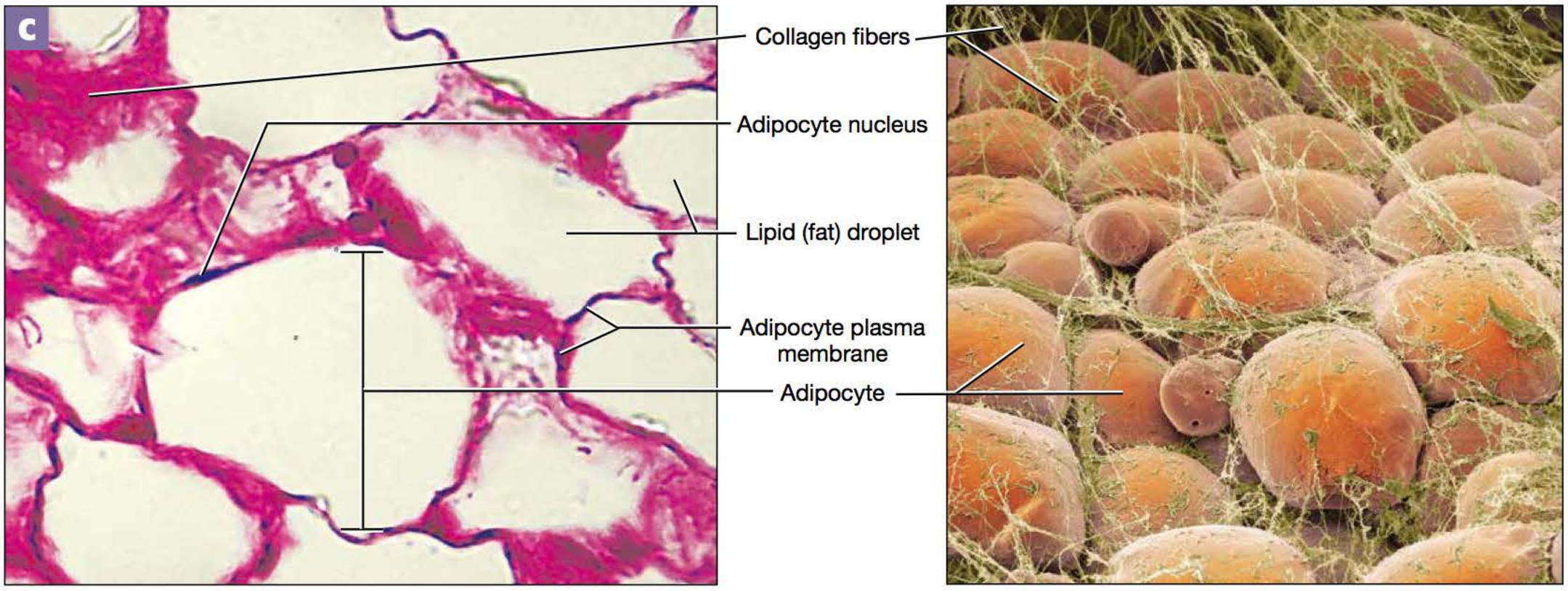


FIGURE **4.4** Loose connective tissues *(cont.)*: (**B**) reticular CT from the spleen; (**C**) adipose tissue (light micrograph and SEM, respectively).

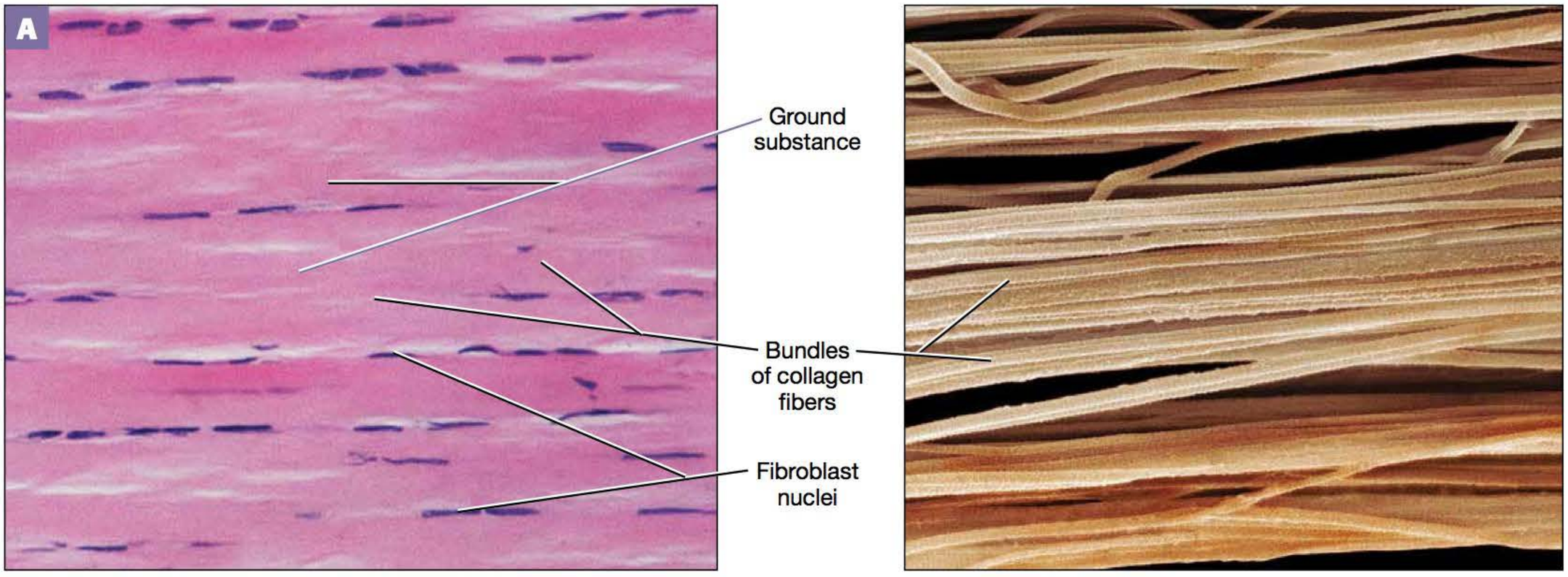


FIGURE **4.5** Dense connective tissues: (**A**) dense regular collagenous CT from a tendon (light micrograph and SEM, respectively) *(continues)*

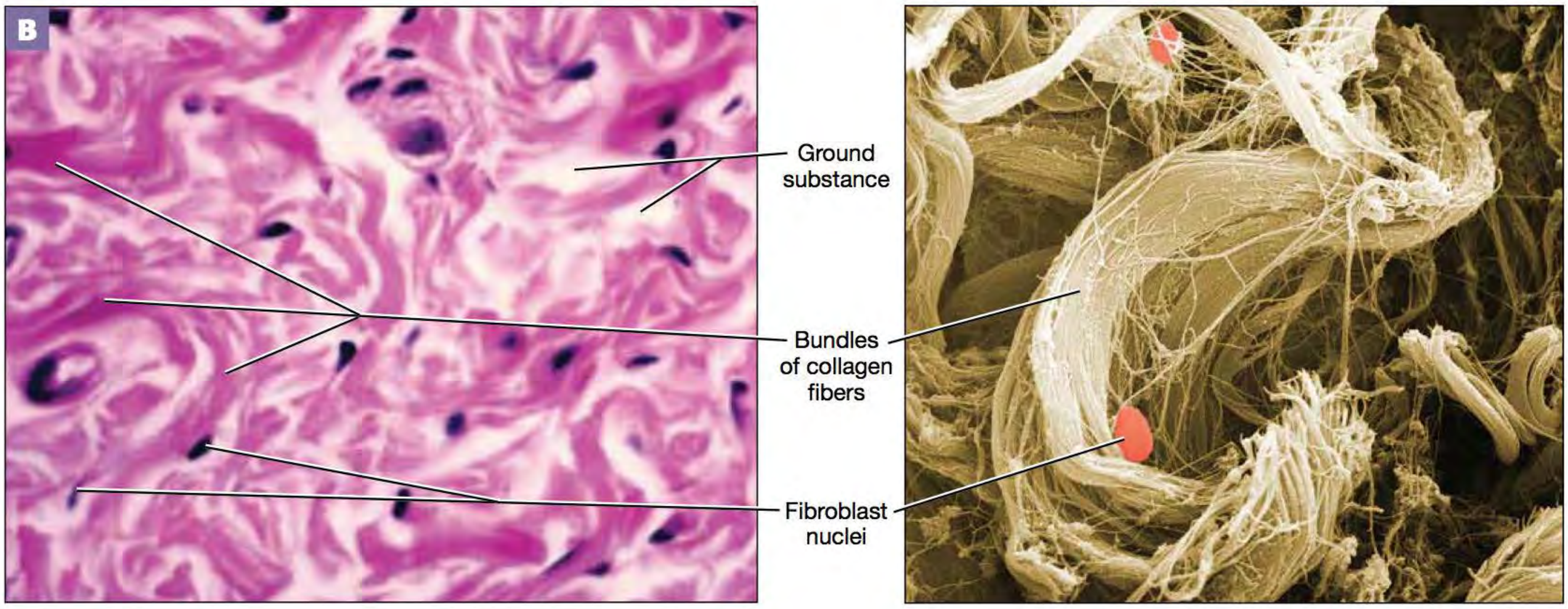


FIGURE **4.5** Dense connective tissues *(cont.)*: (**B**) dense irregular collagenous CT from the dermis (light micrograph and SEM, respectively); (**C**) dense elastic CT from the aorta.

haphazard fashion without a consistent pattern. You can see the difference clearly in the scanning electron micrographs of the two tissues. Like dense regular CT, **dense irregular collagenous CT** also is quite strong and is located in places that require tensile strength in multiple planes, such as the dermis and joint and organ capsules.

- **Dense elastic CT. Dense elastic CT** contains elastic fibers arranged in parallel bundles (Figure 4.5C). We find dense elastic CT lining large blood vessels and in certain ligaments.

2. **Cartilage. Cartilage** is a tough but flexible tissue resistant to tension, twisting, and compressive forces. It consists of cells called **chondrocytes** (KAHN-droh-syt′z) located in cavities called **lacunae** (lah-KOO-nee) embedded in the ECM. Cartilage is notable among the connective tissues for being avascular. Each of the three types of cartilage has a different ECM composition.

   - **Hyaline cartilage.** Notice in Figure 4.6A that **hyaline cartilage** (HY-ah-lin) contains mostly chondrocytes scattered in ground substance with few visible protein fibers. This gives hyaline cartilage a smooth, glassy appearance and makes it an ideal tissue to cover the ends of bones where they form joints with another bone. The smooth texture of hyaline cartilage provides a nearly frictionless surface on which bones can articulate. Hyaline cartilage also is found connecting the ribs to the sternum, in the nose, and forming the framework for certain respiratory passages.

Fibrocartilage. As you can see in Figure 4.6B, **fibrocartilage** is named appropriately because its ECM is full of protein fibers (mostly collagen). This makes fibrocartilage tough and extremely strong but not at all smooth (think of the surface of fibrocartilage like a flannel sheet, with the cotton fibers representing the protein fibers). For this reason, fibrocartilage does not form articular cartilage, but it does reinforce ligaments and form *articular discs*, tough structures that improve the fit of two bones. In addition, fibrocartilage is found in joints where hyaline cartilage has been damaged.

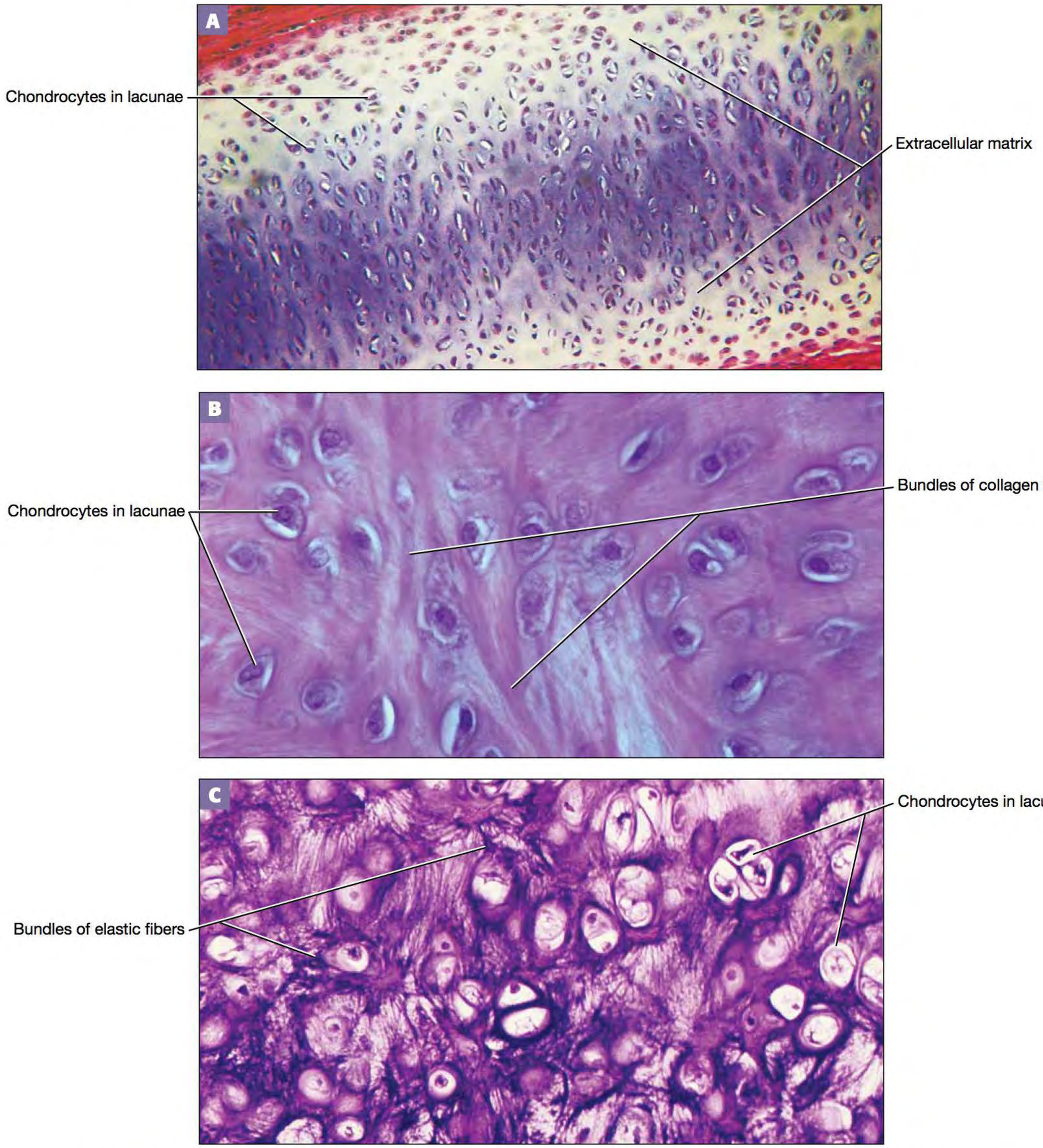


FIGURE **4.6** Connective tissues: (A) hyaline cartilage from a joint; (B) fibrocartilage from an articular disc; (C) elastic cartilage from the ear.

- **Elastic cartilage.** The final type of cartilage, **elastic cartilage,** is shown in Figure 4.6C. Its ECM is filled with elastic fibers that allow it to stretch and recoil. Elastic cartilage is found in the ear and in the epiglottis.

3. **Bone.** Bone tissue, also called **osseous tissue** (AHS-see-us), consists of bone cells called **osteocytes** (AHS-tee-oh-syt′z) encased in an ECM that contains collagen fibers and calcium hydroxyapatite crystals. Note in Figure 4.7 that the ECM is arranged in concentric layers called **lamellae** (lah-MELL-ee), with the osteocytes sandwiched between them. This structure makes bone one of the hardest tissues in the body and very resistant to mechanical stresses.
4. **Blood. Blood** (Figure 4.8) is a unique connective tissue in that it doesn't actually *connect* anything physically. Instead, its main role is to transport oxygen, nutrients, electrolytes, wastes, and many other substances. It consists of a liquid ECM called **plasma,** within which we find cells called **erythrocytes** (eh-RITH-roh-syt′z; red blood cells) and **leukocytes** (LOO-koh-syt′z; white blood cells), and cellular fragments called **platelets.**

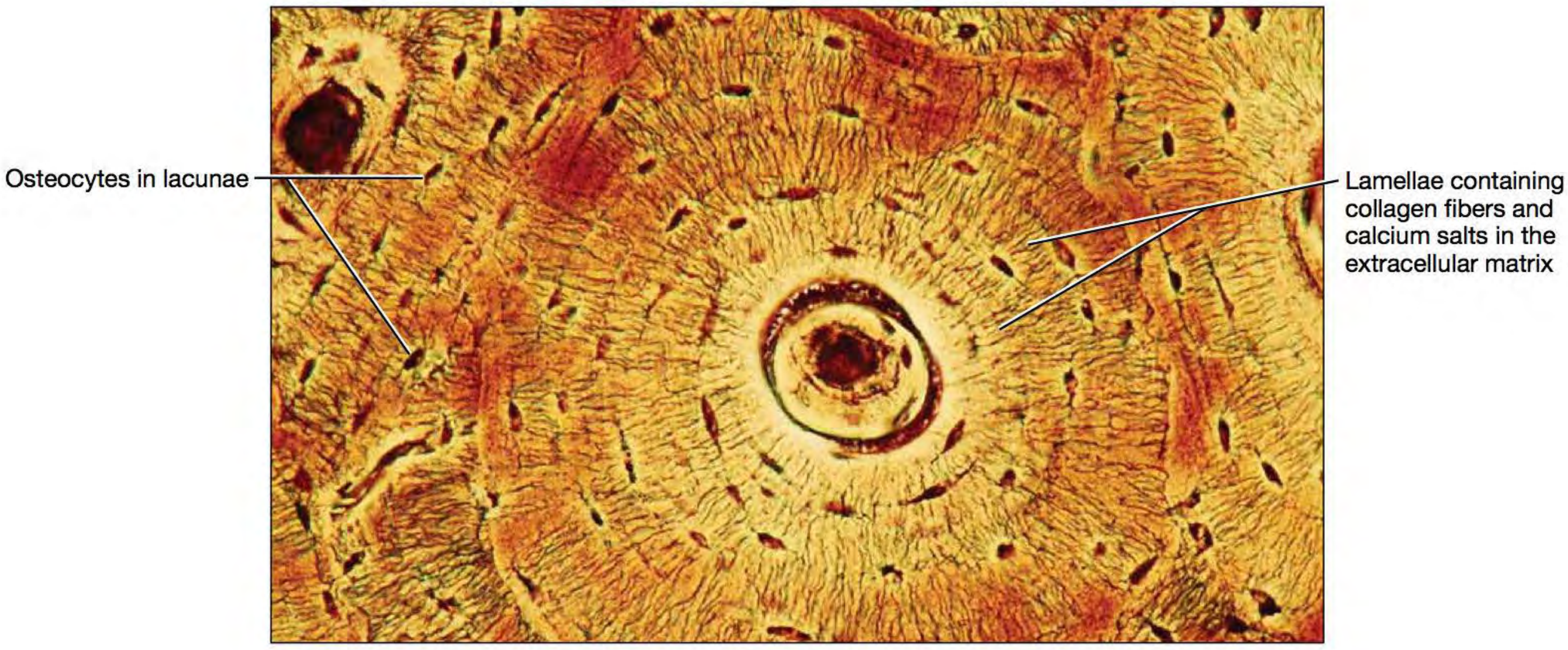


FIGURE **4.7** Bone tissue.

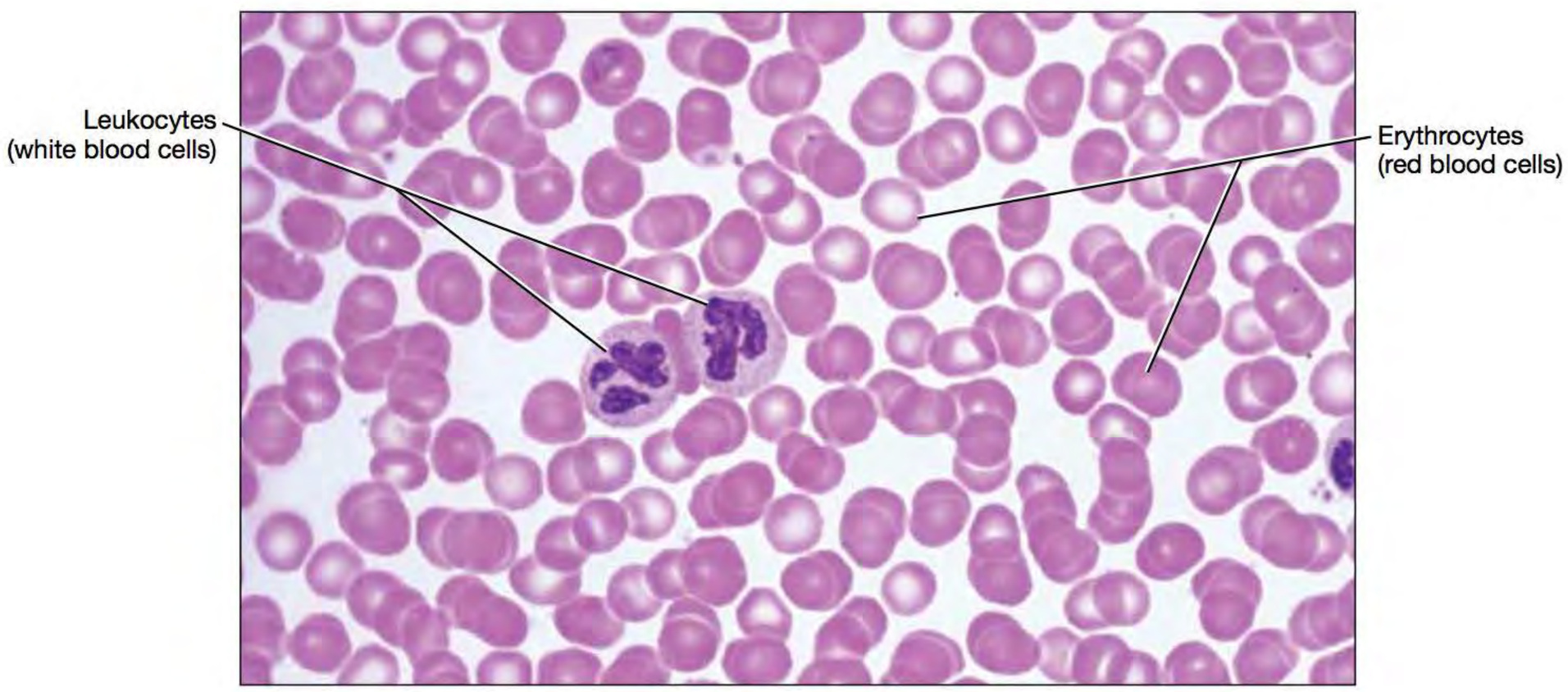


FIGURE **4.8** Blood.

HINTS & TIPS

How to Approach Connective Tissue

Connective tissue really isn't as confusing as it seems. If you approach these slides systematically, and use the figures in this manual as a guide, you will find they are surprisingly simple. The following points will help you to identify the various connective tissues and differentiate them from other tissue types:

- Usually in connective tissue, you will see a large amount of space between the cells and they aren't packed tightly together (adipose tissue is an exception). Remember to look for the nucleus and plasma membrane to find the cells.
- You will often see a lot of straight or wavy lines running through a connective tissue section. These are just protein fibers. Many types of CT can be distinguished by the types of fibers they contain:
  - Reticular fibers are the thinnest fibers, and typically stain brown or black. Look for reticular fibers in loose and reticular CT.
  - Collagen fibers are thick fibers that often stain pink. Look for collagen fibers in fibrocartilage, dense regular collagenous CT, dense irregular collagenous CT, and loose CT.
  - Elastic fibers are thinner than collagen fibers and may have a wavy appearance. Their color ranges from purple-black to blue, depending on the stain used. Look for them in dense elastic tissue, elastic cartilage, and loose CT.
- Cartilage is easy to tell apart from CT proper by looking at the shape of the cells. Fibroblasts are generally small and flat, whereas chondrocytes are much larger and round. In addition, chondrocytes sit in lacunae, so there is often clear space around the cells.
- Blood and bone are perhaps the two easiest tissues you will examine in this lab. They should look much like they do in Figures 4.7 and 4.8, and no other tissues resemble them.

Procedure 1 Microscopy of Connective Tissue Proper

View prepared slides of each type of connective tissue proper. Use colored pencils to draw pictures of what you see under the microscope, and label your drawings with the terms from Figures 4.4–4.5. Then (a) describe what you see, and (b) give examples of locations in the body where this tissue is found. When you have completed the exercise, answer Check Your Understanding questions 1 through 3 (p. 93).

1 Loose (areolar) CT

a _____

_____

b _____

_____

2 Reticular CT

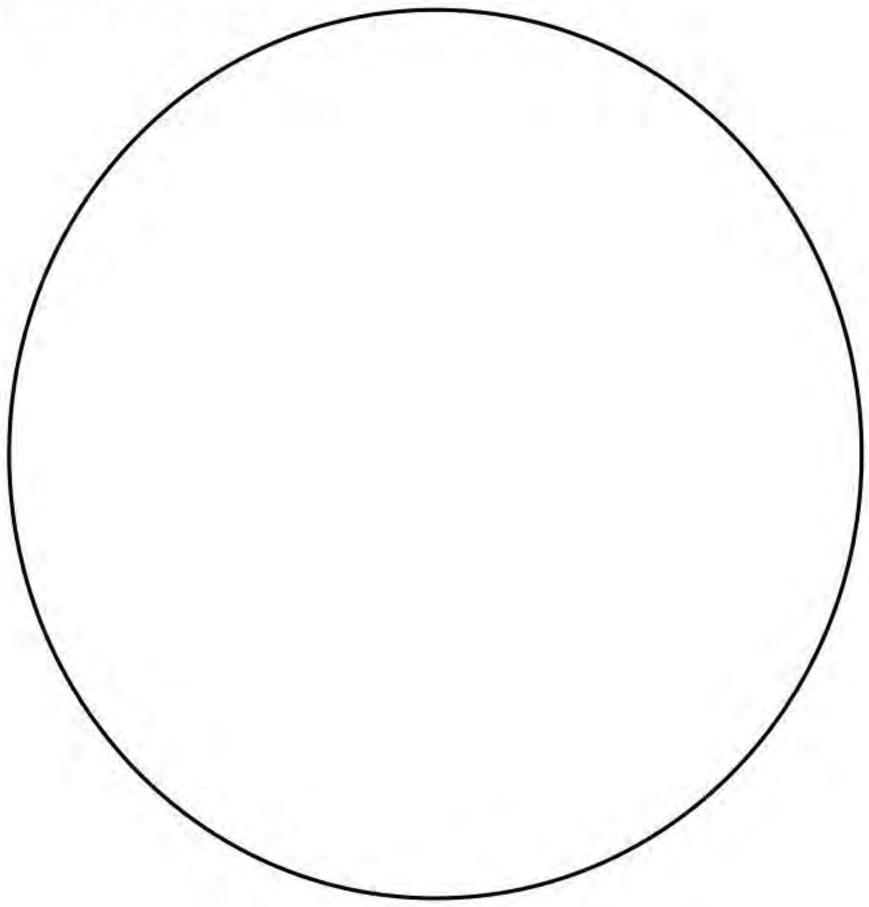
a _____

_____

b _____

_____

3 Adipose tissue



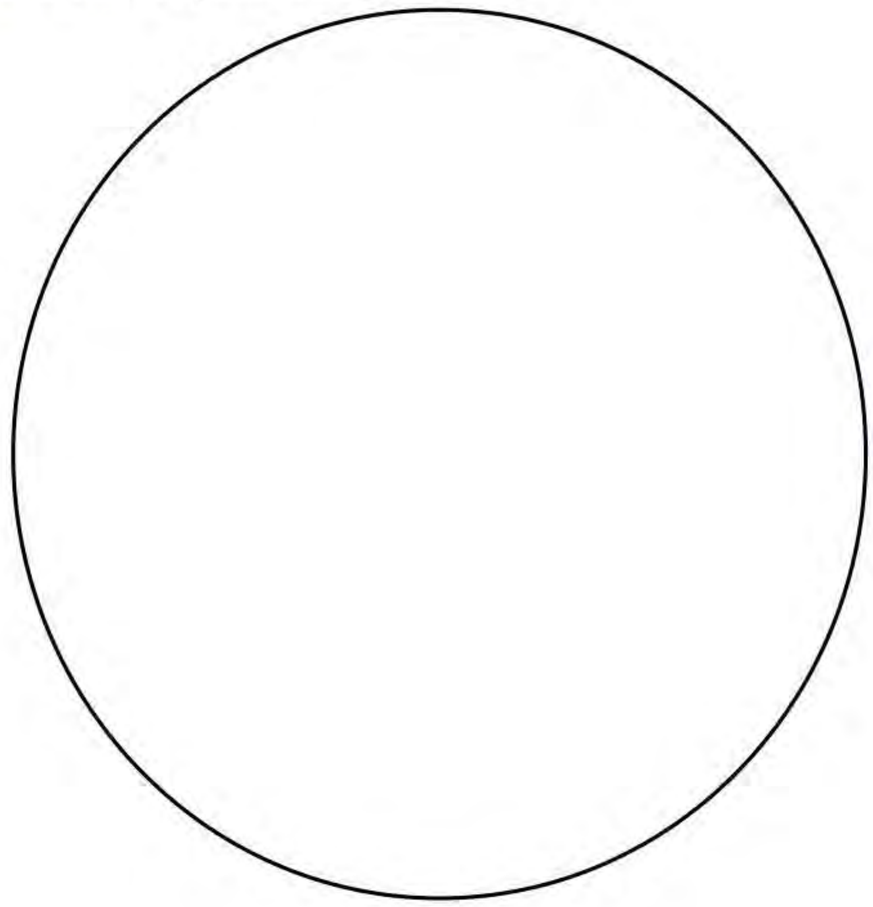
a _____

_____

b _____

_____

4 Dense regular collagenous CT



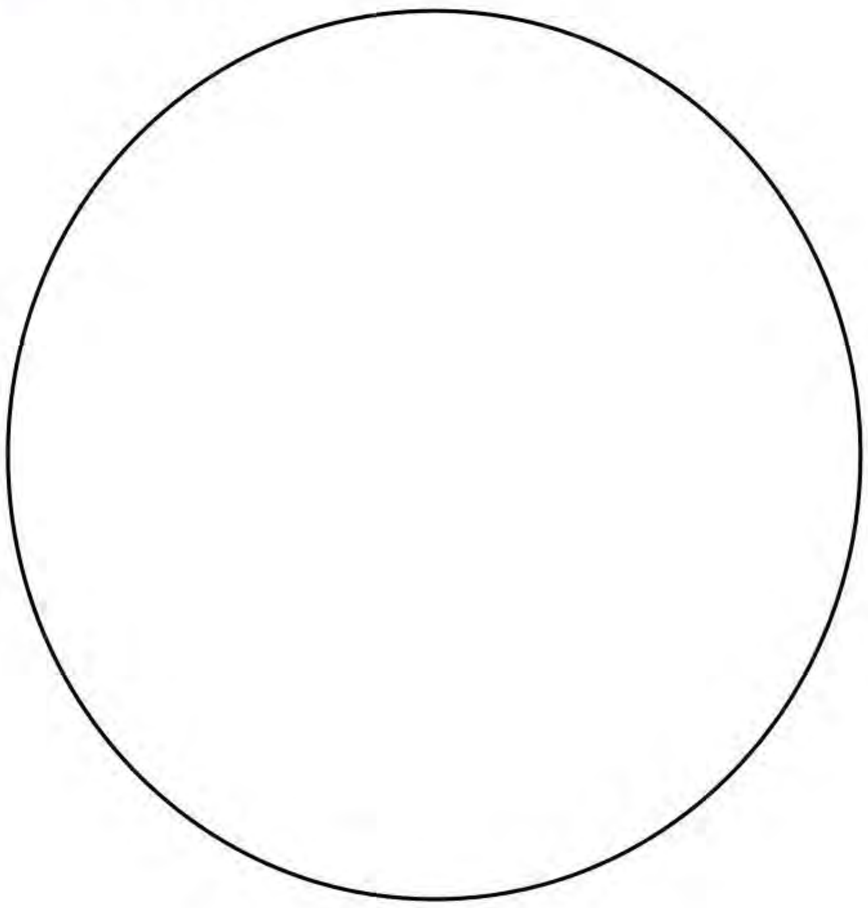
a _____

_____

b _____

_____

5 Dense irregular collagenous CT



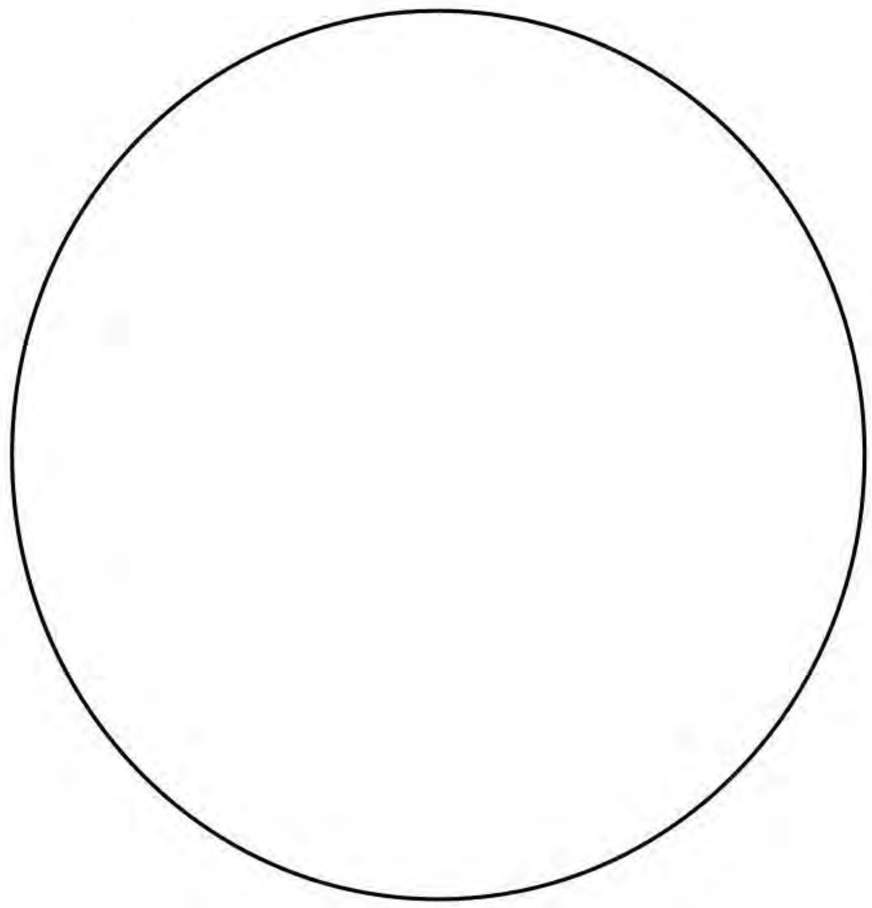
a _____

_____

b _____

_____

6 Dense elastic CT



a _____

_____

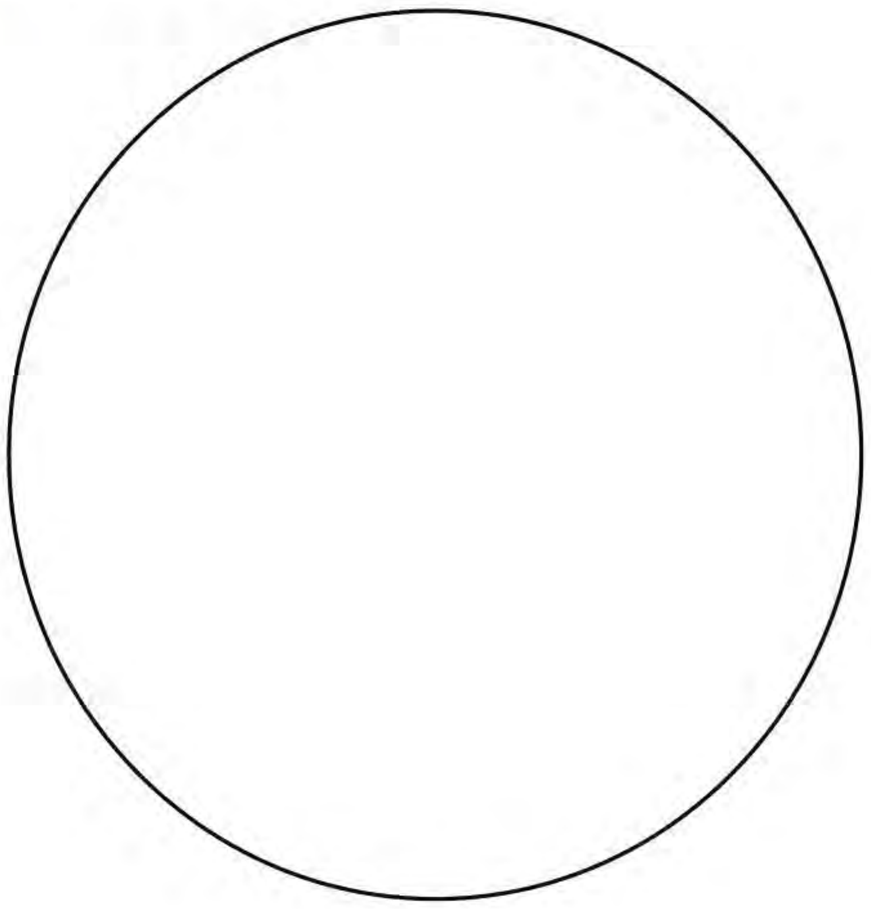
b _____

_____

Procedure 2 Microscopy of Cartilage

View prepared slides of the three types of cartilage. Use colored pencils to draw pictures of what you see under the microscope, and label your drawings with the terms from Figure 4.6. Then (a) describe what you see, and (b) give examples of locations in the body where this tissue is found. When you have completed this activity, answer Check Your Understanding question 4 (p. 93).

1 Hyaline cartilage



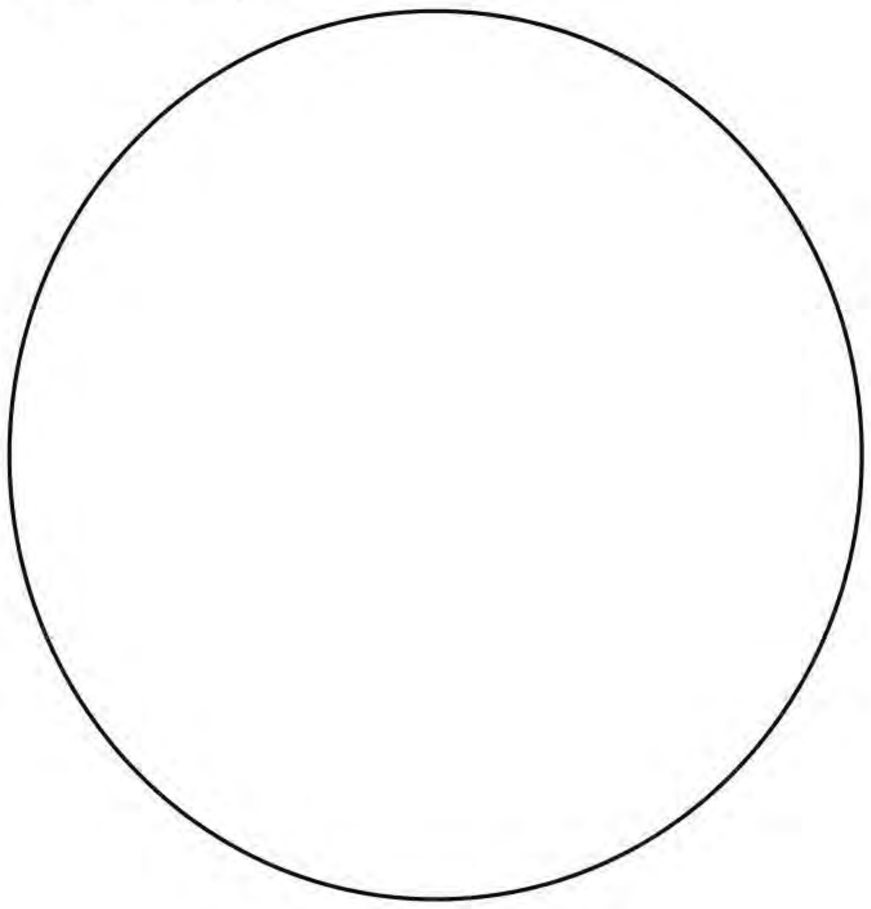
a _____

_____

b _____

_____

2 Fibrocartilage



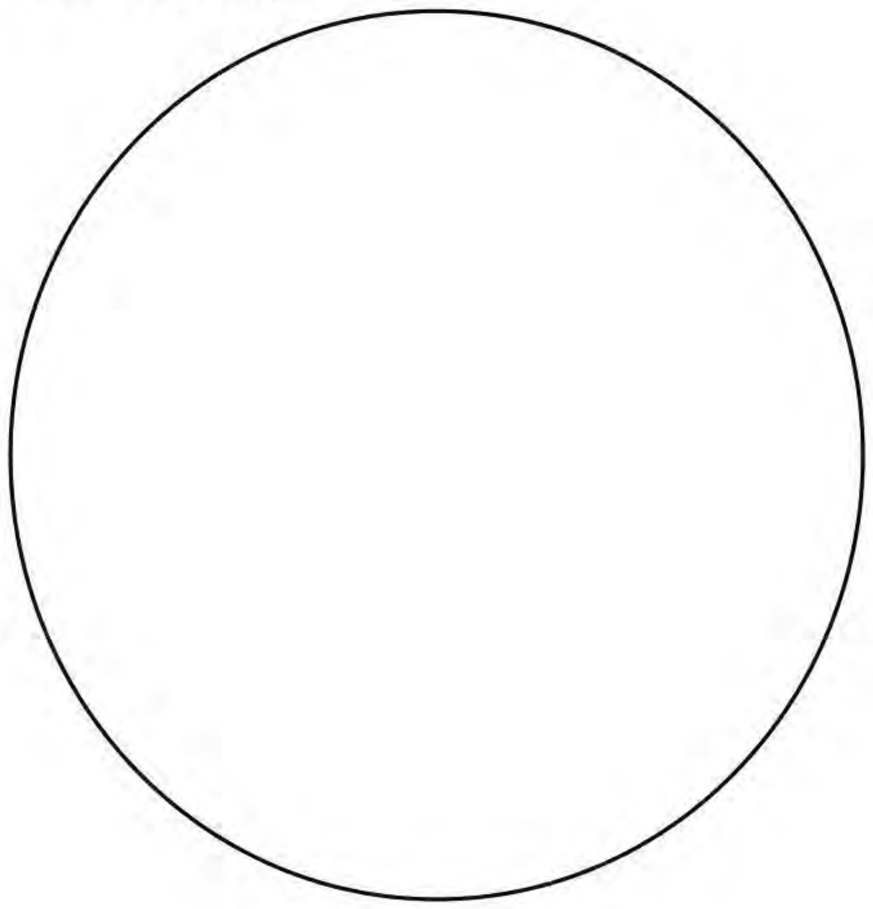
a _____

_____

b _____

_____

3 Elastic cartilage



a _____

_____

b _____

_____

Procedure 3 Microscopy of Bone and Blood

View prepared slides of bone and blood. Use colored pencils to draw pictures of what you see under the microscope, and label your drawings with the terms in Figures 4.7–4.8. Then (a) describe what you see, and (b) give examples of locations in the body where this tissue is found. When you have completed all of the connective tissue slides, answer Check Your Understanding question 5 (p. 94).

1 Bone

a _____

_____

b _____

_____

2 Blood

a _____

_____

b _____

_____

Exercise 4-3

Muscle Tissue

MATERIALS

- ❑ Muscle tissue slides
- ❑ Light microscope
- ❑ Colored pencils

Muscle tissue is located in skeletal muscles, in the walls of hollow organs, in the heart, and in other locations such as the iris of the eye. It consists of muscle cells, sometimes called **myocytes** (MY-oh-syt'z) or **muscle fibers**, and a small amount of ECM called the **endomysium** (en-doh-MY-see-um). Note that the endomysium blends with connective tissue surrounding groups of muscle fibers and is often called connective tissue as a result. As you can see in Figures 4.9A–C, myocytes aren't shaped like the cells of epithelial or connective tissues. For this reason, muscle tissue is easy to tell apart from the other tissue types.

There are three types of muscle tissue:

1. **Skeletal muscle tissue**. The myocytes of **skeletal muscle tissue** are long, tubular, and **striated** (striped) in appearance (Figure 4.9A). The striations result from the arrangement of proteins within the muscle fiber called **myofilaments**. Skeletal muscle fibers are formed from the fusion of cells called **myoblasts** and for this reason have multiple nuclei.
2. **Cardiac muscle tissue**. The myocytes of **cardiac muscle tissue**, located in the heart, are short, wide, striated, and tend to be branching (Figure 4.9B). Adjacent myocytes are linked by specialized junctions called **intercalated discs** (in-TUR-kuh-lay-tid) that contain desmosomes and gap junctions. Cardiac myocytes typically have only one nucleus, but some may have two or more.
3. **Smooth muscle tissue.** The myocytes of **smooth muscle tissue** are flat with a single nucleus in the center of the cell (Figure 4.9C). The arrangement of myofilaments within smooth muscle fibers differs from that of skeletal and cardiac muscle fibers, and as a result, these cells lack noticeable striations (hence the name *smooth* muscle). Smooth muscle lines all hollow organs and is found in the skin, the eyes, and surrounding many glands.

We revisit each type of muscle tissue in later units in this book.

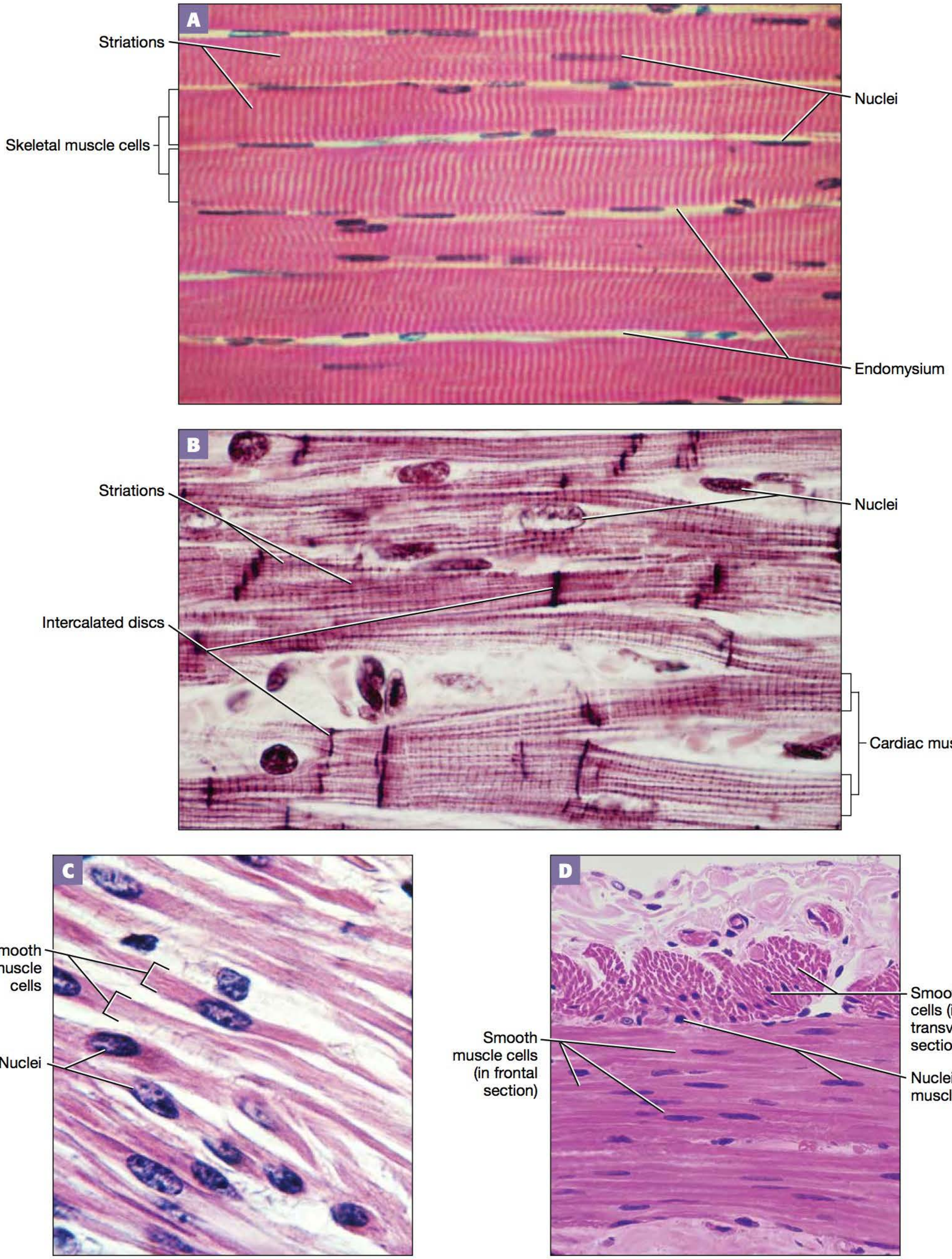
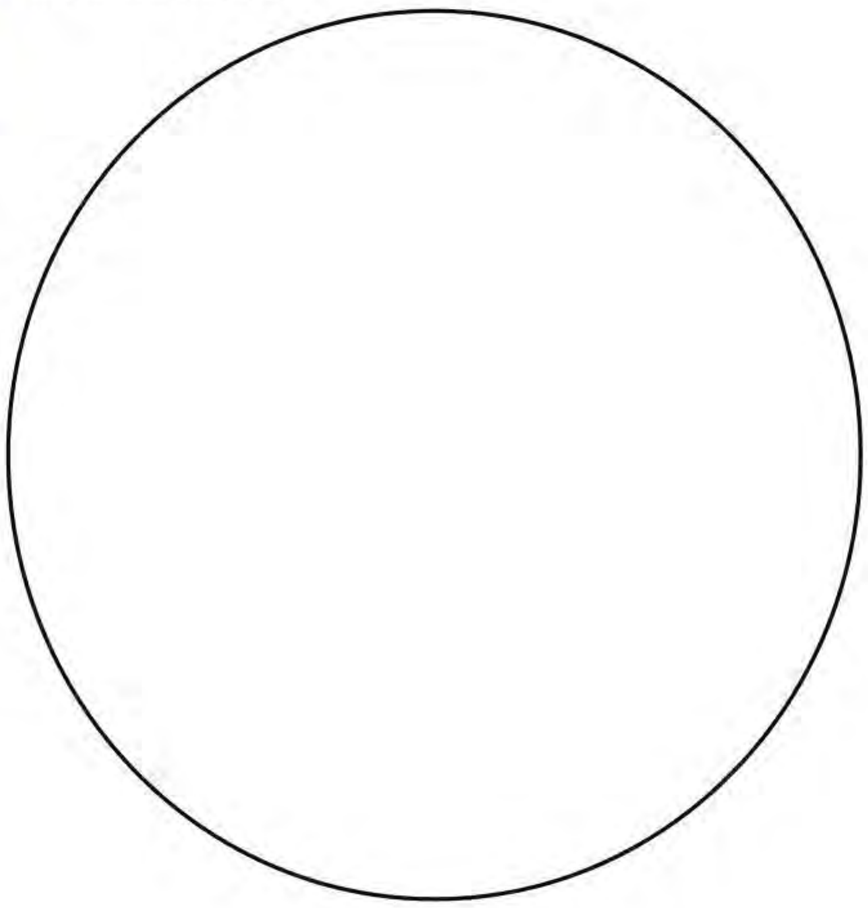


FIGURE **4.9** Muscle tissue: (A) skeletal muscle tissue; (B) cardiac muscle tissue; (C) teased smooth muscle cells; (D) smooth muscle cells in an organ.

Procedure 1 Microscopy of Muscle Tissue

View prepared slides of skeletal, smooth, and cardiac muscle tissue. Use colored pencils to draw what you see under the microscope, and label your drawing with the terms from Figure 4.9. Record your observations of each slide in Table 4.1. When you have completed the microscope slides, answer Check Your Understanding question 6 (p. 94).

1 Skeletal muscle



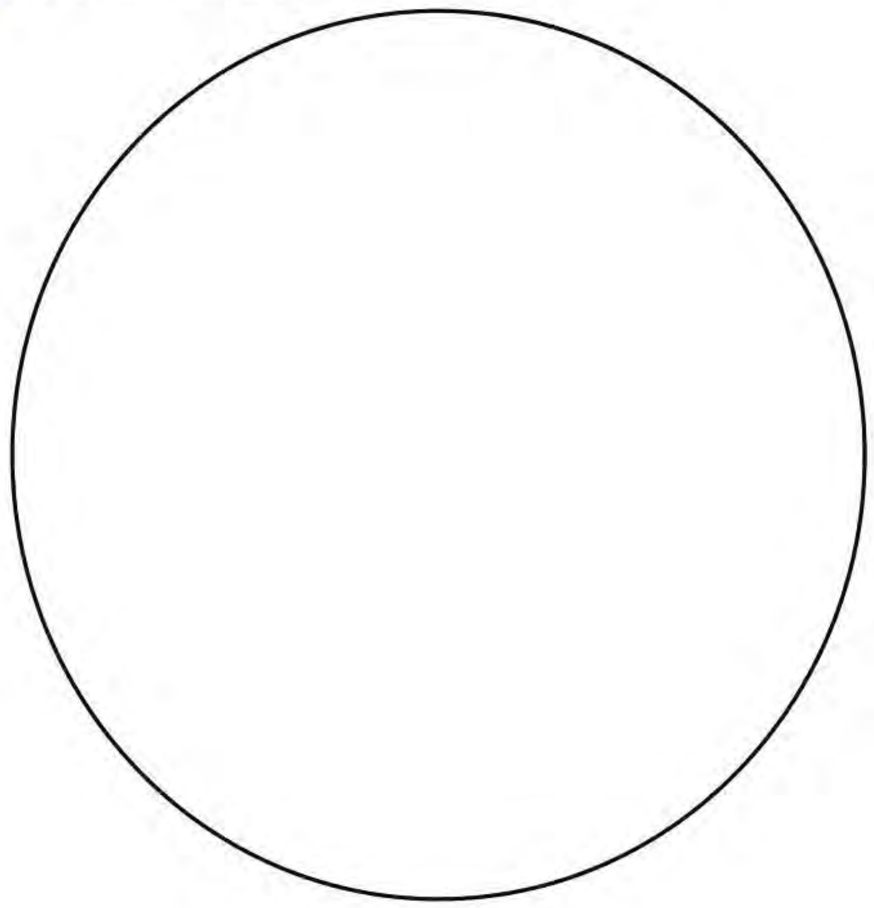
a _____

_____

b _____

_____

2 Cardiac muscle



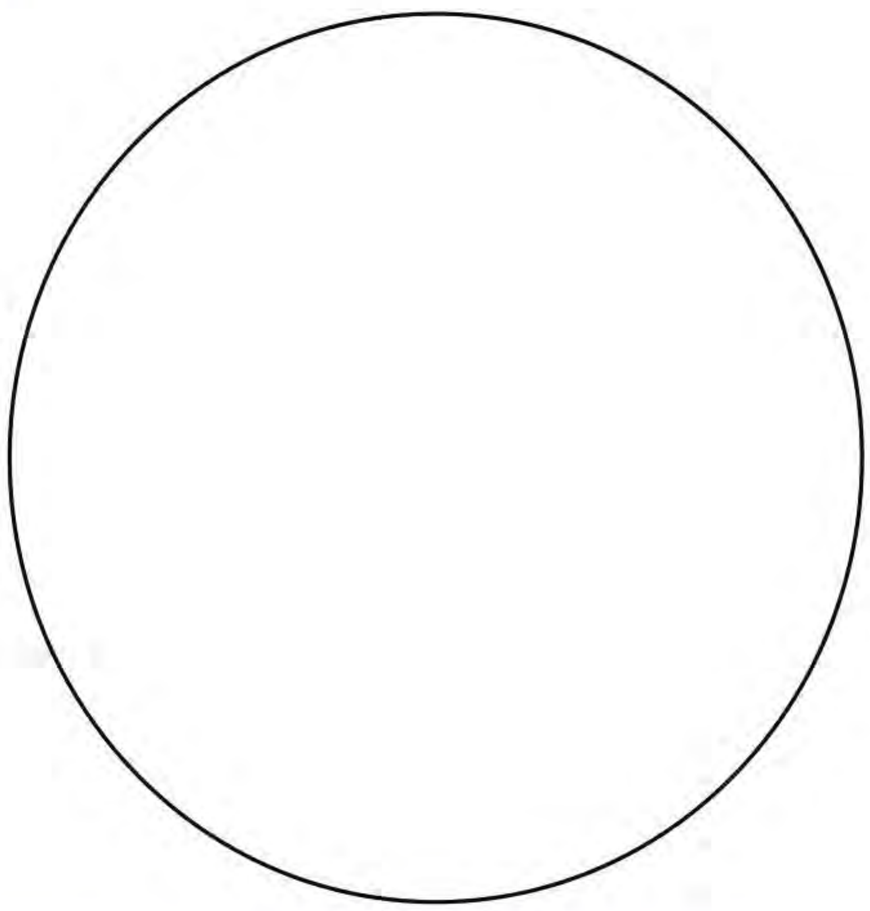
a _____

_____

b _____

_____

3 Smooth muscle



a _____

_____

b _____

_____

TABLE **4.1** Characteristics of Muscle Tissues

Muscle Tissue Type	Striated or Nonstriated	One or Multiple Nuclei	Size and Shape of Cells	Special Features
Skeletal muscle				
Cardiac muscle				
Smooth muscle				

Exercise 4-4

Nervous Tissue

MATERIALS

- ❑ Nervous tissue slide
- ❑ Light microscope
- ❑ Colored pencils

Nervous tissue (Figure 4.10) is the primary component of the brain, the spinal cord, and the peripheral nerves. It consists of a unique ECM and two main cell types:

1. **Neurons.** The **neurons** (NOOR-ahnz) are responsible for sending and receiving messages within the nervous system. On your slide they are the larger of the two cell types. The large, central portion of the neuron is called the **cell body**. Within the cell body we find the nucleus and many of the neuron's organelles, including clusters of rough endoplasmic reticulum called **Nissl bodies**. Most neurons contain two types of long armlike processes extending from the cell body: the **dendrites** (DEN-drytz), which receive messages from other neurons, and the **axon** (AX-ahn), which sends messages to other neurons, muscle cells, or gland cells.
2. **Neuroglial cells.** The smaller and more numerous cells around the neurons are the **neuroglial cells** (noor-oh-GLEE-uhl). The six different types of neuroglial cells vary significantly in shape and appearance. Neuroglial cells in general perform functions that support the neurons or the ECM in some way.

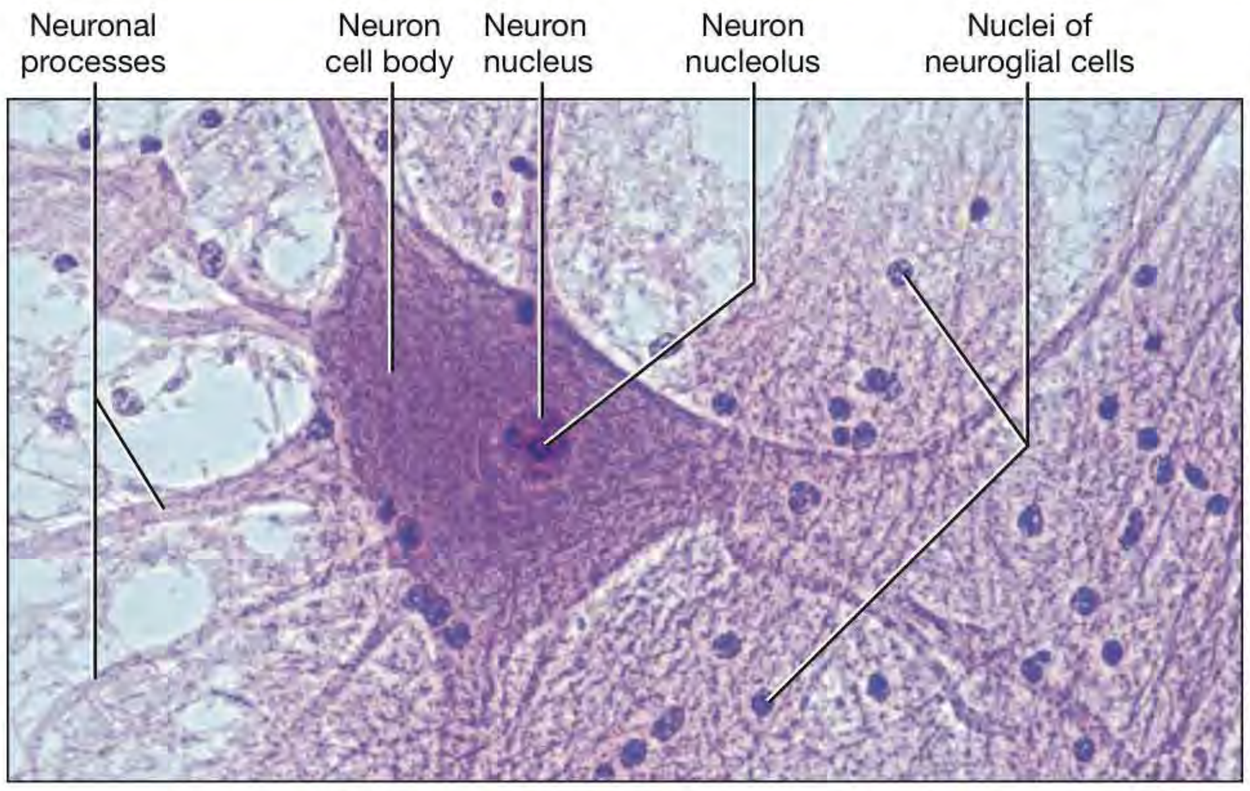
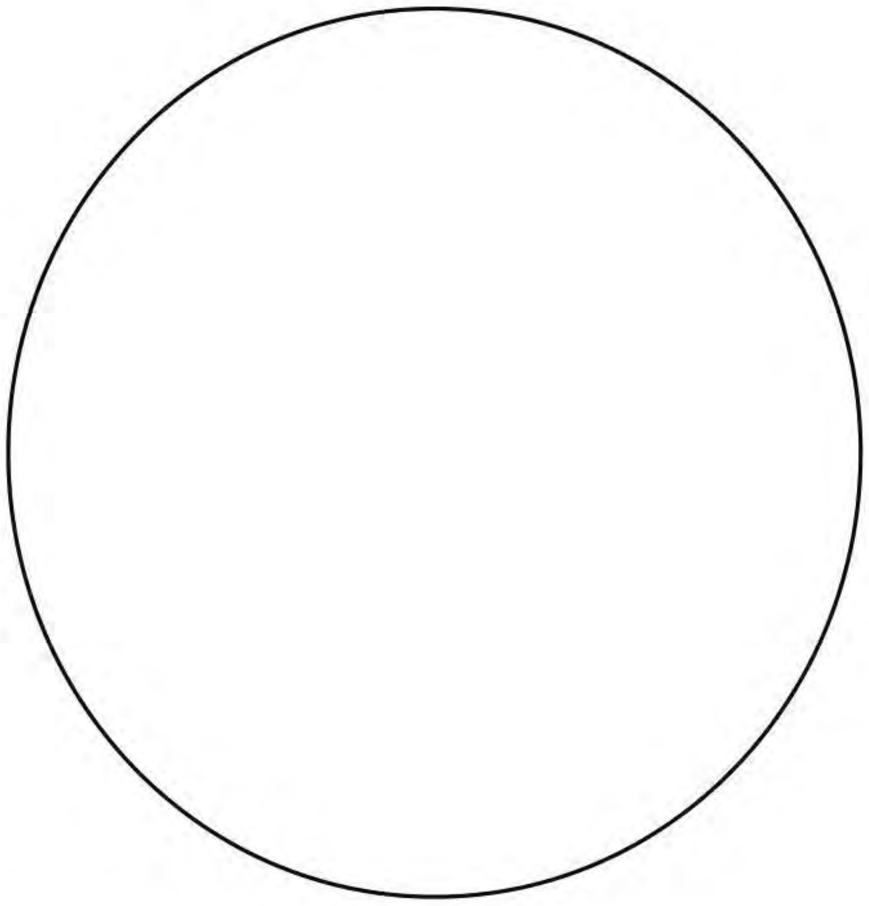


FIGURE **4.10** Nervous tissue.

Procedure 1 Microscopy of Nervous Tissue

View a prepared slide of nervous tissue (the slide might be called a "motor neuron smear"). Use colored pencils to draw a picture of what you see under the microscope, and label your drawing with the terms from Figure 4.10. Then (a) describe what you see, and (b) give examples of locations in the body where this tissue is found.



a _____

_____

b _____

_____

Exercise 4-5

Organology

MATERIALS

- ❑ 5 colors of modeling clay

All organs consist of two or more tissues that must work together to enable the organ to function properly. The study of the tissues that make up the body's organs is called **organology**. Most organs are made of layers of tissues stacked upon one another and "glued" together by proteins and other molecules in the ground substance. This exercise introduces you to organology, a topic we explore repeatedly in the remainder of this lab manual.

Procedure 1 Determine Major Tissue Types of Organs

Use your textbook to determine the main tissue types that constitute each of the following organs, and record this information in Table 4.2. Be specific about which type of muscle, epithelial tissue, and connective tissues are found in the organ.

TABLE 4.2 Organs and Their Component Tissues

Organ	Major Tissue Types
Urinary bladder	
Blood vessel	
Skin	
Lymph node	
Knee joint and capsule	
Heart	
Trachea	
Esophagus	
Auricle (external ear)	
Brain (and brain coverings)	

Procedure 2 Build an Organ

For this exercise, choose one or more of the organs from Table 4.2, and build it with modeling clay. Use the following color code when building your organ:

Yellow = epithelial tissue (Be sure to use more than one layer if the tissue is stratified.)

Blue = connective tissue proper

Orange = cartilage

Red = muscle tissue

Green = nervous tissue (Don't forget that nearly every organ in the body has nerves that supply it. To place the nerves properly, find out which tissue layer of the organ is innervated.)

Name _____

Section _____ Date _____

UNIT 4 REVIEW

Check Your Recall

1 Identify each of the following tissues in Figure 4.11.

a _____ **e** _____

b _____ **f** _____

c _____ **g** _____

d _____ **h** _____

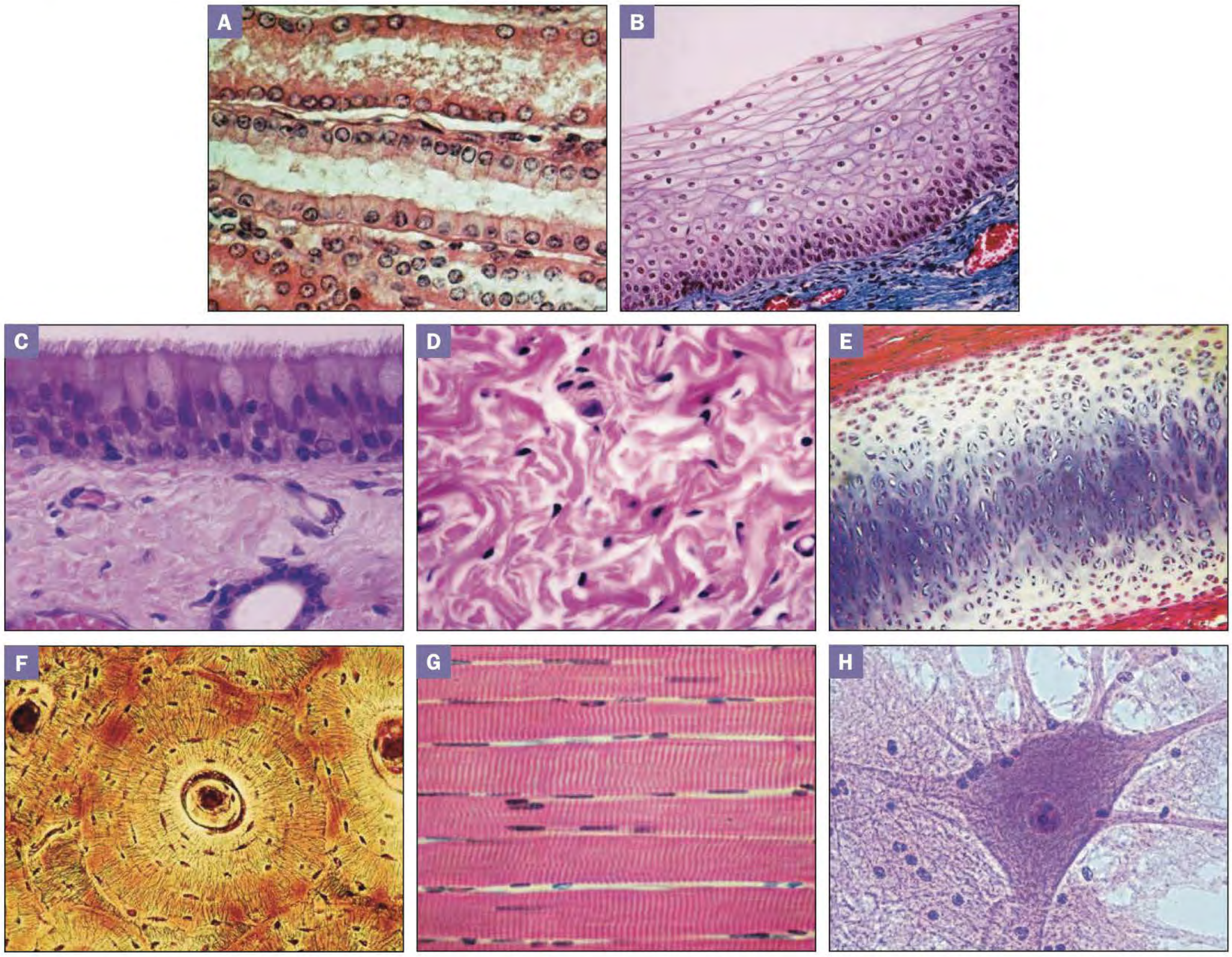


FIGURE **4.11** Unknown tissues for question 1.

2 List the four basic tissue types:

_____ _____

_____ _____

3 *Fill in the blanks:* All tissues consist of two main components: _____ and _____,

which consists of a gelatinous substance called _____ and numerous different _____.

4

4 Which of the following statements about epithelial tissue is *false*?

a. Epithelial tissues are avascular.
b. Epithelial tissues consist of few cells and an extensive ECM.
c. The ECM of epithelial tissues is located in the basal lamina.
d. Epithelial tissues are our covering and lining tissues.

5 How do simple and stratified epithelial tissues differ?

6 Which of the following statements about connective tissue is *false*?

a. All connective tissues stem from a common embryonic tissue called mesenchyme.
b. Connective tissues may contain three types of protein fibers: collagen, elastic, and reticular fibers.
c. Most connective tissues are highly vascular, with the exception of cartilage.
d. Most connective tissues consist largely of cells with little ECM.

7 How do loose and dense connective tissues differ?

8 Which of the following statements about muscle tissue is *true*?

a. Skeletal muscle and cardiac muscle tissues have no striations.
b. Smooth muscle tissue is found in the heart.
c. The cells of skeletal muscle tissue are long, tubular, and multinucleated.
d. Smooth muscle cells are joined by intercalated disks.

9 *Fill in the blanks:* Nervous tissue is composed of _____ and two types of cells:

_____ and _____.

Name _____

Section _____ Date _____

UNIT 4

10 *Matching:* **Match the tissue type with its location in the body.**

_____ Simple squamous epithelium

_____ Transitional epithelium

_____ Loose CT

_____ Cardiac muscle

_____ Nervous tissue

_____ Stratified squamous epithelium

_____ Hyaline cartilage

_____ Smooth muscle

_____ Dense regular collagenous CT

_____ Reticular CT

A. Part of the basement membrane, walls of hollow organs
B. Spleen and lymph nodes
C. Air sacs of the lungs
D. Oral cavity, pharynx, vagina, anus
E. Lining hollow organs, in the skin, in the eye, and surrounding many glands
F. Brain, spinal cord, peripheral nerves
G. Urinary bladder
H. Tendons and ligaments
I. Joints, connecting the ribs to the sternum, nose
J. In the heart

Name _____

Section _____ Date _____

UNIT 4 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 The condition *Marfan syndrome* results from the production of abnormal elastin, the main protein component of elastic fibers. Predict the potential consequences of defective elastic fibers. (*Hint:* Consider the organs and tissues in which elastic fibers are found. How would defective elastic fibers impair the functions of these organs and tissues?)

2 Collagen vascular diseases affect the protein collagen, the main component of collagen fibers. Predict the possible consequences of defective collagen fibers on specific organs and tissues.

3 How would the effects of a collagen vascular disease that affected only the collagen in reticular fibers differ from the effects seen with question 2? Why?

4 The formation of fibrocartilage is a common response to injury of hyaline cartilage. Do you think fibrocartilage would provide an articular surface (i.e., the cartilage in joints) as smooth as the original hyaline cartilage? Why or why not?

5 **Explain how the structure of each of the following tissues follows its function:**

a Stratified squamous keratinized epithelium _____

_____

_____

_____

b Simple squamous epithelium _____

_____

_____

_____

c Hyaline cartilage _____

_____

_____

d Bone _____

_____

_____

_____

6 **When muscle tissue dies, it usually is replaced with dense irregular collagenous connective tissue. How do these tissues differ in structure? Will the muscle be able to function normally? Why or why not?**

_____

_____

_____

_____

_____

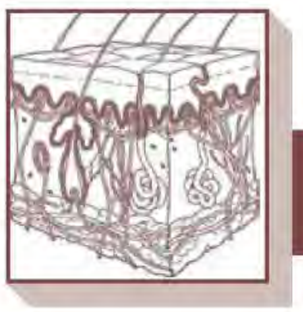
Integumentary System

5

OBJECTIVES

Once you have completed this unit, you should be able to:

1. Identify structures of the integumentary system.
2. Describe the gross and microscopic structure of thick and thin skin.
3. Map the distribution of touch receptors on different areas of the body.

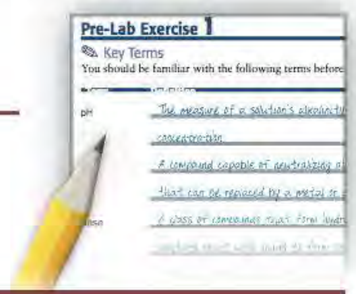


Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.

Pre-Lab Exercise 5-1



✎ Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Epidermal Structures

Epidermis _____

Keratinocyte _____

Melanocyte _____

Stratum corneum _____

Stratum lucidum _____

Stratum granulosum _____

Stratum spinosum _____

Stratum basale _____

Structures of the Dermis

Dermis _____

Dermal papillae _____

Lamellated corpuscle _____

Tactile corpuscle _____

Name _____ Section _____ Date _____

Other Structures

Hypodermis _____

_____

Sweat gland _____

_____

Sebaceous gland _____

_____

Hair follicle _____

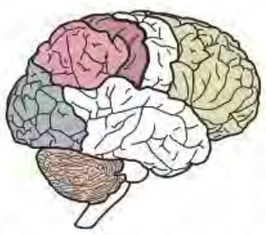
_____

Nails _____

_____

Arrector pili muscle _____

_____



Pre-Lab Exercise 5-2

Skin Anatomy

Label and color the structures of the skin in Figure 5.1 with the terms from Exercise 5-1 (p. 99). Use your text and Exercise 5-1 in this unit for reference.

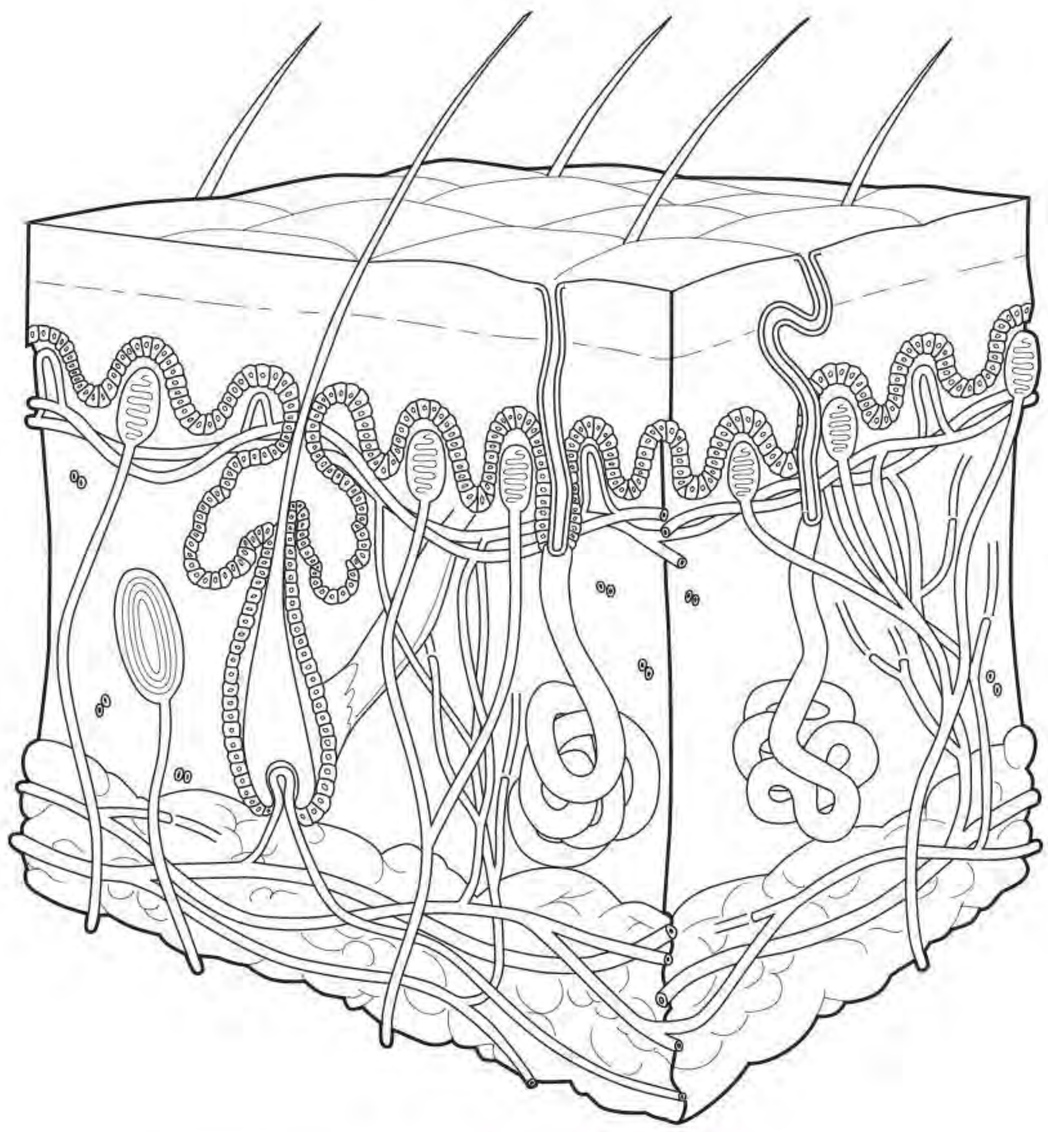
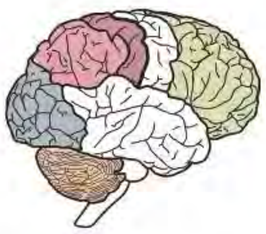


FIGURE **5.1** Skin section.

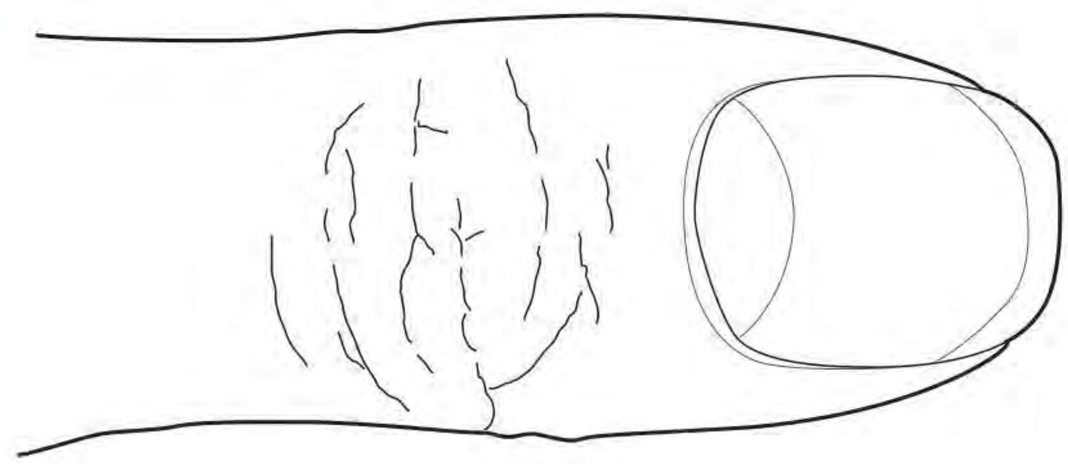


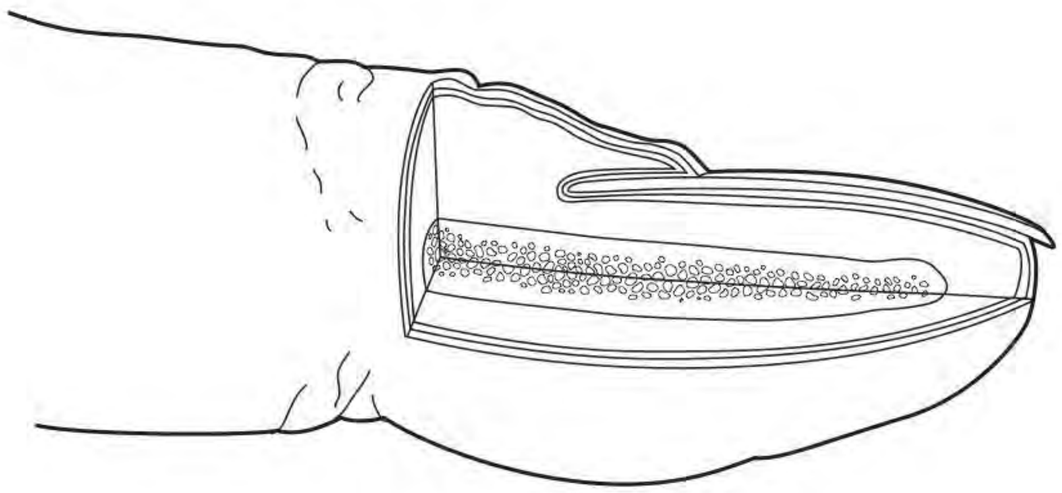
Pre-Lab Exercise 5-3

Hair and Nail Anatomy

Label and color the structures of the hair and nail in Figure 5.2 with the terms from Exercise 5-1 (p. 101). Use your text and Exercise 5-1 in this unit for reference.

A





B

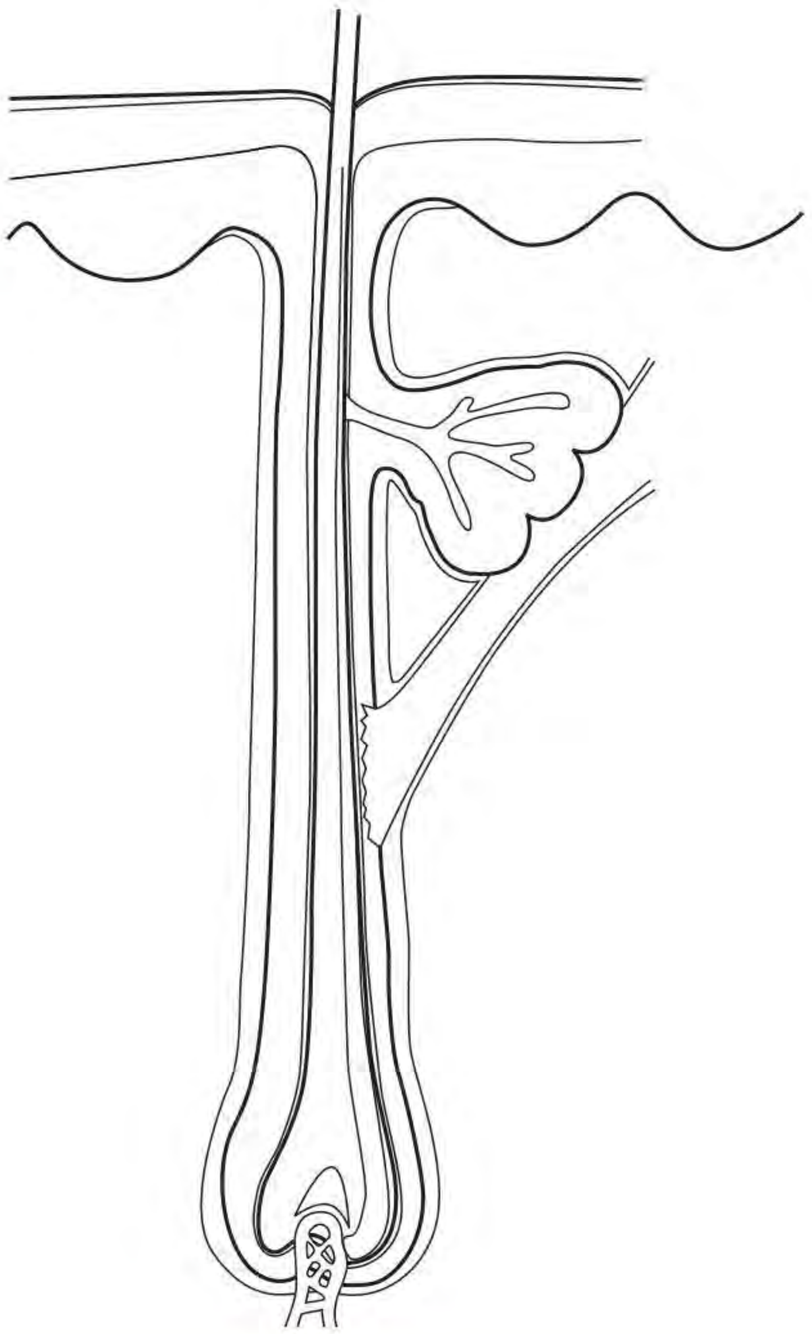


FIGURE **5.2** (A) Nail anatomy; (B) hair structure.

EXERCISES

Although the skin is the largest organ in the body, most people don't realize that it is actually an organ. Like all organs, the skin or **integument** (in-TEG-yoo-ment) is composed of several tissue types, including epithelial tissue, connective tissue, muscle tissue, and nervous tissue. In the following exercises you will examine the tissues of this organ, along with the other structures of the integumentary system, and apply your knowledge of skin anatomy to perform fingerprinting procedures.

Exercise 5-1

Skin Anatomy and Accessory Structures

MATERIALS

- ❑ Skin models and diagrams
- ❑ Colored Pencils

The **integumentary system** is composed of the skin and its **accessory structures**: the **hair**, **glands**, and **nails**. The skin is composed of two general tissue layers: the **epidermis** and the **dermis** (Figure 5.3). The tissue beneath the dermis, called the **hypodermis** or the *subcutaneous tissue*, connects the skin to the underlying tissues and is not considered part of the integument. The hypodermis is richly supplied with blood vessels.

The **epidermis** contains layers (or *strata*) of stratified squamous keratinized epithelium. The predominant cell type found in the epidermis is the keratin-producing **keratinocyte** (kehr-ah-TIN-oh-syt). Keratin is a hard protein that protects the skin from mechanical stresses. From superficial to deep, the layers of the epidermis are as follows (Figure 5.4):

1. **Stratum corneum.** The superficial layer of cells, called the **stratum corneum** (STRAT-um KOHR-nee-um) is composed of dead **keratinocytes.** Under microscopic examination, the keratinocytes of the stratum corneum bear little resemblance to living cells and have a dry, flaky appearance. These cells typically appear dark purple, which is due to the accumulation of keratin in their cytosol.

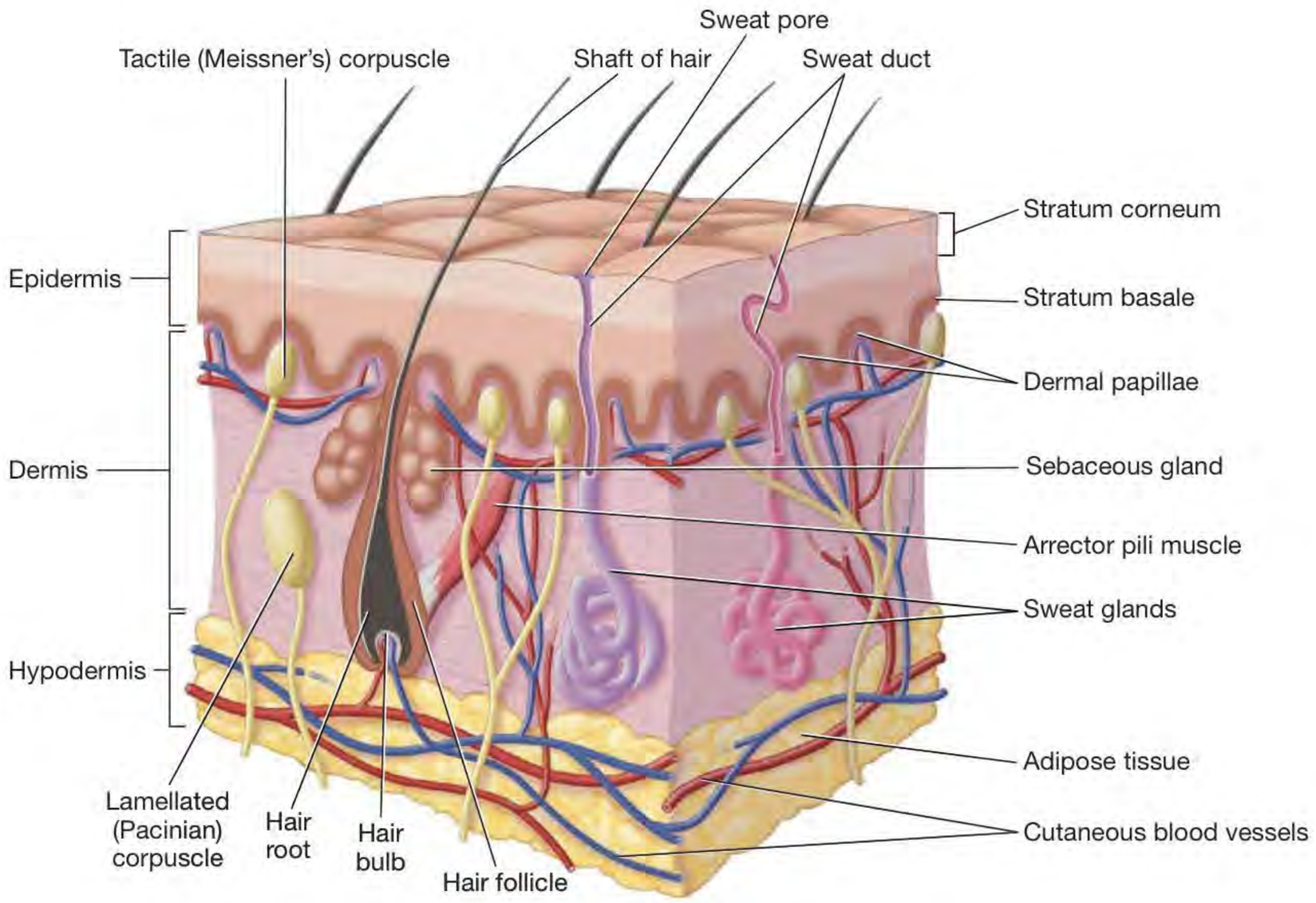


FIGURE **5.3** Skin section.

2. **Stratum lucidum.** The **stratum lucidum** (LOO-sid-um) is a single layer of translucent, dead keratinocytes found only in the skin of the palms and the soles of the feet.
3. **Stratum granulosum.** The third layer of keratinocytes is the **stratum granulosum** (gran-yoo-LOH-sum). Here the superficial keratinocytes are dead, but the deeper cells are alive. This layer is named for the cells' cytoplasmic granules, which contain keratin and a lipid-based substance. This lipid-based substance is found in **lamellar granules**, and helps to keep the skin water-resistant.
4. **Stratum spinosum.** The first actively metabolizing cells are encountered in the fourth cell layer, the **stratum spinosum** (spin-OH-sum). The pigment **melanin** (MEL-uh-nin) is found in this layer, which provides protection from UV light and also decreases production of vitamin D (to prevent the body from overproducing it).
5. **Stratum basale.** The **stratum basale** (bah-SAH-lay) is the deepest layer and contains a single row of actively dividing keratinocytes. Here we also find **melanocytes** (mel-AN-oh-syt'z), which produce melanin.

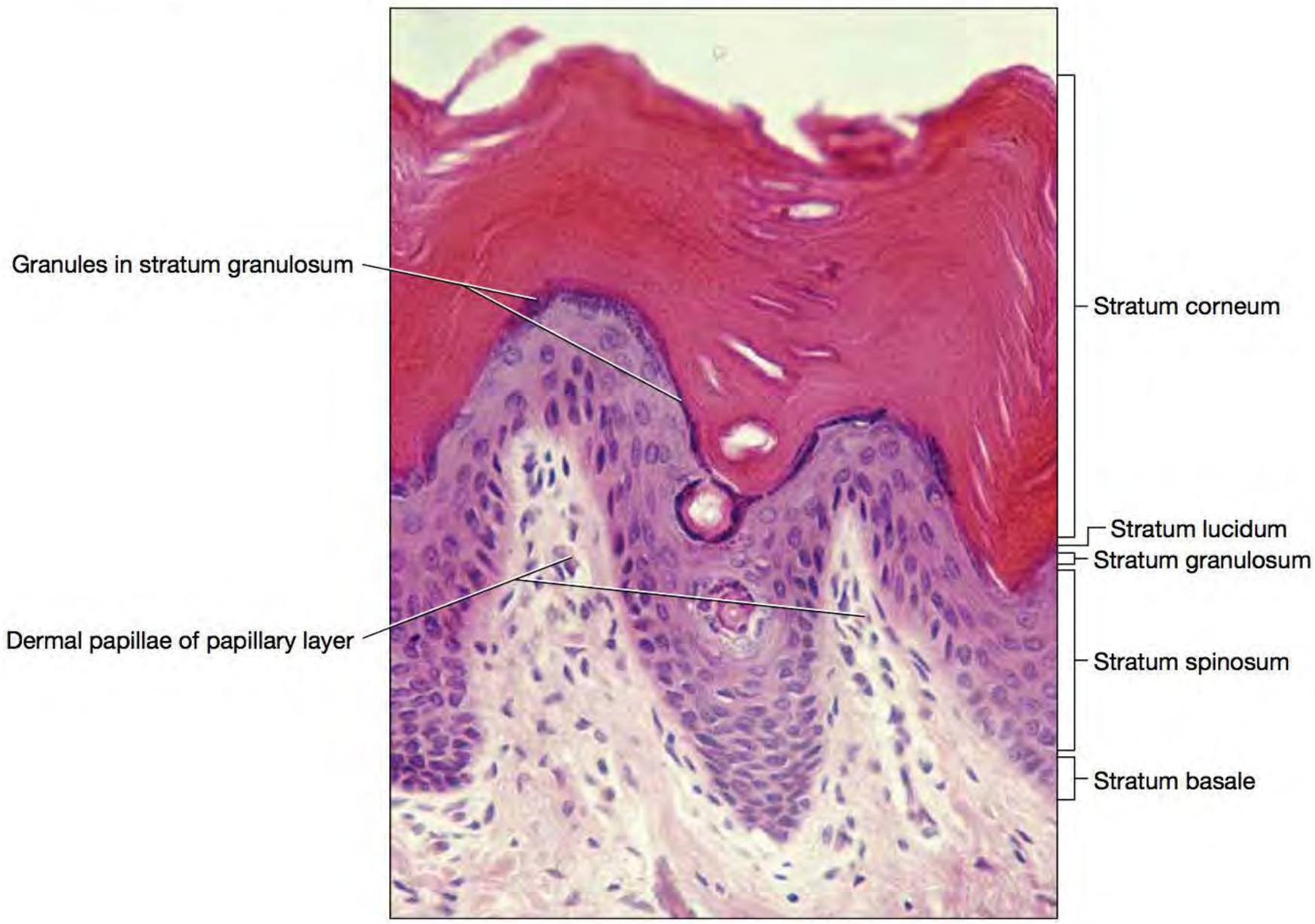


FIGURE **5.4** Layers of the epidermis.

Why does the epidermis have so many dead cells? Recall that the epidermis is composed of epithelial tissue, and epithelial tissue is avascular (has no blood supply). All epithelial tissues require oxygen and nutrients to diffuse to them from the deeper tissues. In the case of the epidermis, this deeper tissue is the dermis. Only the cells of the deeper parts of the stratum granulosum, the stratum spinosum, and the stratum basale are close enough to the blood supply in the dermis to get adequate oxygen and nutrients for survival. For this reason, as the cells migrate farther away from the blood supply, they begin to die.

Immediately deep to the stratum basale of the epidermis is the **basement membrane**, which consists of the basal lamina, composed of ECM produced by keratinocytes, and the reticular lamina, composed of ECM produced by the dermis. The basement membrane holds the epidermis in place with molecular "glue" that prevents it from separating from the dermis.

Deep to the epidermis is the **dermis**, which is composed of highly vascular connective tissue. It contains two layers:

1. **Papillary layer.** The superficial **papillary layer** is composed of loose connective tissue. It contains fingerlike projections called the **dermal papillae** (pah-PILL-ee) that project into the epidermis, which you can see in Figure 5.4. The dermal papillae contain touch receptors called **tactile corpuscles** and capillary loops that provide blood supply to the avascular epidermis.

2. **Reticular layer.** The thick **reticular layer** is composed of dense irregular collagenous connective tissue. It houses structures such as **sweat glands**, oil-producing **sebaceous glands** (seh-BAY-shuhs), blood vessels, and pressure receptors called **lamellated corpuscles.**

Both hair and nails are accessory structures of the integumentary system (Figure 5.5). A **hair** consists of two basic parts: (a) the long, slender **shaft** composed of dead keratinocytes that projects from the skin's surface, and (b) the hair **root** embedded in the dermis (Figure 5.5A). The base of the root is indented by a projection from the dermis called the **hair papilla**; the papilla and root together are known as the **hair bulb.** The hair is embedded in a sheath known as the **hair follicle.** The inner lining of the hair follicle is epithelium that is continuous with the epidermis, and the outer lining is dermal connective tissue. A band of smooth muscle called an **arrector pili muscle** (ah-REK-tohr PIL-eye) attaches to this dermal sheath, and can pull the hair into an upright or erect position when it contracts.

Like hairs, **nails** are composed primarily of dead keratinocytes (Figure 5.5B). A nail consists of a flat **nail plate** surrounded by folds of skin on all three sides, known as **nail folds.** The folds on the sides of the nails are **lateral nail folds**, and the fold at the base is the **proximal nail fold.** The stratum corneum of the proximal nail fold grows over the nail plate to form a thin structure called the **eponychium** (ep-oh-NIK-ee-um) or *cuticle*. Often near the eponychium, we find a thickened area of the nail plate, the **lunula** (LOON-yoo-luh), which generally has a half-moon shape (note that many nails lack a lunula). Deep to the proximal nail fold is a group of dividing cells from which the nail plate grows known as the **nail matrix.**

Other accessory structures of the integumentary system are its **sebaceous glands** and **sweat glands. Sebaceous glands** are exocrine glands that secrete **sebum** (SEE-bum; oil) into a hair follicle. **Sweat glands** are also exocrine glands; they secrete sweat that travels through a **sweat duct** and is released onto the surface of the skin through a small **sweat pore** (see Figure 5.3).

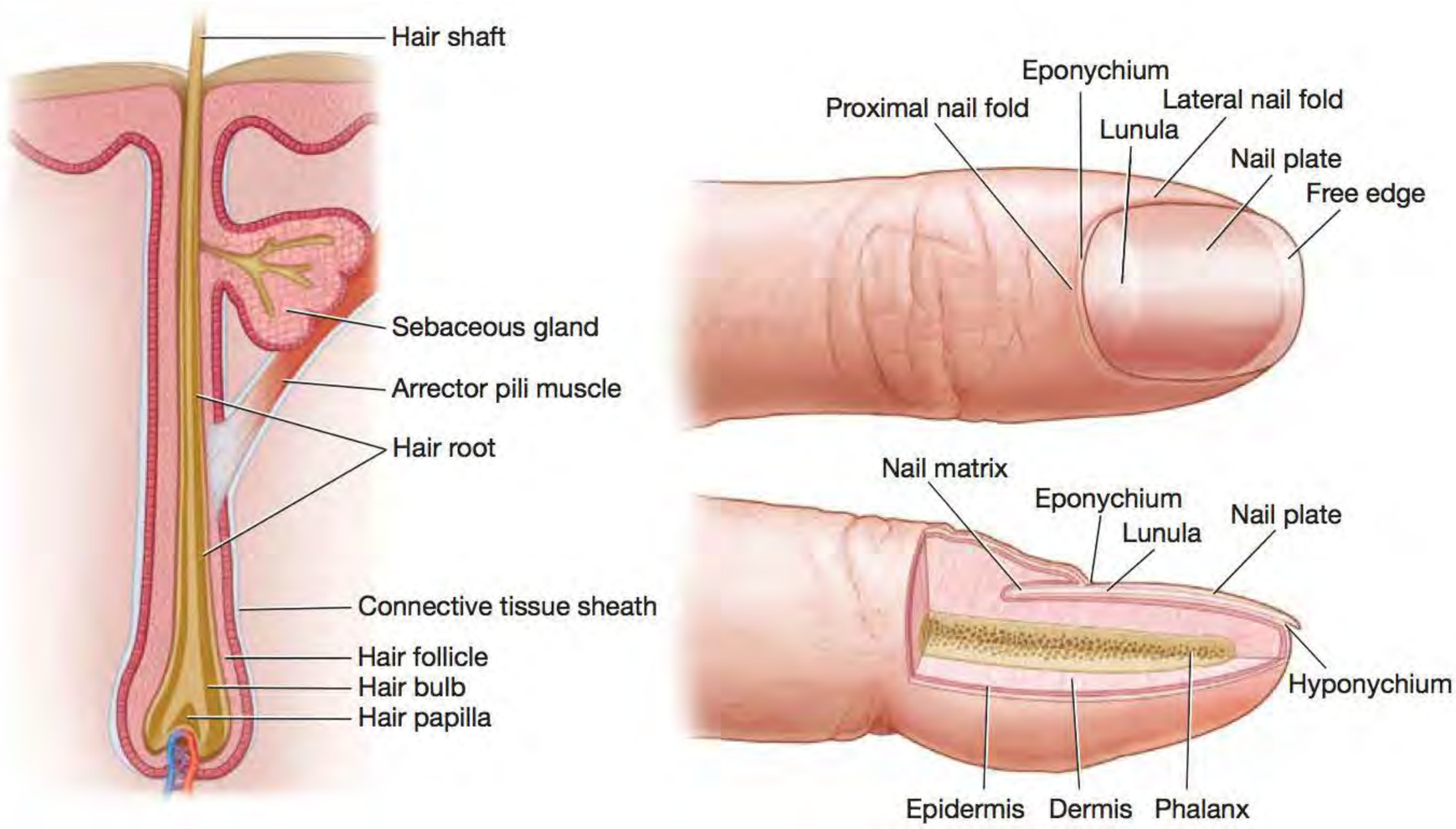


FIGURE **5.5** (A) Hair structure; (B) nail anatomy.

Procedure 1 Model Inventory for the Integumentary System

Identify the following structures of the integumentary system on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 5.1. When you have completed this activity, answer Check Your Understanding questions 1 through 4 (p. 113).

Structures of the Skin

1. Epidermal layers
   a. Stratum corneum
   b. Stratum lucidum
   c. Stratum granulosum
   d. Stratum spinosum
   e. Stratum basale
2. Dermal layers
   a. Papillary layer
   b. Reticular layer
3. Dermal papillae
4. Blood vessels
5. Nerve endings
   a. Lamellated corpuscle
   b. Tactile corpuscles

Other Structures

1. Hair
   a. Hair shaft
   b. Hair root
   c. Hair papilla
   d. Hair bulb
   e. Hair follicle
   f. Arrector pili muscle
2. Nail
   a. Nail plate
   b. Nail fold (proximal and lateral)
   c. Eponychium
   d. Lunula
   e. Nail matrix
3. Sebaceous gland
4. Sweat gland
   a. Sweat duct
   b. Sweat pore

TABLE 5.1 Model Inventory for the Integumentary System

Model/Diagram	Structures Identified

Procedure 2 Time to Draw

In the space below, draw, color, and label one of the skin models that you examined. In addition, write the main function of each structure that you label.

Exercise 5-2

Histology of Integument

MATERIALS

- ❑ Slide of thick skin
- ❑ Slide of thin skin
- ❑ Colored pencils
- ❑ Light microscope

5

In this exercise we will examine prepared slides of skin and hair. The skin sections are taken from different regions of the body so we can compare and contrast two types of skin: (a) **thick skin**, found on the palms and soles of the feet, and (b) **thin skin**, found everywhere else (Figure 5.6).

Before moving on, review the basics of microscopy from Units 2 and 4. Remember to follow a step-by-step approach when examining the slides: Look at the slide with the naked eye first, then begin your examination on low power, and advance to higher power to see more details.

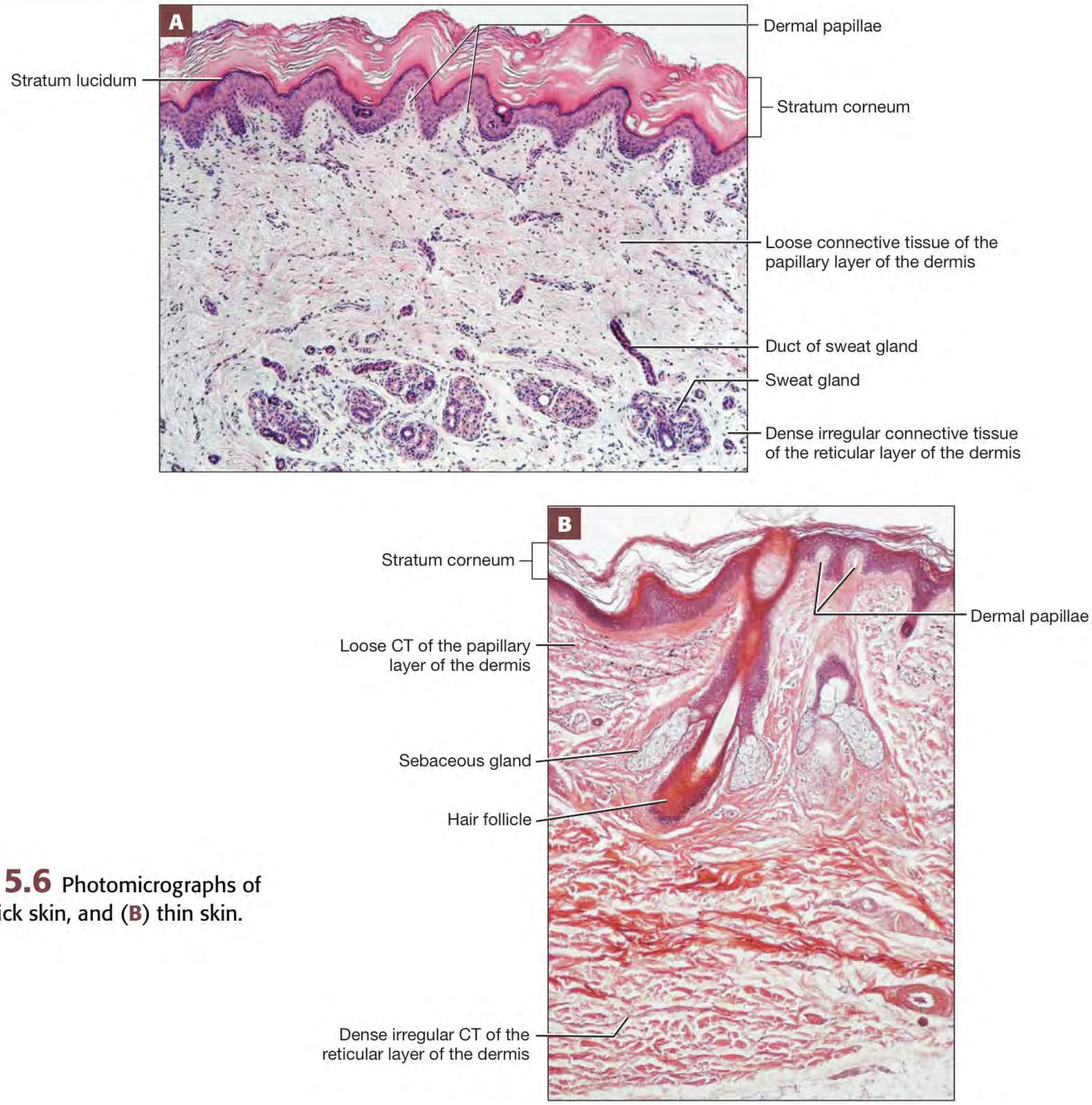


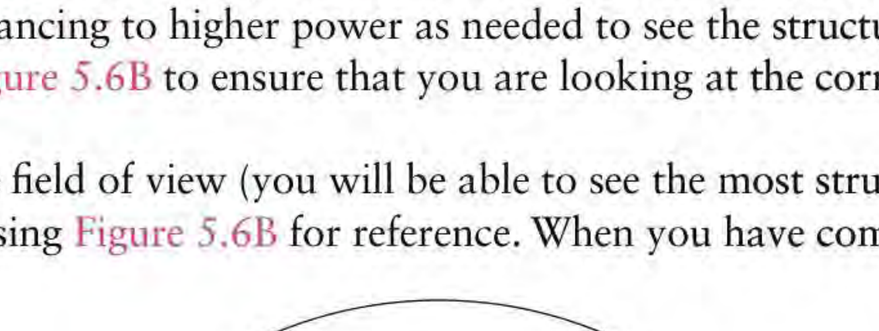
FIGURE **5.6** Photomicrographs of (**A**) thick skin, and (**B**) thin skin.

Procedure 1 Microscopy of Thick Skin

Obtain a prepared slide of thick skin (which may be labeled "palmar skin"), and examine it with the naked eye to get oriented. Once you are oriented, place the slide on the stage of the microscope, and scan it on low power. You should be able to see the epidermis with its superficial layers of dead cells and the dermis with its pink clusters of collagen bundles that make up the dense irregular collagenous connective tissue. Compare it to Figure 5.6A to make sure that are you are looking at the right slide and the right magnification. Advance to higher power to see the cells and associated structures in greater detail.

Use your colored pencils to draw what you see in the field of view (you will be able to see the most structures on low power). Label your drawing with the following terms, using Figure 5.6A for reference. When you have completed your drawing, fill in the first part of Table 5.2.

1. Epidermis
   a. Stratum corneum
   b. Stratum lucidum
   c. Stratum granulosum
   d. Stratum spinosum
   e. Stratum basale
2. Dermis
   a. Dermal papillae
   b. Collagen bundles
   c. Sweat gland



Procedure 2 Microscopy of Thin Skin

Obtain a prepared slide of thin skin (which may be called "scalp skin"). As before, examine the slide with the naked eye, then scan the slide on low power, advancing to higher power as needed to see the structures more closely. Compare what you see in your field of view to Figure 5.6B to ensure that you are looking at the correct region of the slide.

Use your colored pencils to draw what you see in the field of view (you will be able to see the most structures on low power). Label your drawing using the terms below, using Figure 5.6B for reference. When you have completed your drawing, fill in the remainder of Table 5.2.

1. Epidermis
   a. Stratum corneum
   b. Stratum granulosum
   c. Stratum spinosum
   d. Stratum basale
2. Dermis
   a. Dermal papillae
   b. Collagen bundles
3. Hair follicle
4. Sebaceous gland
5. Sweat gland
6. Arrector pili muscle

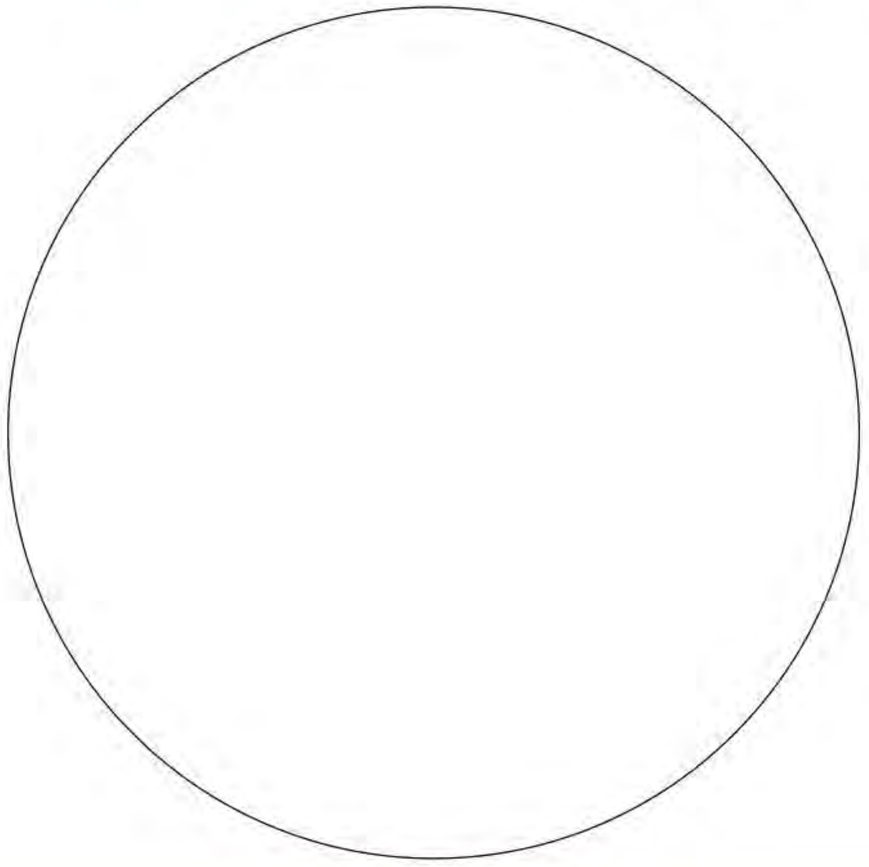


TABLE **5.2** Characteristics of Thick and Thin Skin

Characteristic	Thick Skin	Thin Skin
Thickness of stratum corneum		
Hair follicles present?		
Sebaceous glands present?		
Stratum lucidum present?		
Arrector pili muscles present?		

Procedure 3 Microscopy of Hair

Obtain a prepared slide of a sectioned hair. As before, examine the slide with the naked eye, then scan the slide on low power, advancing to higher power as needed to see the structures more closely. Compare what you see in your field of view to Figure 5.7 to ensure that you are looking at the correct region of the slide.

Use your colored pencils to draw what you see in the field of view (you will be able to see the most structures on low power). Label your drawing using the terms below, using Figure 5.7 for reference.

1. Cortex
2. Medulla
3. Hair papilla
4. Matrix
5. Hair follicle

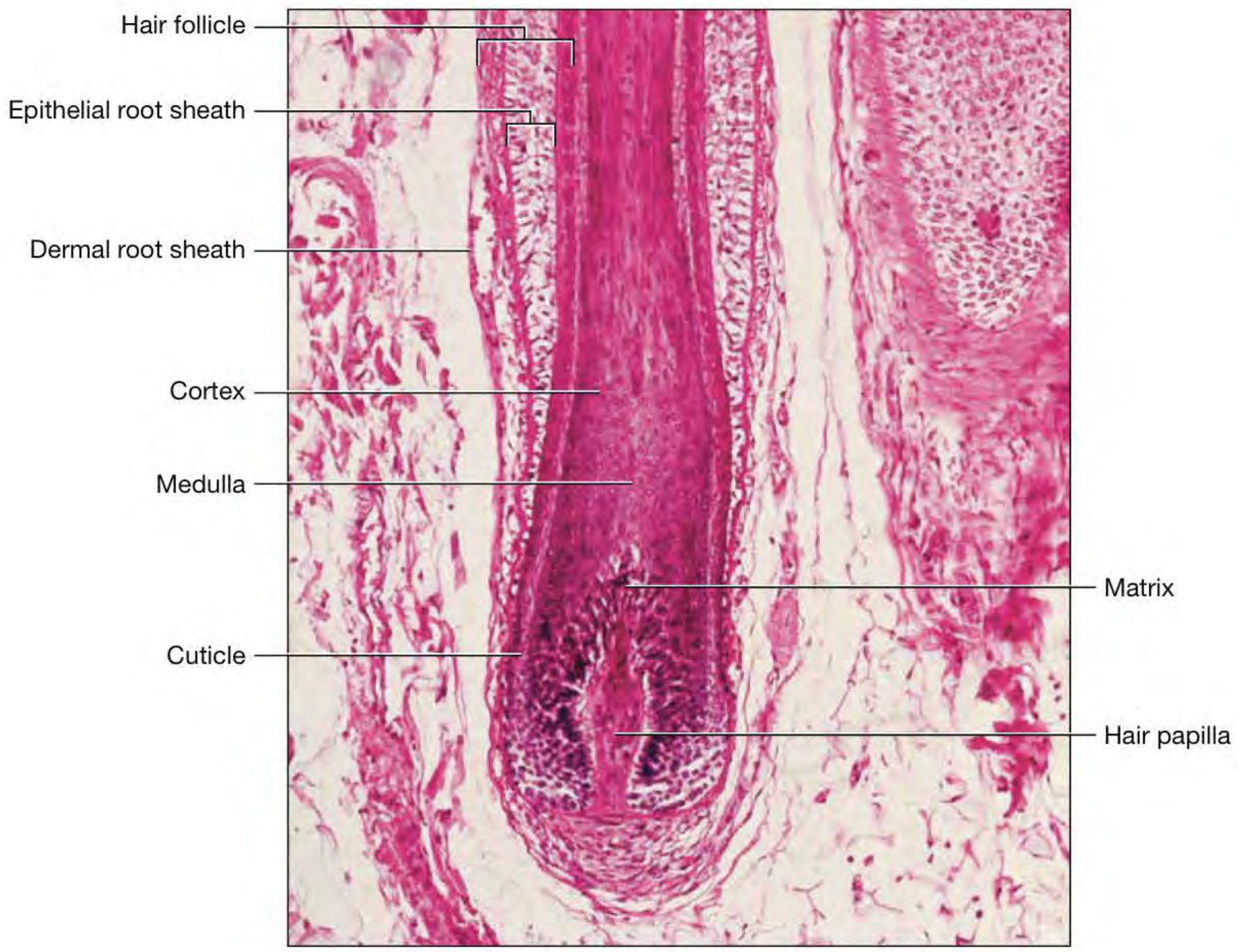


FIGURE **5.7** Light micrograph of a sectioned hair.

Exercise 5-3

Touch Receptor Distribution

MATERIALS

- ❑ Water-soluble marking pen
- ❑ Ruler
- ❑ Monofilament

5

The two types of sensory receptors in the skin that detect fine touch are called **tactile corpuscles** and **Merkel discs**. The distribution of these receptors can be mapped using an instrument called a monofilament (Figure 5.8) that applies 10 grams of force as it is pressed on the skin (10 grams of force is generally accepted as the maximum amount of force required to activate the tactile corpuscles and Merkel discs). If a monofilament is not available, a similar instrument may be made using a stiff-bristle hair glued to a toothpick. When you have completed the activity, answer Check Your Understanding questions 5 and 6 (pp. 113–114).

Procedure 1 Mapping Touch Receptor Distribution

1. Use a centimeter ruler to measure a 2-centimeter square on your partner's palm. Mark this square with a water-soluble marking pen.
2. Have your partner close his or her eyes.
3. Apply the monofilament to one of the corners of the square. Press only until the monofilament bends slightly.
4. If your partner can perceive the sensation of the monofilament, mark this spot with a different-colored water-soluble marker.
5. Repeat this process for the remainder of the square, advancing the monofilament 1–2 millimeters each time. Be certain to apply the same amount of pressure with each application.
6. When you have completed the square, record the number of receptors found on the palm.

   Number of receptors on palm: _____

7. Repeat this process on the posterior shoulder. Record the number of receptors found on this location.

   Number of receptors on the posterior shoulder: _____

FIGURE **5.8** Monofilament.

Exercise 5-4

Fingerprinting

MATERIALS

- ❑ Blank glass slide (one per person)
- ❑ Ink pad
- ❑ Fingerprint card (one per person)
- ❑ Dusting powder
- ❑ Dusting brush
- ❑ Fingerprint lifting tape
- ❑ Latex gloves
- ❑ Sharpie® marker

Specific patterns in the epidermis are created in thick skin, where the dermal papillae are folded into **dermal ridges**. These dermal ridges indent the overlying epidermis to create **epidermal ridges**, which increase gripping ability. They also lead to the characteristic patterns of finger, toe, palm, and footprints. The patterns of the epidermal ridges are unique to each individual, even identical twins.

Sweat pores open at the top of the epidermal ridges, which causes us to leave behind a thin film when we touch surfaces. This film can be detected in a variety of ways, most commonly using a powder that binds to it.

Fingerprinting was not a widely accepted means of identification in the United States until 1902, when the New York Civil Service began collecting and using fingerprints. Prior to this, fingerprints had been studied widely and even were used to solve a murder case in Argentina in 1892.

Fingerprints can be broadly classified into three ridge flow patterns: loop, arch, and whorl (Figure 5.9). Once the ridge flow pattern has been identified, the characteristics of the ridges, also called *Galton points*, are examined. The three basic ridge characteristics are the ridge ending, the island (or the dot), and the bifurcation (Figure 5.10). In professional laboratories the fingerprint is analyzed further on the basis of minute details, or "points," in the fingerprint. Much of this is done currently with the help of computers.

In this exercise you will be playing the role of detective, searching for a "thief" among your group members (which may end up being you!). Your group will determine the thief's identity by analyzing the ridge flow patterns and ridge characteristics of the fingerprints of your group members. When you have completed the activity, answer Check Your Understanding question 7 (p. 114).

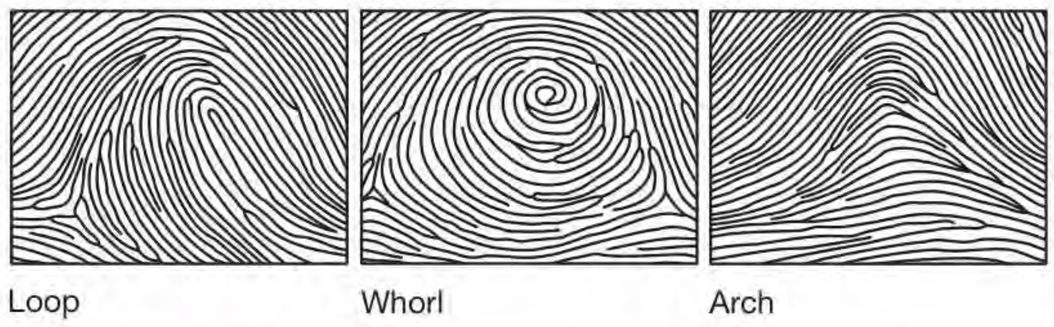


FIGURE **5.9** The three basic patterns of fingerprints.

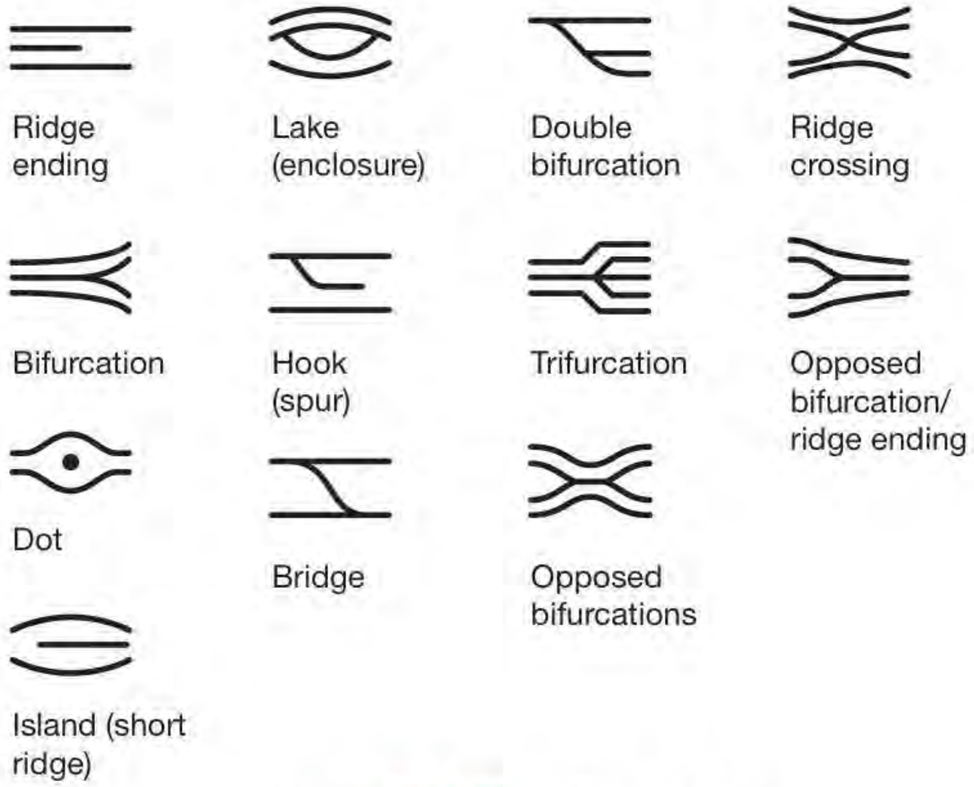


FIGURE **5.10** Galton points.

Procedure 1 Fingerprint Analysis

1. Assemble into groups of a minimum of four people.
2. Obtain one blank glass slide, and handle it by the edges as you clean it off with a paper towel and water.
3. Once the slide is clean and dry, place two or three large fingerprints (use different fingers) somewhere on one side of the slide.
4. After placing one or more fingerprints on the slide, put on gloves, and use the Sharpie at your table to write your initials on the upper right-hand corner of the slide.
5. Bring the slides for the entire table to your instructor, and your instructor will pick one slide from the group, cover the initials in the corner, and designate that person as the "thief." The thief is one of your group members, so you are all suspects.
6. Fingerprint each member of the group (using the ink and cards provided):
   a. Obtain a blank fingerprinting card or a blank sheet of paper.
   b. Roll each finger individually on the ink pad from right to left. Be certain not to get excessive ink on your fingers.
   c. Roll each finger individually on the fingerprinting card slowly from left to right.
7. When all of the fingerprinting is completed, don a pair of latex gloves.
8. Use a dusting brush to lightly sweep some dusting powder onto the slide containing the thief's fingerprints. Use the dusting powder *sparingly*, because too much powder will obscure your prints. Brush away the excess dusting powder. (You can tap the slide on its side to help with this.)
9. Place a piece of fingerprint lifting tape on the fingerprints that have appeared. Pat the tape into place firmly, and remove it slowly. Place the tape on a blank sheet of white paper for comparison.
10. With the help of Figures 5.9 and 5.10, identify the thief by comparing the fingerprints lifted from the slide with the fingerprints taken from the suspects. Be careful not to tell your group mates which fingers you used. Remember—you don't want to be caught!

Who is the thief from your table? _____

How did you arrive at this conclusion? _____

Name _____

Section _____ Date _____

UNIT 5 REVIEW

Check Your Recall

1 Label the following parts of the skin on Figure 5.11.

- ❑ Arrector pili muscle
- ❑ Cutaneous blood vessels
- ❑ Dermal papillae
- ❑ Dermis
- ❑ Epidermis
- ❑ Hair root
- ❑ Hair follicle
- ❑ Hair shaft
- ❑ Hypodermis
- ❑ Sebaceous gland
- ❑ Sweat gland
- ❑ Sweat pore

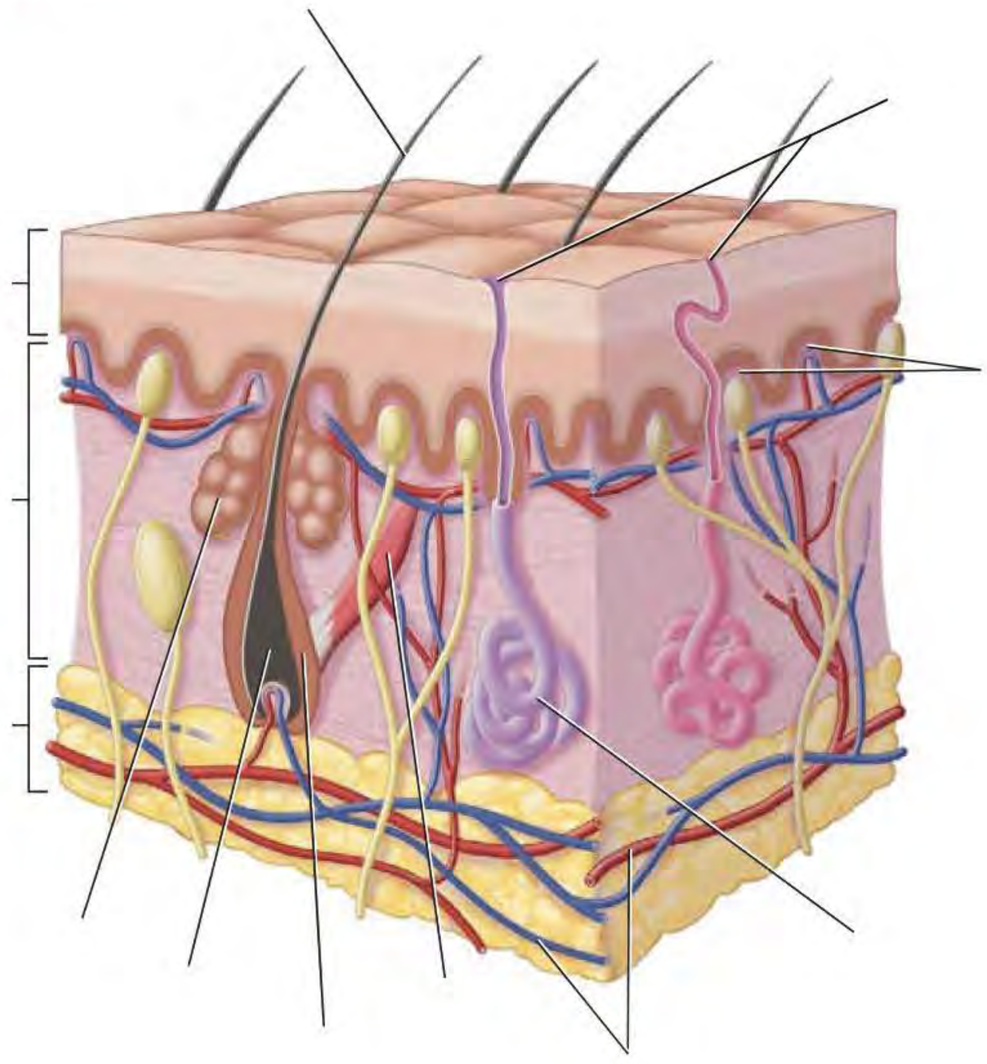


FIGURE **5.11** Skin section.

2 The main cell type in skin is the

a. melanocyte.
b. reticulocyte.
c. monocyte.
d. keratinocyte.

3 Number the layers of the epidermis, with 1 being the most superficial layer and 5 being the deepest layer.

_____ Stratum lucidum

_____ Stratum basale

_____ Stratum corneum

_____ Stratum spinosum

_____ Stratum granulosum

4 **Which layers of the epidermis contain living cells?**

a. Stratum granulosum only
b. Stratum corneum, stratum granulosum, stratum lucidum
c. Stratum basale, stratum spinosum, stratum granulosum
d. All of the layers of the epidermis contain living cells.
e. None of the layers of the epidermis contain living cells.

5 **From where do the cells of the epidermis obtain oxygen and nutrients?**

a. From blood vessels in the epidermis
b. Diffusion from blood vessels in the dermis
c. Diffusion from the air
d. From blood vessels in other epithelial tissues

6 ***Matching:*** **Match the following terms with the correct description.**

_____ Papillary layer
_____ Sebaceous gland
_____ Lamellated corpuscle
_____ Hair follicle
_____ Dermal papillae
_____ Hair shaft
_____ Reticular layer
_____ Sweat gland

A. Secrete product through a pore
B. Pressure receptor in the dermis
C. Projections of the dermis that indent the epidermis
D. Superficial layer of the dermis; loose connective tissue
E. Sheath of epithelial and connective tissue around a hair
F. Deep layer of the dermis; dense irregular collagenous connective tissue
G. Secretes sebum (oil)
H. Portion of the hair that projects from the skin's surface

7 **Which of the following are characteristics of thick skin? (*Circle all that apply.*)**

a. Located over the palms and the soles of the feet
b. Contains hair and arrector pili muscles
c. Contains sweat glands
d. Very thick stratum corneum
e. Contains sebaceous glands
f. Contains a stratum lucidum

8 **The dividing cells of a nail are located in the**

a. nail fold.
b. nail plate.
c. nail bed.
d. nail matrix.

9 **The two types of receptors in the skin that detect fine touch are the**

a. Merkel discs.
b. lamellated corpuscles.
c. tactile corpuscles.
d. Both a and b are correct.
e. Both a and c are correct.

10 **Fingerprints are the result of**

a. epidermal ridges.
b. projections from the hypodermis.
c. epidermal papillae that create dermal ridges.
d. dermal papillae that house sebaceous glands.

UNIT 5 REVIEW

Name _____

Section _____ Date _____

Check Your Understanding

Critical Thinking and Application Questions

1 Explain why a superficial skin scrape (such as a paper cut) doesn't bleed. Why don't you bleed when a hair is pulled out?

2 Shampoos and hair conditioners often claim to have nutrients and vitamins your hair must have to grow and be healthy. Taking into account the composition of hair, do you think these vitamins and nutrients will be beneficial? Why or why not?

3 Many drugs can be applied to the skin without entering the blood. How is this fact explained by the structure of the skin?

4 The disease bullous pemphigoid results in the destruction of proteins within the basement membrane that hold the epidermis and dermis together. How would this likely affect the epidermis? Would the skin be an effective barrier with this disease?

5 Would you have expected to have found more tactile corpuscles and Merkel discs on the palm or on the posterior shoulder? Why?

6 In which areas of the body would you expect to find the most Merkel discs and tactile corpuscles? Why?

5

7 Why do you have unique markings on your fingers, toes, palms, and soles but not on any other part of the body? Why do you leave behind fingerprints when you touch certain surfaces?

Introduction to the Skeletal System

6

OBJECTIVES

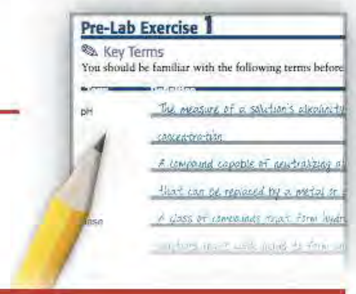
Once you have completed this unit, you should be able to:

1. Identify the structures and components of osseous tissue.
2. Explain the role of minerals and protein fibers in the function of osseous tissue.
3. Classify bones according to their shape.
4. Identify the parts of the long bone.
5. Define and provide examples of various bone markings.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 6-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

6

Types of Bone Tissue

Compact bone _____

Spongy bone _____

Structures of the Osteon

Osteon _____

Lamellae _____

Central canal _____

Perforating canal _____

Lacunae _____

Osteocytes _____

Canaliculi _____

Periosteum _____

Endosteum _____

Name _____ Section _____ Date _____

Bone Shapes

Long bone _____

Short bone _____

Flat bone _____

Irregular bone _____

Sesamoid bone _____

Sutural bone _____

Structures of Long Bones

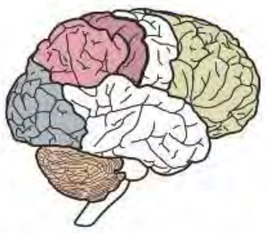
Diaphysis _____

Epiphysis _____

Epiphyseal plate/line _____

Medullary cavity _____

Bone marrow _____



Pre-Lab Exercise 6-2

Microscopic Anatomy of Compact Bone

Label and color the microscopic anatomy of compact bone tissue in Figure 6.1 with the terms from Exercise 6-1 (p. 119). Use your text and Exercise 6-1 in this unit for reference.

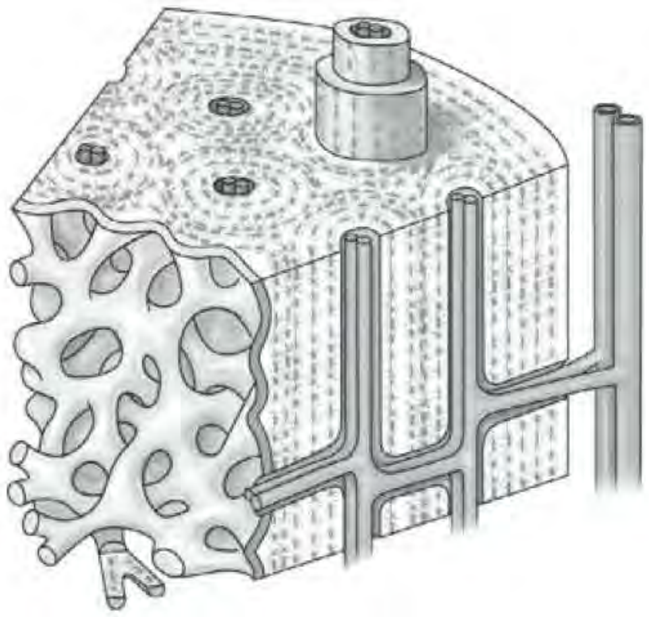
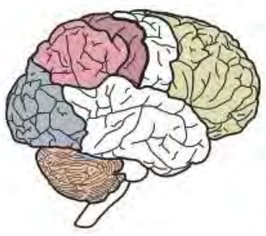


FIGURE **6.1** Microscopic anatomy of compact bone.



Pre-Lab Exercise 6-3

Structure of a Long Bone

Label and color the diagram of a long bone (the femur) in Figure 6.2 with the terms from Exercise 6-4 (p. 127). Use your text and Exercise 6-4 in this unit for reference.

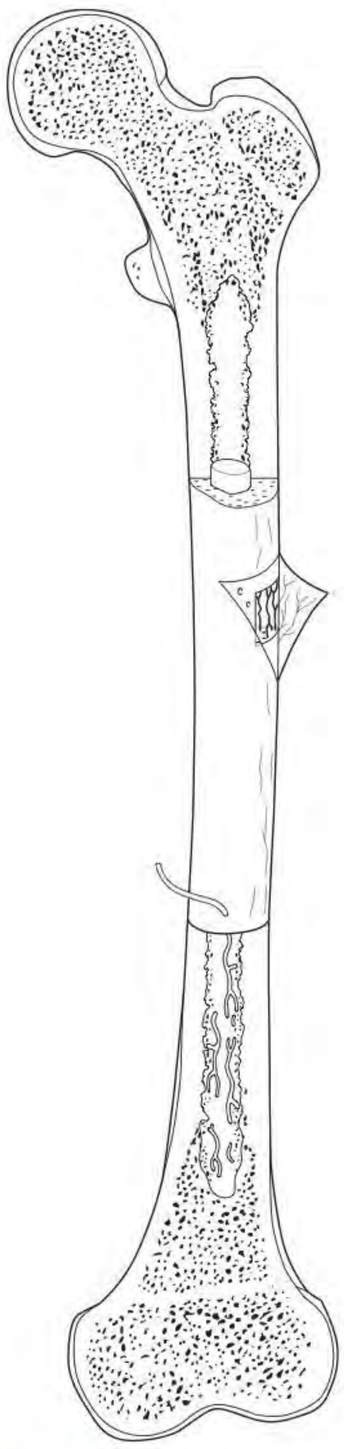


FIGURE **6.2** Long bone (the femur).

EXERCISES

The **skeletal system** consists of the bones and their cartilages. At first it might seem odd that a set of bones makes up an organ system, but remember that each bone is an organ. A bone consists of many tissue types, including osseous tissue, epithelial tissue, dense irregular collagenous connective tissue, and adipose tissue. The following exercises will introduce you to these complex organs and the histology of osseous tissue.

Exercise 6-1

Histology of Osseous Tissue

MATERIALS

- ❑ Osteon model
- ❑ Slide of compact bone
- ❑ Light microscope
- ❑ Colored pencils

The most superficial tissue of a bone is called the **periosteum** (pehr-ee-AH-stee-um). The periosteum is composed of dense irregular collagenous connective tissue richly supplied with blood vessels. The innermost layer of the periosteum contains **osteogenic cells** (ah-stee-oh-JEN-ik) that become cells called **osteoblasts** (AH-stee-oh-blasts), which secrete bone ECM and build new bone. It also contains cells known as **osteoclasts** (AH-stee-oh-klasts), which secrete enzymes that catalyze the breakdown of bone ECM. The periosteum is anchored to the bone by bundles of collagen called **perforating fibers.**

Deep to the periosteum we find **osseous tissue,** which is composed of a hardened ECM and different types of bone cells. The two general forms of **osseous tissue** are **compact bone** and **spongy bone.** **Compact bone** is hard, dense bone tissue found immediately deep to the periosteum. Its hardness comes from its structure, which consists of repeating, densely packed subunits called **osteons** (AH-stee-ahnz; Figures 6.3 and 6.4). Osteons contain several features, including the following:

1. **Lamellae. Lamellae** (lah-MELL-ee) are concentric rings of bone ECM. The lamellae give compact bone a great deal of strength, much like a tree's rings.
2. **Central canal.** Running down the center of each osteon is a **central canal.** Each central canal contains blood vessels and nerves and is lined with a connective tissue membrane called **endosteum** (en-DAH-stee-um). Like the periosteum, the endosteum has an inner layer of osteoblasts, which secrete bone ECM, and osteoclasts, which degrade bone.

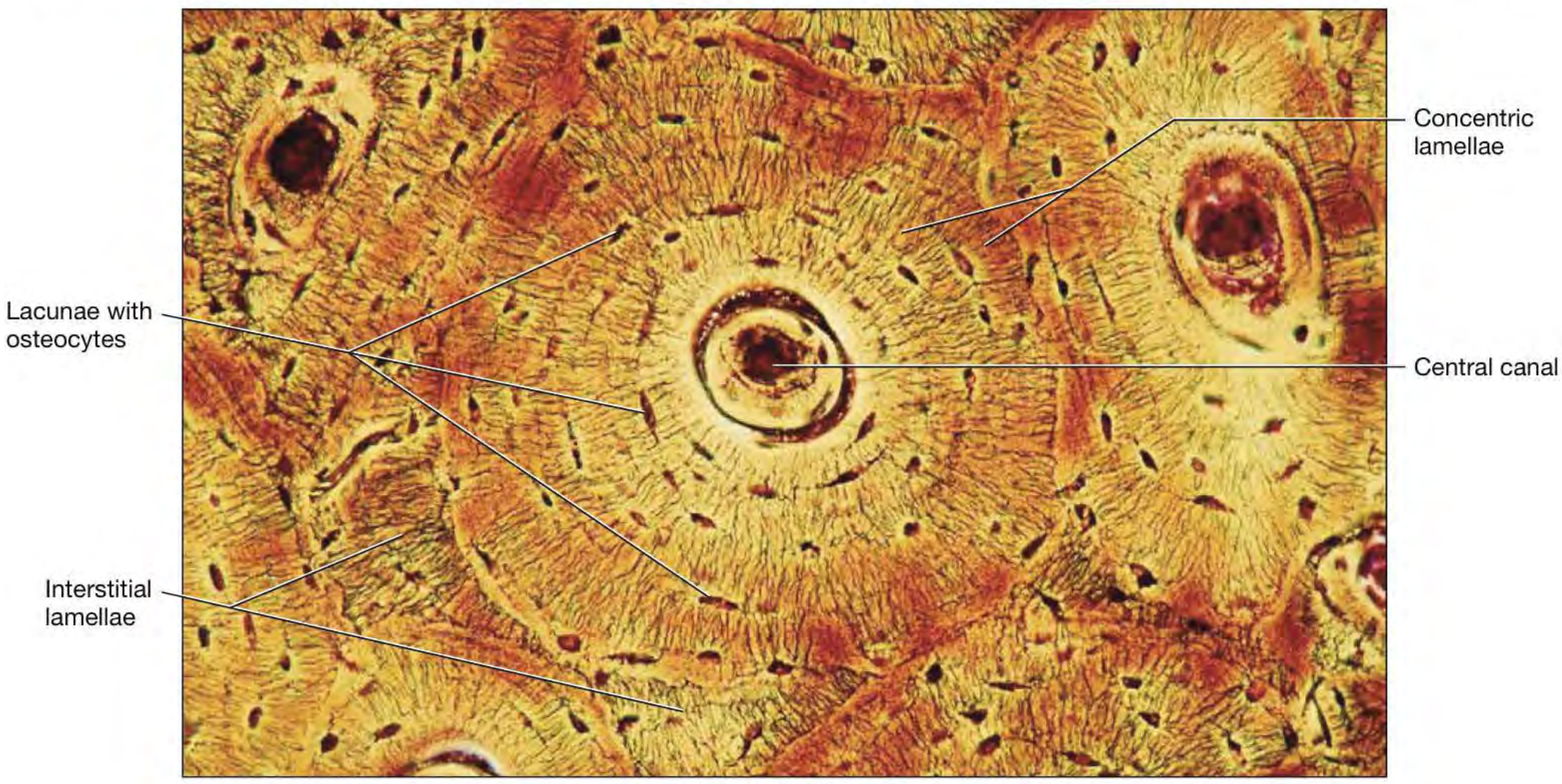


FIGURE **6.3** Compact bone, light micrograph.

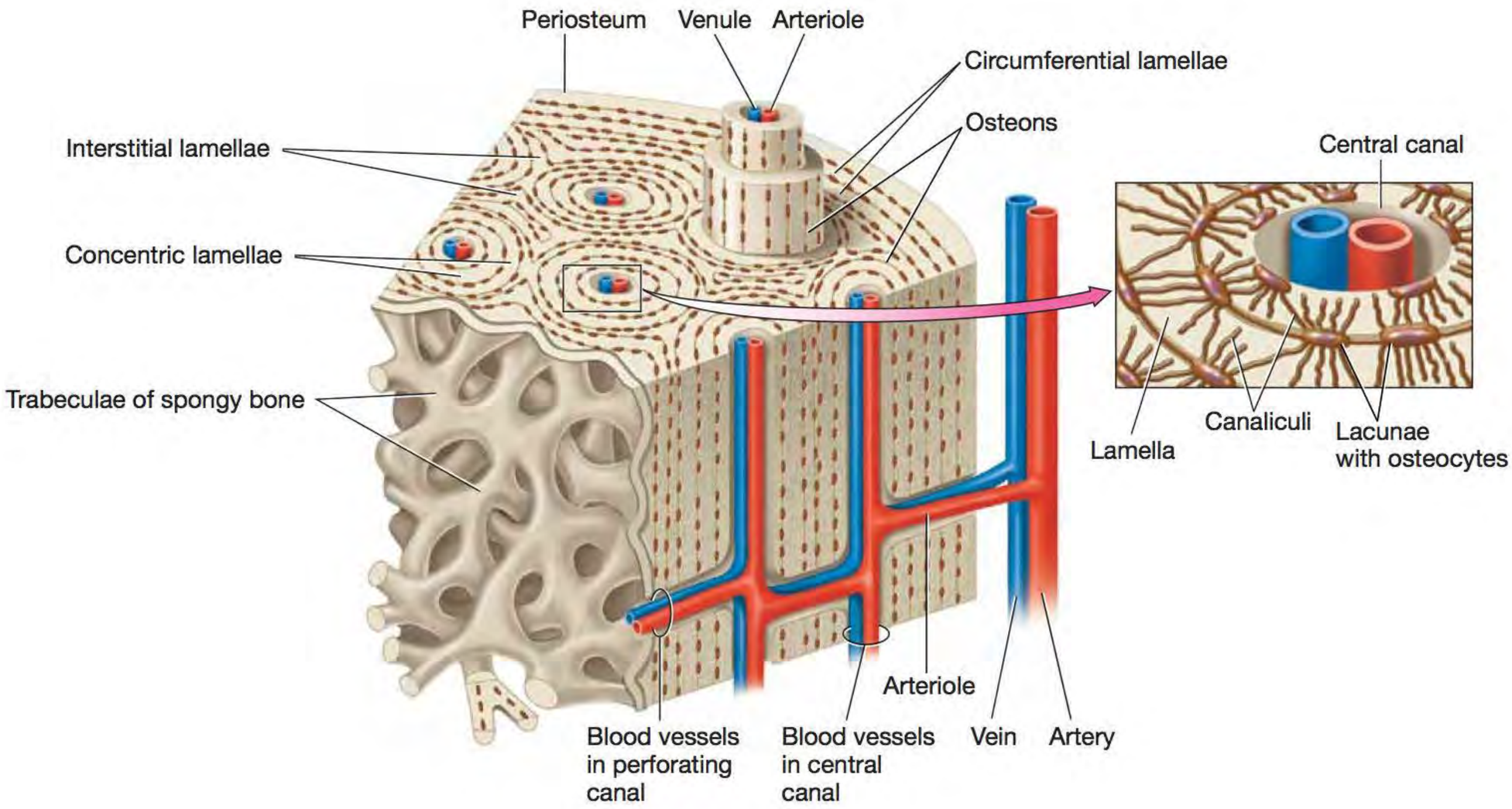


FIGURE **6.4** Compact bone.

3. **Lacunae.** Situated between the lamellae are small cavities called **lacunae** (lah-KOO-nee). Lacunae contain mature osteoblasts called **osteocytes** that monitor and maintain the bone ECM. Neighboring lacunae and osteocytes are connected to each other by tiny canals called **canaliculi** (kan-ah-LIK-yoo-lee).
4. **Perforating canals.** The **perforating canals** run perpendicular to the lamellae and carry blood vessels deep into the bone from the periosteum. Like the central canals, perforating canals are lined by endosteum.

Spongy bone is found on the inside of a bone deep to compact bone, and as its name implies, it somewhat resembles a sponge. It consists of a latticework-type structure with tiny bone spicules called **trabeculae** (trah-BIK-yoo-lee; Figure 6.5). The latticework structure of spongy bone allows it to house another important tissue, the **bone marrow**. The two types of bone marrow are **red bone marrow**, which produces blood cells, and **yellow bone marrow**, which is composed primarily of adipose tissue. As you can see in Figure 6.5, trabeculae are composed of lamellae but are not organized into osteons. For this reason, spongy bone lacks the hardness of compact bone.

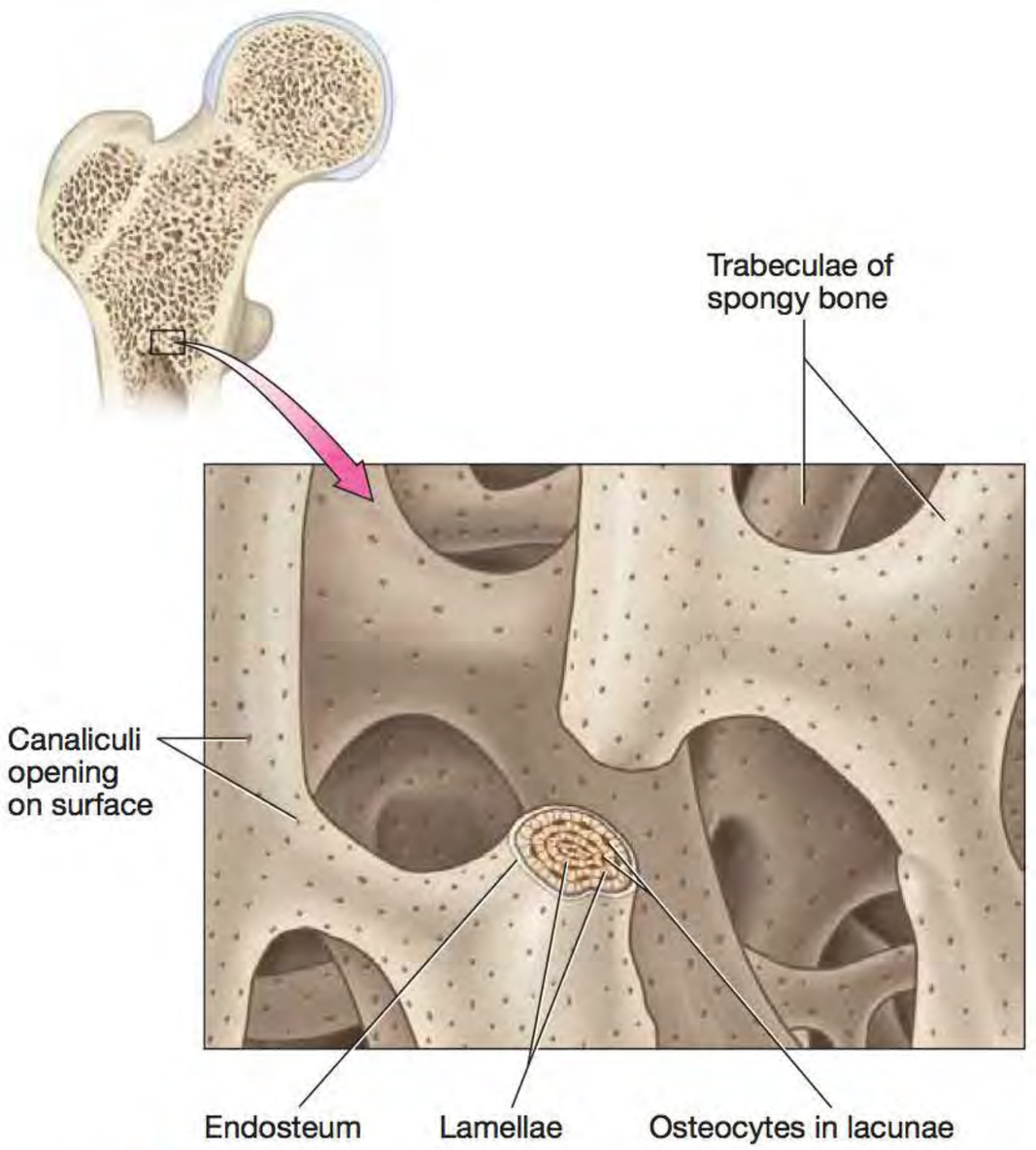


FIGURE **6.5** Microscopic anatomy of spongy bone tissue.

Procedure 1 Model Inventory for Compact and Spongy Bone

Identify the following structures of compact and spongy bone on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record on the model inventory in Table 6.1 the name of the model and the structures you were able to identify. When you have completed the activity, answer Check Your Understanding questions 1 through 2 (p. 133).

Compact Bone Structures

1. Periosteum
2. Perforating fibers
3. Osteons
   a. Lamellae
   b. Central canal
   c. Endosteum
   d. Lacunae
   e. Osteocyte
   f. Canaliculi
   g. Perforating canal

Spongy Bone Structures

1. Trabeculae
2. Red bone marrow
3. Yellow bone marrow

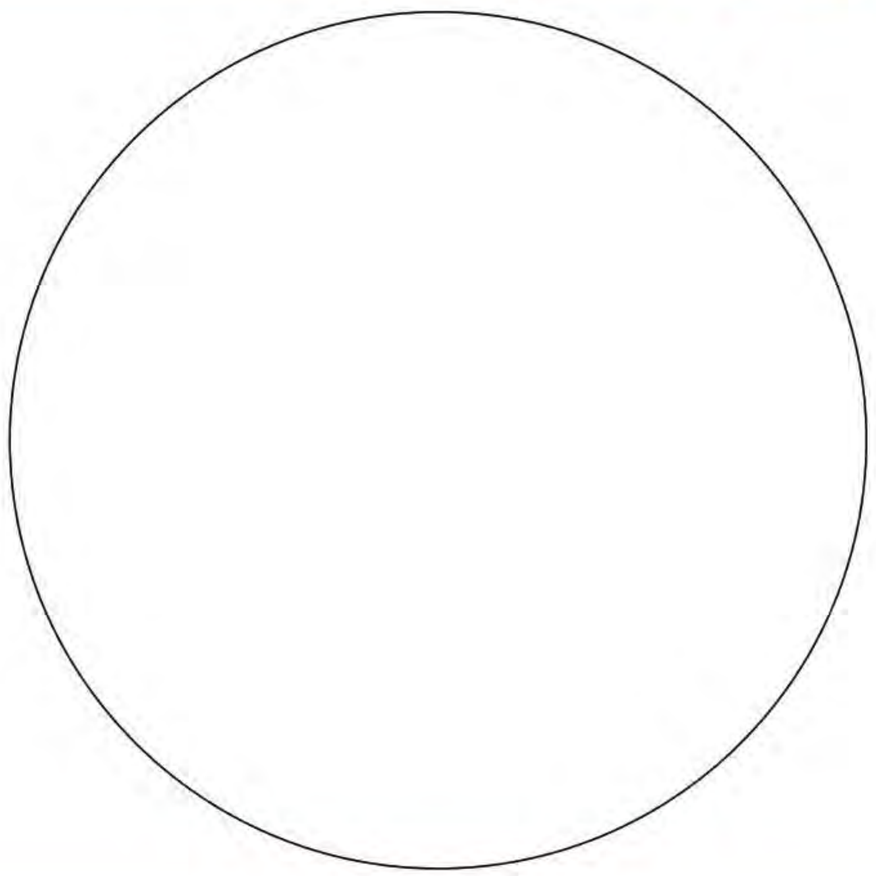
TABLE **6.1** Model Inventory for Osseous Tissue

Model	Bone Structures Identified

Procedure 2 Microscopy

View a prepared slide of compact bone. The structures on the slide should look similar to the osteon models you viewed in lab earlier and Figure 6.3.

Use colored pencils to draw a picture of what you see under the microscope, and label your drawing with the compact bone structures from Procedure 1 (above).



Exercise 6-2

Chemical Components of Bone Tissue

MATERIALS

- ❑ 1 piece of normal bone
- ❑ 1 piece of oven-heated bone
- ❑ 1 piece of bone soaked in nitric acid

The ECM of osseous tissue is made of two main chemical components:

1. The **organic component** consists mostly of protein fibers such as **collagen. Collagen** provides a supportive network that gives the bone *tensile strength* (the ability to withstand stretching and twisting forces). Tensile strength is very important to bone function, as it prevents bones from breaking when muscles pull on them.
2. The **inorganic component** consists mostly of calcium ions in the form of calcium hydroxyapatite crystals. The inorganic component provides the bone *compressional strength* (the ability to withstand compressive forces). Compressional strength is similarly important to bone function, as it allows bones to bear weight without breaking.

Procedure 1 Examining the Chemical Components of Bone

In this exercise you will compare the effects of removing different chemical components of bone. One sample has been heated in an oven. This destroys the organic components of the bone, leaving behind only the calcium hydroxyapatite crystals. The other sample has been treated with nitric acid to destroy the bone's inorganic component, leaving behind mostly collagen fibers (Figure 6.6). When you have completed the activity, answer Check Your Understanding questions 3 through 5 (p. 134).

Safety Note

Safety glasses and gloves are required!

1 Obtain three pieces of bone:

a. one piece of untreated bone,

b. one piece of bone that has been baked in an oven for a minimum of two hours, and

c. one piece of bone that has been soaked in nitric acid.

2 Place the three pieces of bone side by side. Describe their appearance. Do they look different from one another?

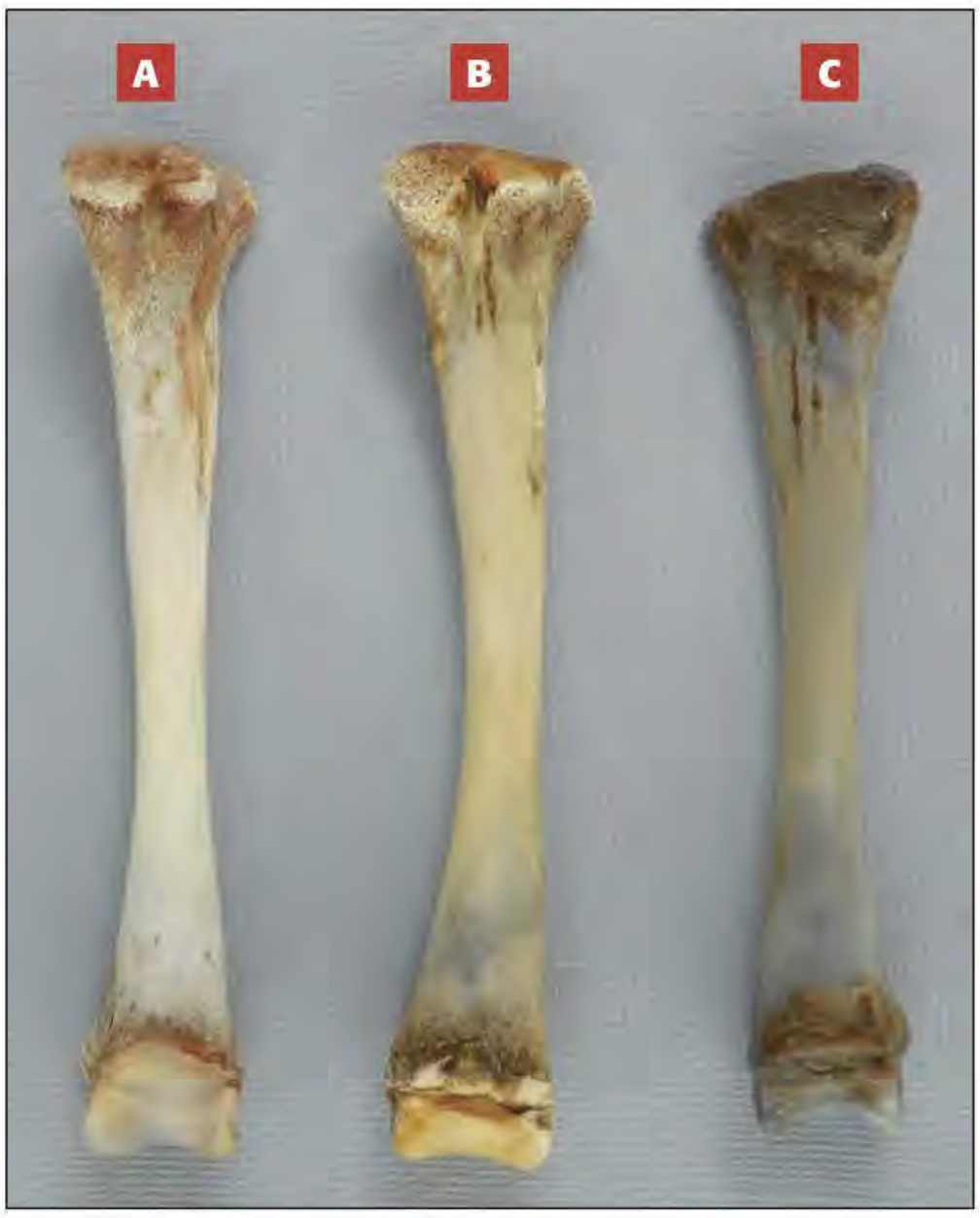


FIGURE **6.6** Three samples of bone: (**A**) untreated; (**B**) heated; (**C**) soaked in nitric acid.

3 Squeeze each bone between your fingers, and twist each sample with your hands. What happens to:

a the untreated bone?

b the heated bone?

c the bone treated with nitric acid?

Exercise 6-3

Bone Markings and Bone Shapes

MATERIALS

- ❑ Disarticulated bones
- ❑ Articulated skeleton

When you examine a skeleton up close, you'll notice that few bones have smooth, flat surfaces. Instead, most bones contain depressions, openings, and projections. These features, collectively known as **bone markings**, perform numerous functions: *Depressions* provide pathways for blood vessels and nerves to travel along a bone or allow two bones to come together to form a joint; structures such as blood vessels and special sensory organs are located within *openings* for protection; and ligaments and tendons attach to bones' *projections*. The major types of bone markings are defined in Table 6.2.

Table 6.2 Bone Markings

Bone Marking	Description
Depressions	
Facet	Shallow indented surface where two bones meet to form a joint
Fossa	Deeper indented surface in a bone, usually allows a rounded surface of another bone to fit inside of it
Fovea	Shallow pit; often the site for the attachment of a ligament
Groove	Long, typically shallow depression that typically allows a nerve or blood vessel to travel along the bone's surface
Sulcus	Another name for a groove
Openings	
Canal	Passageway through a bone
Fissure	Slit within a bone or between bones
Foramen	Hole in a bone through which a structure such as a nerve or blood vessel passes
Meatus	Another name for a canal
Projections	
Condyle	Round end of a bone that fits into a fossa or facet of another bone at a joint
Crest	Ridge along a bone; generally a site of muscle attachment
Epicondyle	Small projection usually proximal to a condyle; generally the site of muscle attachment
Head	Rounded end of the bone that fits into a fossa to form a joint
Line	Ridge along a bone where a muscle attaches
Process	Any bony projection; generally the site of muscle attachment
Protuberance	An outgrowth from a bone due to repetitive pull from a muscle
Trochanter	Large bony projection to which muscles attach; only examples are in the femur (thigh bone)
Tubercle	Small rounded projection where muscles attach
Tuberosity	A larger, more prominent tubercle

Another thing you might notice about the skeleton is the variety of ways that the bones are shaped. As shown in Figure 6.7, there are four general shapes of bones:

1. **Long bones** are longer than they are wide and include the bones of the upper and lower limbs, excluding the ankle and wrist bones.
2. **Short bones** are about as long as they are wide. The bones of the wrist and the ankle are short bones.
3. **Flat bones** are shaped exactly as they're named—they are flat. Flat bones include the ribs, the sternum, the clavicle, certain skull bones, and the bones of the pelvis.
4. **Irregular bones** are those whose shape doesn't fit into any of the other classes. Irregular bones include the vertebrae and certain bones of the skull, such as the mandible (lower jaw bone).

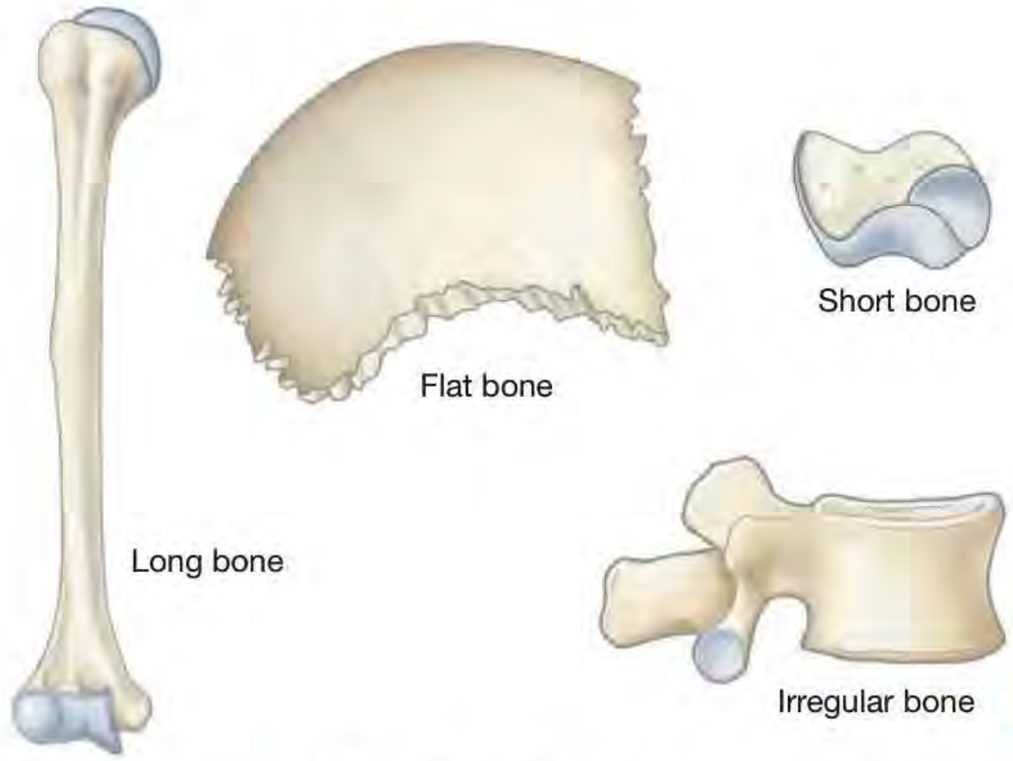


FIGURE **6.7** The four shapes of bones.

Note that there are two other, less common bone shapes: sesamoid bones and sutural bones. **Sesamoid bones** are roughly oval-shaped bones located within tendons. The sesamoid bone with which you are most likely familiar is the patella, or the kneecap. **Sutural bones** (SOO-tchur-ul) are small bones located between the flat bones of the skull. You will likely see sutural bones when you study the skull in the next unit.

HINTS & TIPS

Bone Shape, Not Length

Note that long bones are not named for their length but rather for their shape. Many long bones actually are quite short in length, such as the phalanges (the bones of the fingers and the toes). Be careful when identifying bone shapes to look at the overall shape of the bone rather than its size.

Procedure 1 Identifying Bone Shapes and Markings

Obtain a set of disarticulated bones, and classify them according to their shape. Identify examples of long bones, short bones, flat bones, and irregular bones, and record them in Table 6.3. Then, closely examine each bone and identify examples of bone markings on the bone. You may wish to use the figures in your text or Unit 7 (p. 135) to help you identify the disarticulated bones and their markings.

TABLE **6.3** Examples of Bone Shapes and Markings

Bone	Shape	Marking(s) on the Bone

Exercise 6-4

Anatomy of Long Bones

MATERIALS

- ❑ Long bone, sectioned
- ❑ X-rays (if available)

All long bones share common structures and parts, illustrated in Figure 6.8 with the example of the femur. The **diaphysis** (dy-AEH-fih-sis) is the shaft of the long bone. As you can see in the figure, it consists of a thick collar of compact bone surrounding a hollow area called the **medullary cavity**. This collar of compact bone makes long bones quite strong and able to support the body's weight. The medullary cavity has sparse trabeculae and generally is filled with yellow bone marrow in adult bones.

The ends of a long bone are called the **epiphyses** (eh-PIF-ih-seez). Each epiphysis contains a shell of compact bone surrounding the inner spongy bone. The spongy bone within the epiphyses contains either red or yellow bone marrow. The end of each epiphysis is covered with **articular cartilage** (generally composed of hyaline cartilage), which allows two bones in a joint to move around one another with minimal friction.

At certain epiphysis-diaphysis junctions you will note a thin, calcified line called the **epiphyseal line** (eh-PIF-ih-seel). This structure is the remnant of the **epiphyseal plate**, a band of hyaline cartilage from which long bones grow in length. As you can see in Figure 6.9, there are five regions of an epiphyseal plate:

1. **Zone of reserve cartilage.** The first zone, or the one closest to the epiphysis, is called the zone of reserve cartilage. As its name implies, this zone contains a reserve of chondrocytes that can divide if needed.
2. **Zone of proliferation.** The next region is the zone of proliferation. Again, as suggested by its name, it consists of actively dividing (proliferating) chondrocytes.

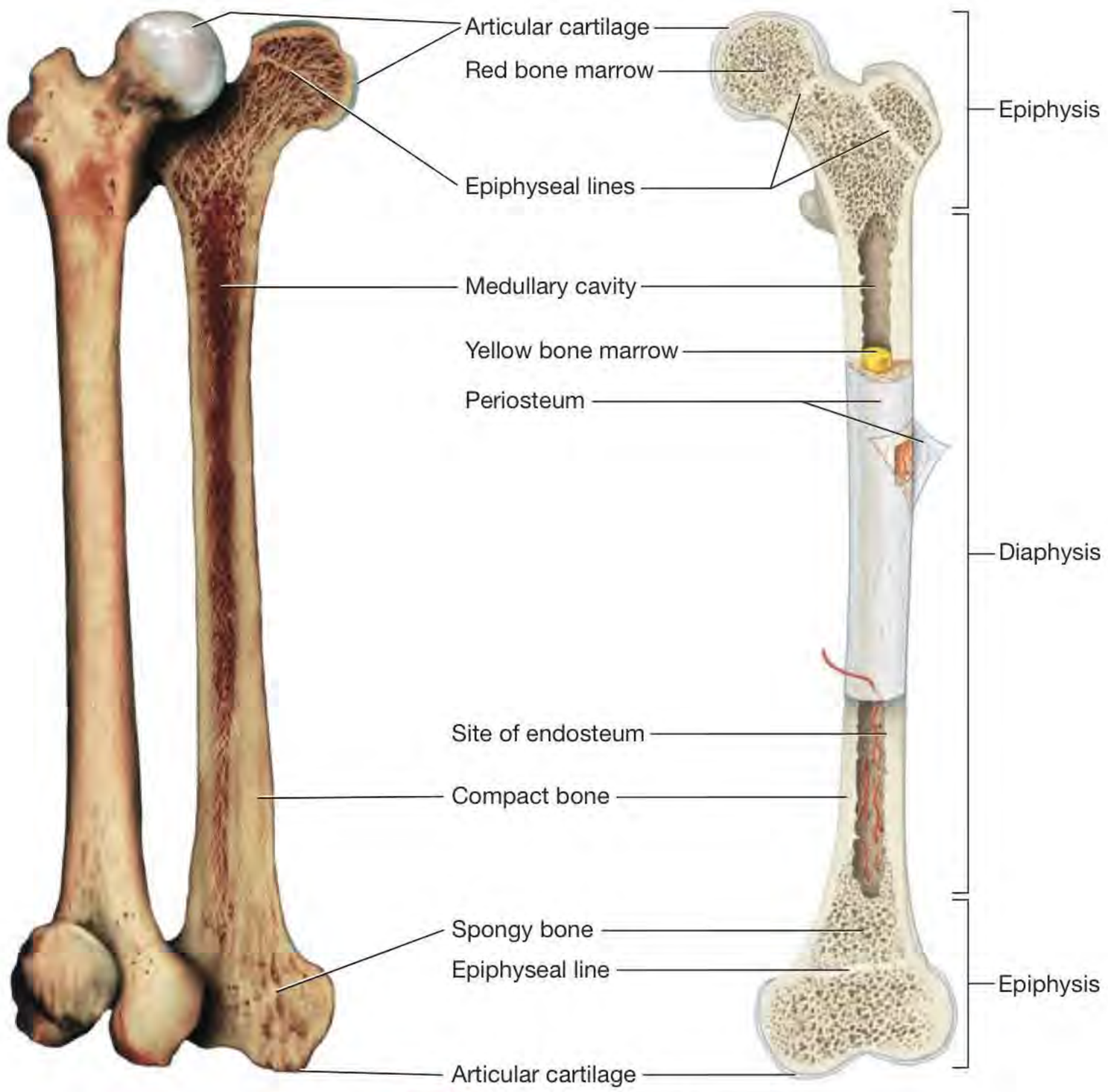


FIGURE **6.8** Long bone: the femur.

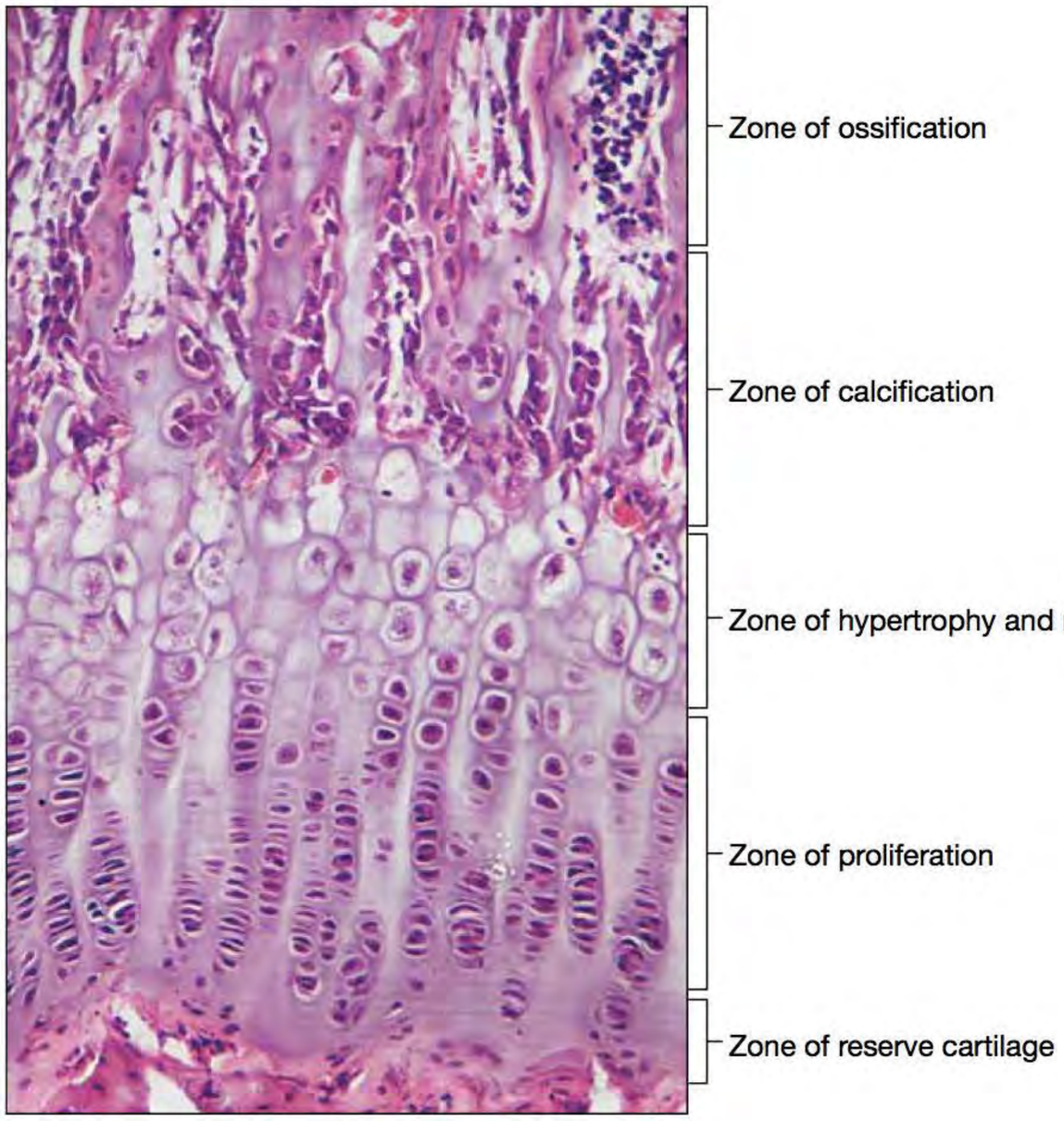


FIGURE **6.9** Epiphyseal plate.

3. **Zone of hypertrophy and maturation.** In the zone of hypertrophy and maturation, the dividing chondrocytes begin to enlarge in their lacunae as they mature.
4. **Zone of calcification.** Chondrocytes in the zone of calcification begin to die. As they die, they accumulate calcium salt deposits and harden.
5. **Zone of ossification.** The last zone, which abuts the diaphysis, is the zone of ossification. It contains calcified chondrocytes and osteoblasts, which blend with the diaphyseal bone.

When longitudinal growth ceases, the chondrocytes of the epiphyseal plate die and are replaced by calcified bone tissue.

Procedure 1 Identification of Long Bone Structures

Identify the following structures of long bones on specimens and X-rays (if available). Check off each structure as you identify it.

- ❑ Compact bone
- ❑ Diaphysis
- ❑ Epiphyseal line
- ❑ Epiphyseal plate (may be visible only on X-ray)
- ❑ Epiphysis
- ❑ Articular cartilage
- ❑ Medullary cavity
- ❑ Red bone marrow
- ❑ Spongy bone
- ❑ Yellow bone marrow

Procedure 2 Microscopy

View a prepared slide of an epiphyseal plate. The structures on the slide should look similar to what you see in Figure 6.9. Use colored pencils to draw a picture of what you see under the microscope, and label your drawing with the zones of the epiphyseal plate.

Procedure 3 Time to Draw

In the space below, draw, color, and label one of the long bone sections or diagrams that you examined. In addition, write the main function of each structure that you label.

Name _____

Section _____ Date _____

UNIT 6 REVIEW

Check Your Recall

1 Label the following parts of compact bone on Figure 6.10.

- ❑ Blood vessels
- ❑ Canaliculi
- ❑ Central canal
- ❑ Concentric lamellae
- ❑ Lacunae
- ❑ Osteon
- ❑ Perforating canal
- ❑ Trabeculae of spongy bone

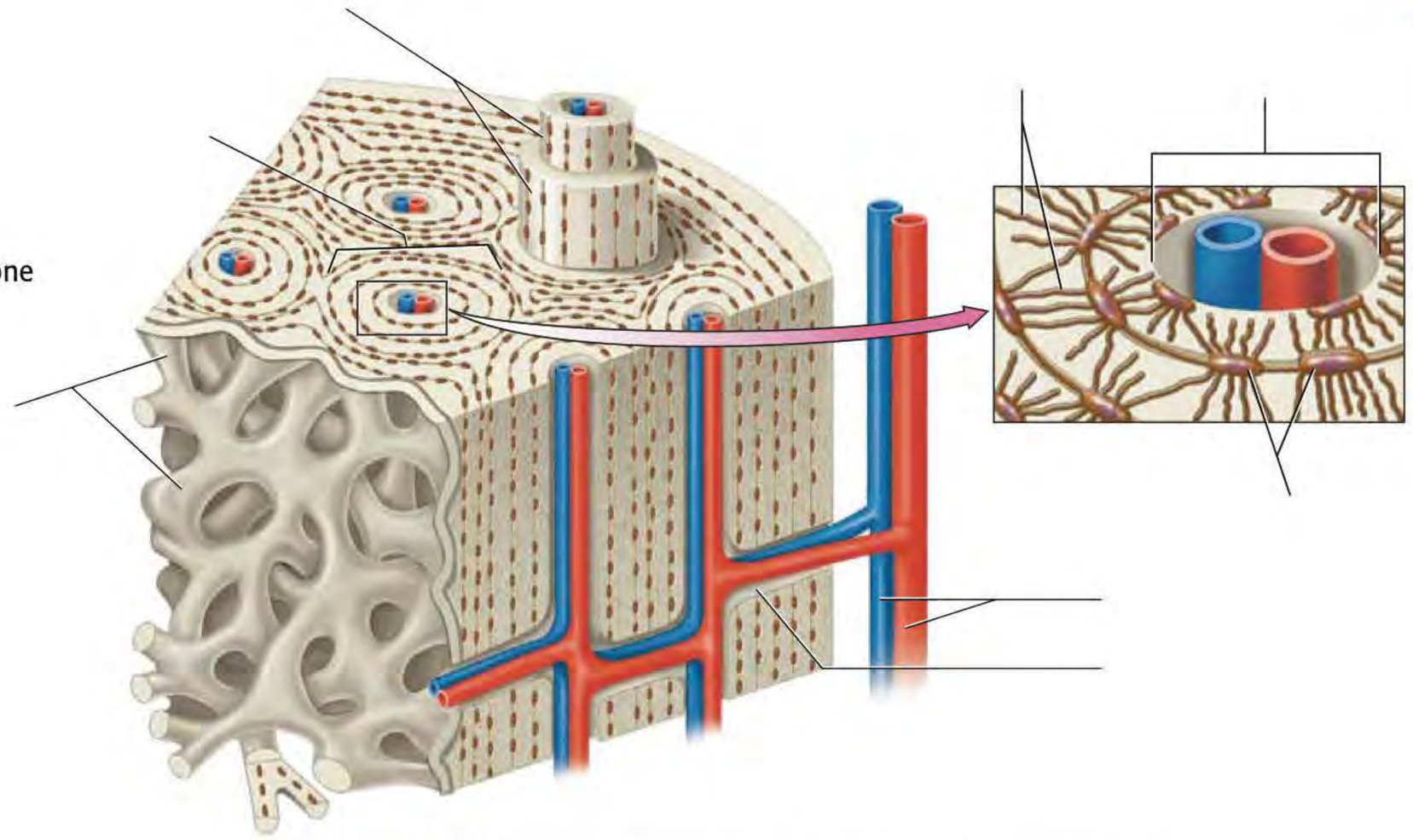


FIGURE **6.10** Microscopic anatomy of compact bone tissue.

2 *Mark the following statements as true (T) or false (F).* If the statement is false, correct it to make it a true statement.

_____ The periosteum contains osteocytes and osteoclasts.

_____ Osteoblasts secrete bone matrix.

_____ Compact bone is the hard, outer bone.

_____ Spongy bone is composed of spicules called osteons.

_____ Spongy bone houses red and yellow bone marrow.

_____ Perforating fibers anchor the endosteum to the superficial surface of a bone.

3 **The organic component of bone consists of _____ and functions to _____.**

a. collagen; provide compressional strength
b. calcium hydroxyapatite; provide compressional strength
c. collagen; provide tensile strength
d. calcium hydroxyapatite; provide tensile strength

4 **The inorganic component of bone consists of _____ and functions to _____.**

a. collagen; provide compressional strength
b. calcium hydroxyapatite; provide compressional strength
c. collagen; provide tensile strength
d. calcium hydroxyapatite; provide tensile strength

5 **Which of the following statements about long bones is/are false? Mark all that apply.**

a. A long bone is longer than it is wide.
b. They include the bones of the upper and lower extremities except the finger and toes.
c. They include the bones of the upper extremities except the bones of the ankle and wrist.
d. A long bone is named for its length.

6 **Examples of flat bones include**

a. the clavicle.
b. the mandible.
c. ankle bones.
d. Both a and b are correct.
e. Both a and c are correct.

7 **Short bones are**

a. short in length.
b. about as long as they are wide.
c. irregular in shape.
d. flat.

8 **Label the following parts of a long bone on Figure 6.11.**

- ❑ Articular cartilage
- ❑ Diaphysis
- ❑ Epiphyseal line
- ❑ Epiphysis
- ❑ Medullary cavity
- ❑ Periosteum
- ❑ Yellow bone marrow

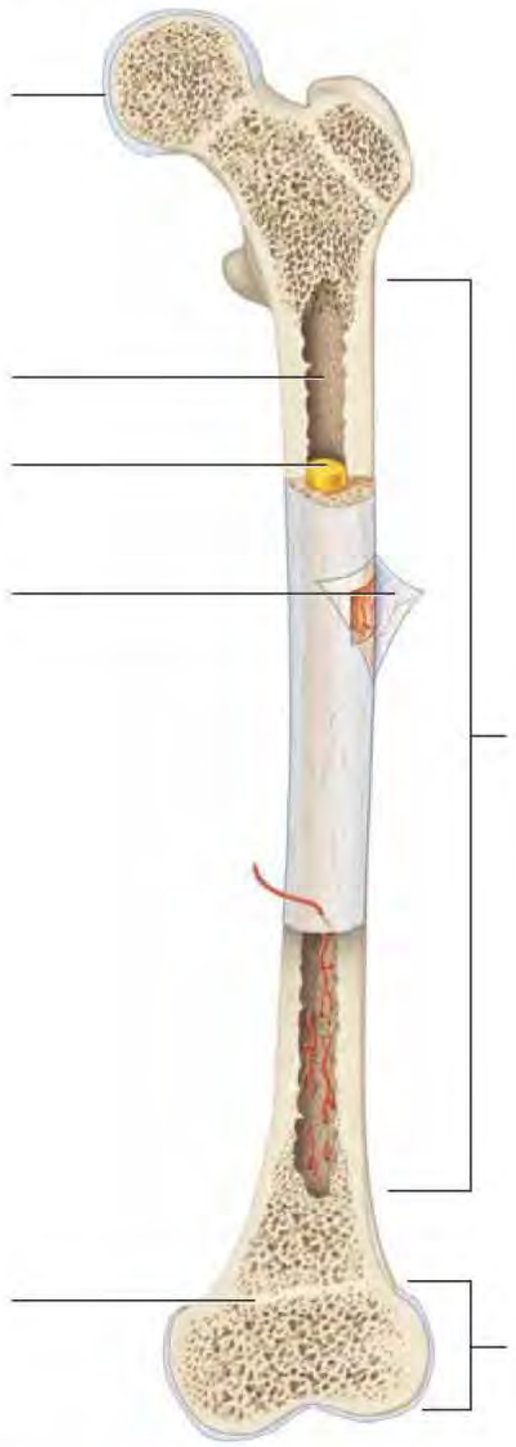


FIGURE **6.11** Structure of a long bone.

9 **The epiphyseal plate is**

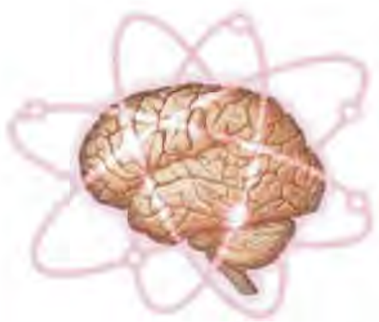
a. the structure from which long bones grow in length.
b. a remnant of the structure from which long bones grow in length.
c. composed of osseous tissue.
d. found lining the surface of the epiphysis.

10 **The medullary cavity is found in the _____ and usually contains the _____.**

a. diaphysis; red bone marrow
b. epiphysis; red bone marrow
c. diaphysis; yellow bone marrow
d. epiphysis; yellow bone marrow

Name _____

Section _____ Date _____



Check Your Understanding

Critical Thinking and Application Questions

1 Explain how each of the following structures follows its function.

a Compact bone _____

b Spongy bone _____

c Long bone _____

2 A bone tumor disrupts the normal structure of osteons, replacing the organized rings with disorganized, irregular masses of bone. How will this affect the ability of a bone to perform its functions?

3 Osteogenesis imperfecta is a congenital condition in which collagen synthesis is defective. Of the three samples of bone you tested in Exercise 6-3, which is most similar to the bones in osteogenesis imperfecta? What symptoms would you expect to find in this disease?

4 Would it benefit a patient with osteogenesis imperfecta to take supplemental calcium salts? Why or why not?

5 The diseases rickets and osteomalacia result from insufficient vitamin D intake, which decreases the amount of calcium ions available for synthesis of the inorganic component of bone. Of the three samples of bone you tested in Exercise 6-3, which is the most similar to the bones in rickets and osteomalacia? What symptoms would you expect to find in these diseases?

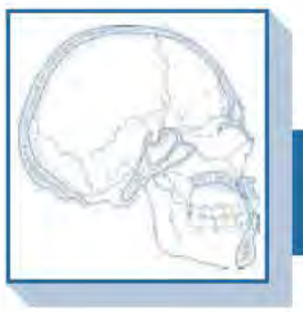
Skeletal System

7

OBJECTIVES

Once you have completed this unit, you should be able to:

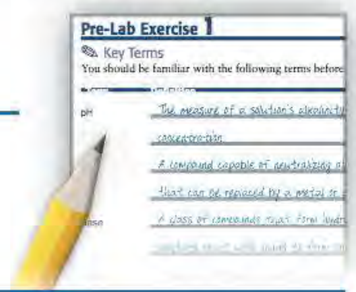
1. Identify bones and markings of the axial skeleton.
2. Identify bones and markings of the appendicular skeleton.
3. Build a skeleton using disarticulated bones.



Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



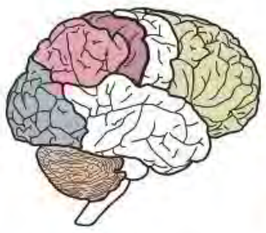
Pre-Lab Exercise 7-1

✎ Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition
Axial Skeleton	
Cranial bones	
Facial bones	
Suture	
Hyoid bone	
Vertebrae	
Ribs	
Sternum	
Appendicular Skeleton—Upper Limb and Pectoral Girdle	
Pectoral girdle	
Clavicle	
Scapula	
Humerus	
Radius	
Ulna	
Carpals	
Metacarpals	
Phalanges	
Appendicular Skeleton—Lower Limb and Pelvic Girdle	
Pelvic girdle	
Femur	
Tibia	
Fibula	
Tarsals	
Metatarsals	

Name _____ Section _____ Date _____



Pre-Lab Exercise 7-2

Bones of the Skull

Label and color the structures of the skull in Figure 7.1 with the terms from Exercise 7-1 (p. 141). Use your text and Exercise 7-1 in this unit for reference.

A

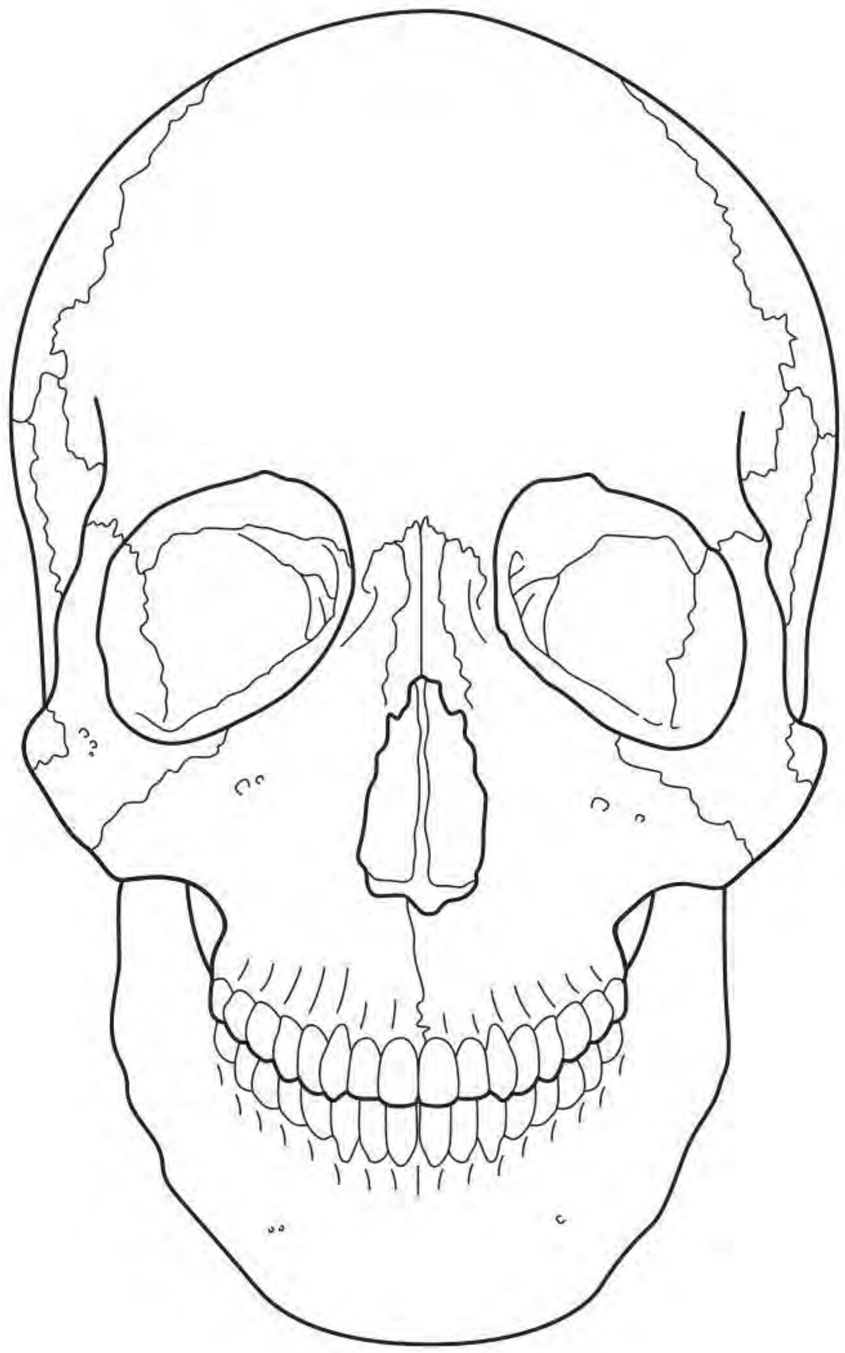
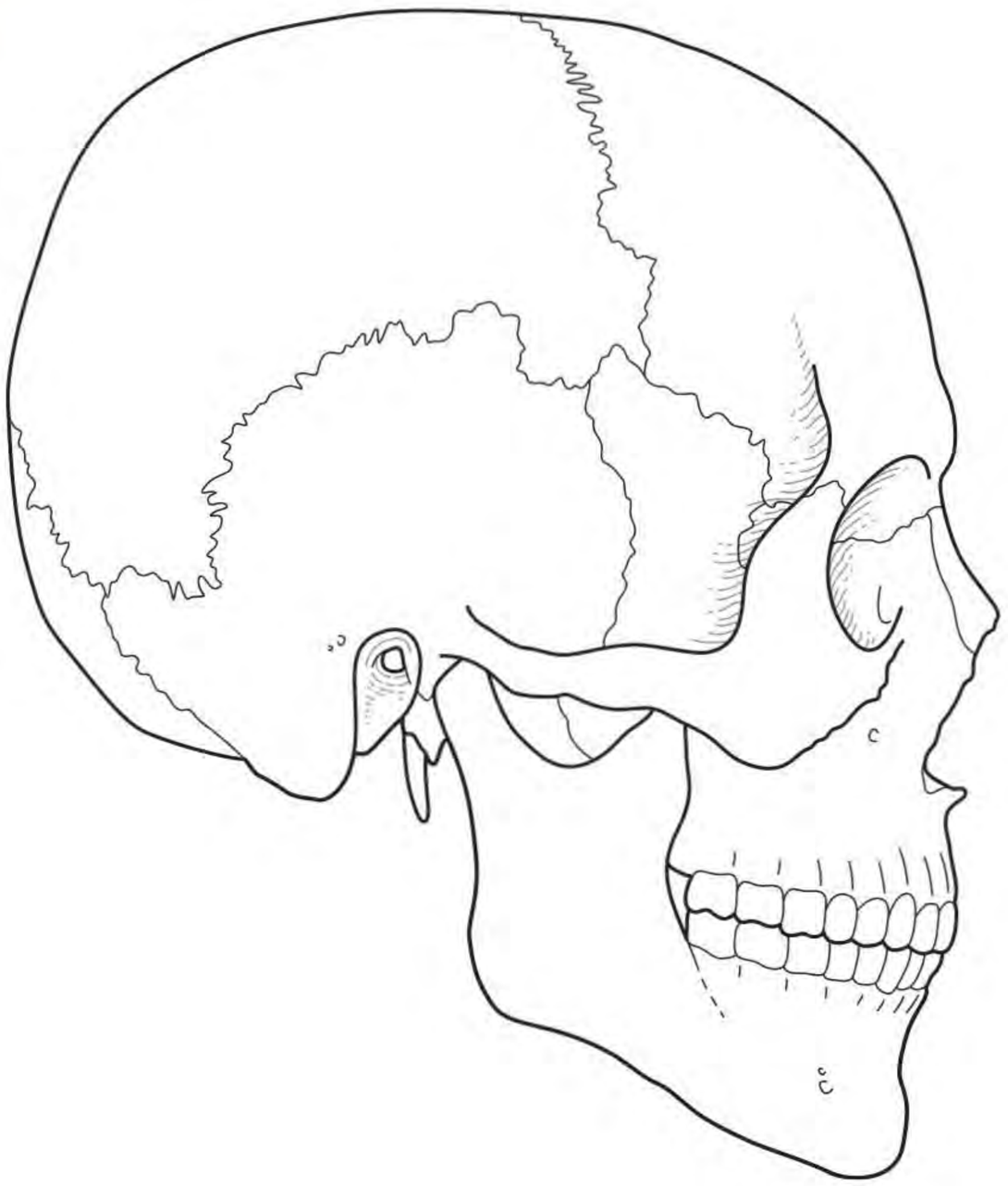


FIGURE 7.1 Skull: (A) anterior view *(continues)*

B



C

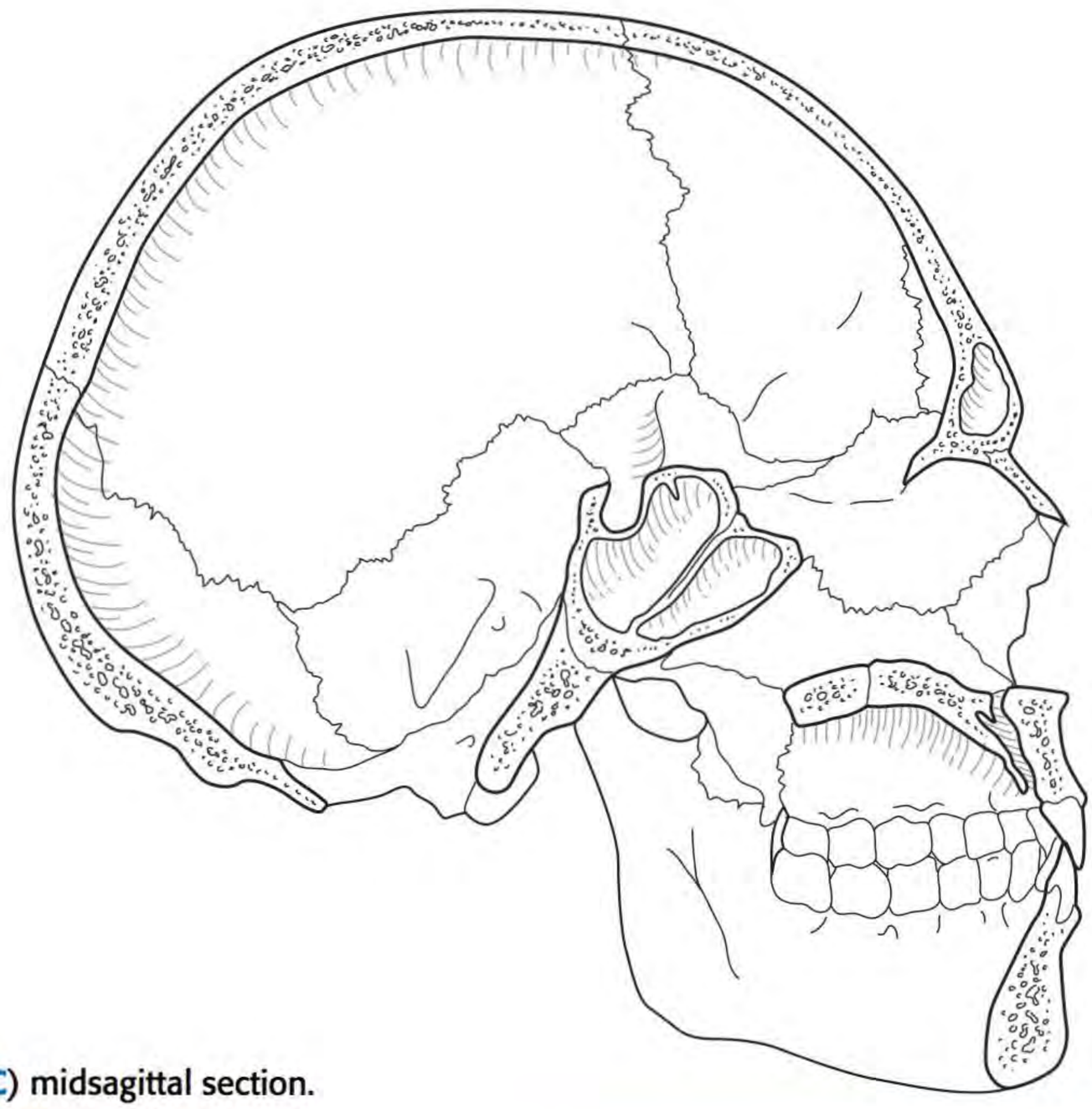


FIGURE **7.1** Skull *(cont)*: (**B**) lateral view; (**C**) midsagittal section.

Name _____ Section _____ Date _____

Pre-Lab Exercise 7-3

Whole Skeleton

Label and color the structures of the skeleton in Figure 7.2 with the terms from Exercises 7-1 to 7-3 (pp. 141–166). Use your text and Exercises 7-1 to 7-3 in this unit for reference.

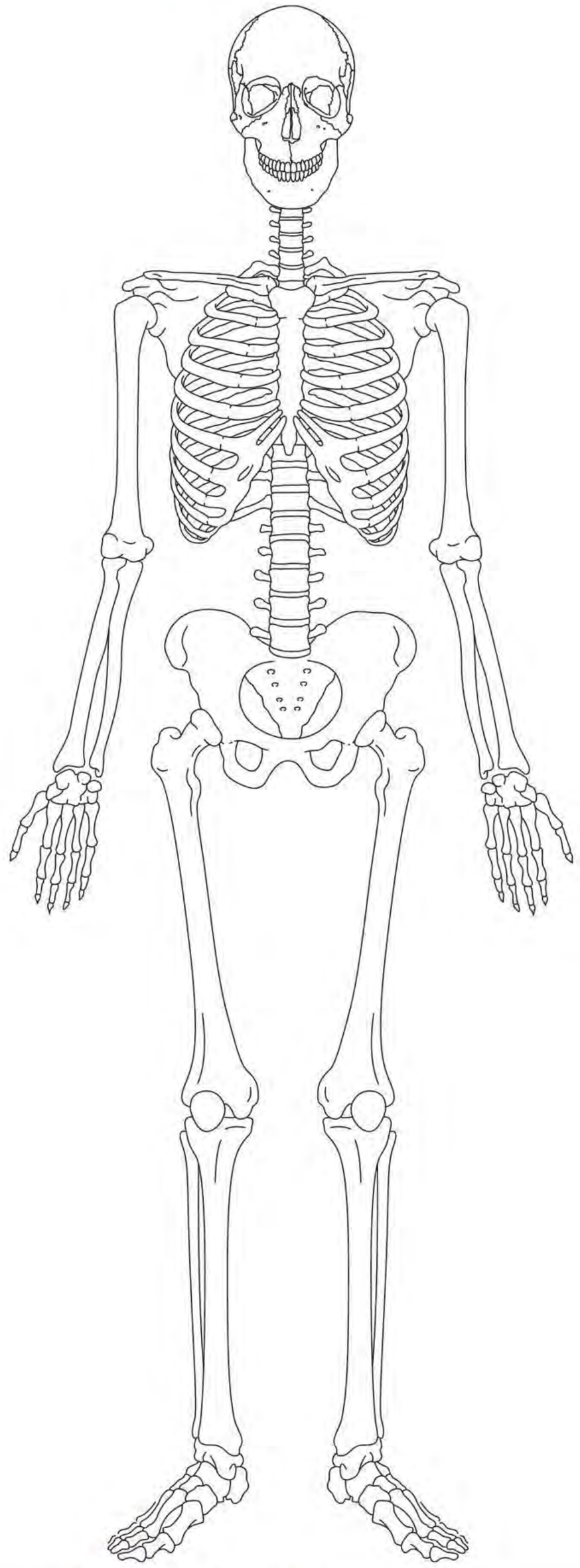


FIGURE 7.2 Skeleton: (A) anterior view *(continues)*

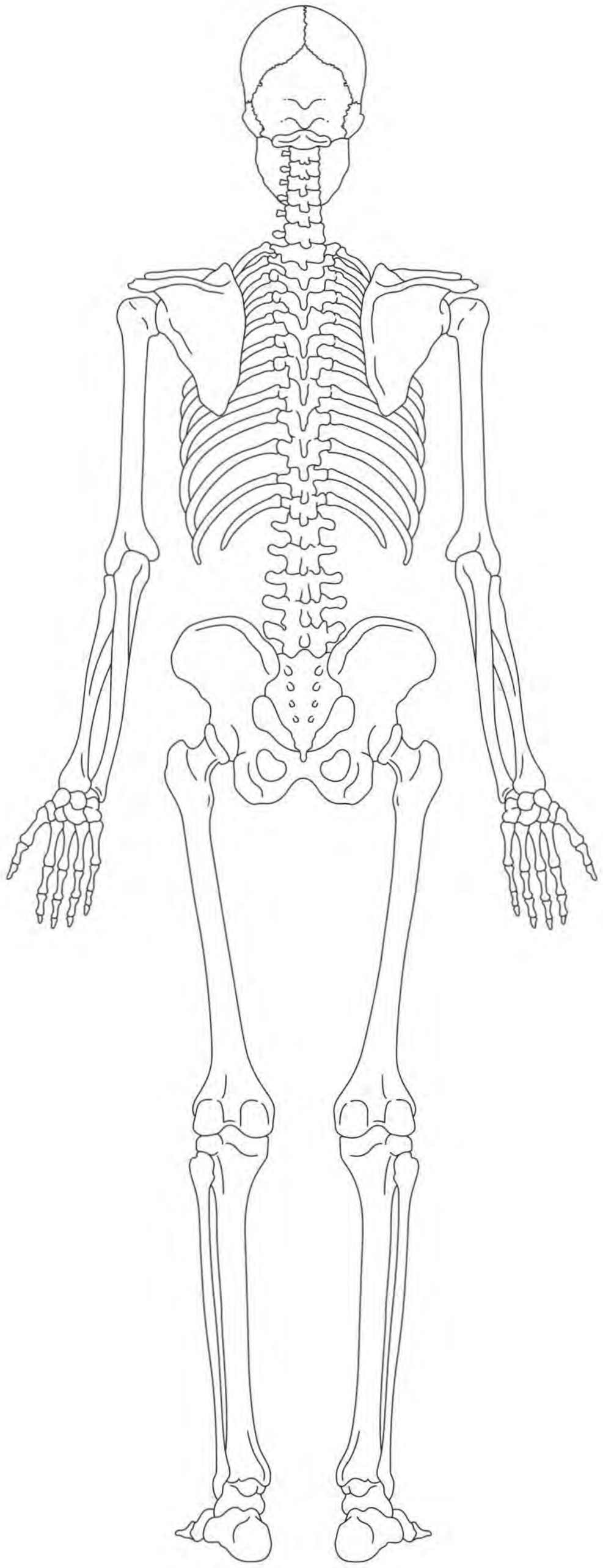


FIGURE **7.2** Skeleton *(cont)*: (**B**) posterior view.

EXERCISES

The **skeletal system** consists of the bones, its associated cartilages, and the joints. Its two divisions are the **axial skeleton** and the **appendicular skeleton**. The **axial skeleton** is composed of the bones of the head, neck, and trunk—specifically, the cranial bones, the facial bones, the vertebral column, the hyoid bone, the sternum, and the ribs. The **appendicular skeleton** consists of the bones of the upper limbs, the lower limbs, the pectoral girdle (the bones forming the shoulder joint), and the pelvic girdle (the bones forming the pelvis and hip joint).

In this unit we explore the anatomy of the bones and bone markings of the skeletal system, which will serve as a foundation for later chapters. For example, the radial and ulnar arteries parallel the radius and the ulna, and the frontal, parietal, temporal, and occipital lobes of the brain are named for the cranial bones under which they are located.

Exercise 7-1

The Skull

MATERIALS

- ❑ Skulls, whole and sectioned
- ❑ Fetal skull

The skull is composed of two classes of bones—the **cranial bones** and the **facial bones** (Figures 7.3–7.9). The **cranial bones** encase the brain and together form the **calvaria** (kal-VEHR-ee-uh; also known as the "skullcap" or *cranial vault*), which consists of several of the cranial bones joined at immovable joints called **sutures** (SOO-tchurz). These bones also form the **cranial base**, which is made up of indentations that support the brain known as the **anterior**, **middle**, and **posterior cranial fossae** (visible in Figure 7.6). The eight cranial bones include the following:

1. **Frontal bone.** The **frontal bone** forms the anterior portion of the cranium, the superior part of the orbit, which houses the eyeball (visible in Figure 7.3), and the anterior cranial fossa. In Figure 7.3 you can see the smooth area between the eyes called the **glabella**, and two small holes over the orbit called the **supraorbital foramina**. Internally the frontal bone contains hollow spaces called the **frontal sinuses**, which are part of the **paranasal sinuses**, a group of bony cavities that surround the nasal cavity (see Figure 7.11). Air from the nasal cavity enters the paranasal sinuses via small openings in the bones, and in the sinuses the air gets filtered, warmed, and humidified.
2. **Parietal bones.** The paired **parietal bones** (pah-RY-eh-tul) form the superior and part of the lateral walls of the cranium. Note in Figures 7.3 and 7.4 that they articulate with one another and many other cranial bones at sutures: They meet one another at the **sagittal suture** (seen in Figures 7.8 and 7.9), they meet the frontal bone at the **coronal suture**, they meet the temporal bones at the **squamous sutures**, and they meet the occipital bone at the **lambdoid suture** (LAMB-doyd).
3. **Temporal bones.** The paired **temporal bones** form the lateral walls of the cranium (best seen in Figure 7.4). Each temporal bone has a complex shape with four general regions.
   a. The flat **squamous region** is the temporal bone's most lateral aspect. As its name implies, it is largely flat; however it does contain a projection called the **zygomatic process** that forms part of the cheekbone. Just inferior to the zygomatic process is an indentation, the **mandibular fossa**, which forms the *temporomandibular joint* with the mandible.
   b. The temporal bone's inferior region is called the **tympanic region** (tim-PAN-ik). It houses the **external acoustic meatus**, an opening to the external auditory canal, which leads to the middle and inner ear. Also in this region is a needlelike projection called the **styloid process.**
   c. Posterior to the tympanic region is the **mastoid region**, which contains the large **mastoid process**. Inside the mastoid process are numerous tiny sinuses known as *mastoid air cells*.
   d. Internally, the temporal bone is shaped like a mountain ridge and is accordingly called the **petrous region**. Within this region we find several openings. The first three are best seen in Figure 7.5, and include the medial and anterior **foramen lacerum** (LAS-er-um), the middle **carotid canal**, and the posterior **jugular foramen**. The next opening, the **internal acoustic meatus**, is best seen in Figure 7.7.

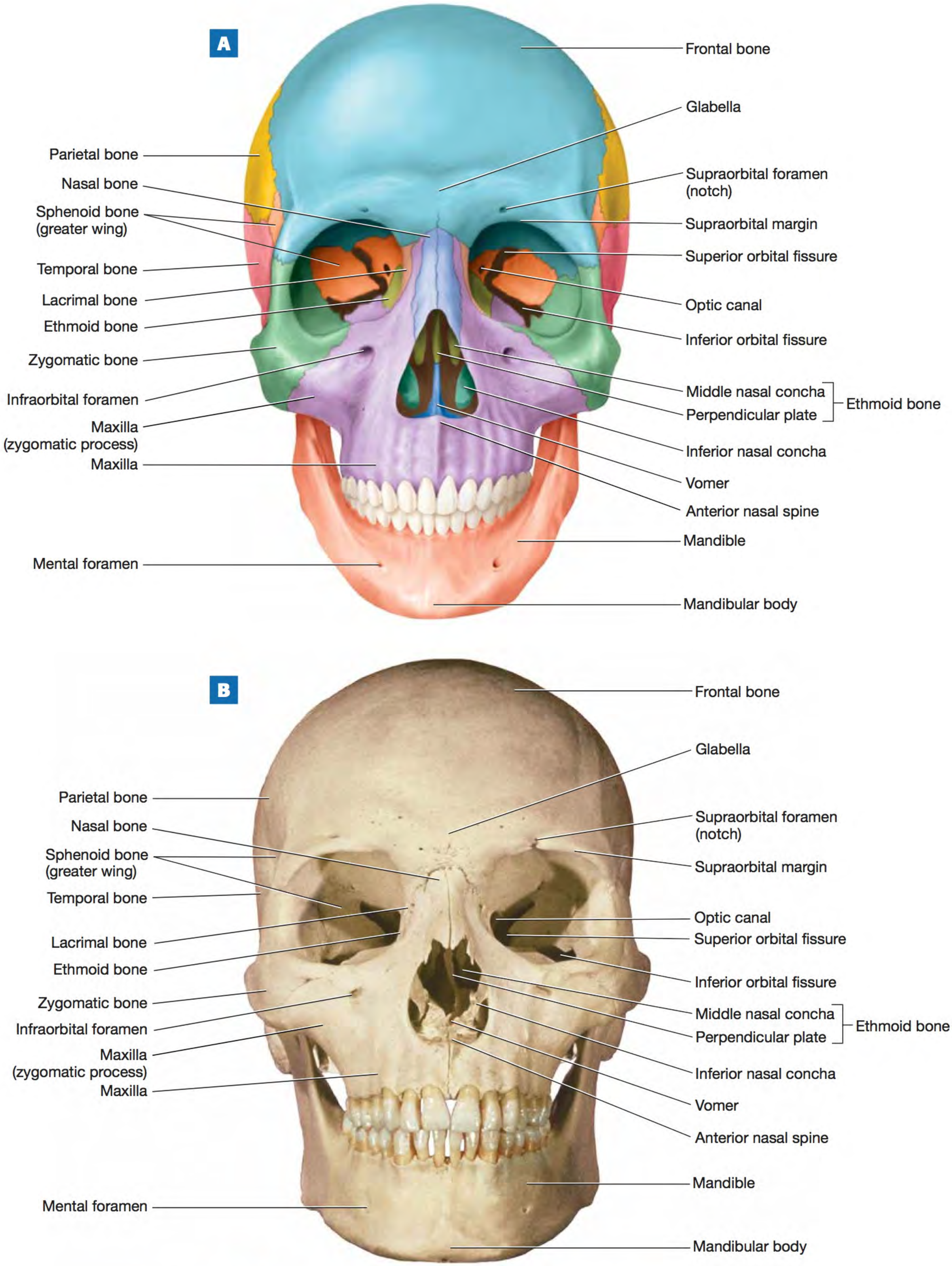


FIGURE **7.3** Anterior view of the skull: (**A**) illustration; (**B**) photograph.

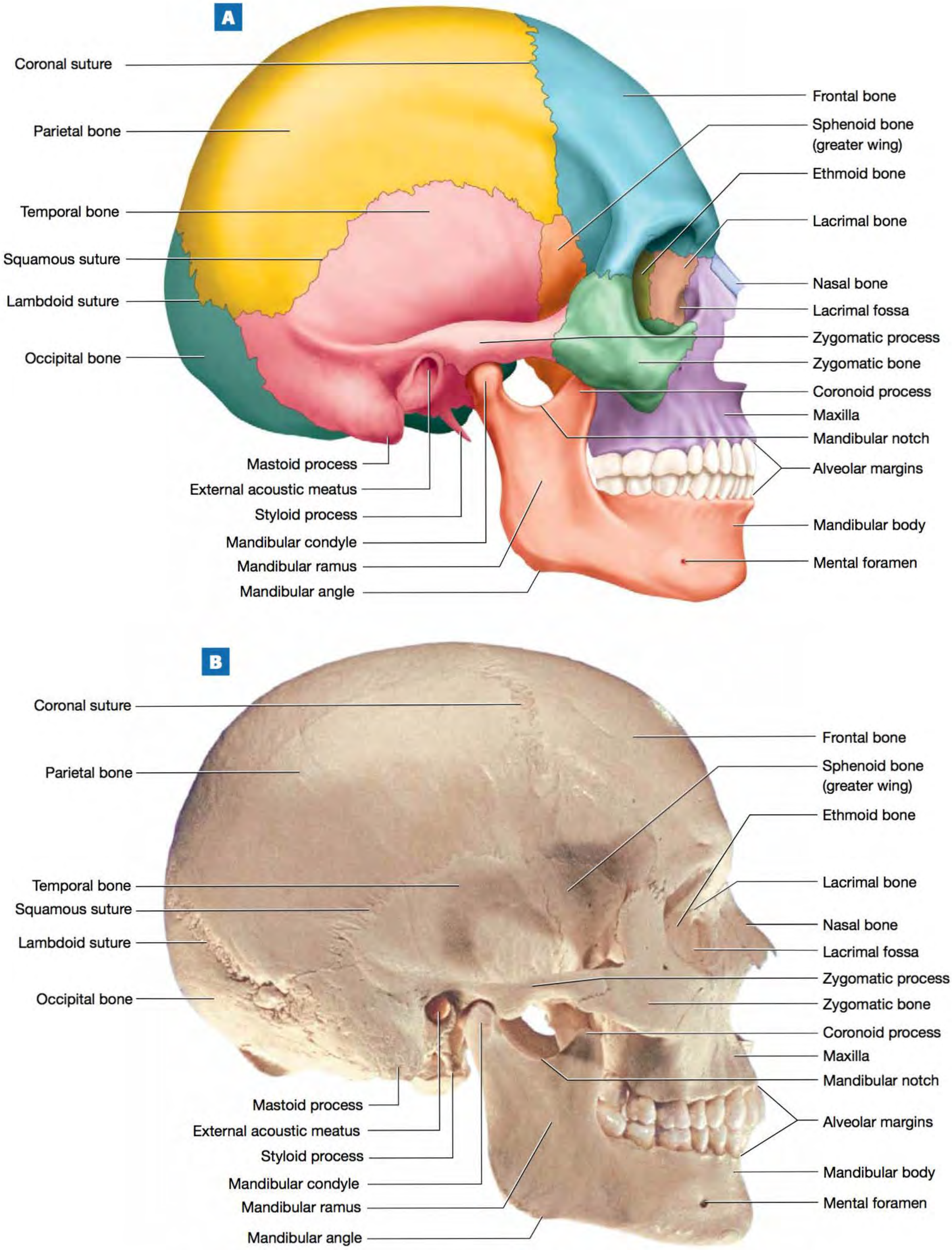


FIGURE **7.4** Lateral view of the skull: (**A**) illustration; (**B**) photograph.

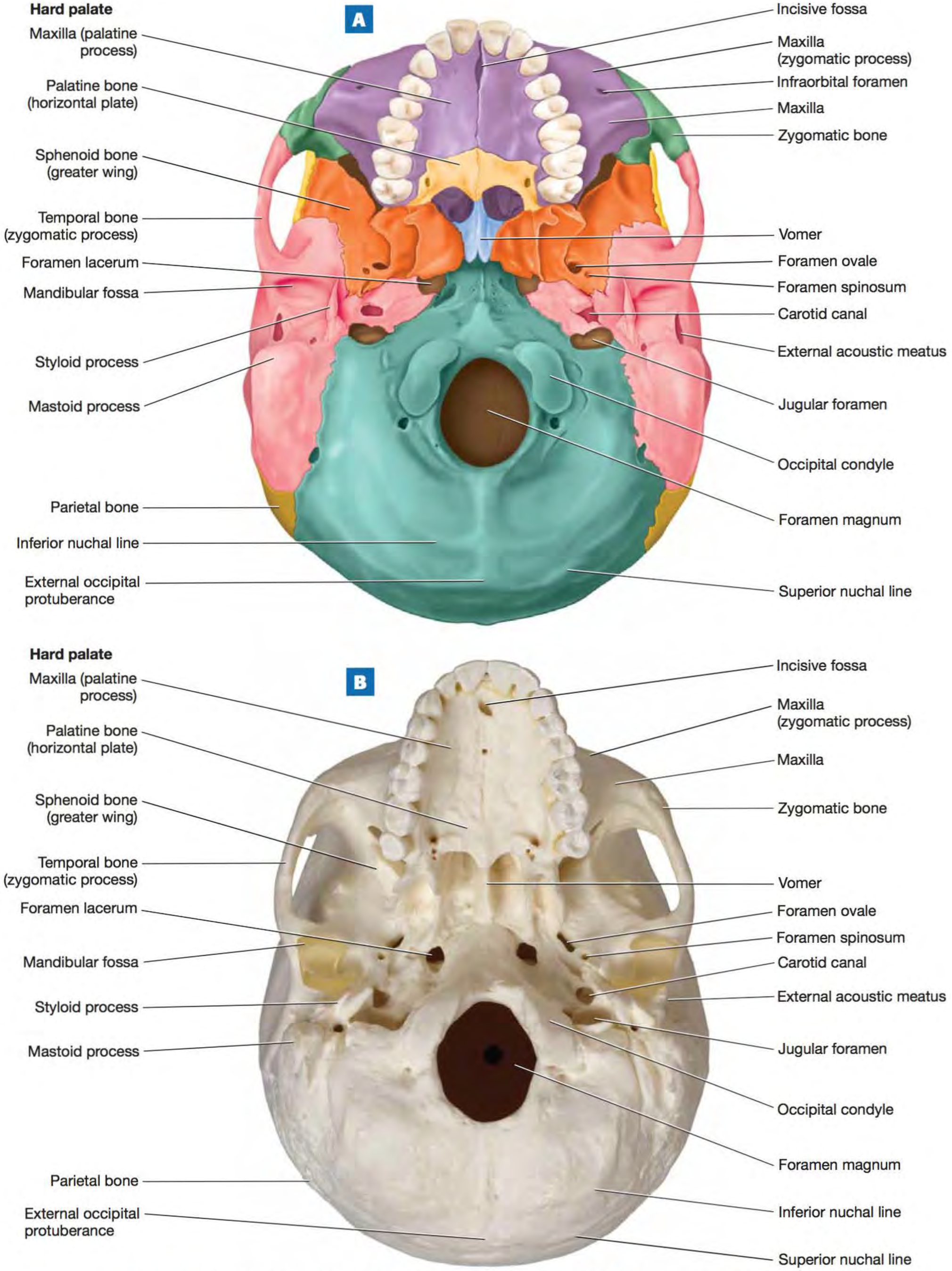


FIGURE **7.5** Inferior view of the skull (mandible removed): (**A**) illustration; (**B**) photograph.

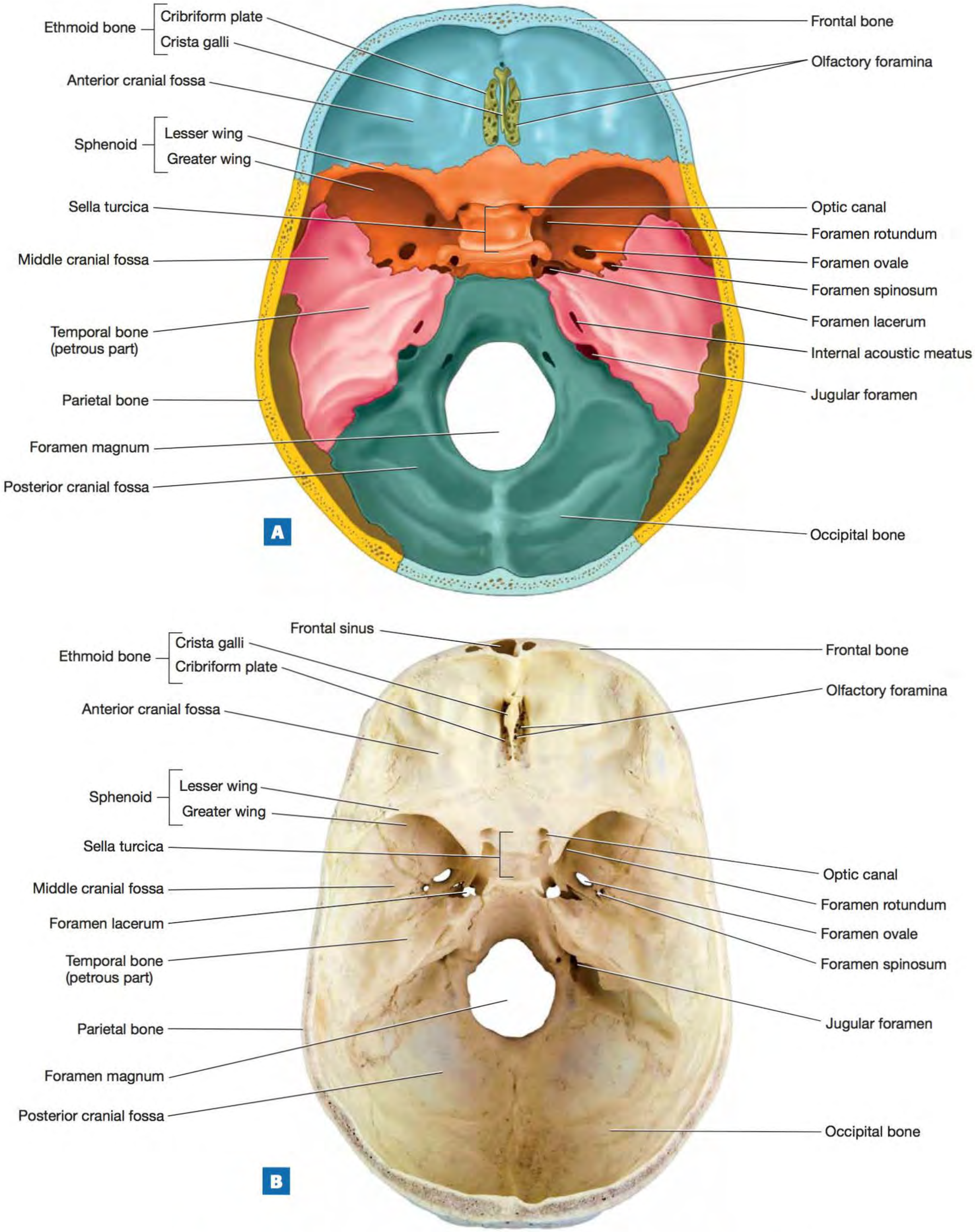


FIGURE **7.6** Interior view of the skull (calvaria removed): (**A**) illustration; (**B**) photograph.

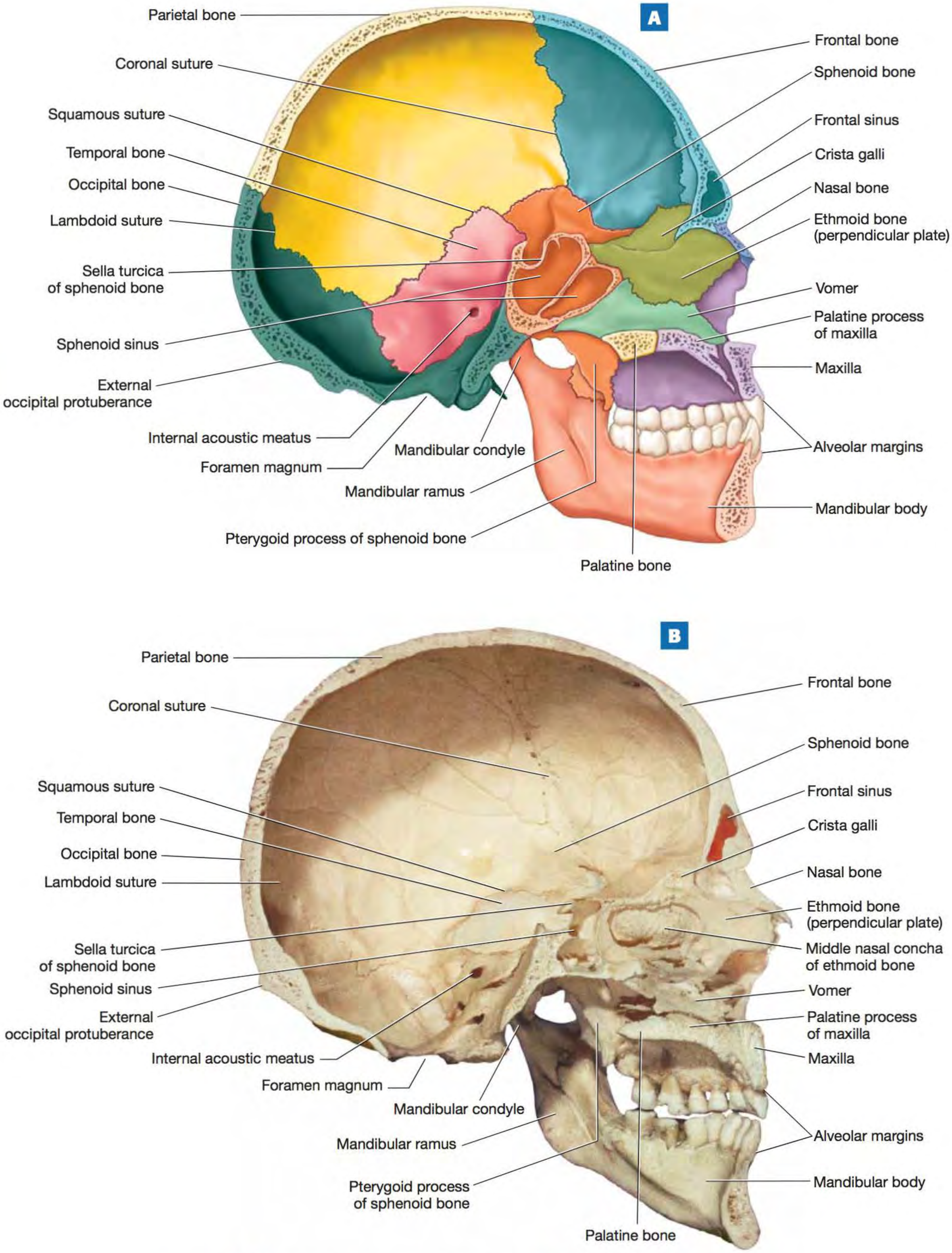


FIGURE **7.7** Midsagittal section of the skull: (**A**) illustration; (**B**) photograph.

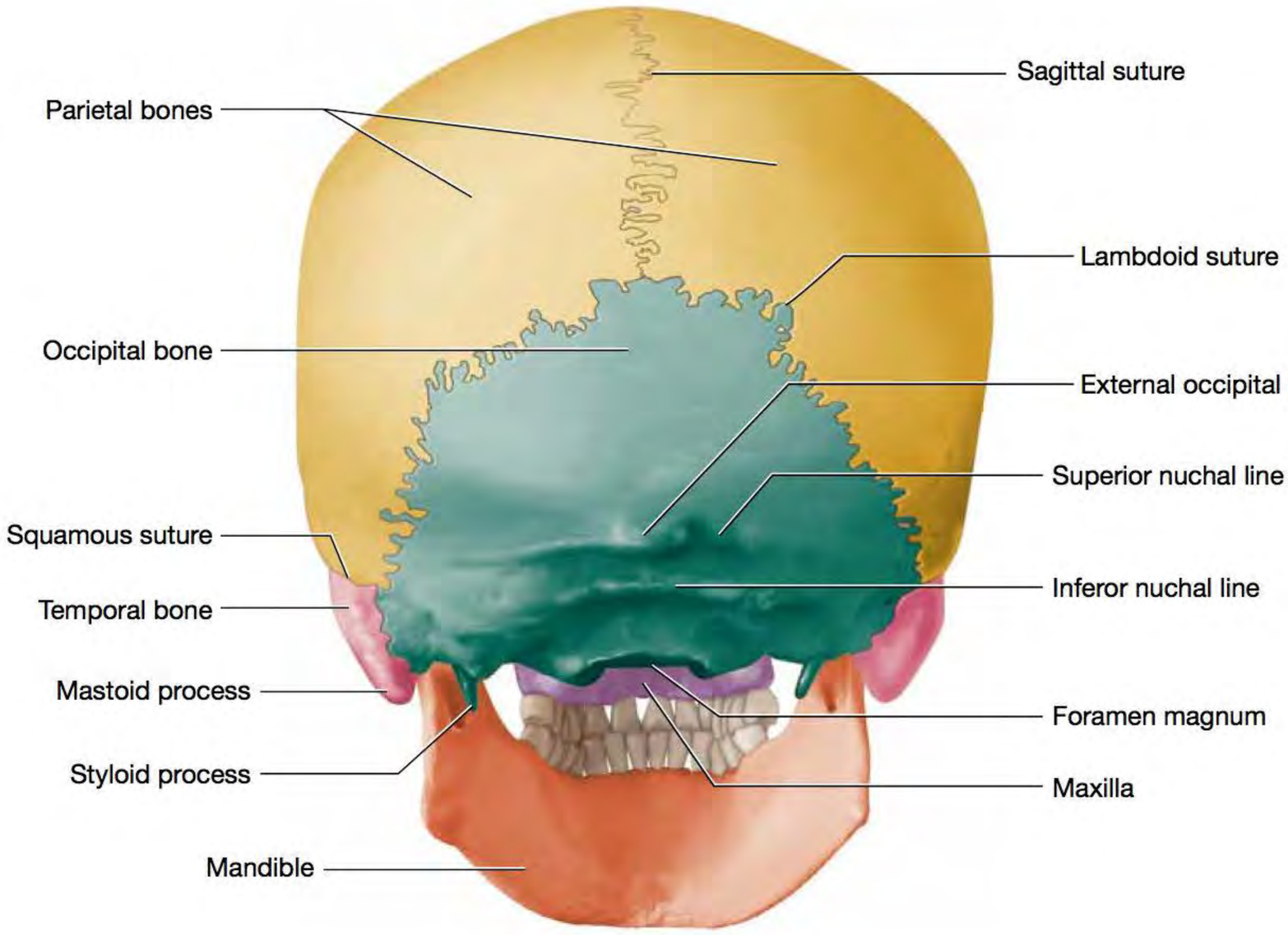


FIGURE **7.8** Posterior view of the skull.

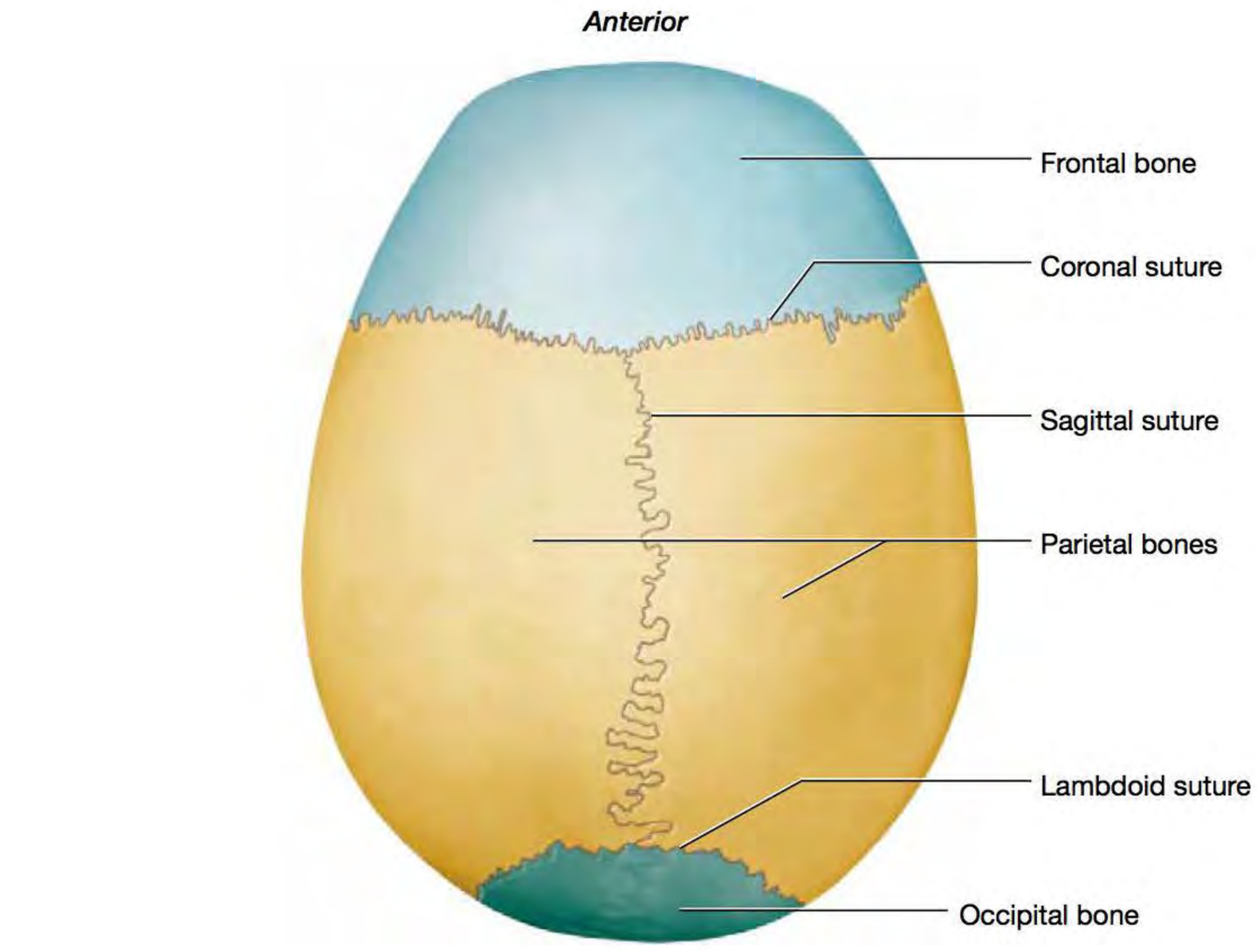


FIGURE **7.9** Superior view of the skull.

4. **Occipital bone.** The posterior cranial bone is the **occipital bone** (ak-SIP-ih-tul; best seen in Figures 7.5 and 7.6). Its most conspicuous feature is found in its base—a large hole called the **foramen magnum** through which the spinal cord passes. Anterior and lateral to the foramen magnum are the two **occipital condyles,** which form a joint with the first cervical vertebra. The occipital bone's posterior surface has two prominent horizontal ridges: the **superior** and **inferior nuchal lines** (NOO-kul). In the middle of the superior nuchal line we find a bump called the **external occipital protuberance.**
5. **Sphenoid bone.** The butterfly-shaped **sphenoid bone** (SFEE-noyd) is posterior to the frontal bone on the interior part of the skull. Centrally it consists of the **body,** the superior surface of which features two canals called the **optic canals** that house the nerve for vision (see Figure 7.6). Also in the body we find the second paranasal sinus, the **sphenoid sinus,** and a saddlelike formation called the **sella turcica** (SELL-uh TUR-sih-kah) that houses the pituitary gland (see Figures 7.6 and 7.7). Extending from the body are three sets of "wings:"
   a. The small **lesser wings** are the superior and most anterior set that are best seen in Figure 7.6.
   b. The larger **greater wings** are the inferior and posterior set of wings. In Figure 7.3, you can see the **superior orbital fissure,** which is a slit between the greater and lesser wings through which nerves pass. As you can see in Figure 7.6, it has three prominent sets of foramina: the anterior **foramen rotundum,** the middle **foramen ovale,** and the posterior **foramen spinosum** (a mnemonic that might help you remember this is, "Rigatoni Over Spaghetti"). On the anterior side, the greater wings form the posterior portion of the orbit.
   c. The inferior set of wings are the narrow **pterygoid processes** (TEHR-ih-goyd), which form part of the posterior walls of the nasal and oral cavities.
6. **Ethmoid bone.** The complex ethmoid bone (Figure 7.10) is the deepest cranial bone and the most difficult to see from standard views of the skull. Located anterior to the sphenoid bone and posterior to the nasal bones of the face, it contains a number of features, including the following:
   a. Its superior surface, called the **cribriform plate,** forms the roof of the nasal cavity. It has small holes, called **olfactory foramina,** through which olfactory nerves pass, and a superior projection called the **crista galli** (KRIS-tah GAL-ee).
   b. The **lateral masses** of the ethmoid bone form part of the orbit and the walls of the nasal cavity. Internally, the lateral masses contain numerous cavities called the **ethmoid sinuses,** which are the third set of paranasal sinuses (Figure 7.11). Extending medially from the lateral masses are two projections into the nasal cavity—the **superior nasal conchae** and **middle nasal conchae** (KAHN-kee). Note that the superior nasal conchae are quite small and are usually difficult to see.
   c. The middle portion of the ethmoid bone, called the **perpendicular plate,** forms the superior part of the bony nasal septum.

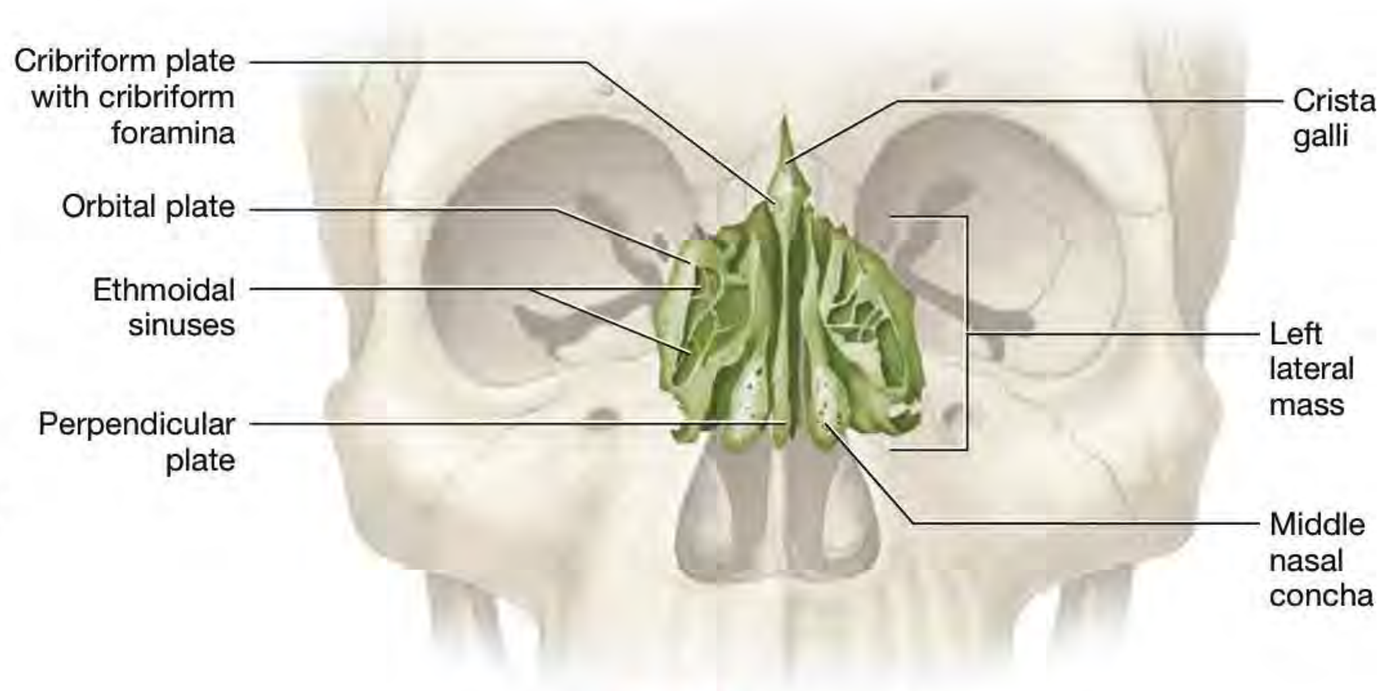


FIGURE **7.10** Ethmoid bone.

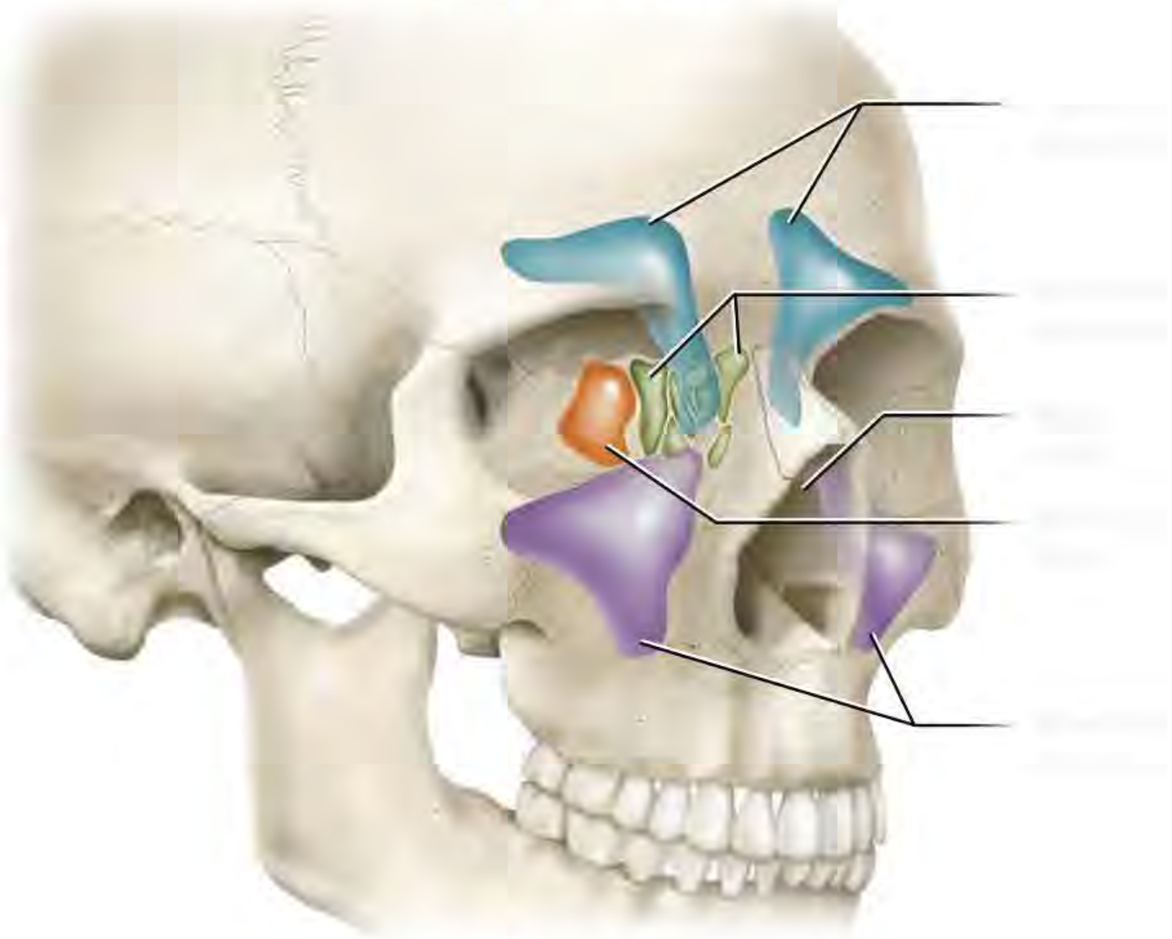


FIGURE **7.11** Paranasal sinuses.

The 14 **facial bones** form the framework for the face, provide openings for ventilation and eating, and form cavities for the sense organs. Several of the facial bones are located deeper in the skull, and you will want to refer to several different figures (noted with each bone) to best locate them and appreciate their structure. These bones are the following:

1. **Mandible.** The **mandible,** or the lower jaw bone, consists of a central **body** and two "arms" called the **mandibular rami** (RAY-mee; see Figures 7.3 and 7.4). As you can see in the figures, the lower teeth are attached to the mandibular body along a border called the **alveolar margin** (al-vee-OH-lahr). On each side of the lateral mandibular body we find a small hole called the **mental foramen.** Just lateral to the mental foramina, the mandibular rami turn superiorly at the **mandibular angle.** Their superior ends have two processes separated by the **mandibular notch:** an anterior process called the **coronoid process** and a posterior process called the **mandibular condyle.** The mandibular condyle fits into the mandibular fossa in the temporal bone to form the **temporomandibular joint, or TMJ.**
2. **Maxillae.** The two fused **maxillae** (mak-SILL-ee) are the upper jaw bones (Figures 7.3–7.5). They form the inferior wall of the orbit and part of the lateral wall of the nasal cavity. Just inferior to the orbit is a small hole called the **infraorbital foramen.** In Figure 7.5, you can see that they also form the anterior portion of the **hard palate** via their **palatine processes.** Within their walls are cavities called the **maxillary sinuses,** the fourth and final set of paranasal sinuses (Figure 7.11). Laterally the maxillae have projections called **zygomatic processes** that form part of the cheekbone. Like the mandible, the maxillae also have an alveolar margin along which the upper teeth are attached.
3. **Lacrimal bones.** The tiny **lacrimal bones** (LAK-rih-mul) are located in the medial part of the orbit, where they form part of the structure that drains tears produced by the lacrimal gland of the eye. They are best seen in Figure 7.4, where you can see the inferior indentation called the **lacrimal fossa.**
4. **Nasal bones.** The two **nasal bones** form the anterior framework of the bridge of the nose.
5. **Vomer.** The single **vomer** forms the inferior portion of the bony nasal septum (best seen in Figure 7.7).
6. **Inferior nasal conchae.** The small **inferior nasal conchae** form part of the lateral walls of the nasal cavity. As their name implies, they are located inferior to the middle nasal conchae of the ethmoid bone (Figure 7.3).
7. **Palatine bones.** The two **palatine bones** form the posterior part of the hard palate (seen in Figure 7.5) and the posterolateral walls of the nasal cavity.
8. **Zygomatic bones.** The two **zygomatic bones** form the bulk of the cheek and a significant portion of the "cheekbone" or zygomatic arch (Figures 7.3 and 7.4).

The **orbit** and the **nasal cavity** are complicated structures with contributions from several bones. The **orbit** is formed by parts of seven bones: the frontal bone, the maxilla, the sphenoid bone, the ethmoid bone, the lacrimal bone, the zygomatic bone, and a tiny piece of the palatine bone (Figure 7.3). The **nasal cavity** is formed by parts of six bones: the ethmoid bone, the maxilla, the palatine bone, the inferior nasal concha, the sphenoid bone, and the vomer (Figures 7.3 and 7.7).

As you can see in Figure 7.12, the fetal skull contains notable differences from the adult skulls you have seen so far. In adults, the sutures are fused, but in the fetus, the sutures have not yet fused and are instead joined by fibrous membranes. This can be seen with the **frontal suture,** also known as the **metopic suture** (met-AHP-ik), seen where the two fetal frontal bones fuse. Where several sutures meet, we find large, membrane-covered areas called the **fontanels,** known to many as "soft spots." The two main fontanels are the **anterior fontanel,** where the sagittal and coronal sutures meet, and the **posterior fontanel,** where the sagittal and lambdoid sutures meet.

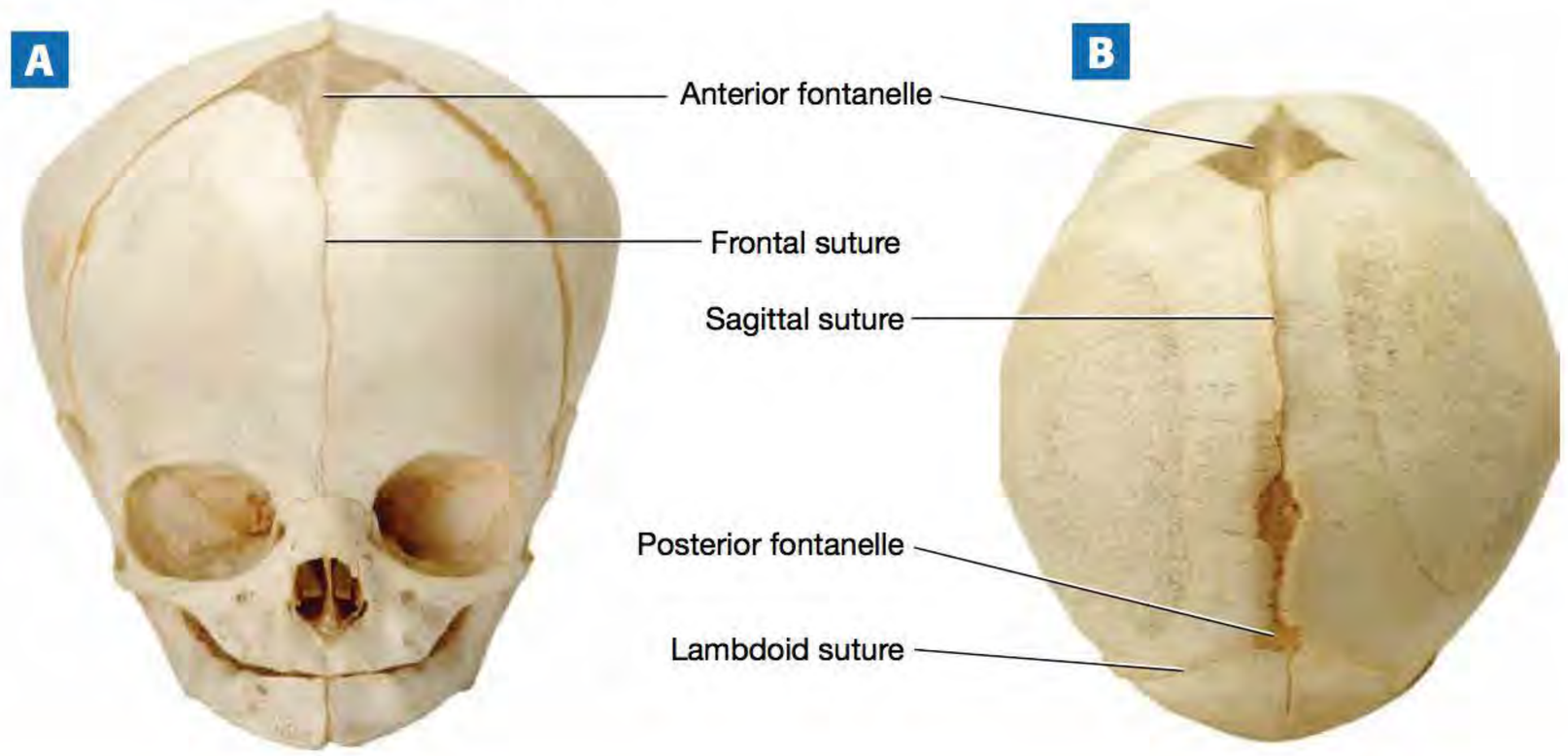


FIGURE **7.12** Fetal skull: (**A**) anterior view; (**B**) posterior view.

Procedure 1 Cooperative Learning for the Skull

This exercise takes an approach called *cooperative learning*, in which you work with your lab partners to teach one another the bones and bone markings. The process may seem a bit confusing at first, but by the end of the first couple of rotations, it should move more quickly and smoothly. After you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 183).

1. Assemble into groups of a minimum of four students; five is optimum.
2. Distribute a skull to each member of the group, and assign each student one of the following five groups of bones and bone markings (the specific structures of each bone are listed on below and on the following page):
   Group A: calvaria, base, and structures of the frontal bone and parietal bones
   Group B: temporal bone and occipital bone structures
   Group C: ethmoid bone and sphenoid bone structures
   Group D: mandible and maxillary bone structures
   Group E: remainder of the facial bones, orbit, sutural bones, and anterior and posterior fontanels.
3. Spend approximately 3 minutes learning the assigned structures on your own.
4. Then have each student spend approximately 1 to 2 minutes teaching the group his or her assigned structures.
5. Rotate the assigned structures clockwise so each student has a new set of structures to learn (the student that was assigned group A will take group B, and so on).
6. Spend approximately 2 to 3 minutes learning your newly assigned structures.
7. Have each student spend approximately 1 to 2 minutes teaching the group his or her assigned structures.
8. Repeat this process (it begins to speed up significantly at this point) until each student has taught each group of structures once. By the end of this activity, each group member will have learned and presented each group of structures.

The following is a list of bones and bone markings of the skull that will be covered in this exercise.

Cranial Bones

Group A Structures

1. Calvaria
2. Base of cranial cavity
   a. Anterior cranial fossa
   b. Middle cranial fossa
   c. Posterior cranial fossa
3. Frontal bone
   a. Frontal sinuses
   b. Glabella
   c. Supraorbital foramen
4. Parietal bones
   a. Coronal suture
   b. Sagittal suture
   c. Squamous suture
   d. Lambdoid suture

Group B Structures

1. Temporal bones
   a. Zygomatic process
   b. Mandibular fossa
   c. External acoustic (auditory) meatus
   d. Styloid process
   e. Mastoid process with mastoid air cells
   f. Foramen lacerum
   g. Carotid canal
   h. Jugular foramen
   i. Internal acoustic meatus
2. Occipital bone
   a. Occipital condyles
   b. Foramen magnum
   c. External occipital protuberance
   d. Superior nuchal line
   e. Inferior nuchal line

Group C Structures

1. Sphenoid bone
   a. Body
   b. Optic canal
   c. Sella turcica
   d. Sphenoid sinus
   e. Lesser wings
   f. Greater wings
   g. Superior orbital fissure
   h. Foramen rotundum
   i. Foramen ovale
   j. Foramen spinosum
   k. Pterygoid processes
2. Ethmoid bone
   a. Cribriform plate
   b. Olfactory foramina
   c. Crista galli
   d. Lateral masses
   e. Ethmoid sinuses
   f. Superior and middle nasal conchae
   g. Perpendicular plate

Facial Bones and Other Structures

Group D Structures

1. Mandible
   a. Body of mandible
   b. Mandibular ramus
   c. Alveolar margin
   d. Mental foramen
   e. Mandibular angle
   f. Mandibular notch
   g. Coronoid process
   h. Mandibular condyle
2. Maxillae
   a. Infraorbital foramen
   b. Palatine processes
   c. Maxillary sinuses
   d. Zygomatic processes
   e. Alveolar margin

Group E Structures

1. Lacrimal bones and lacrimal fossa
2. Nasal bones
3. Vomer
4. Inferior nasal conchae
5. Palatine bones
6. Zygomatic bones and zygomatic arch
7. Orbit
8. Nasal cavity
9. Frontal (metopic) suture
10. Anterior fontanel
11. Posterior fontanel

7

Your instructor may wish to omit certain structures included above or add structures not included in these lists. List any additional structures below:

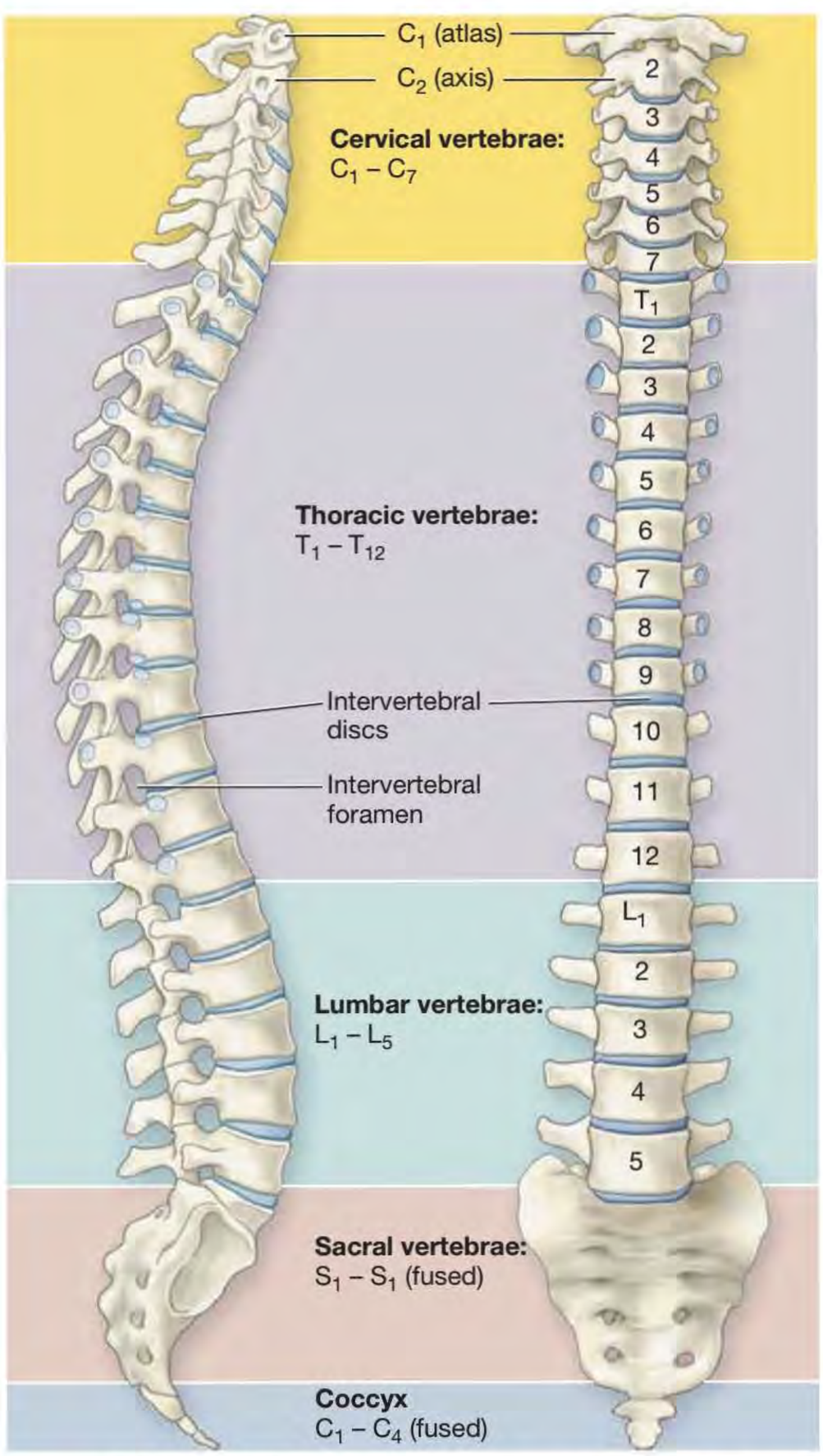
Exercise 7-2

Remainder of the Axial Skeleton

MATERIALS

- ❑ Vertebral column, articulated
- ❑ Disarticulated vertebrae, sacrum, sternum, ribs, hyoid bone
- ❑ Skeleton, articulated

Another key component of the axial skeleton is the **vertebral column**, which consists of 24 vertebrae, the **sacrum** (SAY-krum), and the **coccyx** (KAHX-iks). If you view the vertebral column from the lateral side, as in Figure 7.13, you can see that there are spaces between the adjacent vertebrae called **intervertebral foramina**. In addition, the vertebral column has four curvatures: the concave **cervical** and **lumbar curvatures** and the convex **thoracic** and **sacral curvatures**. The cervical and lumbar curvatures are particularly important to our ability to walk upright.



Right lateral view *Anterior view*

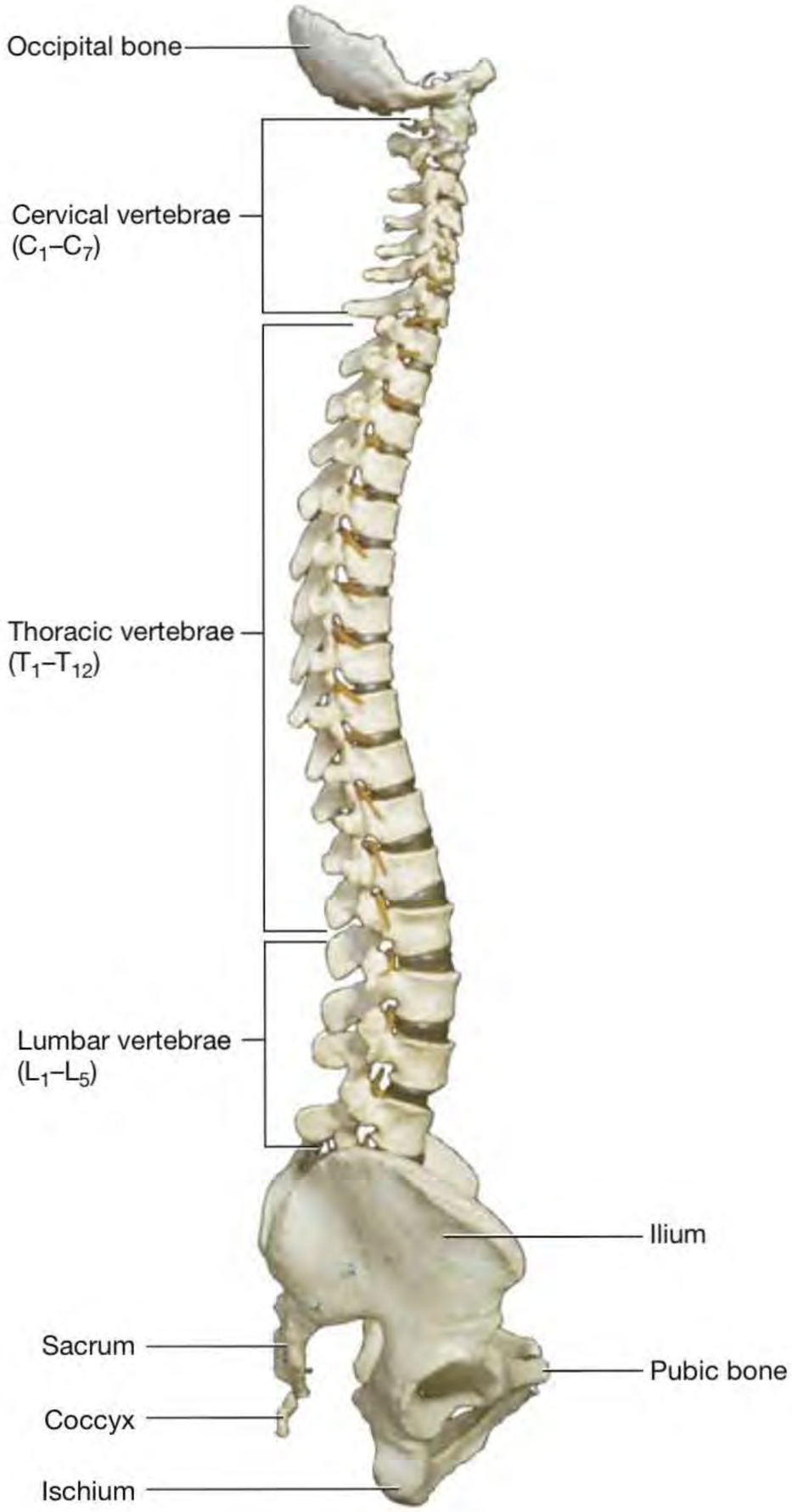


FIGURE **7.13** Vertebral column: (**A**) illustration; (**B**) photograph.

The 24 vertebrae consist of 7 cervical vertebrae, 12 thoracic vertebrae, and 5 lumbar vertebrae (remember this as, "breakfast at 7, lunch at 12, dinner at 5"). Nearly all vertebrae share certain general features, which are visible in the typical cervical vertebra shown in Figure 7.14A. These features include a posterior **spinous process**, two lateral **transverse processes**, a central **vertebral foramen**, and an anterior **vertebral body**. In between each vertebral body is a fibrocartilage pad called an **intervertebral disc** that absorbs shock as the vertebral column moves. Extending from the vertebral body to the transverse processes on both sides are two short extensions known as **pedicles**, which enclose the vertebral foramen along with two posterior extensions, the **laminae**.

The basic properties of each region of the vertebral column are as follows:

1. The seven **cervical vertebrae** are located in the neck (Figure 7.14A–C). All cervical vertebrae have holes in their transverse processes called **transverse foramina** that permit the passage of blood vessels called the *vertebral artery* and *vein*. In addition, the spinous processes of cervical vertebrae are often forked. Two cervical vertebrae are named differently than the others because of their unique features:
   a. **Atlas** (C1): The **atlas** is the first cervical vertebra, and it articulates with the occipital condyles of the occipital bone. It is easily identified because it has a large vertebral foramen, no body, and no spinous process (Figure 7.14B).
   b. **Axis** (C2): The **axis** is the second cervical vertebra. It is also easily identified by a superior projection called the **dens** (or the **odontoid process**; Figure 7.14C). The dens fits up inside the atlas to form the *atlantoaxial joint*, which allows rotation of the head.

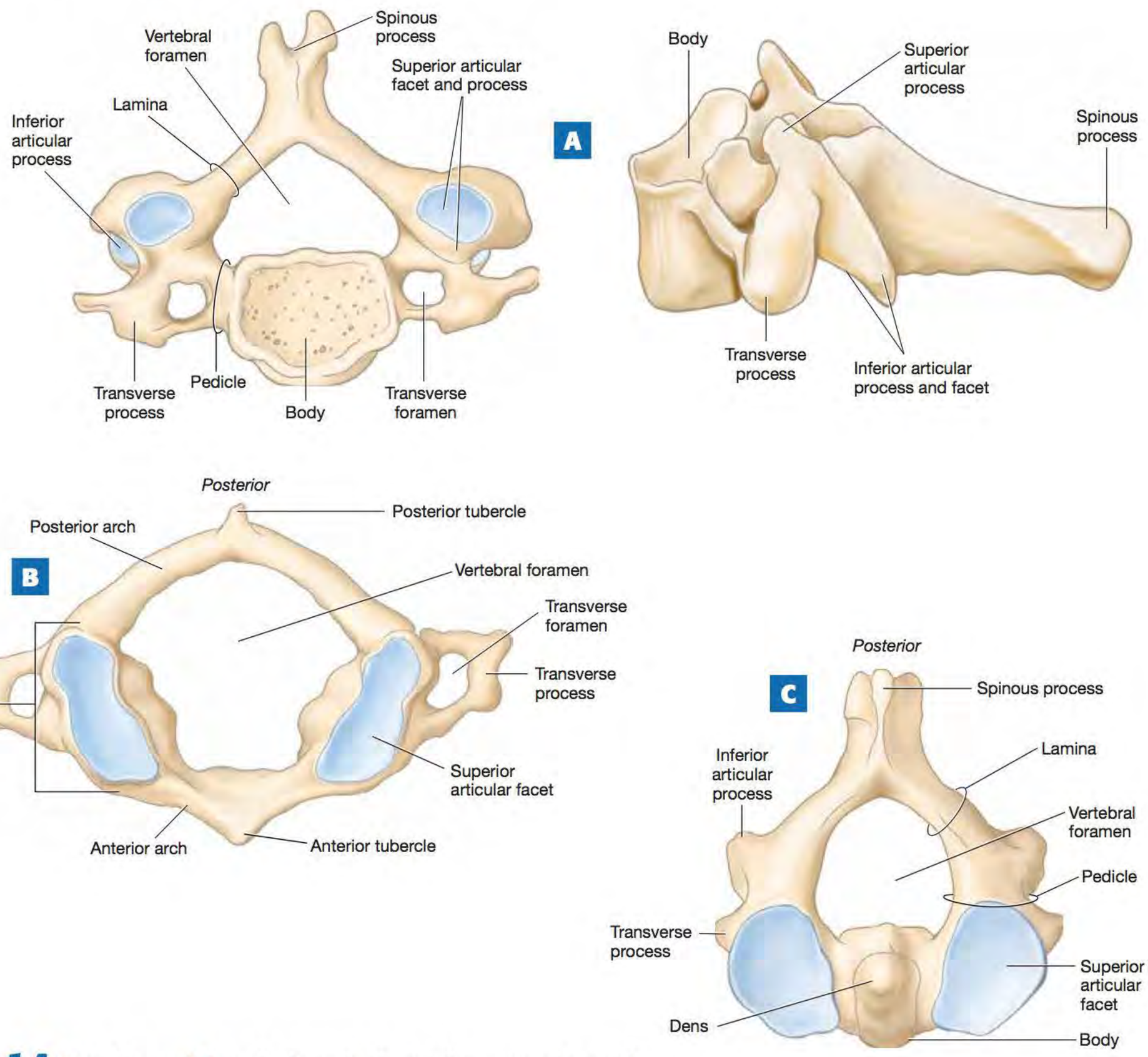


FIGURE **7.14** Vertebrae: (**A**) typical cervical vertebra, superior and lateral views; (**B**) atlas (C_1), superior view; (**C**) axis (C_2), superior view *(continues)*

2. The 12 **thoracic vertebrae** each articulate with a pair of ribs, and they share the following common features (Figure 7.14D):
   a. The spinous processes are thin and point inferiorly.
   b. All have two *costal facets* that articulate with the ribs (there are 12 pairs of ribs).
   c. All have approximately triangular vertebral foramina.
   d. If you look at a thoracic vertebra from the posterolateral side, it looks like a giraffe. Try it—it really does!
3. The five large **lumbar vertebrae** share the following common features (Figure 7.14E):
   a. All have a large, blocklike body.
   b. The spinous processes are thick and point posteriorly.
   c. If you look at a lumbar vertebra from the posterolateral side, it looks like a moose.

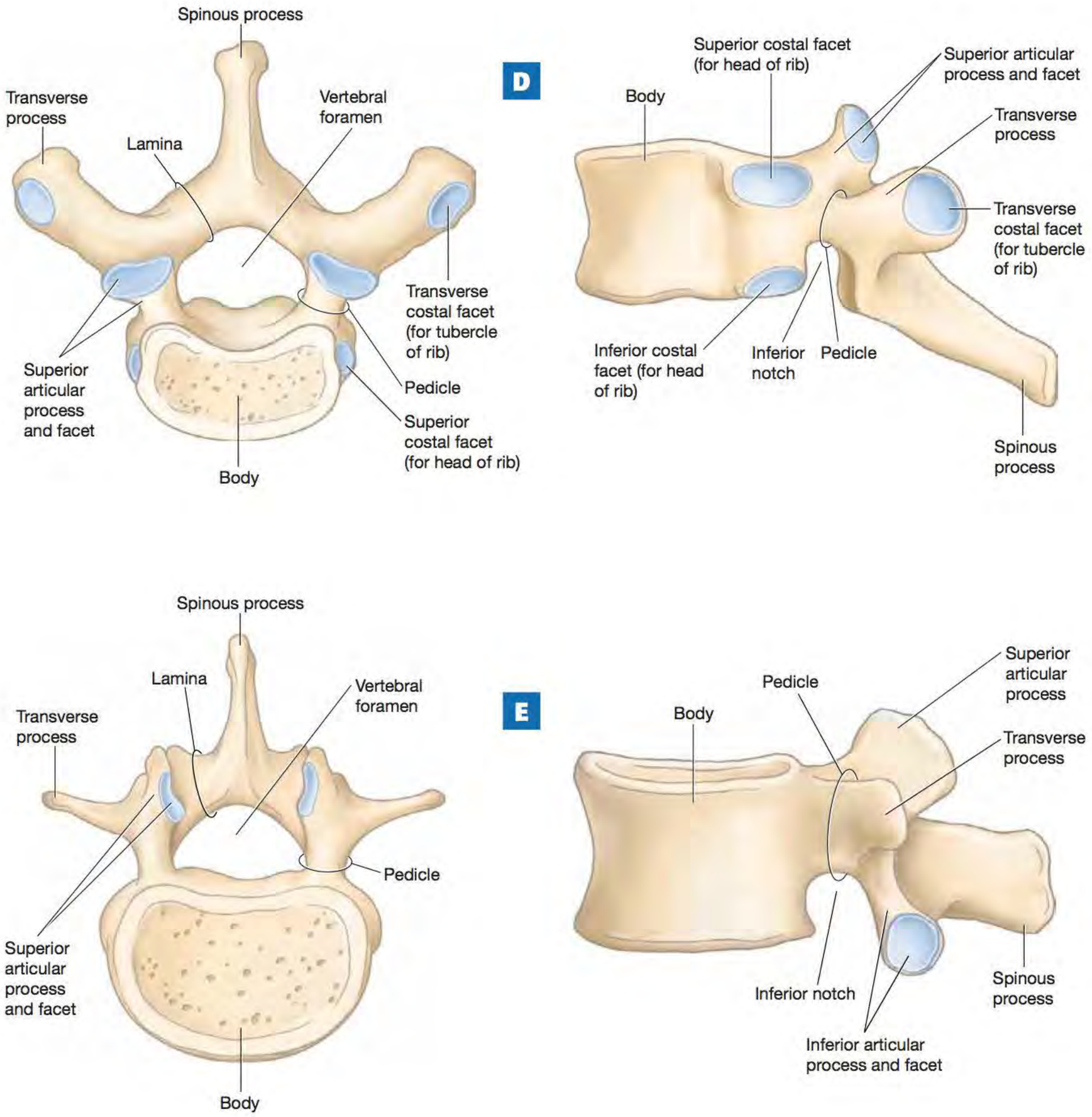


FIGURE **7.14** Vertebrae *(cont.)*: (**D**) typical thoracic vertebra, superior and lateral views; (**E**) typical lumbar vertebra, superior and lateral views *(continues)*

4. The **sacrum** consists of five fused vertebrae (Figures 7.14F and 7.14G). On its superior surface we find the **sacral promontory,** which is the portion of the first sacral body that projects anteriorly into the pelvic cavity. Just posterior to the sacral promontory is the **sacral canal,** through which the inferior bundle of spinal nerve roots passes from the vertebral foramen of the fifth lumbar vertebra. You can see the fused spinous processes of the vertebrae on the sacrum's posterior side as the **median sacral crest.** Spinal nerves pass through holes called **anterior** and **posterior sacral foramina** that flank both sides of the sacral bodies. The lateral surfaces of the sacrum articulate with the hip bones to form the **sacroiliac joints** (say-kroh-ILL-ee-ak).
5. The **coccyx** consists of three to five small, fused vertebrae that articulate superiorly with the sacrum.

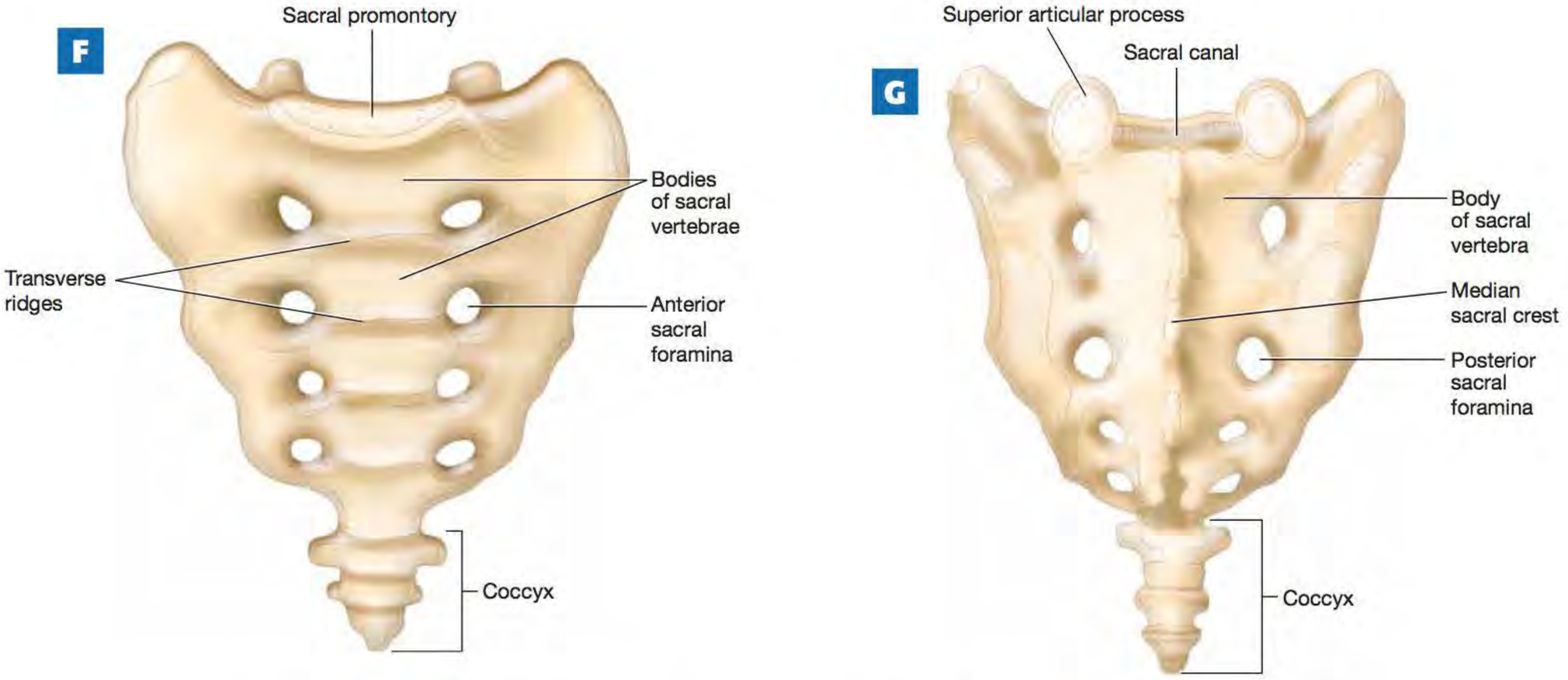


FIGURE **7.14** Vertebrae *(cont.)*: (F) sacrum, anterior view; (G) sacrum, posterior view.

The remainder of the axial skeleton consists of the bones of the thoracic cavity (the **sternum** and the **ribs,** Figures 7.15 and 7.16) and the **hyoid bone** in the neck (Figure 7.17). The **sternum** is the central bone of the thorax. It is divided into three parts—the superior **manubrium** (mah-NOO-bree-um), the middle **body,** and the inferior **xiphoid process** (ZY-foyd). It is the body of the sternum that you compress during the chest compressions of cardiopulmonary resuscitation (CPR), and the xiphoid process that you must take care not to break.

The twelve pairs of **ribs** enclose the thoracic cavity and protect its vital organs (note that men and women have the same number of ribs). The spaces between the ribs are known as **intercostal spaces,** and they contain muscles, blood vessels, nerves, and lymphatic vessels. Ribs articulate anteriorly with the sternum via **costal cartilage.** They are classified according to the structure of their costal cartilage: Ribs 1–7 are considered **true ribs,** because they attach directly to the sternum by their own costal cartilage. Ribs 8–12 are classified as **false ribs,** because they lack this direct attachment to the sternum. Ribs 8-10 attach to the sternum via the cartilage of the true ribs. Ribs 11–12, often called **floating ribs,** lack an attachment to the sternum. The inferior border of the costal cartilage of the false ribs is known as the **costal margin.**

In Figure 7.16 you can see the rib's **superior** and **inferior facets** on the rib's posterior **head** where it articulates with a vertebra. Lateral to the head we find the **neck,** which contains a **tubercle** that articulates with a vertebra's transverse process. The rib curves around anteriorly at its **angle,** after which the main anterior portion becomes known as the **shaft.** On the shaft's interior surface is the **costal groove,** which is where blood vessels and nerves travel.

The **hyoid bone,** shown in Figure 7.17, is located in the superior neck where it is occasionally classified as a skull bone. Note, however, that it does not articulate with any skull bone, or any other bone for that matter. It is held in place in the superior neck by muscles and ligaments, and it helps to form part of the framework for the larynx (LEHR-inks; voice box). It also serves as an attachment site for the muscles of the tongue and aids in swallowing. When a person is choked manually, the hyoid bone is often broken.

The bones and bone markings of the axial skeleton are listed with Exercise 7-3 (p. 157), where they will be included with another cooperative learning exercise.

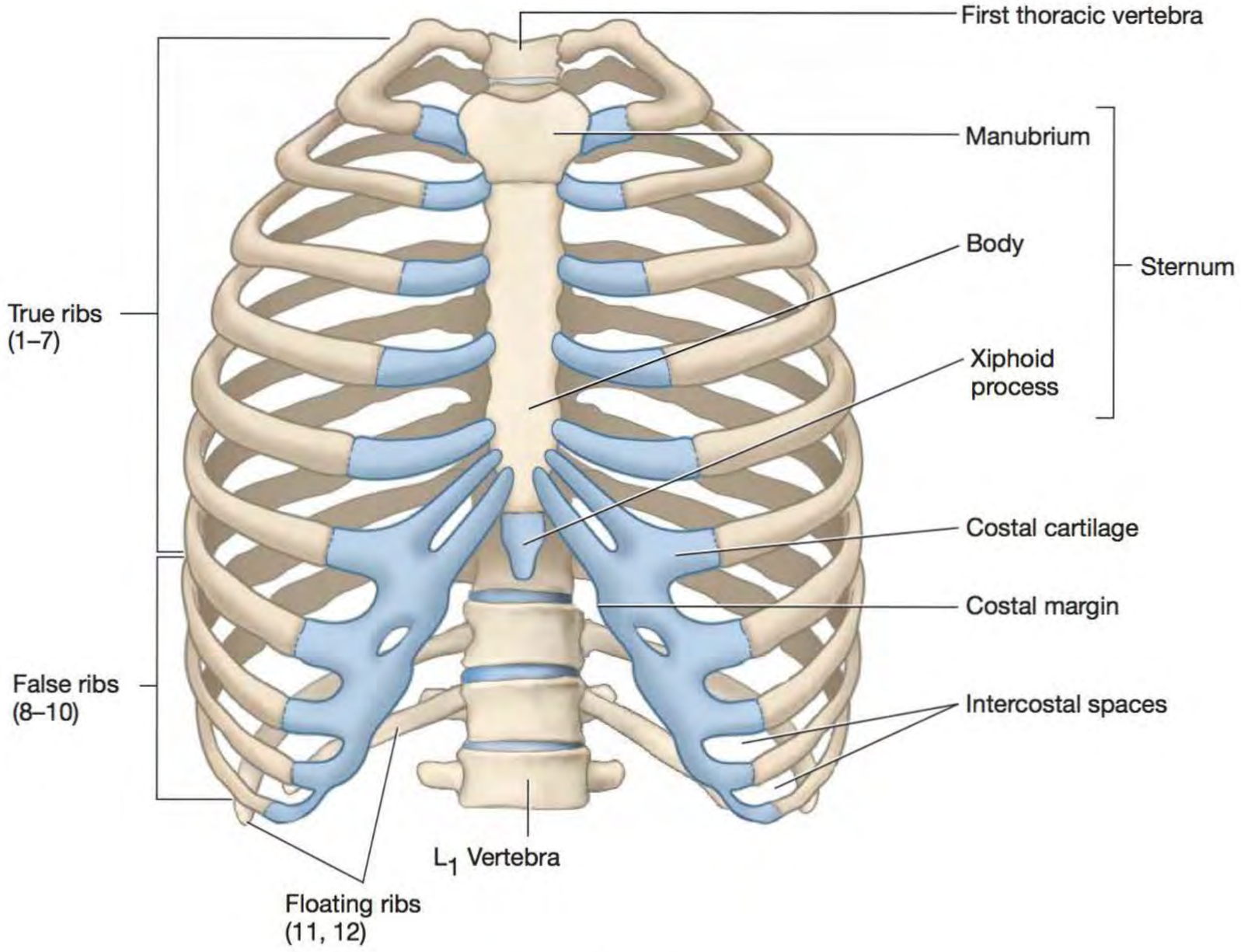


FIGURE **7.15** Thoracic cage.

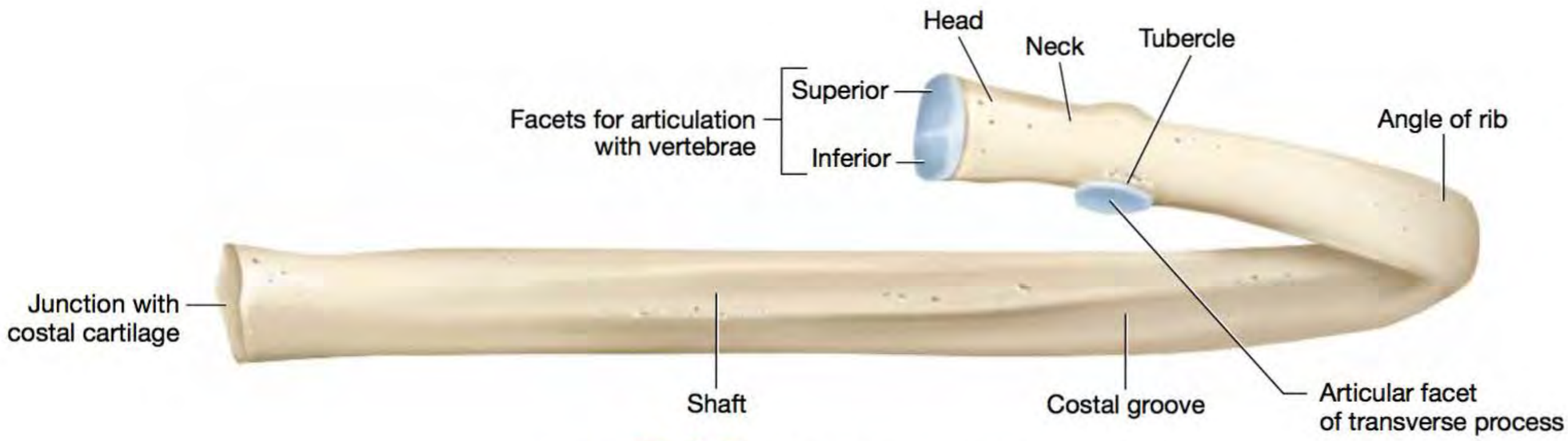


FIGURE **7.16** Rib, posterior view.

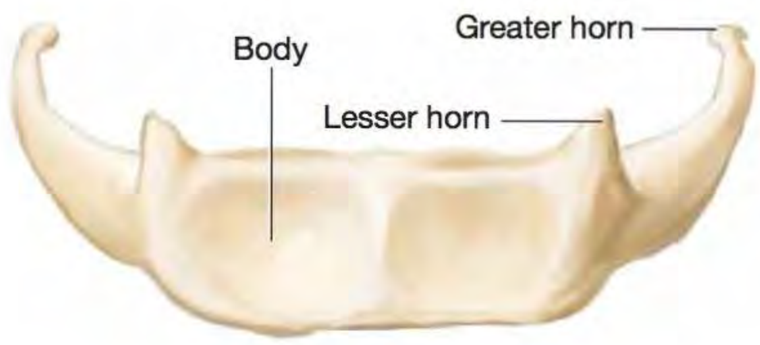


FIGURE **7.17** Hyoid bone.

Exercise 7-3

The Appendicular Skeleton

MATERIALS

- ❑ Disarticulated bones
- ❑ Skeleton, articulated
- ❑ Male and female pelvises

The bones of the appendicular skeleton can be divided into those of the **pectoral girdle**, the upper limb, the **pelvic girdle**, and the lower limb.

Pectoral Girdle

The **pectoral girdle** consists of the two bones that frame the shoulder: the **scapula** and the **clavicle** (Figure 7.18). The **scapula** (SCAP-yoo-lah), shown in Figure 7.19, is a roughly triangular shaped bone with **superior, lateral,** and **medial borders**. The corners of the "triangle" are known as the **superior, lateral,** and **inferior angles**. The scapula's broad, flat surface is the **body**. On the anterior surface (Figure 7.19A), the body has a broad indentation, the **subscapular fossa**. On its lateral surface (Figure 7.19B) is a shallow depression called the **glenoid cavity** that forms the shoulder joint with the humerus. From this side you can also get a good view of its two superior projections: the anterior **coracoid process** (KOHR-ah-koyd) and the posterior **acromion** (ah-KROH-mee-ahn). The acromion forms a joint with the lateral portion of the clavicle called the **acromioclavicular** (ah-kroh-mee-oh-clah-VIK-yoo-lur; **AC**) joint. When we turn to the scapula's posterior surface (Figure 7.19C), we find a prominent ridge called the **spine of the scapula** that is palpable as your "shoulder blade." Superior and inferior to the spine are two depressions: the **supraspinous** and **infraspinous fossae**.

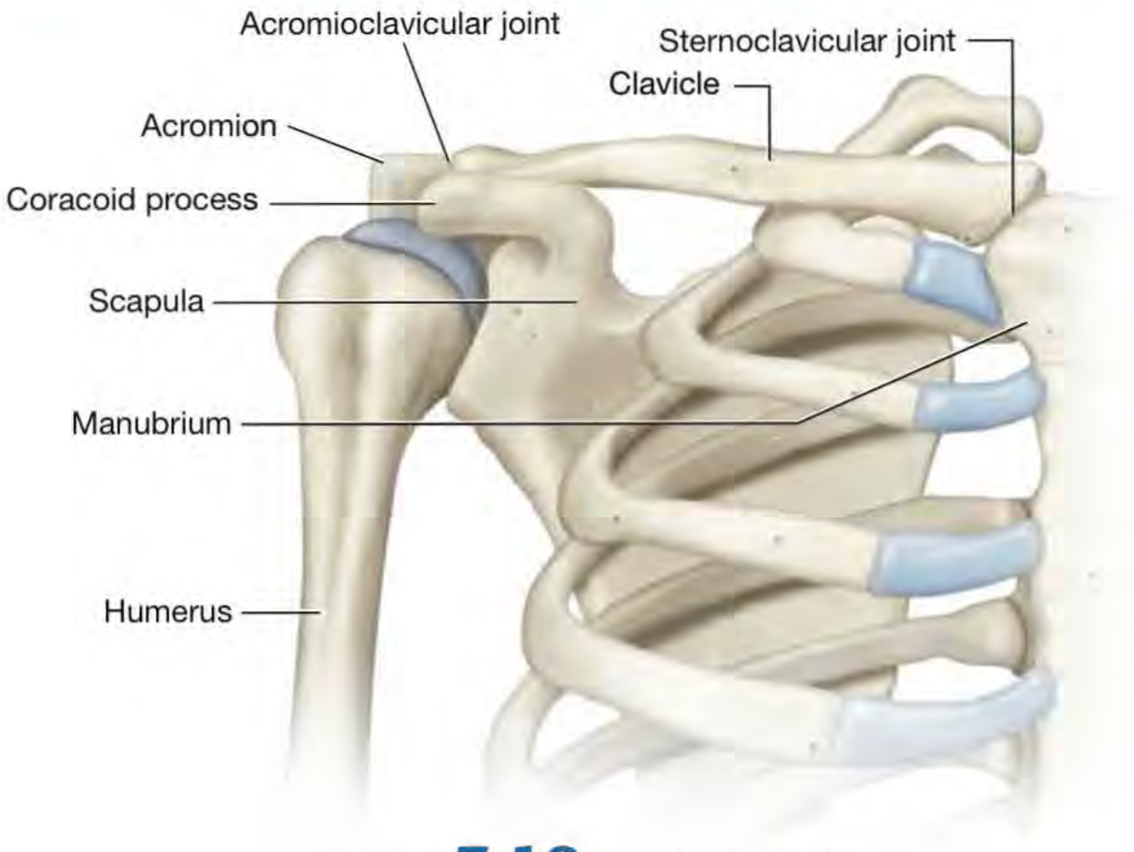


FIGURE **7.18** Pectoral girdle.

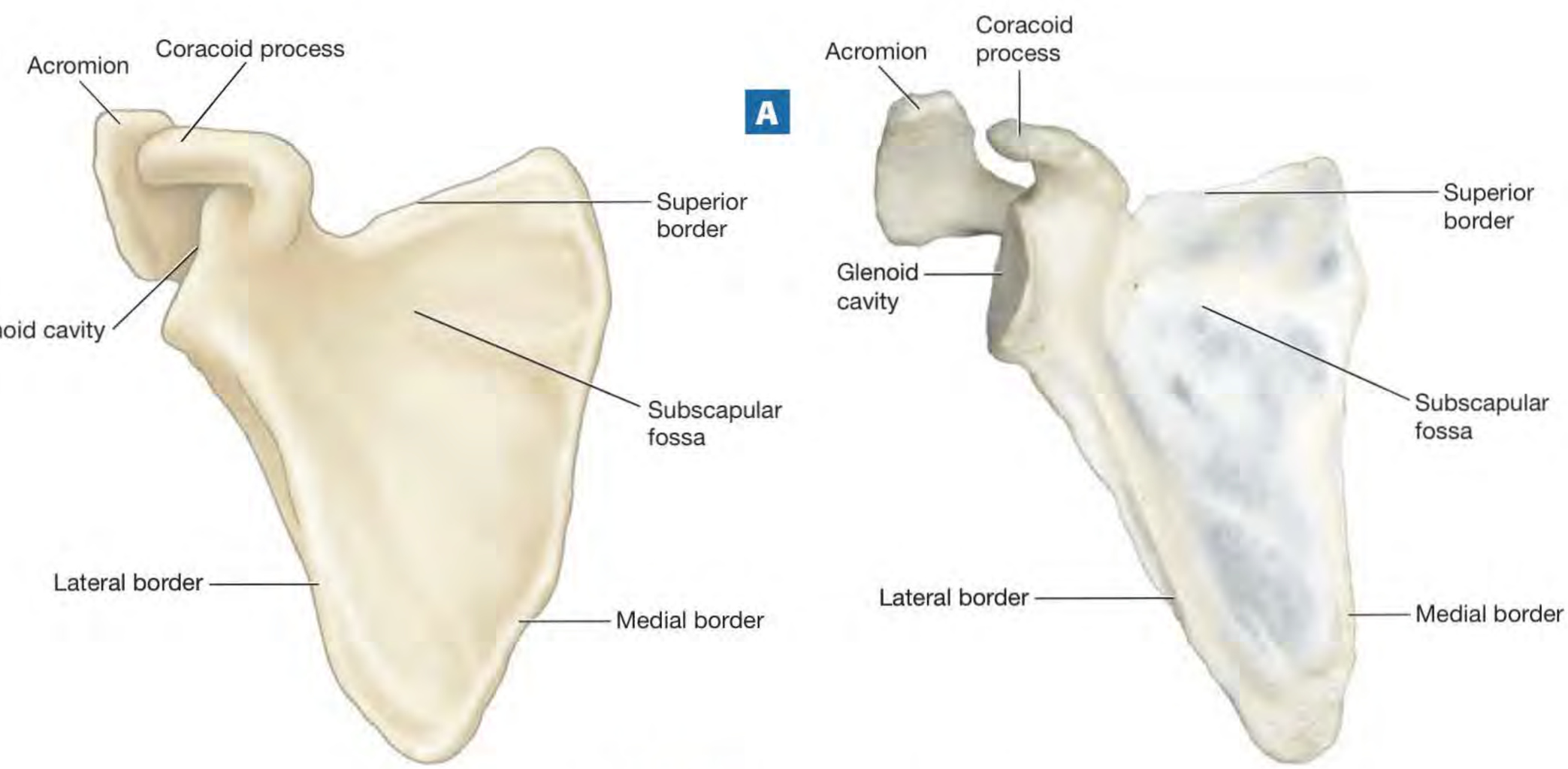


FIGURE **7.19** Right scapula: (**A**) anterior view *(continues)*

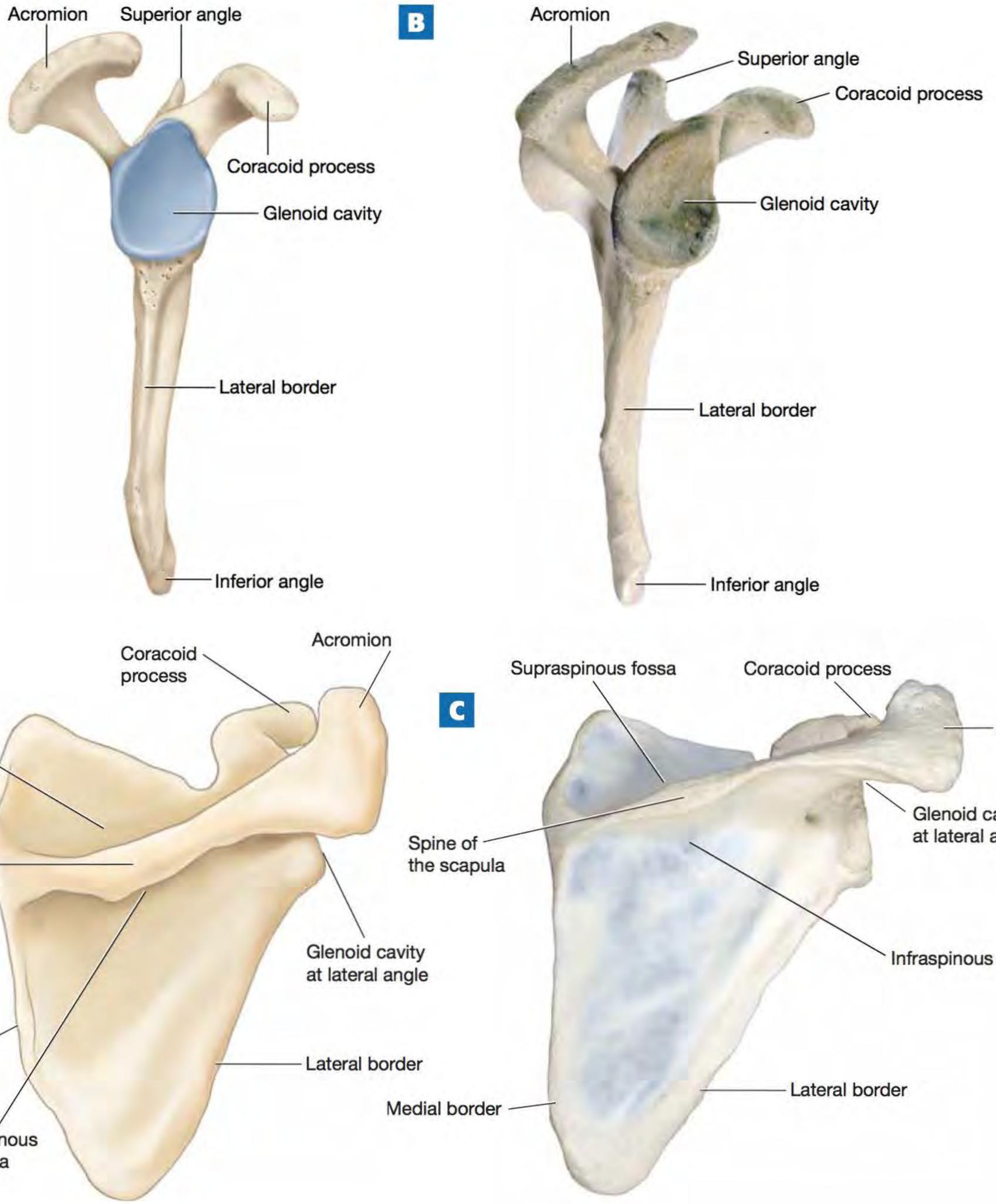


FIGURE **7.19** Right scapula *(cont.)*: (**B**) lateral view; (**C**) posterior view.

The **clavicle** is a small S-shaped bone that spans between the acromion of the scapula at its lateral **acromial end** and the manubrium of the sternum at its medial **sternal end.** Note its S-shape is best appreciated from the superior view shown in Figure 7.20, as the clavicle appears nearly straight from an anterior view. Functionally, the clavicle acts somewhat like a brace, holding the upper limb in place away from the body.

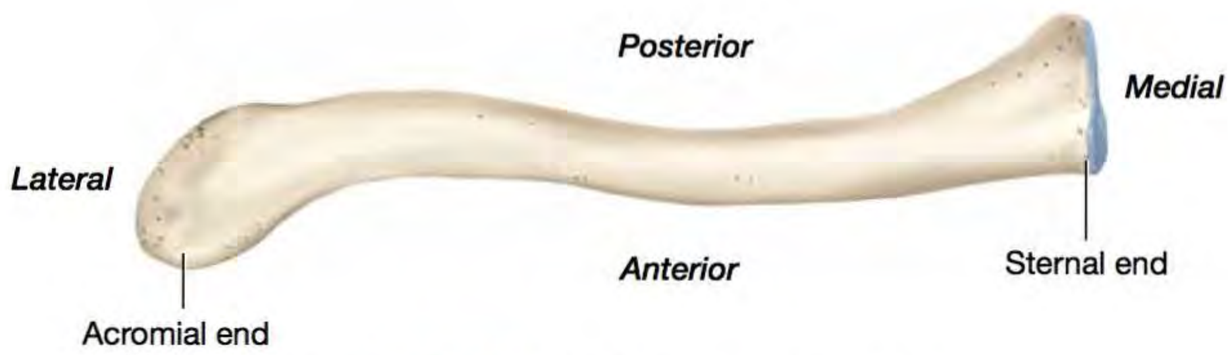


FIGURE **7.20** Clavicle, superior view.

Upper Limb

The **upper limb** consists of the arm, the forearm, the wrist, and the hand. The only bone within the arm is the **humerus** (HYOO-mur-us), a long bone that forms the shoulder joint with the scapula at its proximal end and the elbow joint with the ulna and radius at its distal end. The humerus has a number of features, including the following (Figure 7.21):

- At its proximal end is a rounded **head** that fits into the glenoid cavity. Just lateral to the head is the **greater tubercle,** separated from the smaller **lesser tubercle** by the **intertubercular sulcus** (in-ter-too-BUR-kyoo-lur SUL-kuss).
- The diaphysis of the humerus features a projection called the **deltoid tuberosity,** where the deltoid muscle attaches.
- At the humerus' distal end we find two small projections called the **medial** and **lateral epicondyles.** Distal to these are two larger condyles: the medial **trochlea** (TROH-klee-uh), which is shaped like a spool of thread, and the lateral **capitulum** (kah-PIT-yoo-lum), which is ball-shaped. Just proximal to the trochlea are indentations in the humerus where the ulna articulates: the anterior **coronoid fossa** and the posterior **olecranon fossa** (oh-LEK-rah-nahn).

The two forearm bones, shown in Figure 7.22, are the lateral **radius** and medial **ulna** (if you have a hard time remembering which is which, stand in anatomical position and take your radial pulse; the pulse is on the lateral side of the forearm, just like the radius). The ulna is wide proximally where it articulates with the humerus and thin distally where it articulates with the bones of the wrist. Its proximal end has two processes—the large, posterior **olecranon process** and the smaller, anterior **coronoid process**—separated by a deep curve called the **trochlear notch.** Just distal to the coronoid process is the **radial notch,** which is where the radius and ulna articulate at the **proximal radioulnar joint.**

As its name implies, the trochlear notch fits around the trochlea of the humerus to form the elbow joint. The olecranon process is the actual "elbow bone," which you can feel on your posterior arm. The trochlear notch and the ulna's two processes form a "U" shape when the ulna is held on its side. This makes the ulna easy to differentiate from the radius (think "U" for "ulna").

The distal end of the ulna is known as the **ulnar head.** On its medial side, it has a small projection called the **styloid process** that is palpable through the skin.

The radius has a width distribution opposite from that of the ulna: It is skinny proximally and wide distally. Proximally it consists of a round, flattened **radial head** that articulates with the radial notch of the ulna at the **proximal radioulnar joint.** Note in Figure 7.22 that the two bones also articulate at their distal ends at the **distal radioulnar joint.** Here

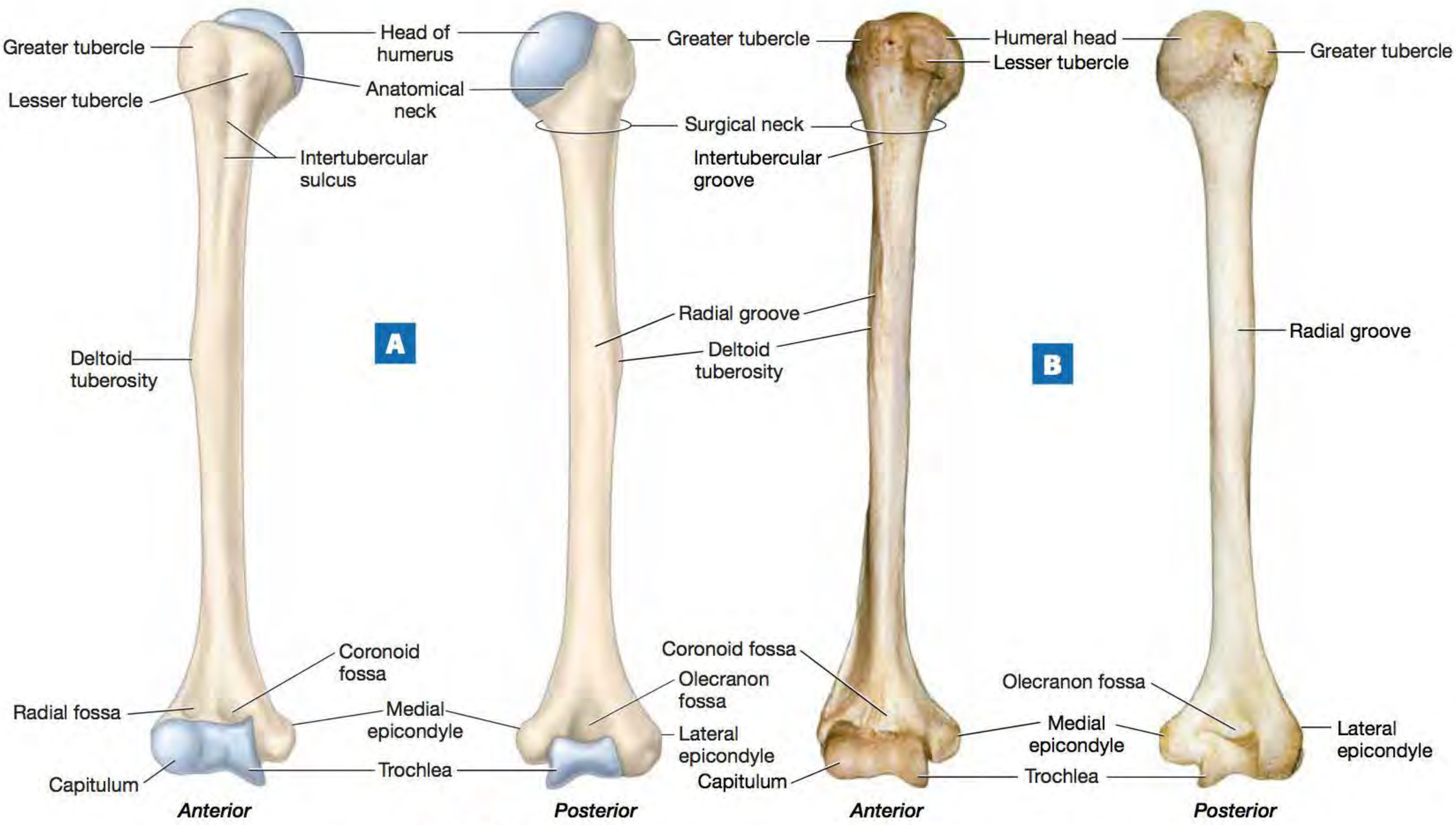


FIGURE **7.21** Right humerus: (A) illustration; (B) photograph.

on the radius is an indentation called the **ulnar notch** where the ulna fits into the radius. Distal to the radial head we find the **radial neck** and a projection called the **radial tuberosity**. At its most distal end is a lateral **styloid process**, just as we found on the ulna.

The wrist is composed of eight short bones called **carpals**, labeled individually in Figure 7.23. The carpals articulate proximally with the radius and the ulna, and distally with the five long bones in the hand called the **metacarpals**. The metacarpals articulate distally with the fingers, which are formed from 14 long bones called **phalanges**. The second through fifth digits have three phalanges each (the *proximal*, *intermediate* [or *middle*], and *distal phalanges*); the thumb has only two (a *proximal* and a *distal phalanx*).

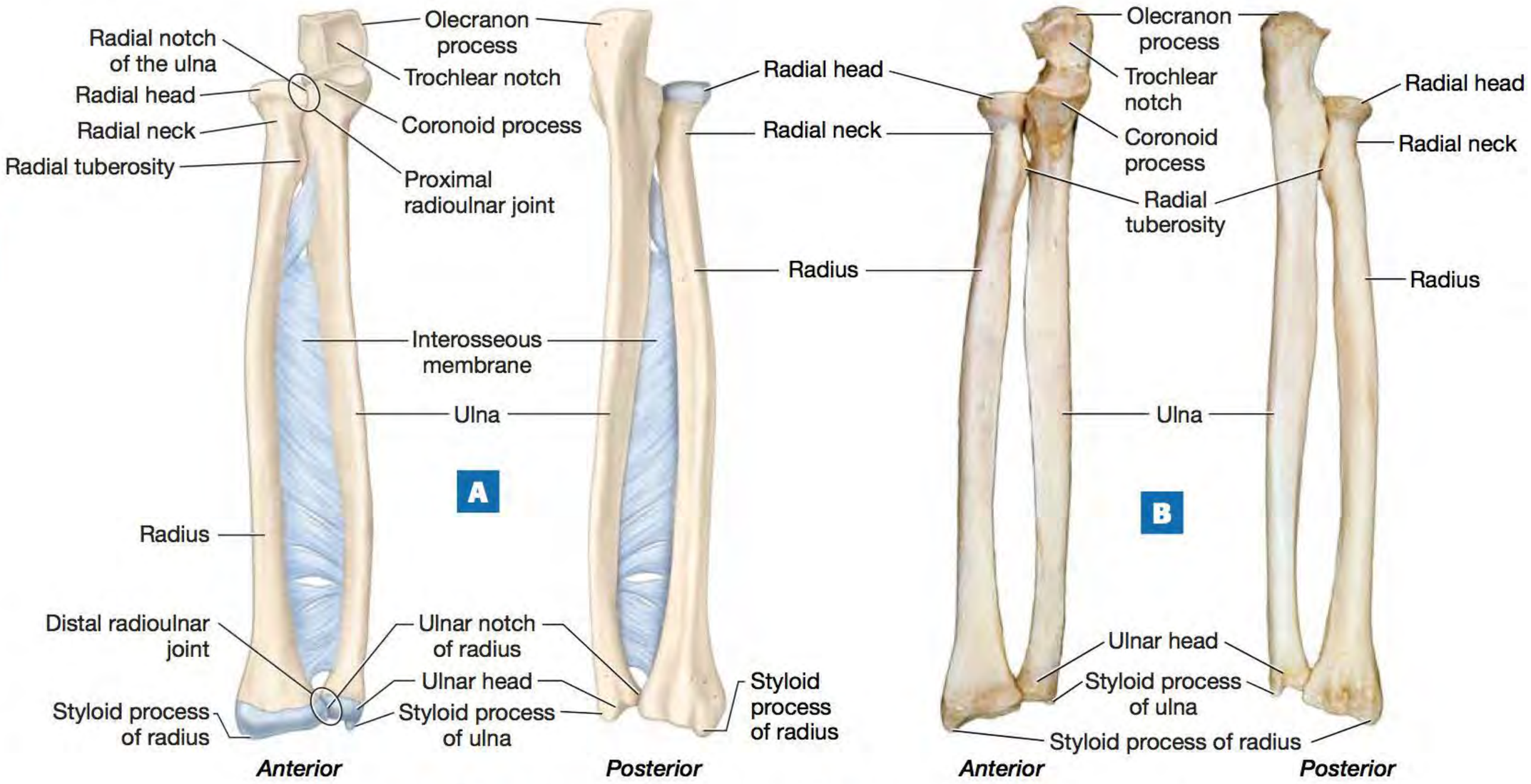


FIGURE **7.22** Right radius and ulna: (A) illustration; (B) photograph.

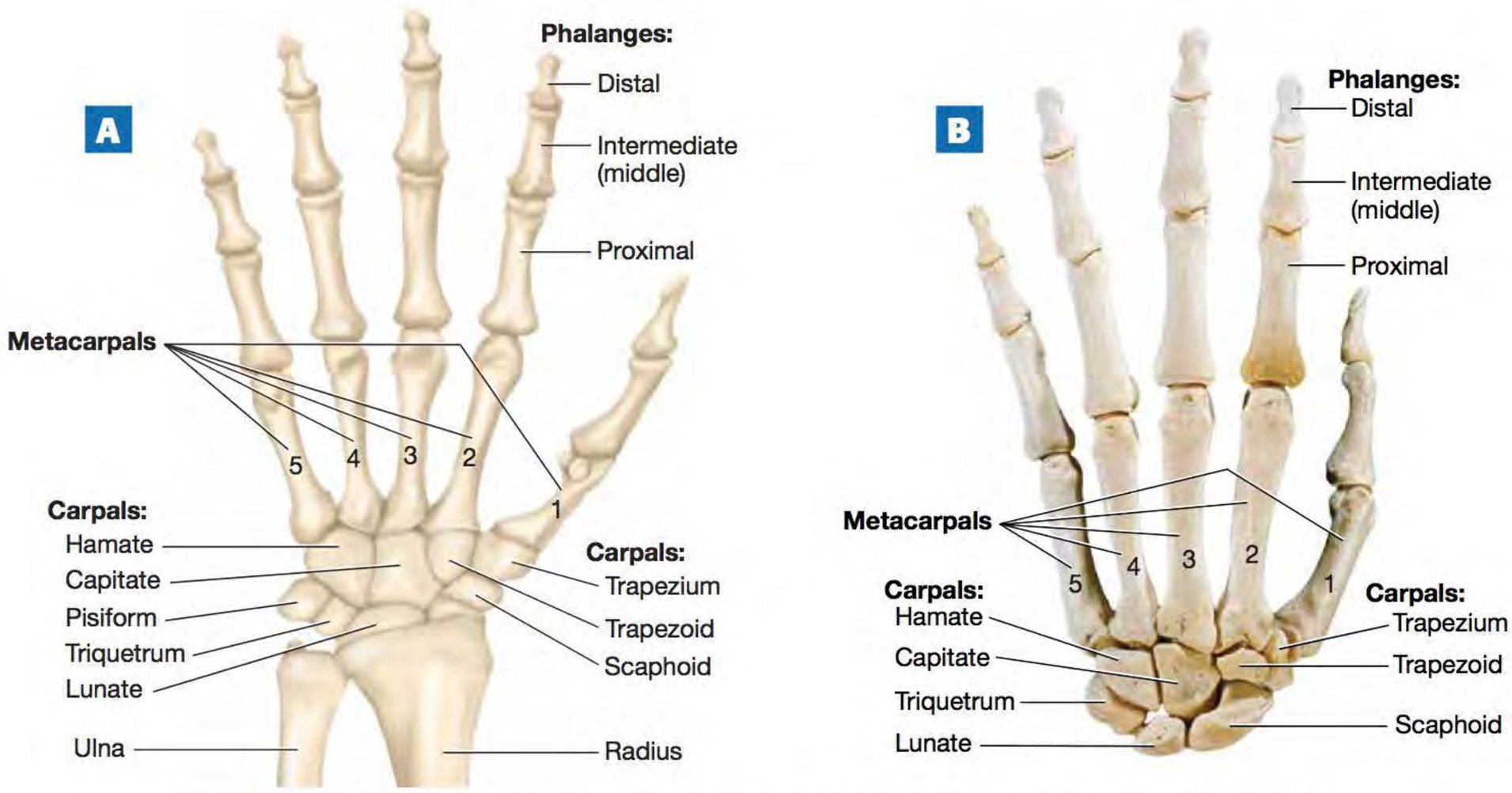


FIGURE **7.23** Anterior view of right wrist and hand: (A) illustration; (B) photograph.

Pelvic Girdle

The **pelvis** connects the lower limbs to the trunk, supports the pelvic organs, and transmits the weight of the trunk to the legs. It is formed by the sacrum and the **pelvic girdle**, which itself is composed of two **coxal bones** (Figure 7.24). The coxal bones meet the sacrum at the two **sacroiliac joints** (say-kroh-ILL-ee-ak). The opening into the pelvis is known as the **pelvic inlet**; the ridge around the inlet is the **pelvic brim**. The pelvic inlet and brim separate what is known as the **greater pelvis**, which sits superior to the pelvic inlet, from the **lesser pelvis**, which sits inferior to it. As you can see in Figure 7.24B, we find the **pelvic outlet** at the inferior edge of the lesser pelvis.

Each coxal bone is also known as a **hemipelvis**. Three fused bones—the **ilium**, the **ischium**, and the **pubis**—make up each coxal bone (Figure 7.25). Notice that the lateral side of the hip has a place where all three bones come together to form a deep socket. This socket, called the **acetabulum** (ah-seh-TAB-yoo-lum), forms the hip joint with the femur. Notice also that where the ischium and pubis meet there is a large hole called the **obturator foramen** (AHB-too-ray-tohr). In a living person this hole is covered with a membrane and allows only small blood vessels and nerves to pass through.

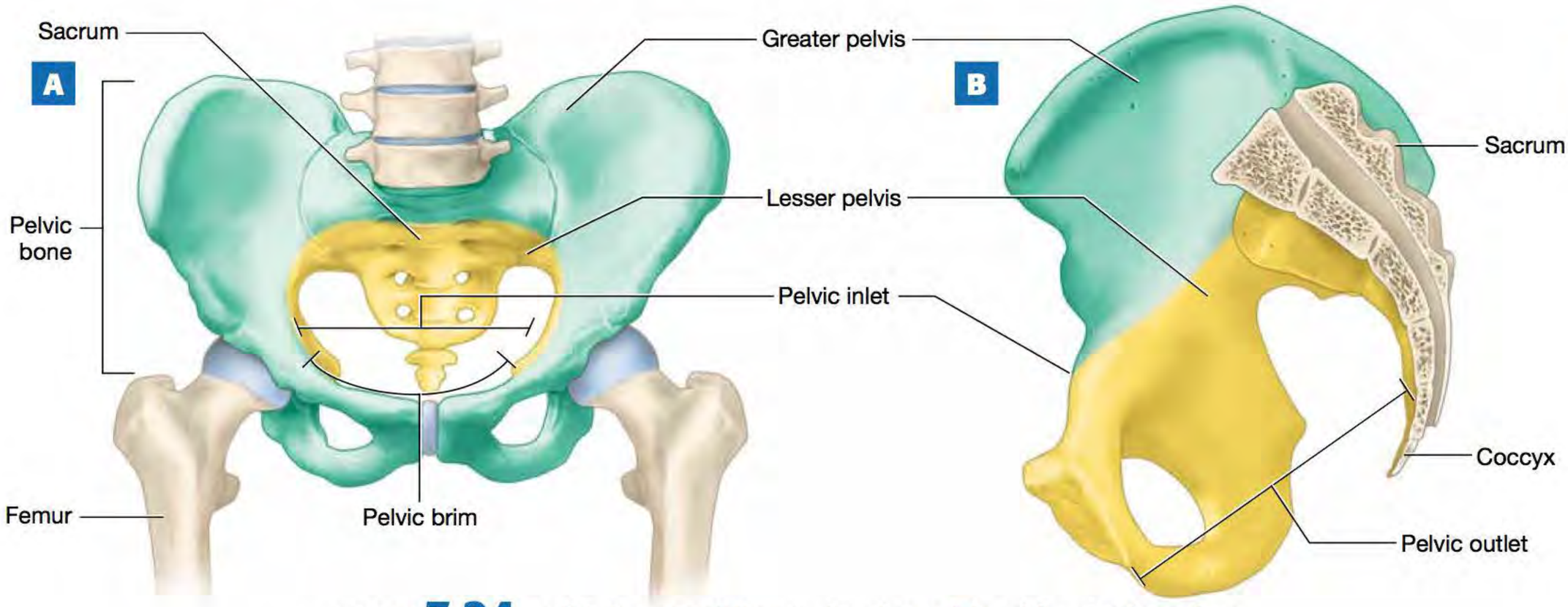


FIGURE **7.24** Pelvic bones: (A) anterior view; (B) midsagittal section.

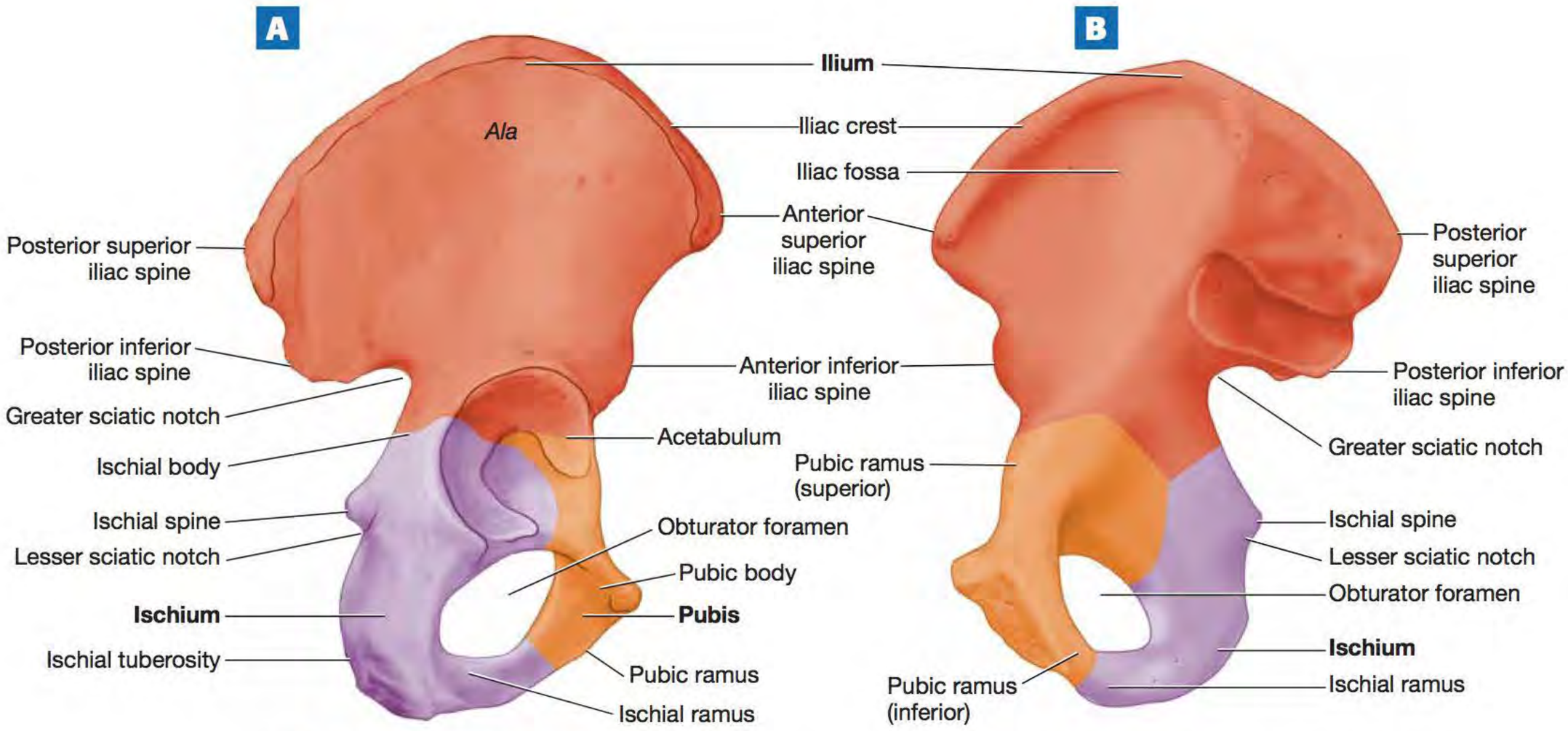


FIGURE **7.25** Hemipelvis: (A) right coxal bone, lateral view; (B) right coxal bone, medial view.

The three bones of the pelvic girdle have the following features:

1. **Ilium.** The **ilium** (ILL-ee-um) is the largest of the three bones. Its main portion is called the **body**, and its superior "wing" is called the **ala**. The ridge of the ala, called the **iliac crest**, is where you rest your hands when your hands are on your hips. At the anterior end of the crest we find a projection called the **anterior superior iliac spine**, and inferior to it the smaller **anterior inferior iliac spine**. A similar but smaller **posterior superior iliac spine** is located posteriorly, with a corresponding **posterior inferior iliac spine**. The posterior ilium also features a notch called the **greater sciatic notch** (sy-AEH-tik), which allows the greater sciatic nerve to pass from the pelvis to the thigh.
2. **Ischium.** The **ischium** (ISS-kee-um) makes up the posteroinferior pelvis. It contains three features on its posterior side: the superior **ischial spine**, the middle **lesser sciatic notch**, and the thick, inferior **ischial tuberosity**. The ischial tuberosities are the "butt bones," or the bones that bear your weight when you sit down.
3. **Pubis.** The pelvis' anterior portion is formed by the **pubis** (PYOO-bis) or the **pubic bone**. The pubis consists of a **body** and two extensions called the **superior** and **inferior rami**. The bodies of the two pubic bones meet at a fibrocartilage pad called the **pubic symphysis** (SIM-fih-sis). The angle that these bones form when they meet, called the **pubic arch**, can help to determine the sex of a skeleton (see the "Hints and Tips" box).

HINTS & TIPS

How to Determine Sex Based upon Pelvic Features

A skeleton's sex can be determined based upon the differences between the male and female pelvises. In general, the male and female pelvis can be distinguished by the features listed below, shown in Figure 7.26:

Feature	Female Pelvis	Male Pelvis
Pelvic inlet shape	Wider and oval-shaped	Narrower and heart-shaped
Pubic arch	Wide angle	Narrow angle
Acetabulae	Farther apart	Closer together
Ischial tuberosities	Everted	Inverted
Coccyx	Straighter, more movable	Curved anteriorly, less movable

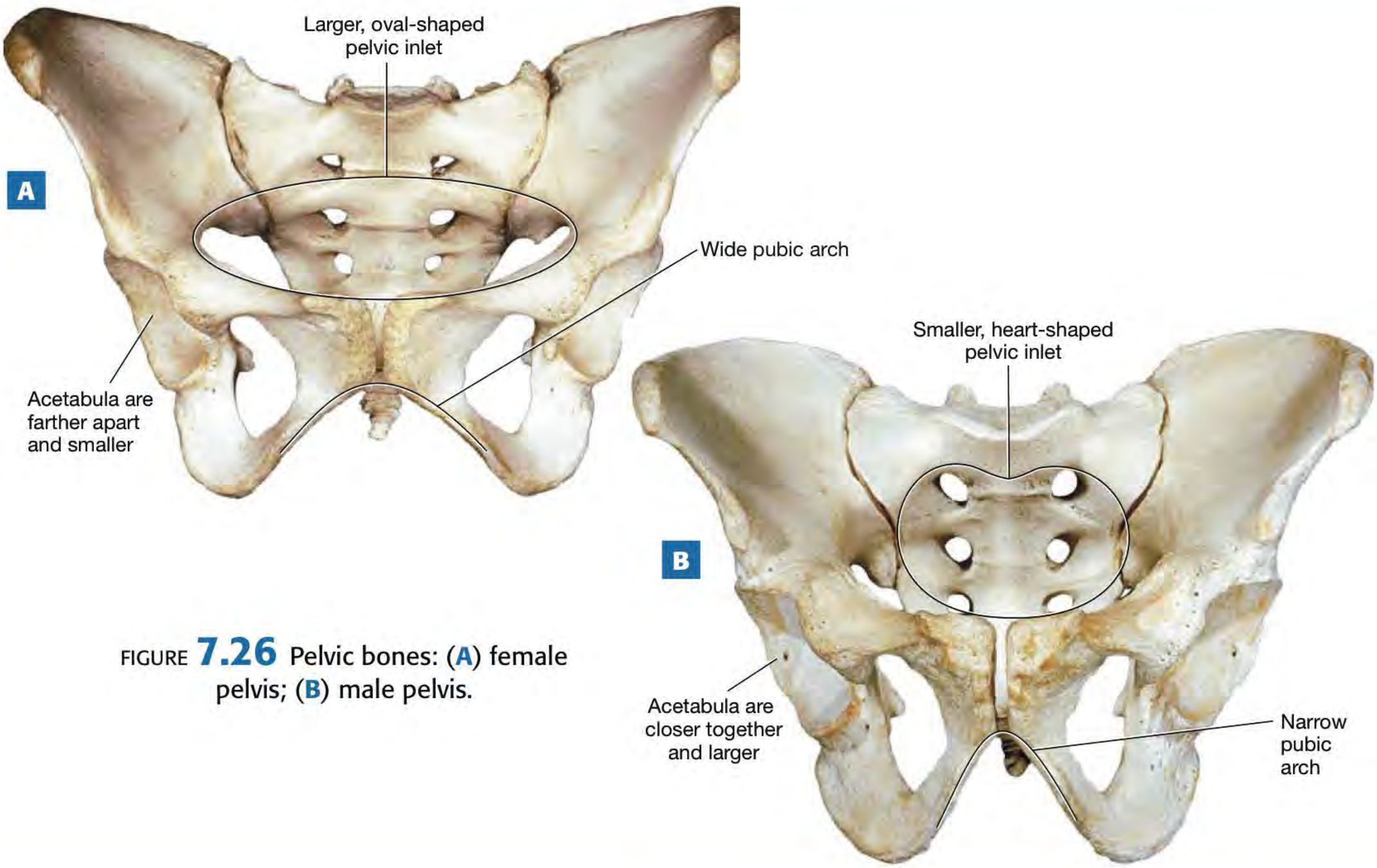


FIGURE **7.26** Pelvic bones: (**A**) female pelvis; (**B**) male pelvis.

Lower Limb

The lower limb consists of the thigh, the **patella** (kneecap), the leg, the ankle, and the foot. The thigh contains only a single bone, the large, heavy **femur** (Figure 7.27). Proximally, the femur articulates with the acetabulum at its rounded **head.** In the center of the femoral head we find a pit called the **fovea capitis** (FOH-vee-ah CAP-ih-tiss). This is the point of attachment for a ligament that holds the femur in the acetabulum. Just distal to the femoral head is the **neck** of the femur, the weakest part of the femur and the most common location for it to fracture (when the femoral neck fractures, it is usually called a "broken hip," even though the hip itself doesn't fracture). Where the femoral neck meets the femoral shaft, we find two large prominences—the anterolateral **greater trochanter** (TROH-kan-tur) and the posteromedial **lesser trochanter.** Between the two trochanters on the anterior side is a ridge called the **intertrochanteric line** (in-ter-troh-kan-TEHR-ik), and on the posterior side is another ridge in the same location known as the **intertrochanteric crest.**

The femoral diaphysis is mostly smooth, save for a few features that mark the attachment points for specific muscles on the posterior side:

- The proximal **gluteal tuberosity** is a rough projection that serves as the attachment spot for one of the gluteal muscles (the gluteus maximus).
- The **linea aspera** (LIN-ee-ah ASS-per-ah) is a prominent line that runs along the femoral diaphysis. It serves as an attachment point for many muscles that move the femur.
- Near the femoral epiphysis, the linea aspera splits into the **medial** and **lateral supracondylar lines** (soo-prah-KAHN-dah-lar), where hamstring muscles attach to the femur.

Distally, the femur expands into two small projections, the **medial** and **lateral epicondyles** (ep-ee-KAHN-dylz), distal to which we find the large the **medial** and **lateral condyles,** which form the knee joint with the largest bone of the leg, the **tibia.** On the posterior side of the femur is a depression between the two condyles, the **intercondylar fossa.**

The **tibia** (TIB-ee-ah) is the medial and larger of the two leg bones (Figure 7.28). It is flattened proximally at its articular surface where its **medial** and **lateral condyles** fit together with those of the femur. Just distal to the condyles on the tibia's anterior surface is a rough projection called the **tibial tuberosity,** which is where the patellar ligament inserts. Along the

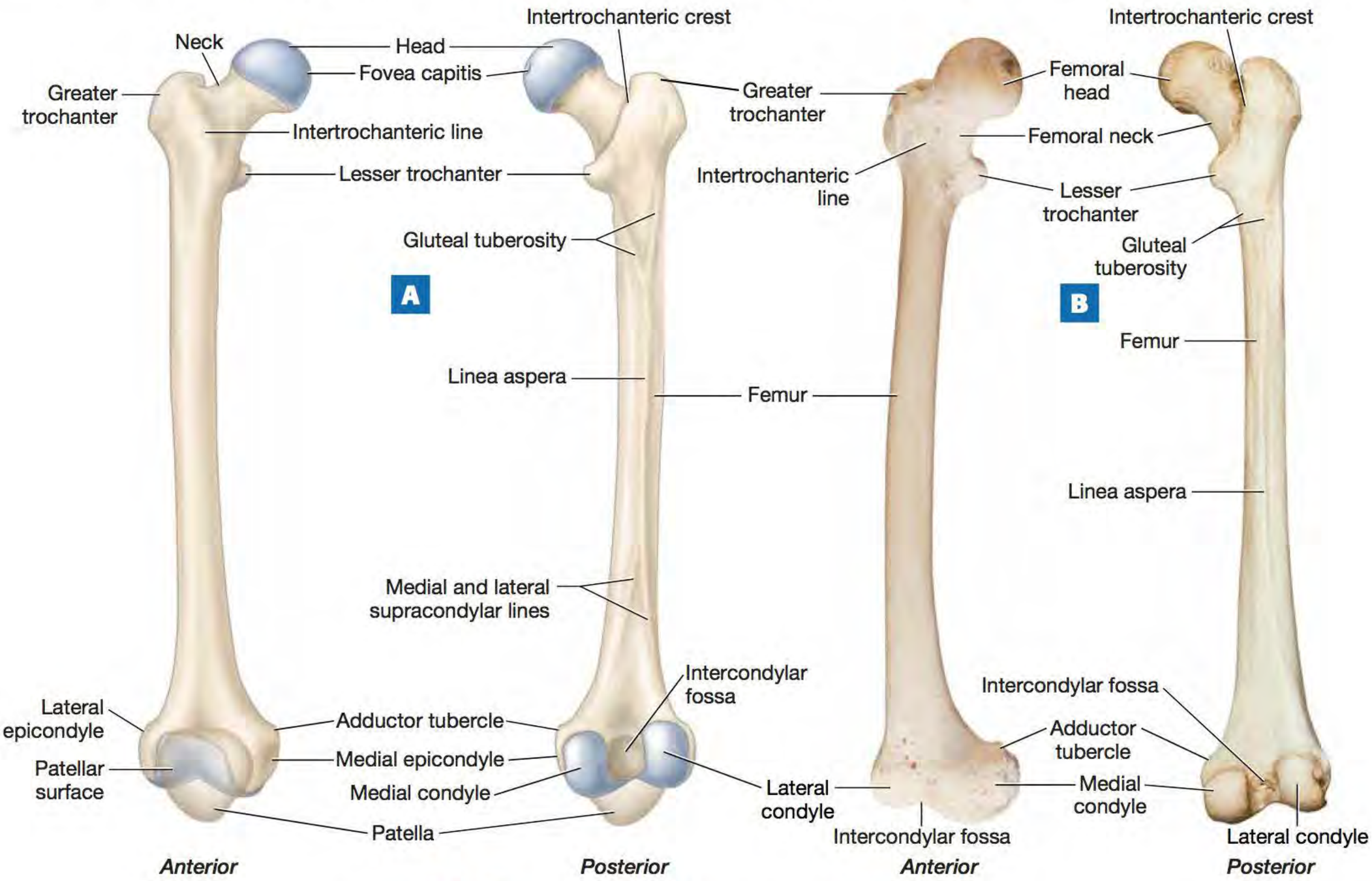


FIGURE **7.27** Right femur: (A) illustration; (B) photograph.

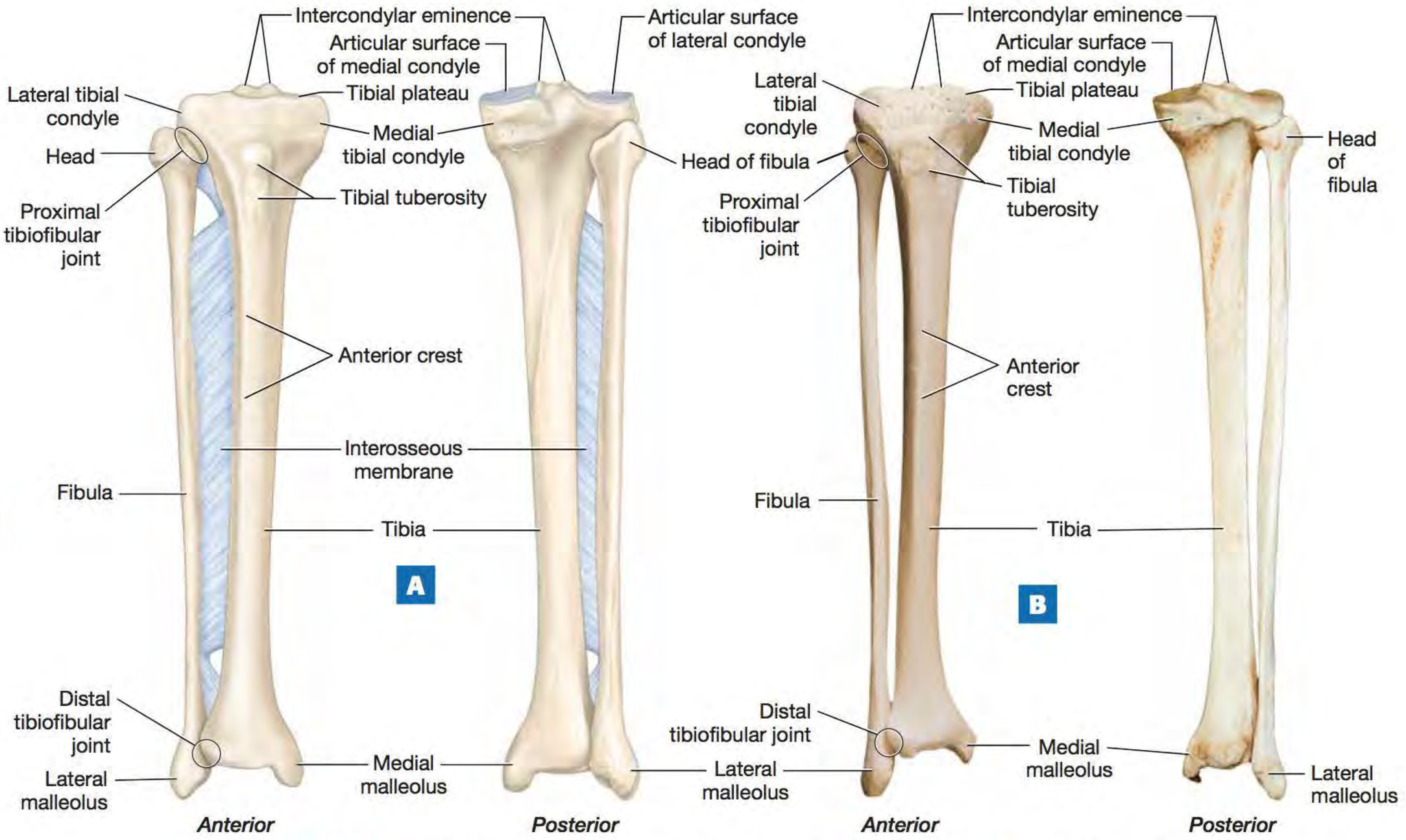


FIGURE **7.28** Right tibia and fibula, anterior view: (A) illustration; (B) photograph.

anterior tibial diaphysis is a sharpened ridge known as the **anterior crest,** which is commonly known as the "shin." At the tibia's distal epiphysis, it articulates with a tarsal bone called the **talus** (TAY-luss), with which it forms the ankle joint. At its terminal end is a projection called the **medial malleolus** (mal-ee-OH-lus), the medial ankle bone.

The other leg bone is the thin, lateral **fibula** (FIB-yoo-lah). The proximal fibular end is called the **head,** and its distal end is the **lateral malleolus** (*lateral ankle bone*). It articulates with the lateral side of the tibia at *proximal* and *distal tibiofibular joints*.

The ankle is composed of seven short bones called **tarsals,** labeled individually in Figure 7.29. The tarsals articulate distally with the five long bones in the foot called **metatarsals.** Like the bones of the fingers, the bones of the toes also consist of 14 **phalanges.** The second through fifth digits have three phalanges each (the *proximal*, *intermediate* [or *middle*], and *distal phalanges*); and the big toe or *hallux* has only two (a *proximal* and a *distal phalanx*).

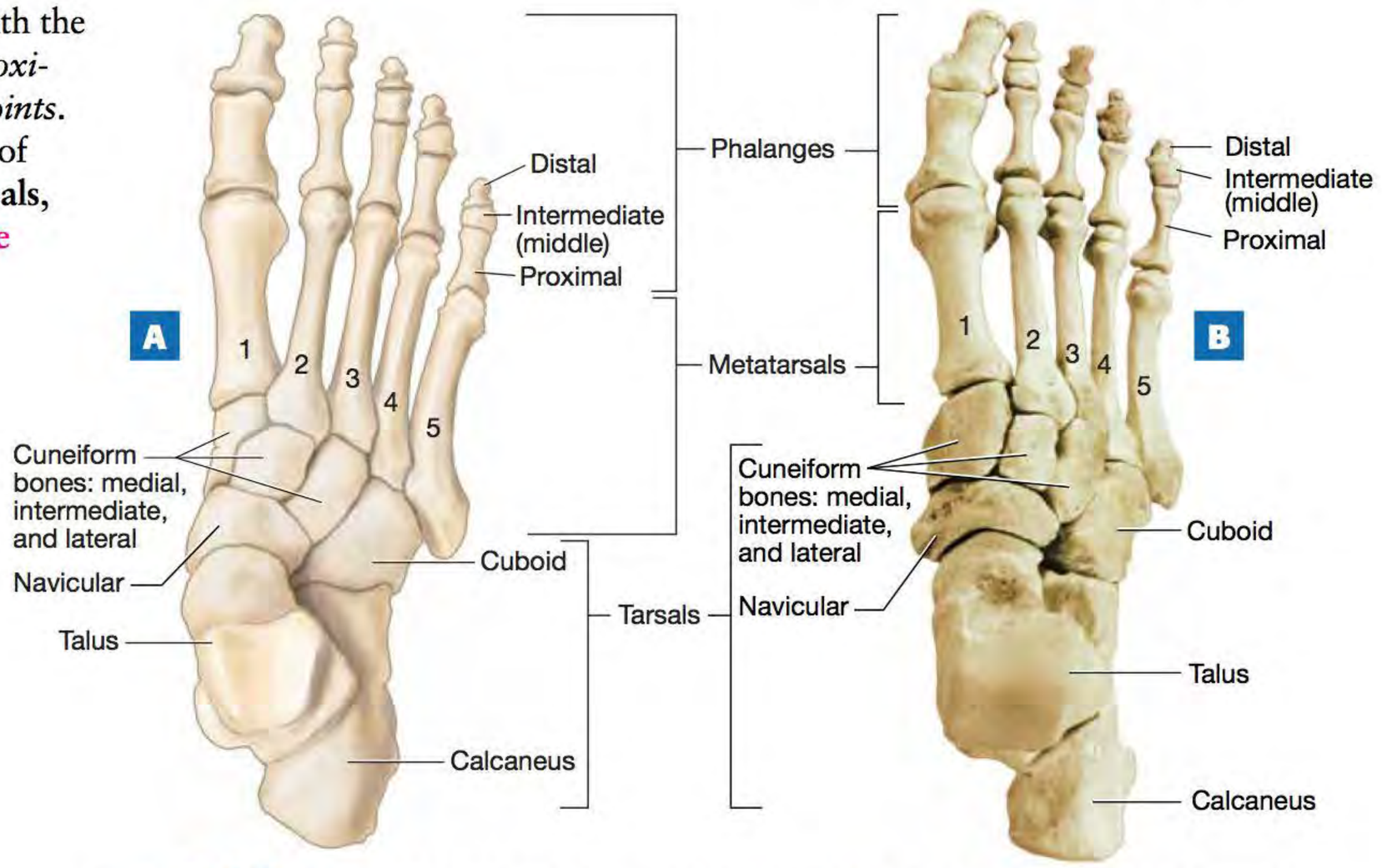


FIGURE **7.29** Right foot and ankle, superior view: (A) illustration; (B) photograph.

Procedure 1 Cooperative Learning for the Axial and Appendicular Skeletons

We will follow essentially the same procedure here as we did in Exercise 7-1, but with different groups of bones and bone markings. Note that this cooperative learning exercise includes the structures from Exercises 7-2 and 7-3. When you have completed this activity, answer Check Your Understanding questions 4 through 6 (p. 184).

1. Assemble into groups with a minimum of four students; five is optimum.
2. Distribute a bone or set of bones to each member of the group, and assign each student one of the following five groups of bones and bone markings (the specific structures of each bone are listed below and on the following page:

   Group A: cervical, thoracic, and lumbar vertebrae and vertebral markings; ribs and rib markings; sternum structures and the hyoid bone

   Group B: scapula structures, clavicle structures, humerus structures

   Group C: radius and ulna markings, carpals, metacarpals, and phalanges

   Group D: ilium, ischium, and pubis structures, and the difference between the male and female pelvises

   Group E: femur, tibia, fibula structures, tarsals, metatarsals, phalanges.
3. Spend approximately 3 minutes learning the assigned structures on your own.
4. Ask each student to spend approximately 1 to 2 minutes teaching the group his or her assigned structures.
5. Rotate the assigned structures clockwise so each student has a new set of structures to learn (the student that was assigned group A will take group B, and so on).
6. Spend approximately 2 to 3 minutes learning your newly assigned structures.
7. Then ask each student to take approximately 1 to 2 minutes to teach the group his or her assigned structures.
8. Repeat this process (it begins to speed up significantly at this point) until each student has been taught each group of structures once. By the end of this "game," each group member will have learned and presented each group of structures.

The following is a list of bone and bone markings of the appendicular skeleton covered in this exercise.

Remaining Structures of the Axial Skeleton

Group A Structures

1. Vertebral column
   a. Intervertebral foramina
   b. Cervical curvature
   c. Lumbar curvature
   d. Thoracic curvature
   e. Sacral curvature
2. Vertebrae
   a. Spinous process
   b. Transverse processes
   c. Vertebral foramen
   d. Vertebral body
   e. Intervertebral disc
   f. Pedicle
   g. Lamina
3. Cervical vertebrae
   a. Transverse foramina
   b. Atlas
   c. Axis
   d. Dens
4. Thoracic vertebrae
   a. Costal (articular) facets
5. Lumbar vertebrae
6. Sacrum
   a. Sacral promontory
   b. Sacral canal
   c. Median sacral crest
   d. Anterior sacral foramina
   e. Posterior sacral foramina
   f. Sacroiliac joints
7. Coccyx
8. Sternum
   a. Manubrium
   b. Body
   c. Xiphoid process
9. Ribs
   a. Intercostal spaces
   b. Costal cartilage
   c. True ribs
   d. False ribs
   e. Floating ribs
   f. Costal margin
   g. Superior and inferior facets
   h. Head of rib
   i. Neck of rib
   j. Tubercle
   k. Angle of rib
   l. Shaft of rib
   m. Costal groove
10. Hyoid bone

Pectoral Girdle and Upper Limb

Group B Structures

1. Scapula
   a. Superior, lateral, and medial borders
   b. Superior, lateral, and inferior angles
   c. Body
   d. Subscapular fossa
   e. Glenoid cavity
   f. Coracoid process
   g. Acromion
   h. Spine
   i. Supraspinous fossa
   j. Infraspinous fossa
2. Clavicle
   a. Acromial end
   b. Sternal end
3. Humerus
   a. Head
   b. Greater tubercle
   c. Lesser tubercle
   d. Intertubercular groove
   e. Deltoid tuberosity
   f. Medial and lateral epicondyles
   g. Capitulum
   h. Trochlea
   i. Olecranon fossa
   j. Coronoid fossa

Group C Structures

1. Ulna
   a. Olecranon process
   b. Coronoid process
   c. Trochlear notch
   d. Radial notch
   e. Ulnar head
   f. Styloid process
2. Radius
   a. Radial head
   b. Ulnar notch
   c. Radial neck
   d. Radial tuberosity
   e. Styloid process
3. Carpals
   a. Scaphoid
   b. Lunate
   c. Triquetrum
   d. Pisiform
   e. Trapezium
   f. Trapezoid
   g. Capitate
   h. Hamate
4. Metacarpals
5. Phalanges

Pelvic Girdle and Lower Limb

Group D Structures

1. Pelvis
   a. Sacroiliac joints
   b. Pelvic inlet
   c. Pelvic brim
   d. Greater pelvis
   e. Lesser pelvis
   f. Pelvic outlet
2. Coxal bone (hemipelvis)
3. Acetabulum
4. Obturator foramen
5. Ilium
   a. Body
   b. Ala
   c. Iliac crest
   d. Anterior superior iliac spine
   e. Anterior inferior iliac spine
   f. Posterior superior iliac spine
   g. Posterior inferior iliac spine
   h. Greater sciatic notch
6. Ischium
   a. Ischial spine
   b. Lesser sciatic notch
   c. Ischial tuberosity
7. Pubis
   a. Body
   b. Superior and inferior rami
   c. Pubic symphysis
   d. Pubic arch
8. Male and female pelvises

Group E Structures

1. Femur
   a. Head
   b. Fovea capitis
   c. Neck
   d. Greater trochanter
   e. Lesser trochanter
   f. Intertrochanteric line and crest
   g. Gluteal tuberosity
   h. Linea aspera
   i. Medial and lateral supracondylar lines
   j. Lateral and medial epicondyles
   k. Medial and lateral condyles
   l. Intercondylar fossa
2. Patella
3. Tibia
   a. Medial and lateral condyles
   b. Tibial tuberosity
   c. Anterior crest
   d. Medial malleolus
4. Fibula
   a. Head
   b. Lateral malleolus
5. Tarsals
   a. Talus
   b. Calcaneus
   c. Navicular
   d. Cuboid
   e. Cuneiforms
6. Metatarsals
7. Phalanges

Your instructor may wish to omit certain structures included above or add structures not included in these lists. List any additional structures below:

Exercise 7-4

More Practice

MATERIALS

- ❑ Disarticulated bones in a box
- ❑ Skeleton, articulated
- ❑ Colored pencils

On average, the human body contains 206 bones and thousands of bone markings, processes, fossae, and foraminae. The previous cooperative learning exercises gave you a solid foundation on which to build your knowledge of the skeleton—but a good foundation is just a start. A lot more work is needed to actually build a house on that foundation. This exercise contains activities to help you build that "house" and practice what you learned in Exercises 7-1 through 7-3.

Procedure 1 Building a Skeleton

1. Obtain a set of disarticulated bones (real bones are best).
2. Assemble the bones into a full skeleton. (If you have an articulated vertebral column and rib cage, go ahead and use them.)
3. Be certain to keep your skeleton in anatomical position. Figure 7.30 gives an overall "big picture" view of the skeleton that you may use for reference.
4. Assemble the bones into a full skeleton.

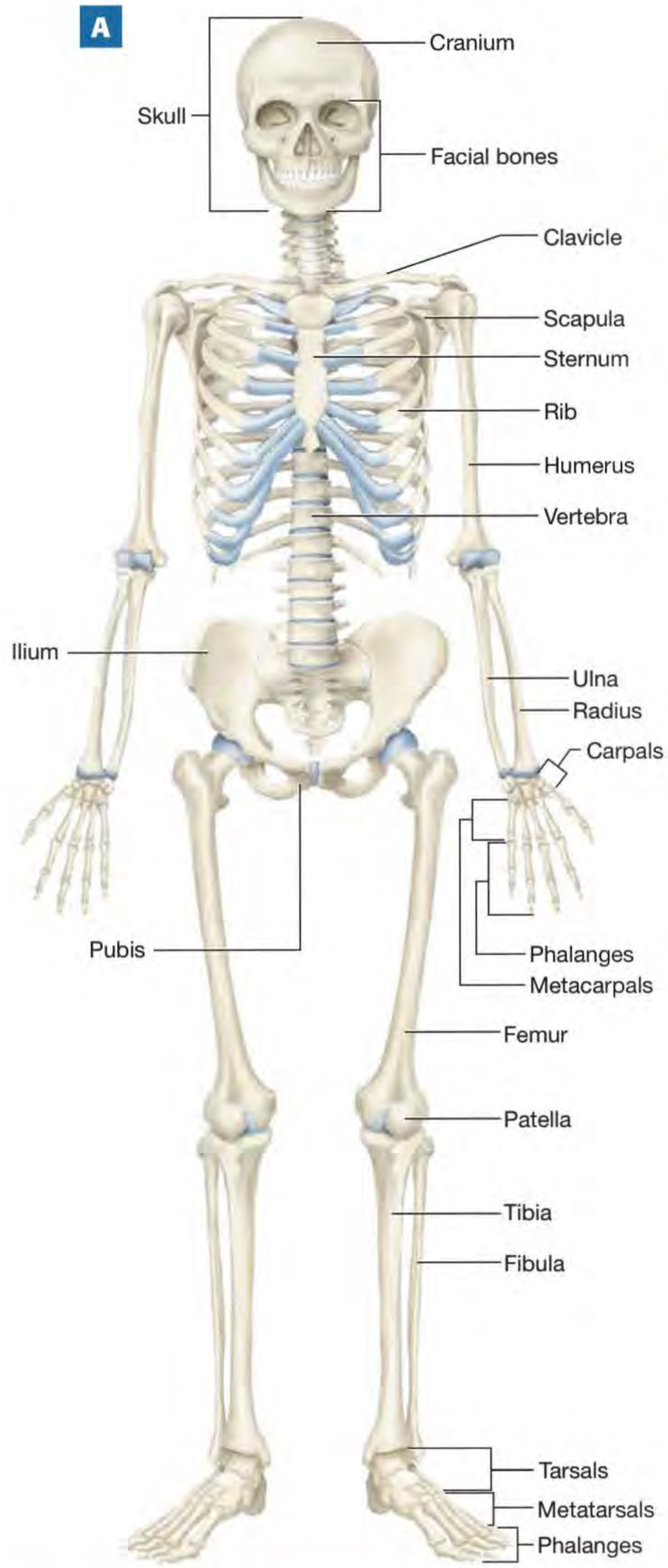


FIGURE **7.30** Articulated skeleton: (**A**) anterior view *(continues)*

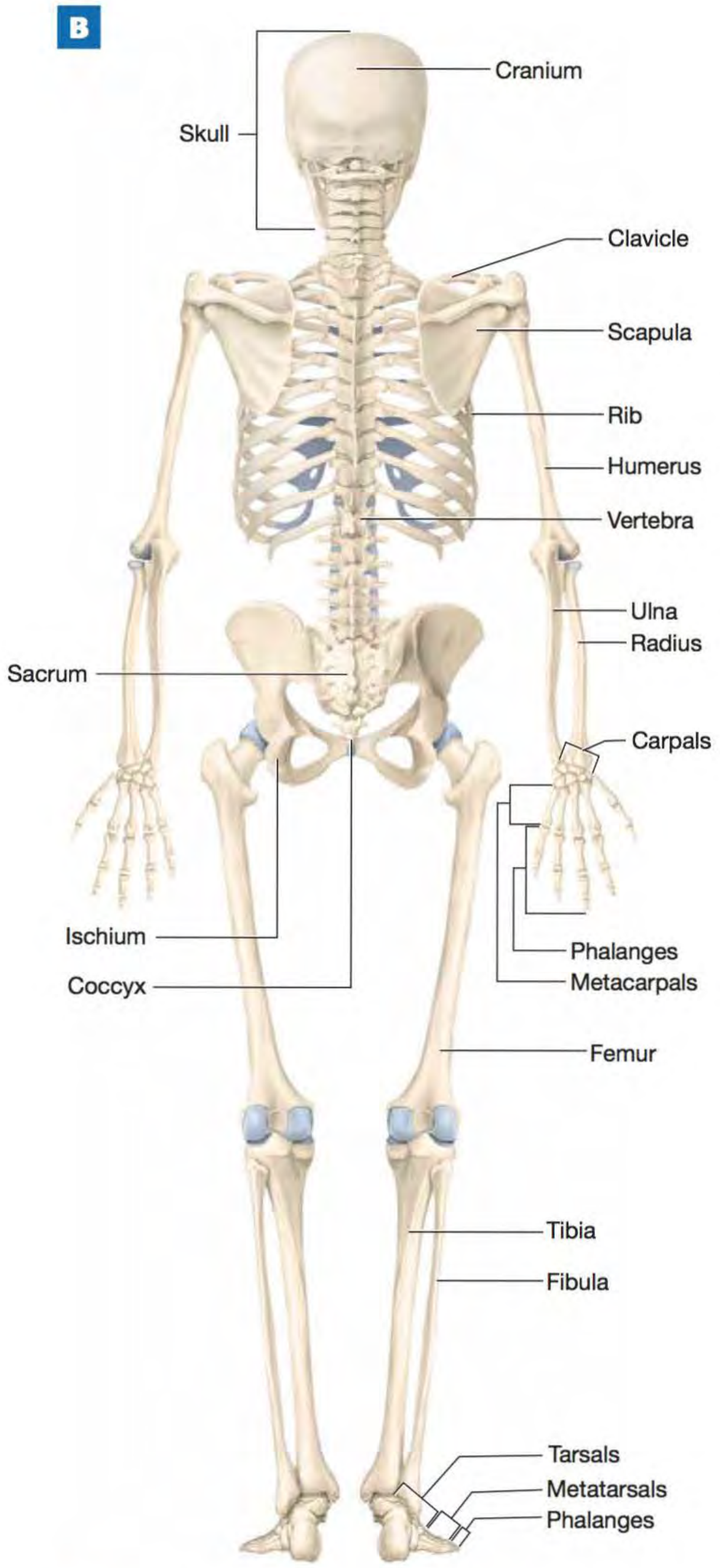


FIGURE **7.30** Articulated skeleton *(cont.)*: (**B**) posterior view.

Procedure 2 Identifying Bones Blindly

1. Place your set of disarticulated bones in a box.
2. Working with your lab partner, close your eyes, reach into the box, grab a bone randomly, and attempt to identify it only by its feel.
3. If you are unable to identify the bone, have your lab partner give you hints to help you work out the bone's identity.

Procedure 3 Comparing Bones on the Right and Left Sides

Examine the following bones, and figure out how you can determine if the bones are from the left or the right side of the body.

Femur

Tibia

Humerus

Scapula

Procedure 4 Time to Draw

Remember from your previous drawing exercises that drawing even the crudest picture of an anatomical structure or physiological pathway engages multiple parts of the brain and greatly enhances memory. So, with that in mind:

1. Draw a skull and a skeleton in the spaces provided.
2. Label and color your drawings.

These drawings are not meant to be works of art, so don't worry if you aren't even remotely skilled as an artist (however, if they turn out well, feel free to take them out of your lab book and put them on your refrigerator).

1 Skull: anterior view

2 Skull: lateral view

3 Skeleton: anterior view

7

Name _____

Section _____ Date _____

UNIT 7 REVIEW

Check Your Recall

1 Label the following bones in Figure 7.31.

- ❑ Clavicle
- ❑ Femur
- ❑ Fibula
- ❑ Humerus
- ❑ Ilium
- ❑ Metacarpals
- ❑ Pubis
- ❑ Radius
- ❑ Sternum
- ❑ Tarsals
- ❑ Tibia
- ❑ Ulna

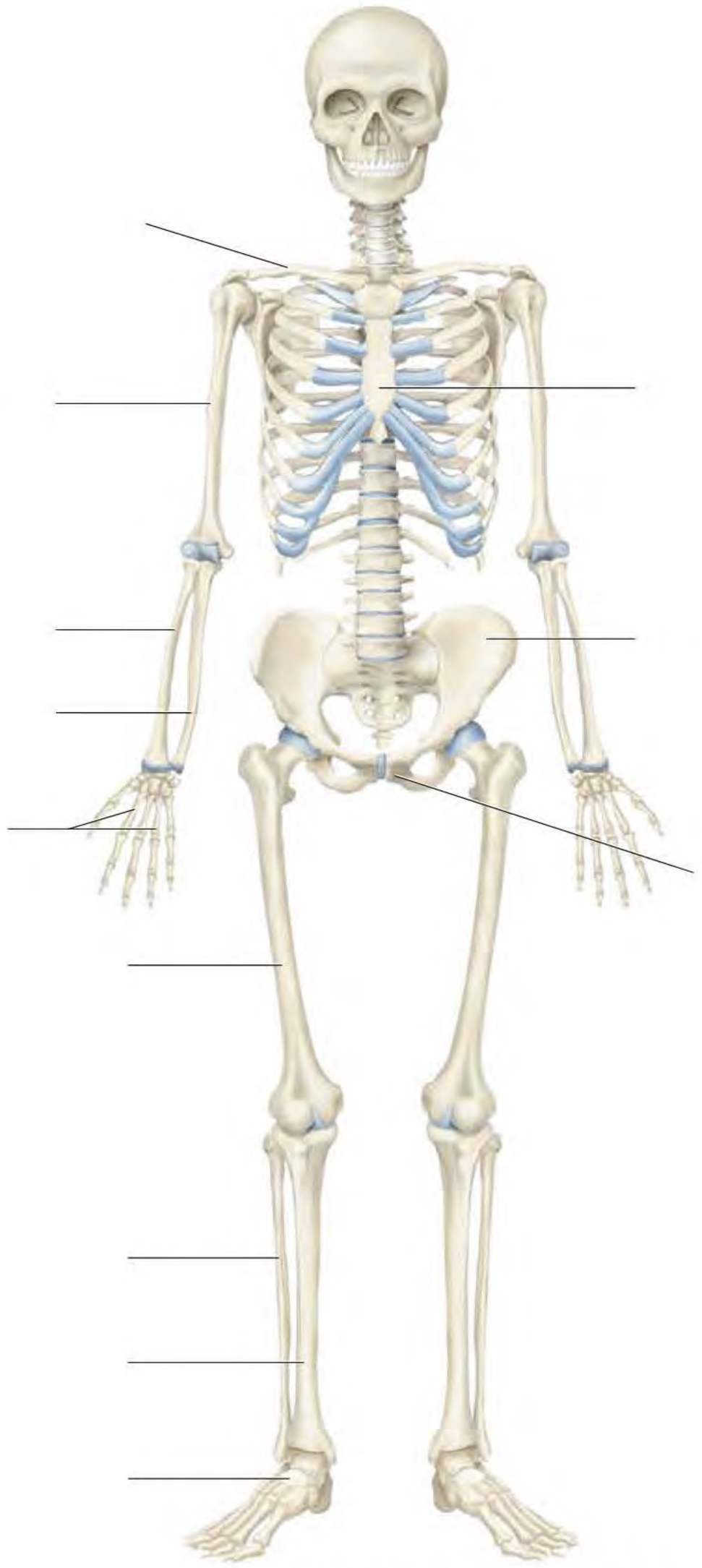


FIGURE **7.31** Anterior view of the skeleton.

2 Label the following bones of the skull in Figure 7.32.

- ❑ Ethmoid bone
- ❑ Frontal bone
- ❑ Inferior nasal concha
- ❑ Lacrimal bone
- ❑ Mandible
- ❑ Maxilla
- ❑ Nasal bones
- ❑ Occipital bone
- ❑ Palatine bone
- ❑ Parietal bone
- ❑ Sphenoid bone
- ❑ Temporal bone
- ❑ Vomer
- ❑ Zygomatic bone

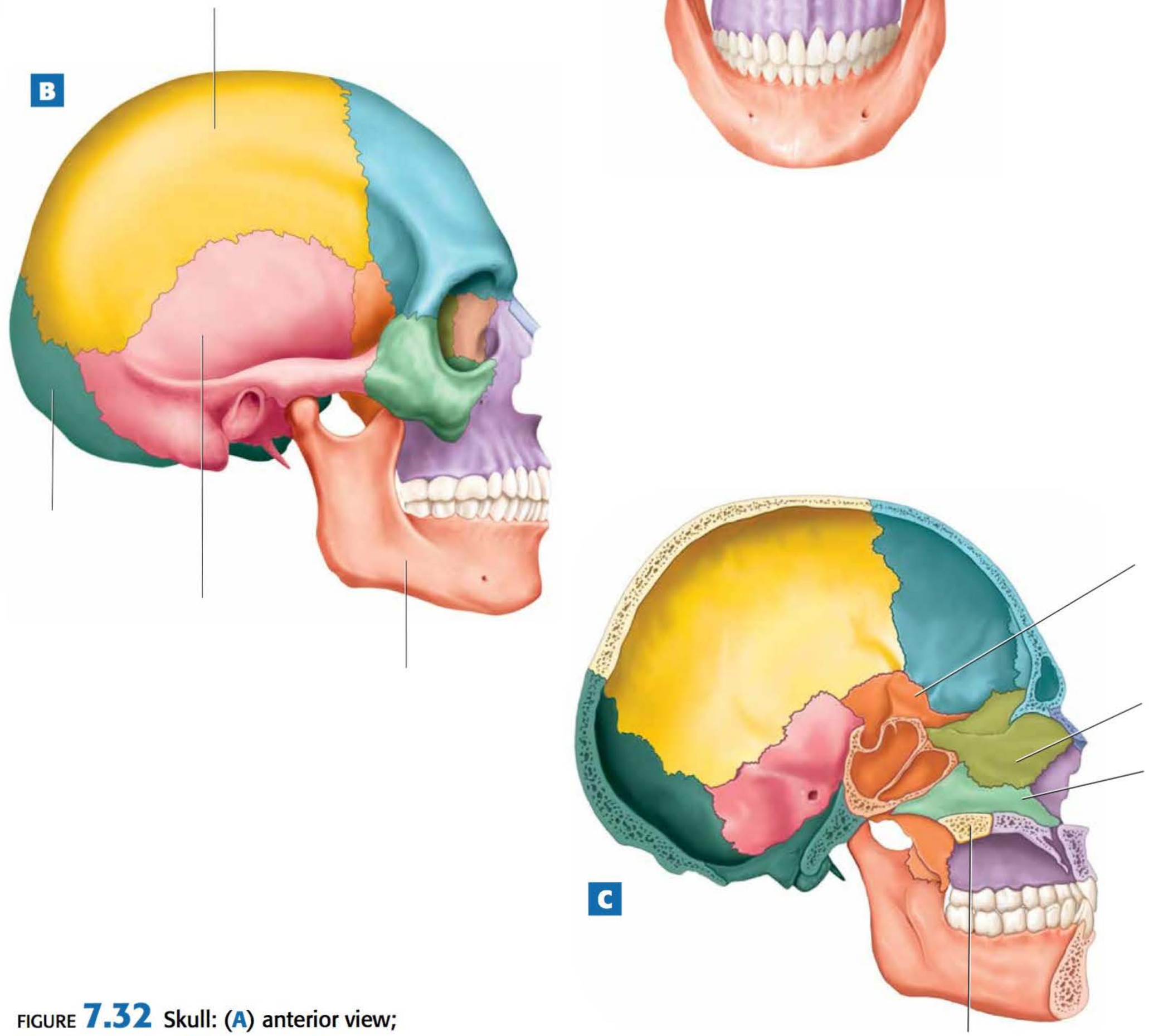


FIGURE **7.32** Skull: (**A**) anterior view; (**B**) lateral view; (**C**) midsagittal section.

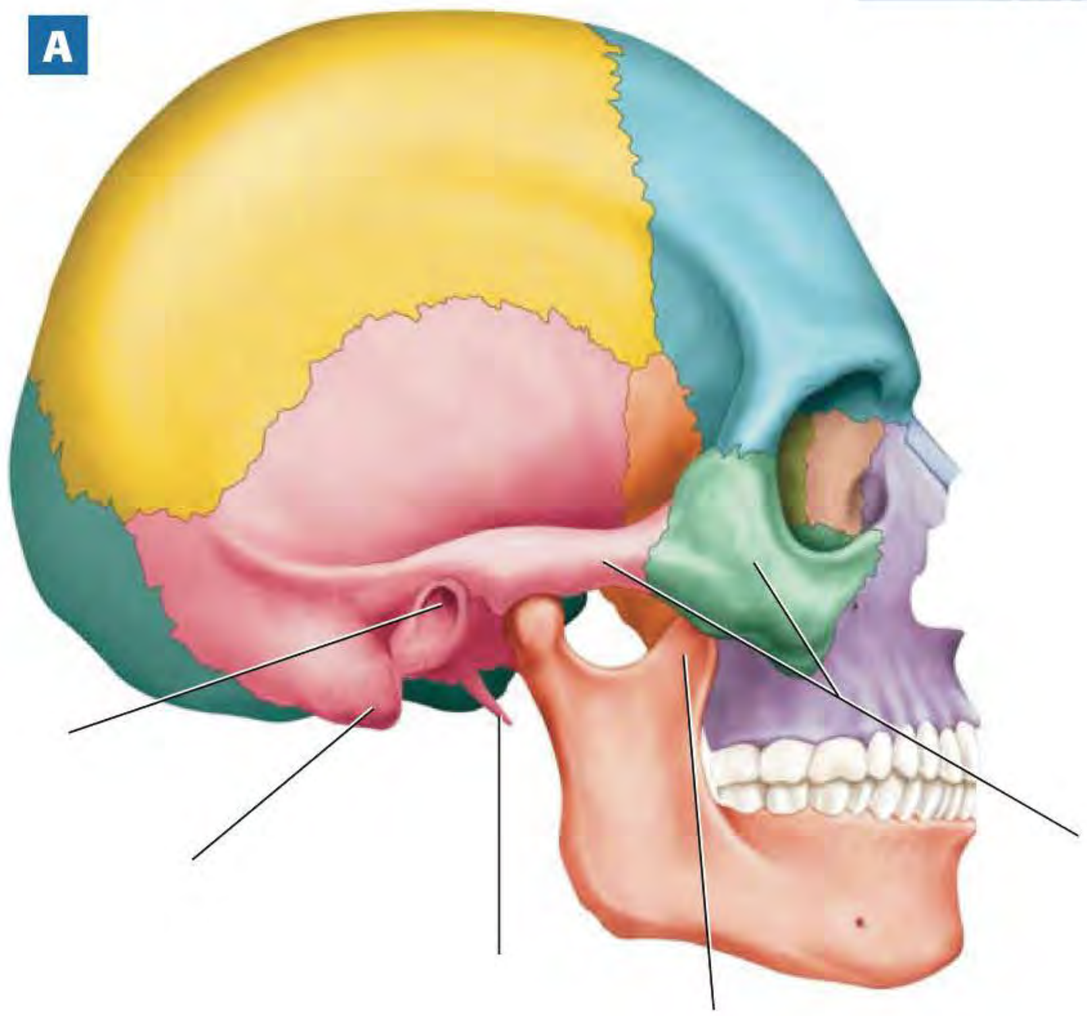
Name _____

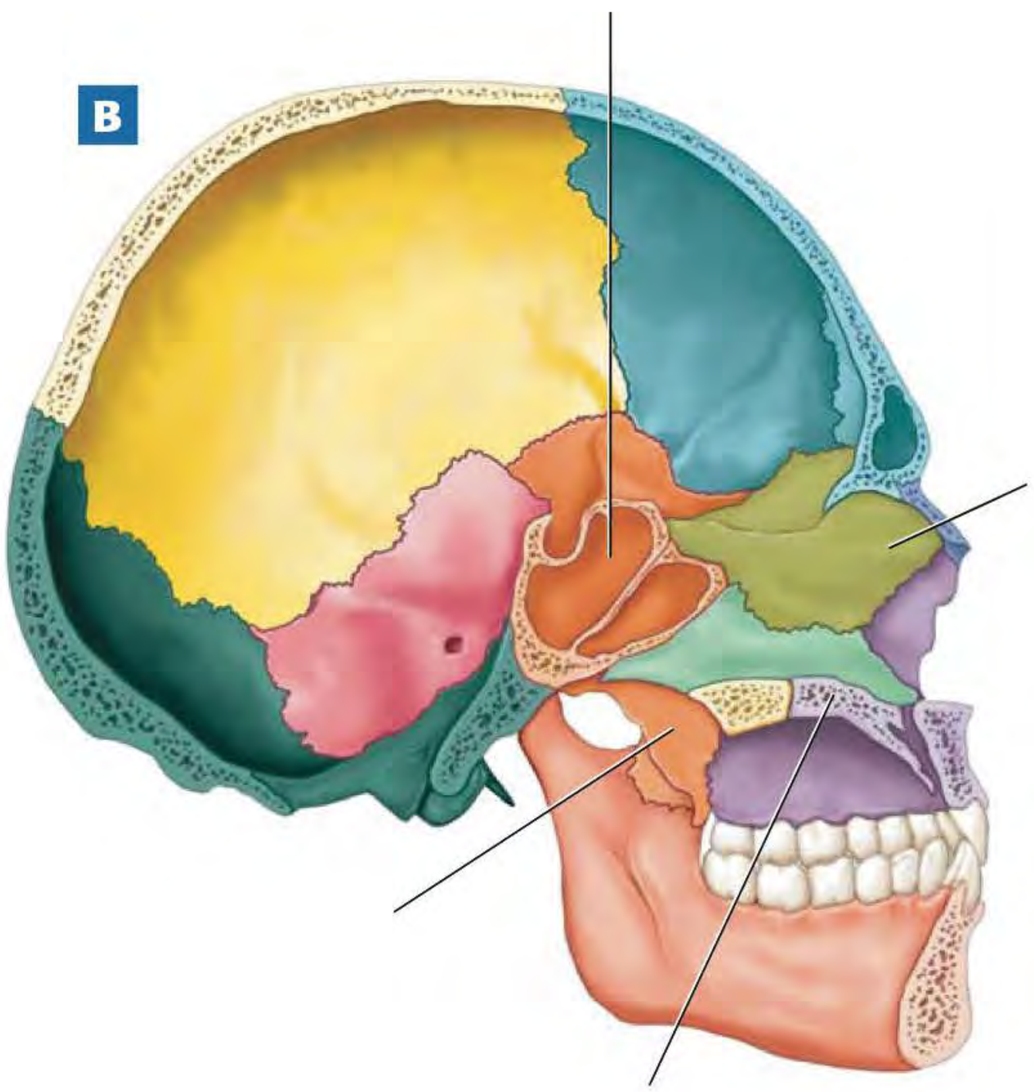
Section _____ Date _____

UNIT 7

3 Label the following skull markings and processes in Figure 7.33.

- ❑ Cribriform plate
- ❑ External acoustic meatus
- ❑ Jugular foramen
- ❑ Pterygoid process
- ❑ Mastoid process
- ❑ Palatine process of maxilla
- ❑ Perpendicular plate of ethmoid bone
- ❑ Sella turcica
- ❑ Sphenoid sinus
- ❑ Styloid process
- ❑ Coronoid process





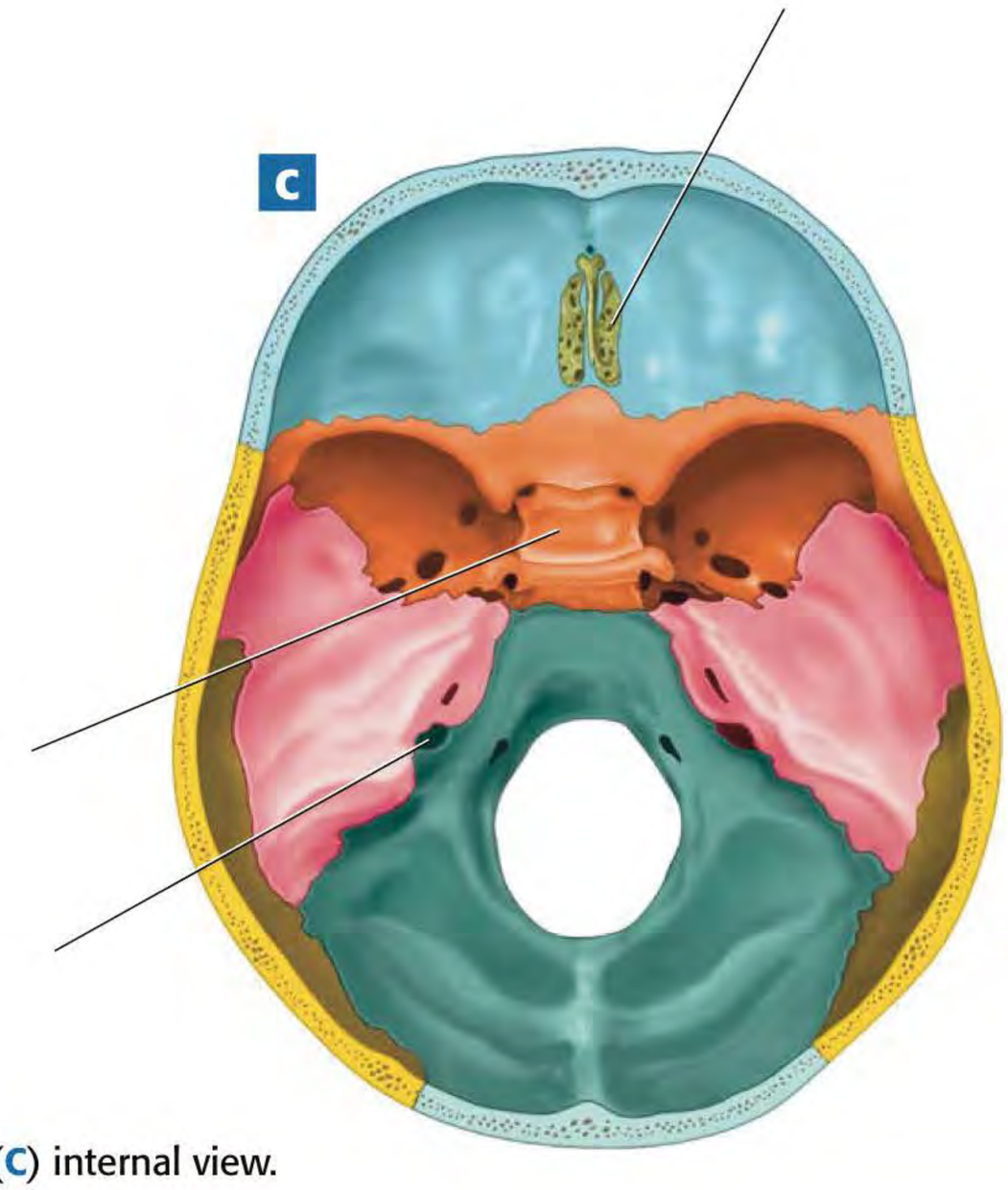


FIGURE **7.33** Skull: (A) lateral view; (B) midsagittal section; (C) internal view.

4 Label the following parts of the vertebral column in Figure 7.34.

- ❑ Atlas
- ❑ Axis
- ❑ Cervical vertebrae
- ❑ Coccyx
- ❑ Lumbar vertebrae
- ❑ Sacrum
- ❑ Thoracic vertebrae
- ❑ Cervical curvature
- ❑ Lumbar curvature
- ❑ Sacral curvature

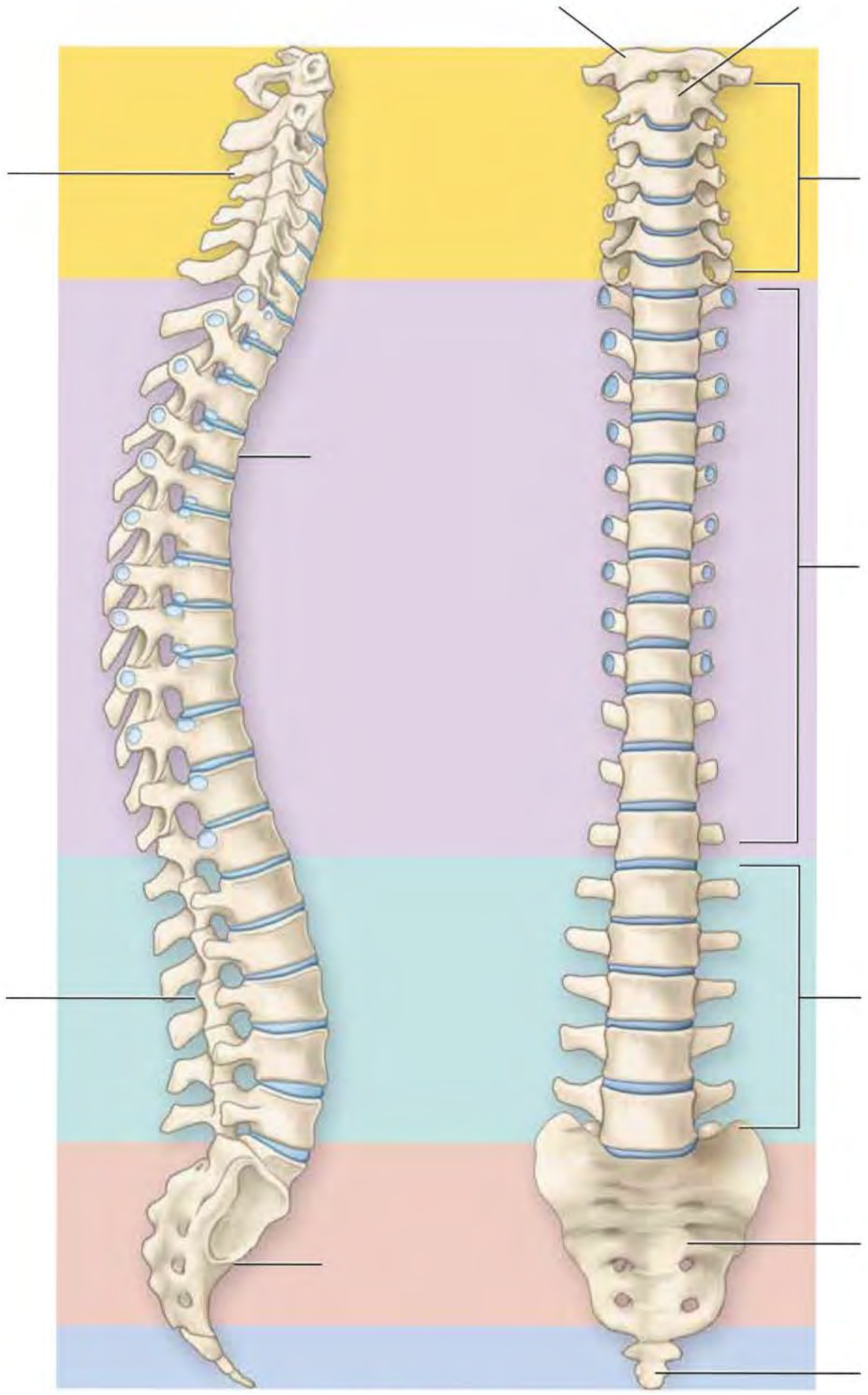


FIGURE **7.34** Vertebral column.

Name _____

Section _____ Date _____

UNIT 7

5 Label the following parts of the axial skeleton in Figure 7.35.

- ❑ False ribs
- ❑ Manubrium
- ❑ Xiphoid process
- ❑ Floating ribs
- ❑ True ribs

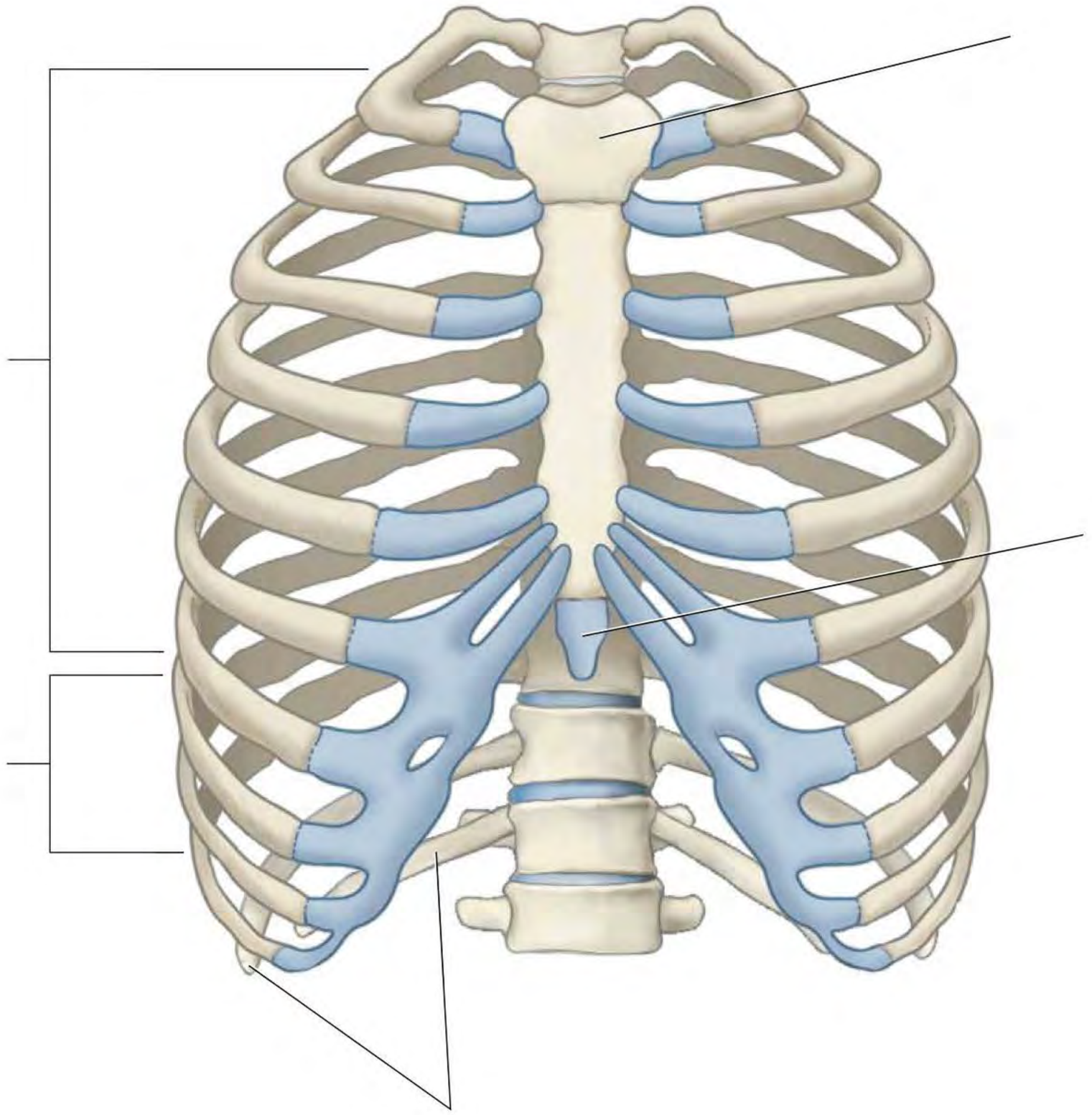


FIGURE **7.35** Thoracic cage.

6 Identify each of the following vertebrae in Figure 7.36 as being cervical, thoracic, or lumbar. Additionally, explain how you arrived at this conclusion.

a _____

_____

b _____

_____

c _____

_____

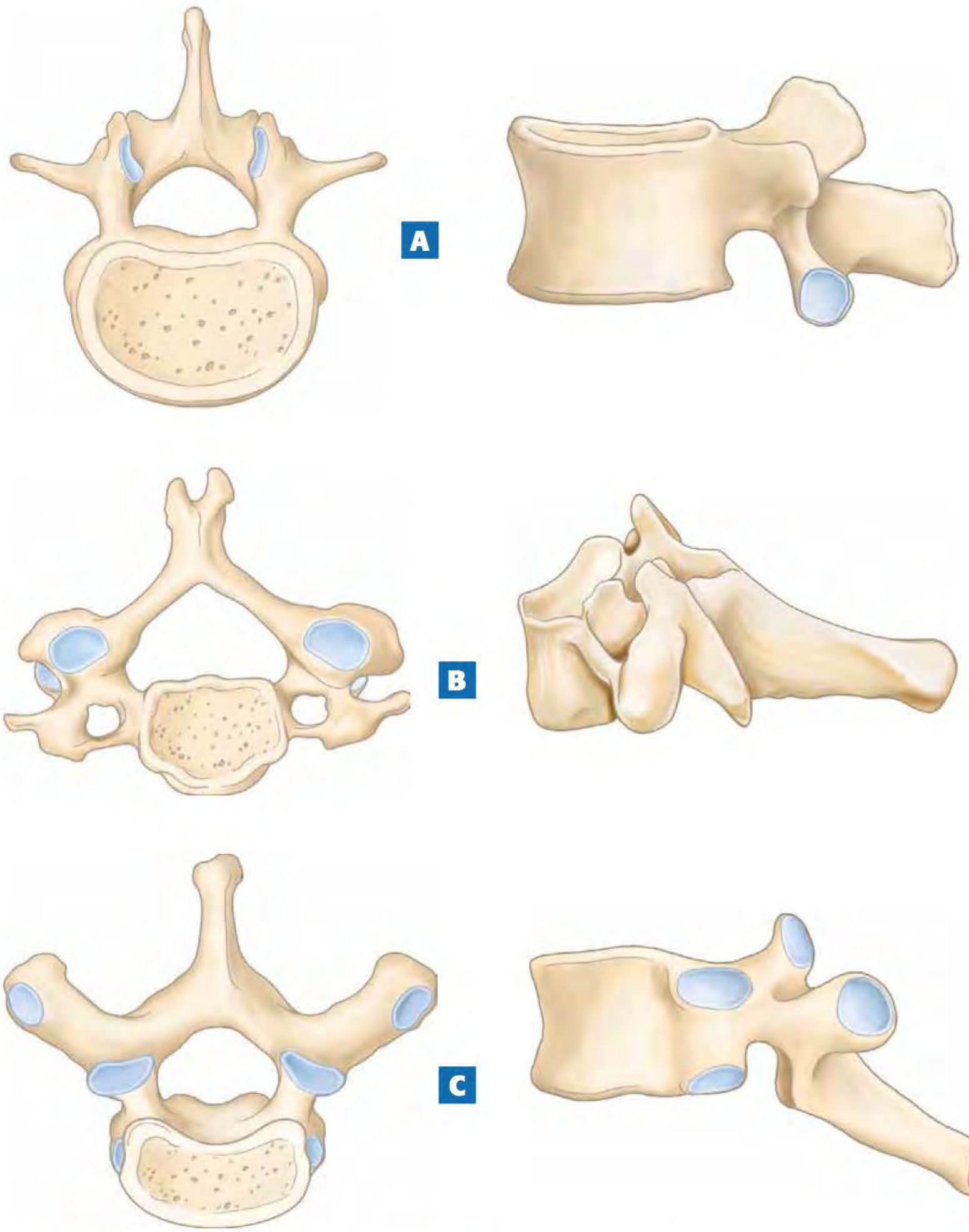


FIGURE **7.36** (A) Unknown vertebra 1; (B) unknown vertebra 2; (C) unknown vertebra 3.

Name _____

Section _____ Date _____

UNIT 7

7 Label the following parts of the scapula in Figure 7.37.

- ❑ Acromion
- ❑ Supraspinous fossa
- ❑ Subscapular fossa
- ❑ Spine
- ❑ Coracoid process
- ❑ Infraspinous fossa
- ❑ Glenoid cavity

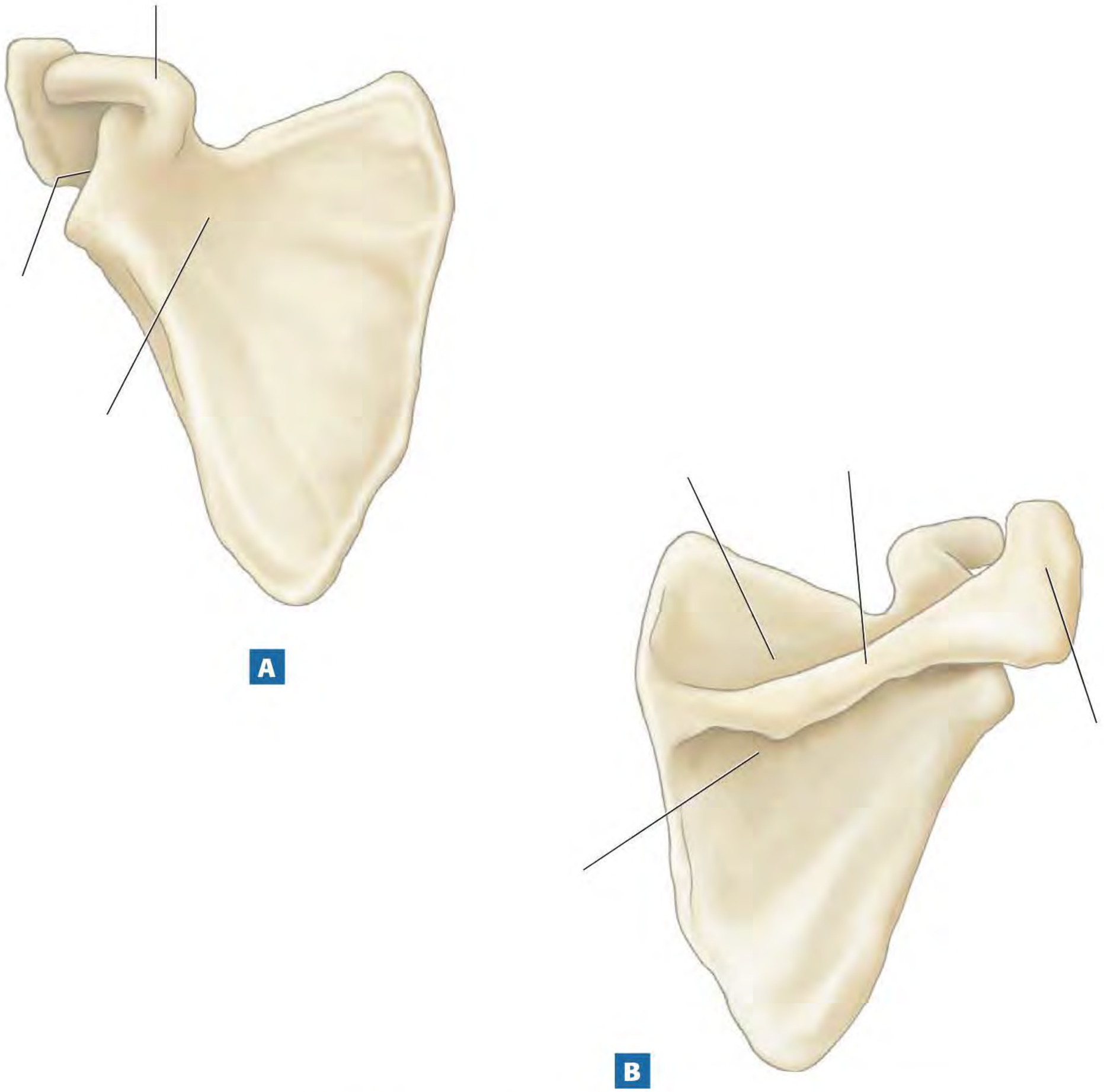


FIGURE **7.37** Scapula: (A) anterior view; (B) posterior view.

8 Label the following parts of the upper limb in Figure 7.38.

- ❑ Capitulum
- ❑ Coronoid process
- ❑ Deltoid tuberosity
- ❑ Greater tubercle
- ❑ Head
- ❑ Intertubercular sulcus
- ❑ Olecranon
- ❑ Radial head
- ❑ Styloid process
- ❑ Trochlea
- ❑ Trochlear notch

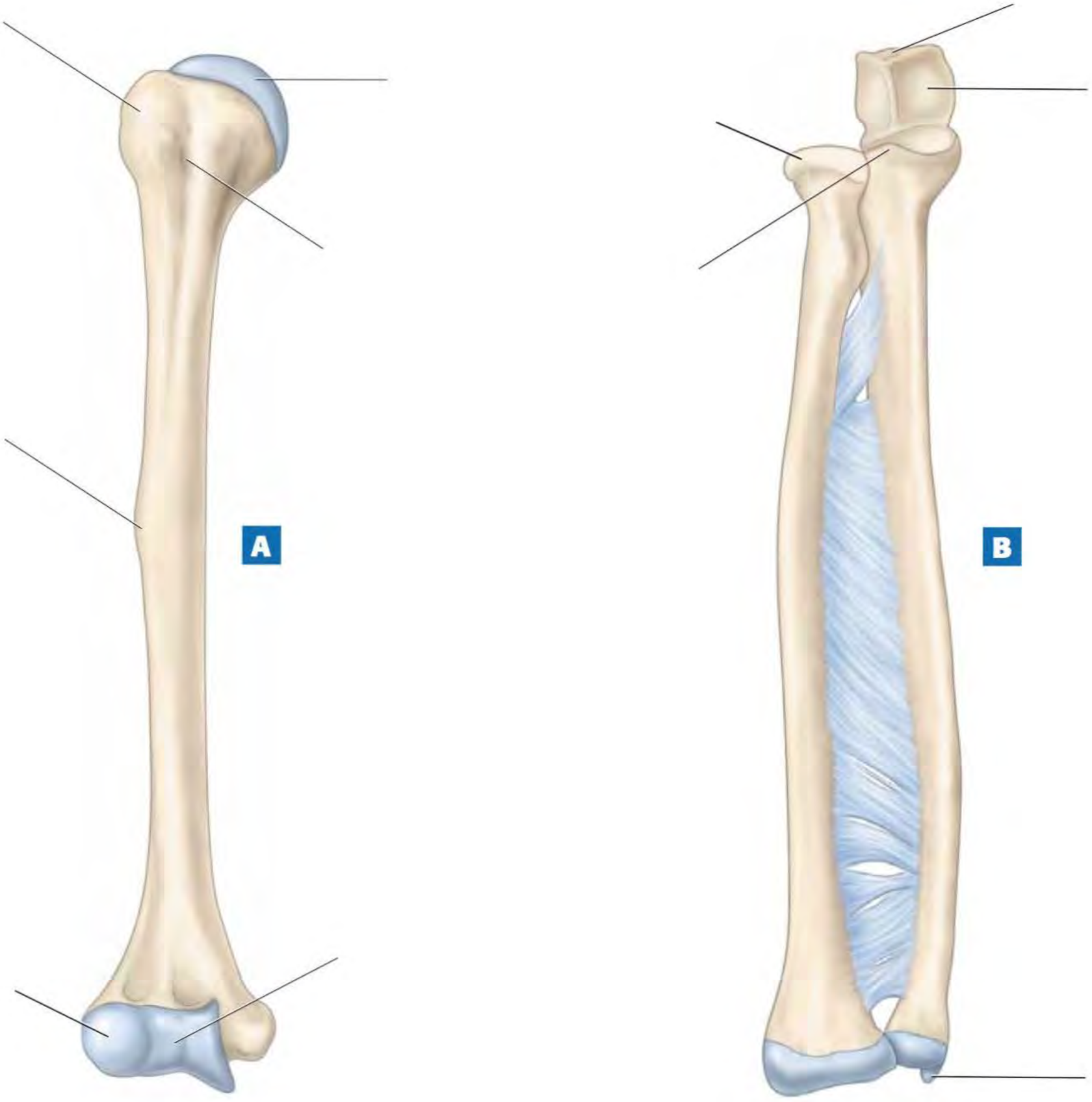


FIGURE **7.38** Upper limb: (**A**) arm, anterior view; (**B**) forearm, anterior view.

Name _____

Section _____ Date _____

UNIT 7

9 Label the following parts of the coxal bone (hemipelvis) in Figure 7.39.

- ❑ Acetabulum
- ❑ Anterior superior iliac spine
- ❑ Greater sciatic notch
- ❑ Iliac crest
- ❑ Ilium
- ❑ Ischial tuberosity
- ❑ Ischium
- ❑ Obturator foramen
- ❑ Pubis
- ❑ Posterior superior iliac spine
- ❑ Ischial spine

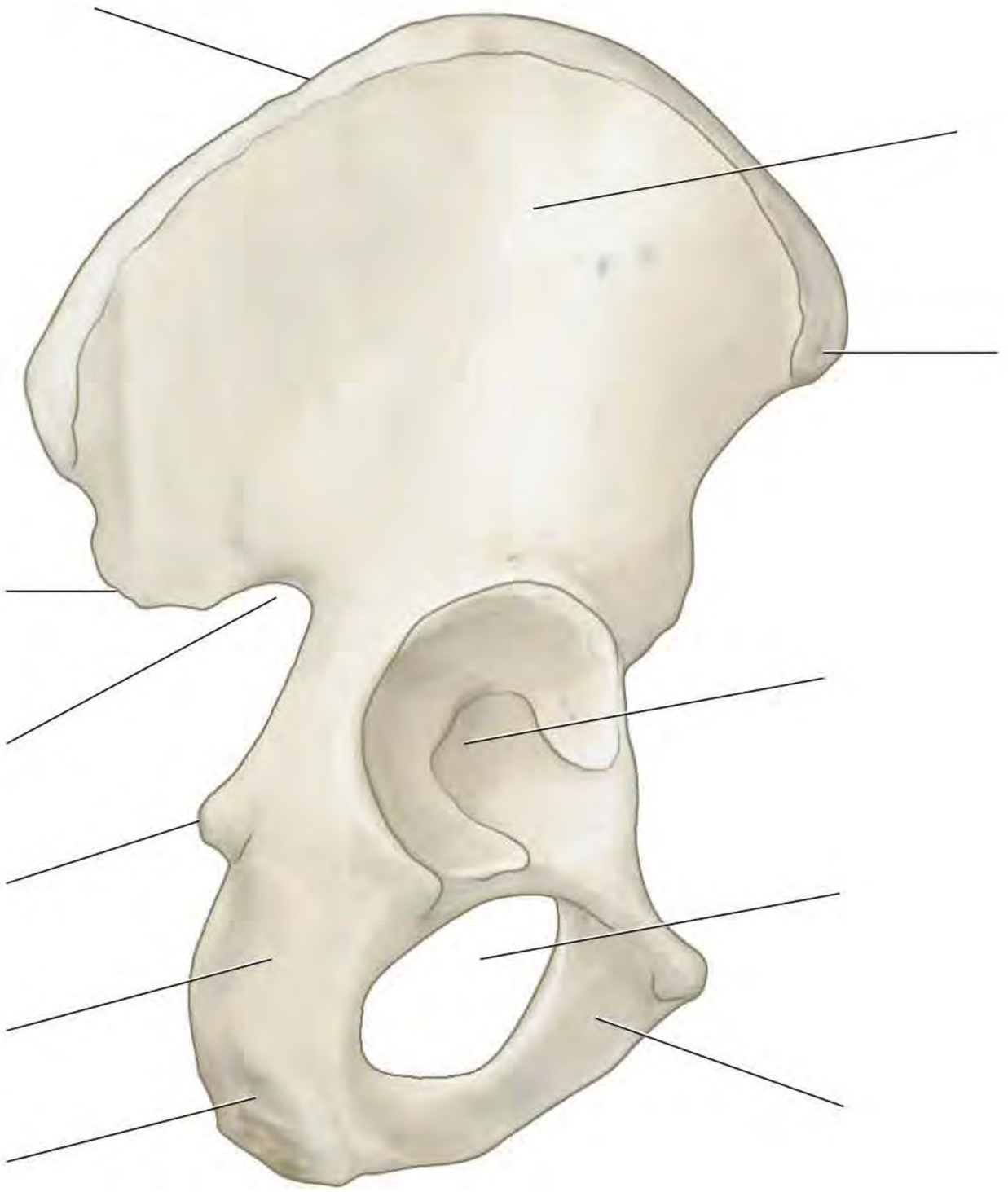
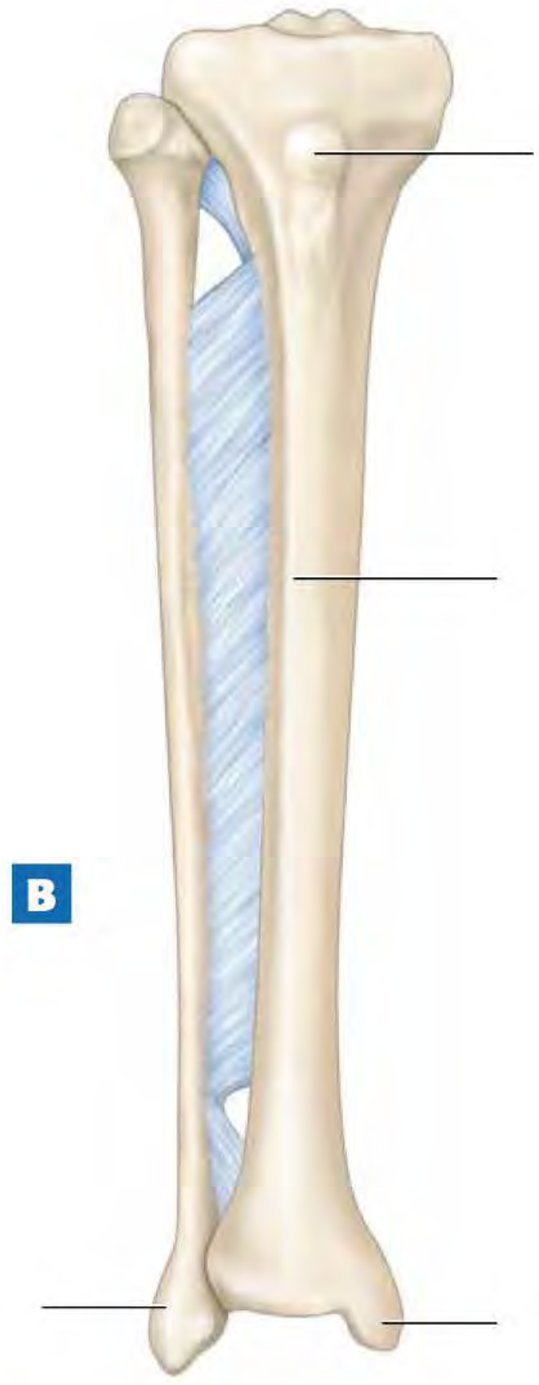


FIGURE **7.39** Right coxal bone, lateral view.

10 Label the following parts of the lower limb in Figure 7.40.

- ❑ Greater trochanter
- ❑ Femoral head
- ❑ Lateral femoral condyle
- ❑ Lateral malleolus
- ❑ Lesser trochanter
- ❑ Medial femoral condyle
- ❑ Medial malleolus
- ❑ Femoral neck
- ❑ Tibial tuberosity
- ❑ Intertrochanteric line
- ❑ Anterior crest
- ❑ Calcaneus
- ❑ Talus
- ❑ Metatarsals



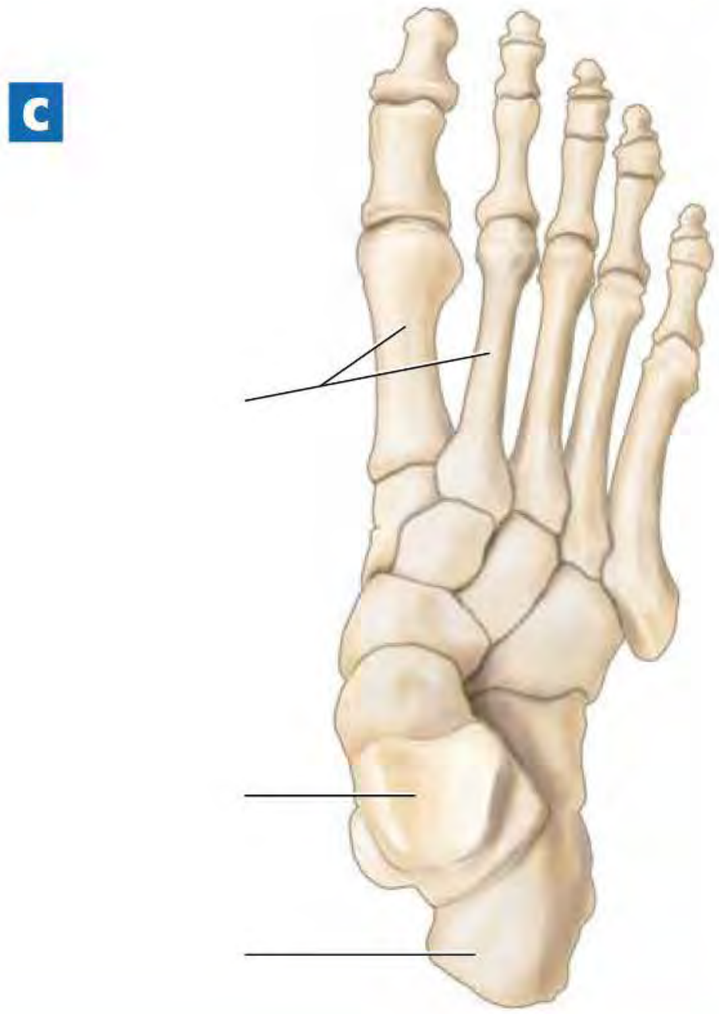
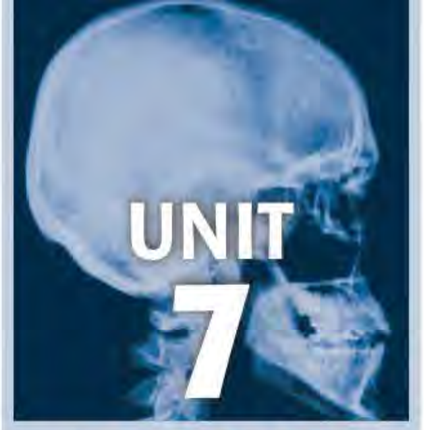


FIGURE **7.40** Lower limb: (**A**) thigh, anterior view; (**B**) leg, anterior view; (**C**) right foot, superior view.

Name _____

Section _____ Date _____



Check Your Understanding

Critical Thinking and Application Questions

1 Which bones potentially could be involved in a fracture of the orbit? Why do you think orbital fractures are often difficult to fixate surgically with screws and plates?

2 Your friend has suffered a "broken nose." Which bones potentially could be involved in a fracture involving the nose and the nasal cavity?

3 The bones of the fetal skull are not yet fused, giving the skull many "soft spots," or fontanels. Why do you think the bones of the fetal skull are not fused at birth?

4 Police officers have found human skeletal remains, including a pelvis, and they ask your help in determining the individual's sex. Which features will you examine to help you make this determination?

5 Many people mistakenly believe that the pelvis is fractured when one has a broken hip. What is actually fractured in a broken hip? Examine this structure, and compare it to the bones of the pelvis. Why do you think it is more likely to fracture than the pelvis?

6 You are presented the following X-ray from a six-year-old child (Figure 7.41).

a Identify the bones in the X-ray.

b Your colleague thinks that there may be a fracture present at the arrow in Figure 7.41. What do you think? Is this a fracture or a normal anatomical feature? Explain.

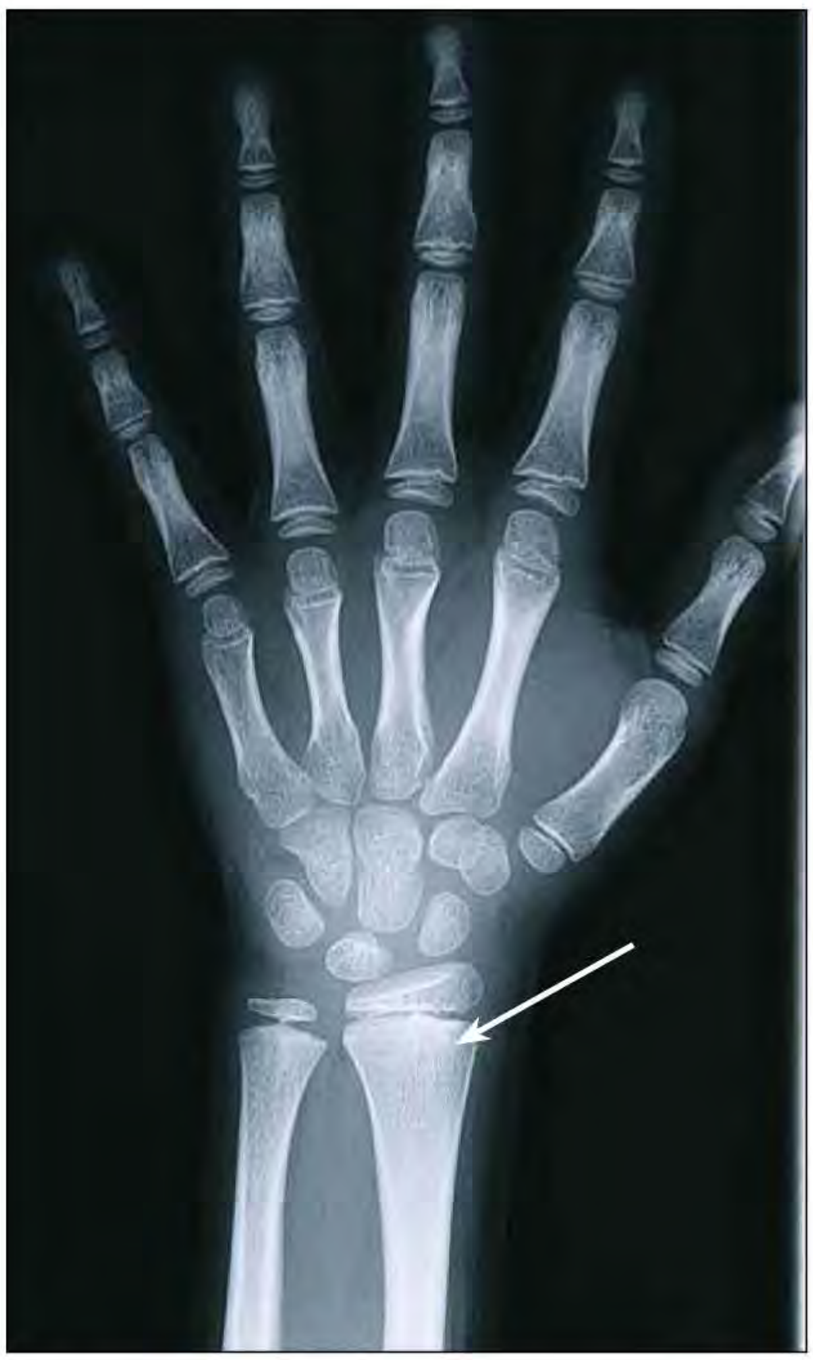


FIGURE **7.41** X-ray from six-year-old child.

8 Articulations

OBJECTIVES

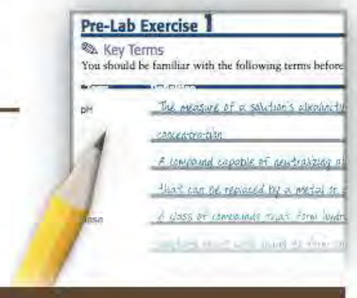
Once you have completed this unit, you should be able to:

1. Classify joints based upon structure and function.
2. Identify examples of the different types of joints.
3. Identify structures associated with synovial joints.
4. Classify synovial joints according to range of motion.
5. Identify structures of the knee and shoulder joints.
6. Demonstrate and describe motions allowed at synovial joints.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 8-1

✎ Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Classes of Joints by Function

Synarthrosis _____

_____

Amphiarthrosis _____

_____

Diarthrosis _____

_____

Classes of Joints by Structure

Fibrous _____

_____

Cartilaginous _____

_____

Synovial _____

_____

Classes of Synovial Joints by Structure

Plane _____

_____

Hinge _____

_____

Pivot _____

_____

Condyloid _____

_____

Saddle _____

_____

Name _____ Section _____ Date _____

Ball and socket _____

Types of Movement in Synovial Joints

Flexion _____

Extension _____

Abduction _____

Adduction _____

Circumduction _____

Rotation _____

Inversion _____

Eversion _____

Plantarflexion _____

Dorsiflexion _____

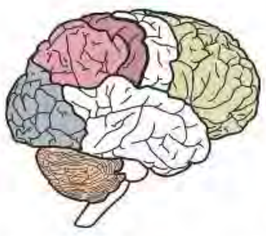
Pronation _____

Supination _____

Elevation _____

Depression _____

Opposition _____



Pre-Lab Exercise 8-2

Anatomy of Synovial Joints

Label and color the structures of synovial joints in Figure 8.1 with the terms from Exercise 8-2 (p. 193). Use your text and Exercise 8-2 in this unit for reference.

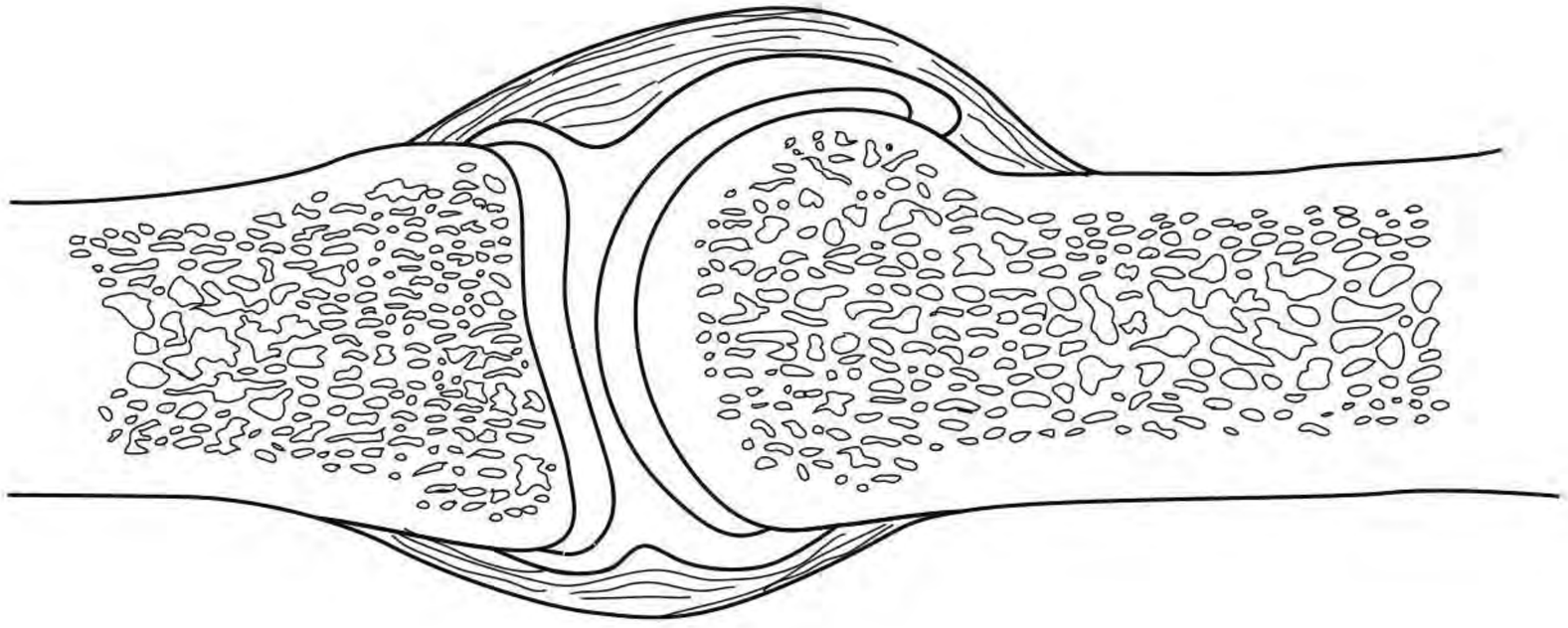
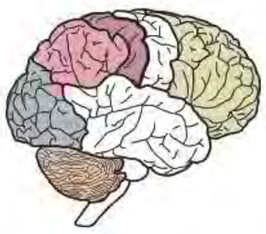


FIGURE **8.1** A basic synovial joint.

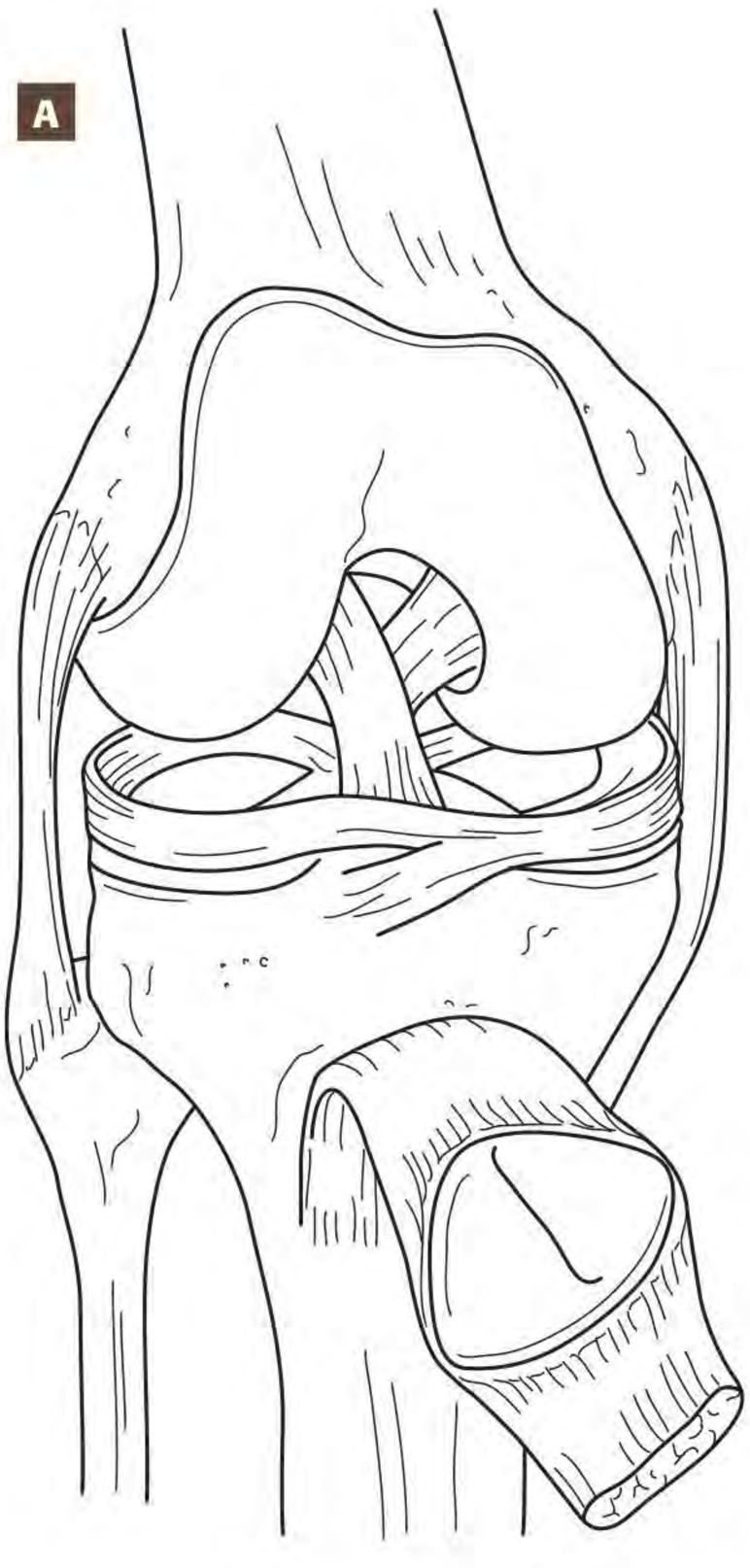
Name _____ Section _____ Date _____



Pre-Lab Exercise 8-3

The Knee Joint

Label and color the knee joint in Figure 8.2 with the terms from Exercise 8-2 (p. 196). Use your text and Exercise 8-2 in this unit for reference.



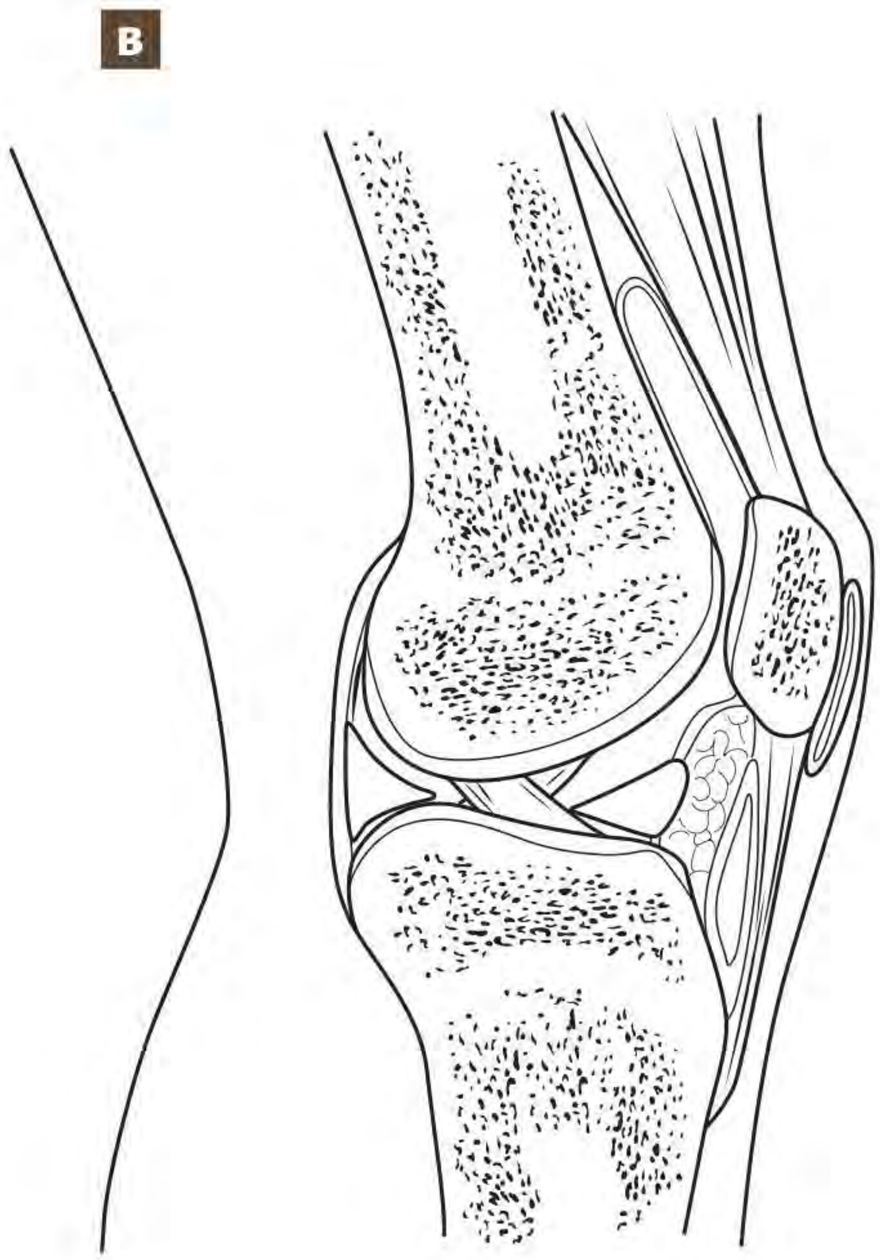
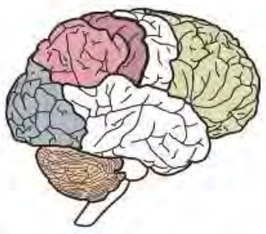


FIGURE **8.2** Knee joint: (**A**) anterior view; (**B**) midsagittal section.



Pre-Lab Exercise 8-4

The Shoulder Joint

Label and color the shoulder joint in Figure 8.3 with the terms from Exercise 8-2 (p. 198). Use your text and Exercise 8-2 in this unit for reference.

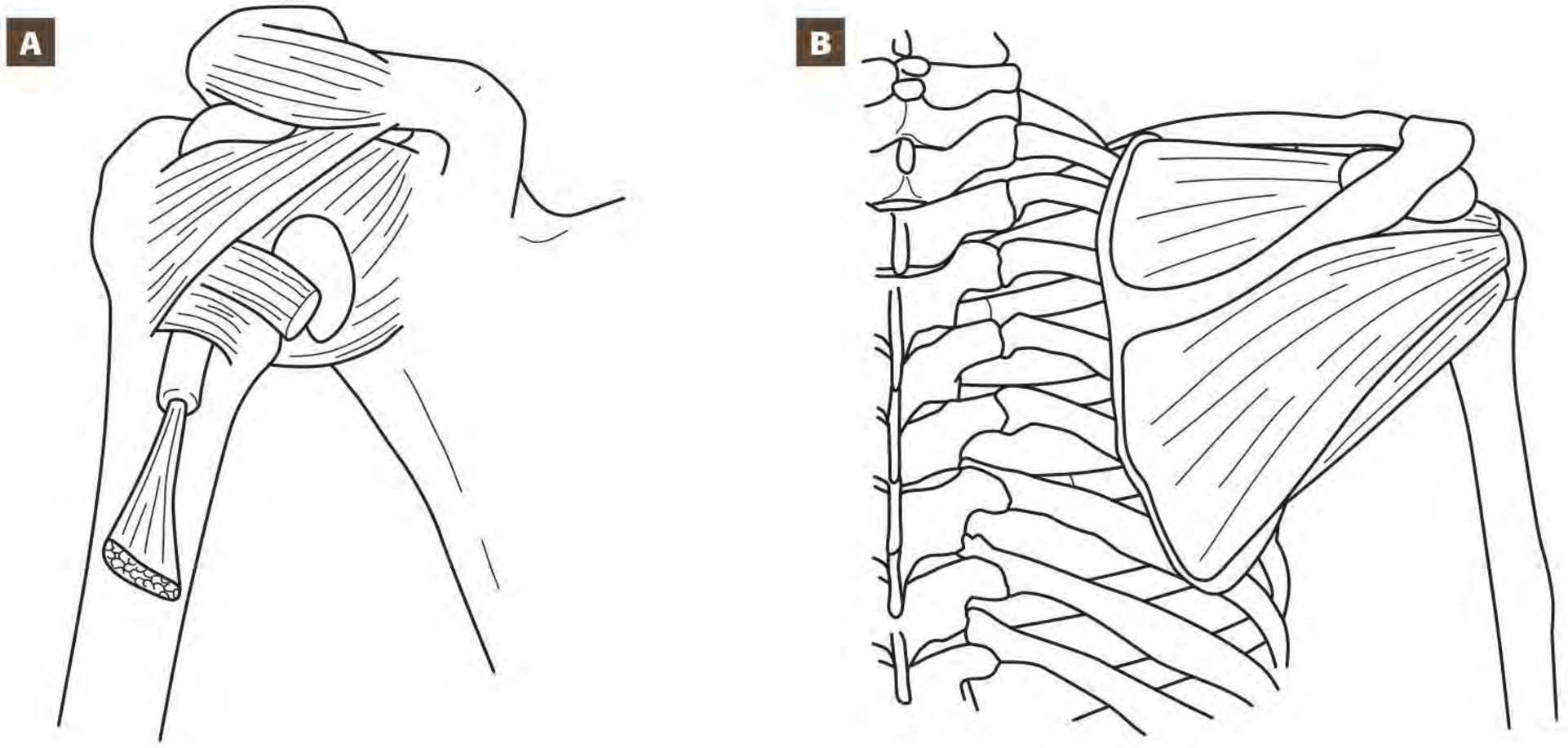
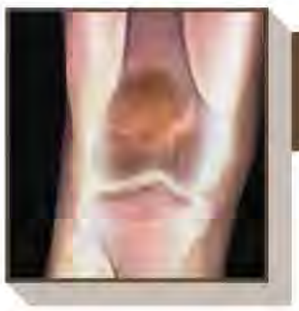


FIGURE **8.3** Shoulder joint: (**A**) anterior view of the joint capsule; (**B**) posterior view of the musculature.



EXERCISES

Most bones in the body form **articulations**, or **joints**, with another bone. These articulations provide stability and allow you to perform the wide variety of motions involved in everyday movement. You probably don't realize just how many joints are articulating when you perform routine activities such as answering the phone, walking to the door, or holding a model in A&P lab. In the following exercises you will identify and classify joints according to structure, function, and the amount of motion that they allow; examine the knee and shoulder joints; and determine which joints are involved in simple everyday movements.

Exercise 8-1

Classification of Joints

MATERIALS

- ❑ Skeleton, articulated
- ❑ Skull

Joints are classified according to both their structure and their function. Functionally, joints are classified by the amount of motion that they allow. There are three functional classes of joints:

1. **Synarthroses** (sin-ar-THROH-seez)—immovable joints,
2. **Amphiarthroses** (am-fee-ar-THROH-seez)—joints that allow some motion, or
3. **Diarthroses** (dy-ar-THROH-seez)—freely moveable joints.

Structurally, joints are classified by the type of connecting elements we find between the two bones. There are also three structural joint classes (Figure 8.4):

1. **Fibrous joints. Fibrous joints** consist of bones joined by short collagen fibers. Most fibrous joints allow no motion and are synarthroses. Their main function is to provide stability between the bones.
2. **Cartilaginous joints. Cartilaginous joints,** as their name implies, consist of bones united by cartilage. Most cartilaginous joints allow some motion and are amphiarthroses. However, certain cartilaginous joints, such as the epiphyseal plate, a structure composed of hyaline cartilage found in growing bones, are synarthroses. The function of most cartilaginous joints is also to provide stability, although most provide somewhat less stability than fibrous joints.
3. **Synovial joints. Synovial joints** (sih-NOH-vee-ul) have a true joint cavity, which makes them diarthroses. The two bones are united by a **joint capsule** composed of dense irregular collagenous connective tissue that surrounds and encloses the joint cavity, which is filled with a liquid called *synovial fluid*. The function of synovial joints is to provide motion between two bones, which makes synovial joints much less stable than either fibrous or cartilaginous joints. We discuss synovial joints further in Exercise 8-2.

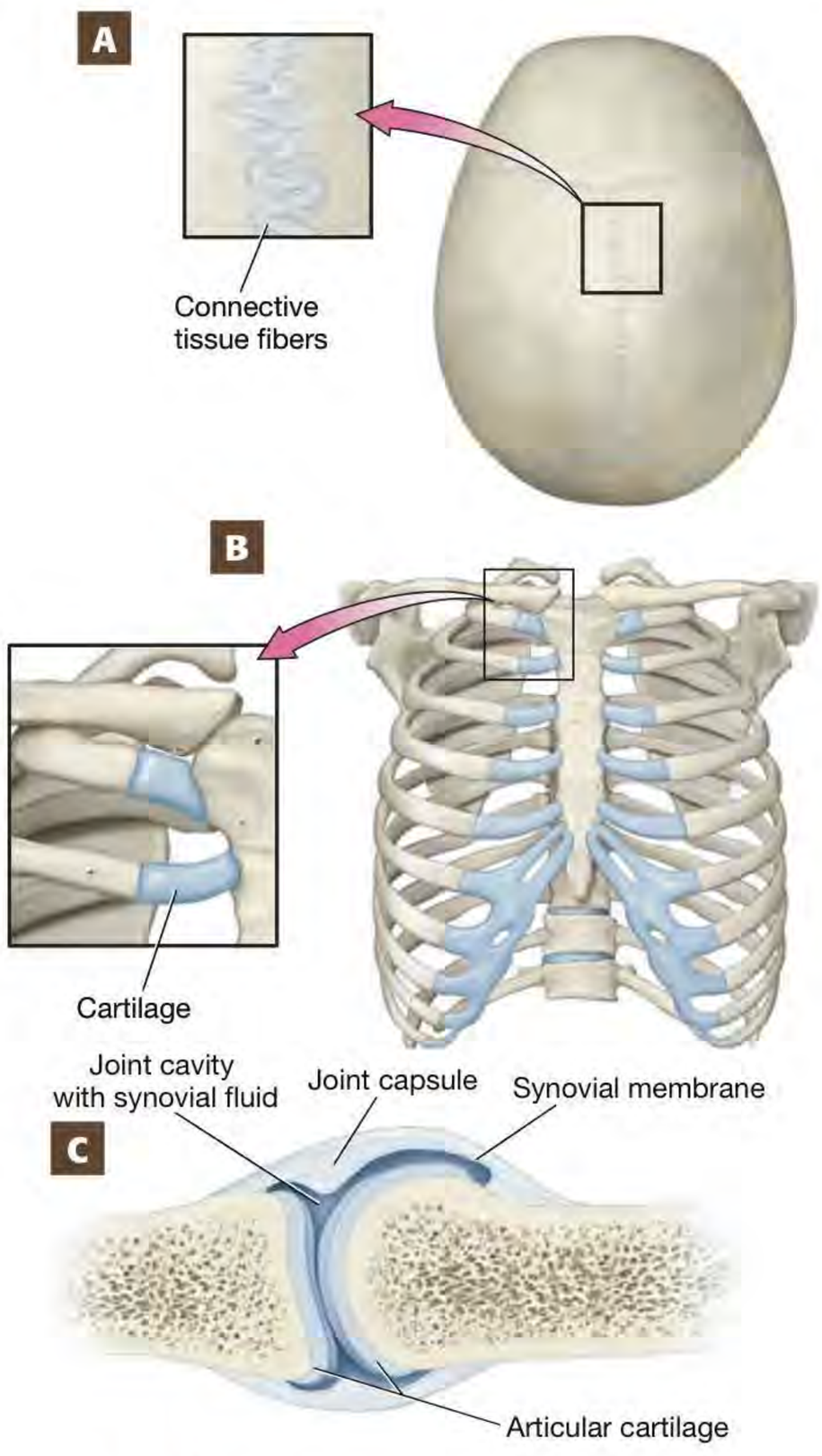


FIGURE **8.4** The three classes of joints: (**A**) fibrous joint; (**B**) cartilaginous joint; (**C**) synovial joint.

Procedure 1 Classifying Joints by Structure and Function

Classify each joint listed in Table 8.1 by its structure. Then examine and manipulate the joint to determine the amount of motion allowed at the joint. When you have determined how much movement is allowed at the joint, classify it functionally. After you have completed the activity, answer Check Your Understanding questions 1 and 2 (p. 205).

TABLE **8.1** Structural and Functional Classification of Joints

Joint	Structural Classification	Amount of Motion	Functional Classification
Intervertebral joint			
Shoulder (glenohumeral) joint			
Intercarpal joint			
Coronal suture			
Pubic symphysis			
Interphalangeal joint			

Exercise 8-2

Synovial Joints

MATERIALS

- ❑ Fresh pig or chicken joints
- ❑ Dissection trays and kits
- ❑ Skeleton, articulated
- ❑ Knee joint model

Synovial joints are freely moveable joints in which the bones are separated by a **joint cavity**. Features common to synovial joints are the following:

- **Articular cartilage.** The articulating ends of the bones are covered with **articular cartilage**, which is usually hyaline cartilage. The cartilage provides a smooth, nearly frictionless surface for articulation.
- **Joint capsule.** As you just read, the **joint capsule** is made of dense irregular collagenous connective tissue. The irregularly-arranged collagen fibers allow the capsule to resist pulling forces in many different planes, which provides strength and structural reinforcement for the joint. Internally, the joint capsule is lined by a thin layer of connective and epithelial tissue known as the **synovial membrane**. This membrane secretes **synovial fluid**, which fills the joint cavity, reducing friction and exchanging oxygen, nutrients, and wastes with the cells of articular cartilage.
- **Ligaments.** The bones in a synovial joint are held together by **ligaments**, cords of dense collagenous connective tissue, which further reinforce the joint. Some ligaments (called *extrinsic ligaments*) are within the joint cavity, whereas others (*intrinsic ligaments*) are embedded in the capsule (they are called "intrinsic" because they are an intrinsic part of the capsule).
- **Articular discs.** Also known as **menisci** (men-ISS-kee), **articular discs** are fibrocartilage pads that improve the fit of two bones to prevent dislocation.

Synovial joints typically are surrounded by **tendons**, the collagenous cords that generally attach a muscle to a bone. Fluid-filled sacs called **bursae** (BURR-see) are often located between tendons and joints, and this also reduces friction. Specialized, elongated bursae are found around certain tendons that are subject to a great deal of friction; such bursae are known as **tendon sheaths**.

Procedure 1 Identifying Structures of Synovial Joints

Identify the following structures on fresh specimens such as pigs' feet. If fresh specimens are not available, use anatomical models instead. When you have completed the activity, answer Check Your Understanding question 3 (p. 205).

- ❑ Joint cavity
- ❑ Articular cartilage
- ❑ Joint capsule
- ❑ Synovial membrane
- ❑ Synovial fluid
- ❑ Ligaments
- ❑ Extrinsic
- ❑ Intrinsic
- ❑ Articular discs (menisci)
- ❑ Bursae
- ❑ Tendon with tendon sheath

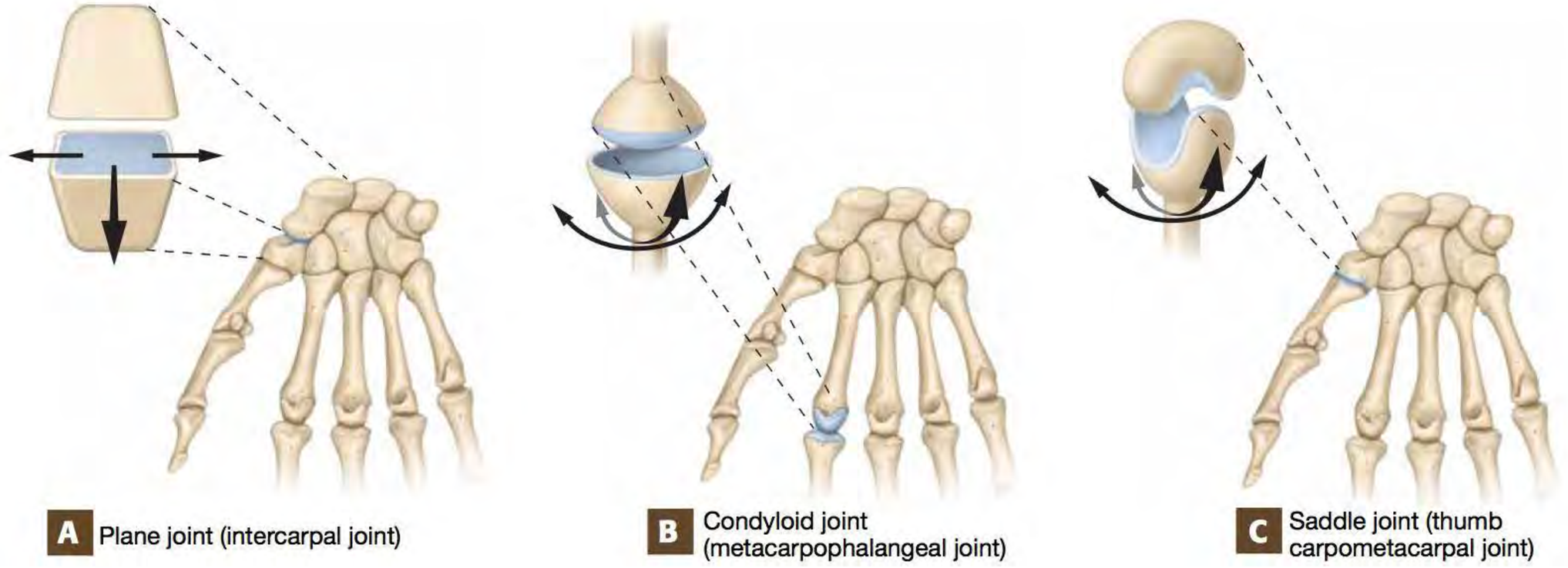
Types of Synovial Joints

The range of motion of a synovial joint is described conventionally in terms of an invisible *axis* about which the bone moves. Synovial joints are classified according to the number of planes of motion in which the bones can move around this axis. The classes are as follows:

1. **Nonaxial joints.** As implied by its name, a **nonaxial joint** does not move around an axis. Instead, the bones in a nonaxial joint simply glide past one another. An example of a nonaxial joint is the vertebrocostal joint (the joint between a thoracic vertebra and a rib).
2. **Uniaxial joints.** Joints that allow motion in one plane or direction only are called **uniaxial joints.** A classic example is the elbow, which permits only flexion and extension.
3. **Biaxial joints.** Joints that allow motion in two planes are called **biaxial joints.** An example of a biaxial joint is the wrist, which allows both flexion/extension and abduction/adduction.
4. **Multiaxial joints.** The joints with the greatest range of motion are **multiaxial joints,** which allow motion in multiple planes. An example of a multiaxial joint is the shoulder joint.

In addition to this classification scheme, synovial joints are classified according to their structure. The structural classes are illustrated in Figure 8.5 and include the following:

- **Plane.** The bones of **plane joints** have flat articular surfaces that allow the bones to glide past one another.
- **Condyloid. Condyloid joints** consist of one bone that fits into the concave surface of another bone.
- **Saddle.** Note in Figure 8.5 that **saddle joints** somewhat resemble condyloid joints but permit a greater range of motion.
- **Hinge.** In a **hinge joint,** the bones fit together much like the hinge of a door. Generally, the convex articular surface of one bone fits into a concave articular surface of another bone.
- **Pivot.** In a **pivot joint,** one bone rotates or "pivots" around another bone. Generally, pivot joints consist of one bone with a rounded projection that fits into a groove of another bone.
- **Ball-and-socket. Ball-and-socket joints** are named for the rounded, ball-like end of one bone that fits into the concave "socket" of another bone.



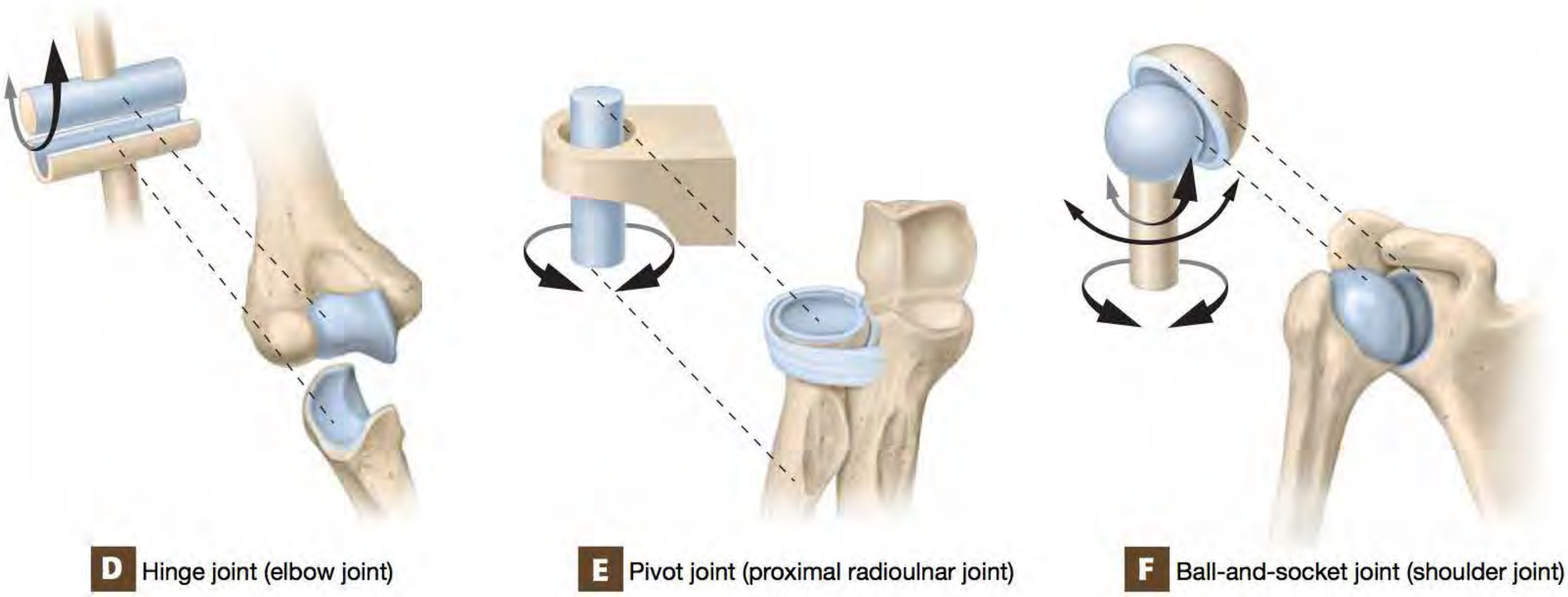


FIGURE **8.5** The structural classes of synovial joints.

Procedure 2 Classifying Synovial Joints

For each of the following joints, first list the joint's structural classification in Table 8.2. Then obtain an articulated skeleton so you can manipulate each joint and determine if the joint is nonaxial, uniaxial, biaxial, or multiaxial. When you have completed this activity, answer Check Your Understanding question 4 (p. 205).

TABLE **8.2** Classification of Synovial Joints

Joint	Structural Classification	Range of Motion (nonaxial, uniaxial, biaxial, or multiaxial)
Shoulder joint		
Intercarpal joint		
Proximal radioulnar joint		
Radiocarpal joint		
Thumb carpometacarpal joint		
Interphalangeal joint		
Knee joint		
Atlantoaxial joint		
Hip joint		

Knee Joint

The **knee joint,** illustrated in Figure 8.6, is a modified hinge joint made up of the medial and lateral femoral condyles and the tibial plateau. It is stabilized by numerous ligaments, including intrinsic ligaments (which are part of the joint capsule) and extrinsic ligaments. Four important extrinsic ligaments include the following:

1. **Anterior cruciate ligament (ACL).** The **anterior cruciate ligament** (KROO-shee-iht), or **ACL,** extends from the anterior tibial plateau to the posterior part of the lateral femoral condyle. Its function is to prevent hyperextension of the knee.
2. **Posterior cruciate ligament (PCL).** The **posterior cruciate ligament,** or **PCL,** extends from the posterior tibial plateau to the anterior part of the medial femoral condyle. It crosses under the ACL, and the two together form an "X." The PCL prevents posterior displacement of the tibia on the femur (i.e, it stops the tibia from sliding backward on the femur).
3. **Tibial collateral ligament.** The **tibial collateral ligament,** also known as the *medial collateral ligament (MCL)*, extends from the medial tibia to the medial femur. It resists stresses that pull the tibia laterally on the femur.
4. **Fibular collateral ligament.** The **fibular collateral ligament,** also known as the *lateral collateral ligament (LCL)*, extends from the lateral fibula to the lateral femur. It resists stresses that pull the tibia medially on the femur.

Two other important supportive structures of the knee joint are the **medial** and **lateral menicsi.** These half-moon-shaped articular discs are located on the outer edges of the tibial plateau, and they help to improve the fit of the tibia and femur. The tibial collateral ligament attaches to the medial meniscus, a fact that becomes apparent when the tibial collateral ligament is injured, as the medial meniscus is often injured along with it.

As you can see in Figure 8.6B, there are also a number of **bursae** around the knee joint. These bursae are particularly concentrated around the patella, as this bone generates a great deal of friction over the femur during motion. For this reason, these bursae can become inflamed as a result of repetitive activities or simply "overdoing" it.

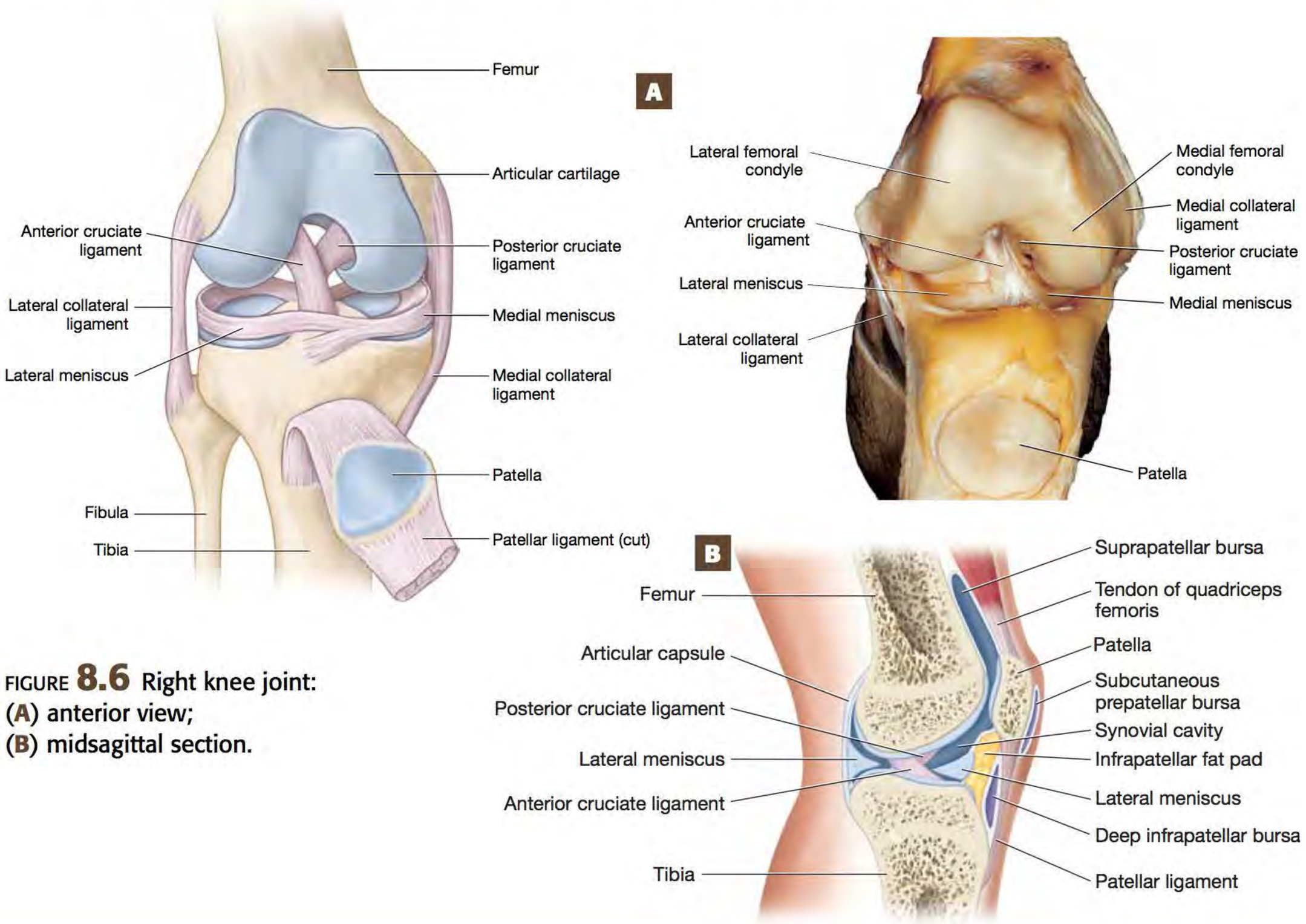


FIGURE **8.6** Right knee joint: (**A**) anterior view; (**B**) midsagittal section.

Procedure 3 Identifying Structures of the Knee Joint

Identify the following structures of the knee joint on anatomical models or fresh specimens. Check off each structure as you identify it.

- ❑ **Medial and lateral femoral condyles**
- ❑ **Tibial plateau**
- ❑ **Joint capsule**
- ❑ **Ligaments**
  - Anterior cruciate ligament (ACL)
  - Posterior cruciate ligament (PCL)
  - Tibial collateral ligament
  - Fibular collateral ligament
- ❑ **Menisci**
  - Medial meniscus
  - Lateral meniscus
- ❑ **Patella**
- ❑ **Patellar bursae**

Procedure 4 Time to Draw

In the space below, draw, color, and label one of the knee models that you examined. In addition, write the function of each structure that you label.

Procedure 5 Testing the Integrity of the ACL and PCL

One of the more common knee injuries is a torn ACL and/or PCL. To assess the integrity of the ACL and PCL, tests known as the **anterior drawer** and **posterior drawer**, respectively, are performed. A normal result of both tests is a minimum amount of motion when the tibia is moved anteriorly and posteriorly. When you have completed the tests, answer Check Your Understanding questions 5 and 6 (p. 206).

1. Have your partner sit with the knees bent at 90° and relaxed.
2. Grasp your partner's leg with both hands around the proximal tibia and fibula.
3. Gently pull the leg anteriorly, being careful not to extend the knee joint.
   - Amount of motion: _____
   - Which ligament was being assessed (ACL or PCL)? _____
4. Now gently push the leg posteriorly. Be careful not to flex the knee joint.
   - Amount of motion: _____
   - Which ligament was being assessed (ACL or PCL)? _____

Shoulder Joint

The **shoulder joint**, more properly called the **glenohumeral joint** (glen-oh-HYOO-mur-uhl), is a multiaxial joint that consists of the head of the humerus and the *glenoid cavity* of the scapula (Figure 8.7). Like the knee joint, the shoulder is supported by a number of surrounding structures, including the following:

- **Glenoid labrum.** The **glenoid labrum** (LAY-brum) is a fibrocartilaginous ring along on the rim of the glenoid cavity that improves the fit of the humeral head in the glenoid cavity (Figure 8.7A).
- **Ligaments.** The shoulder joint has a much greater range of motion than the knee, and as a result its joint capsule is thinner and weaker and its ligaments are fewer in number. One ligament is the **coracohumeral ligament** (kohr-uh-koh-HYOO-muhr-uhl), located in the anterior articular capsule between the humeral head and the coracoid process (Figure 8.7B). In addition, three **glenohumeral ligaments** may be found reinforcing the anterior articular capsule.
- **Biceps brachii tendon.** Another stabilizing force comes from the tendon of the **biceps brachii muscle,** found in the anterior arm. This tendon passes through the articular capsule of the shoulder joint on its way to its attachment point on the scapula.
- **Rotator cuff.** One of the major stabilizing forces of the shoulder joint is a group of four muscles and their tendons—the supraspinatus, infraspinatus, teres minor, and subscapularis—collectively called the **rotator cuff** (Figures 8.7C and D). One of the most common injuries of the shoulder joint is a rotator cuff tear.

Several bursae and tendon sheaths are found around the shoulder joint. One of the largest bursae, the *subacromial bursa*, is frequently inflamed secondary to overuse injuries.

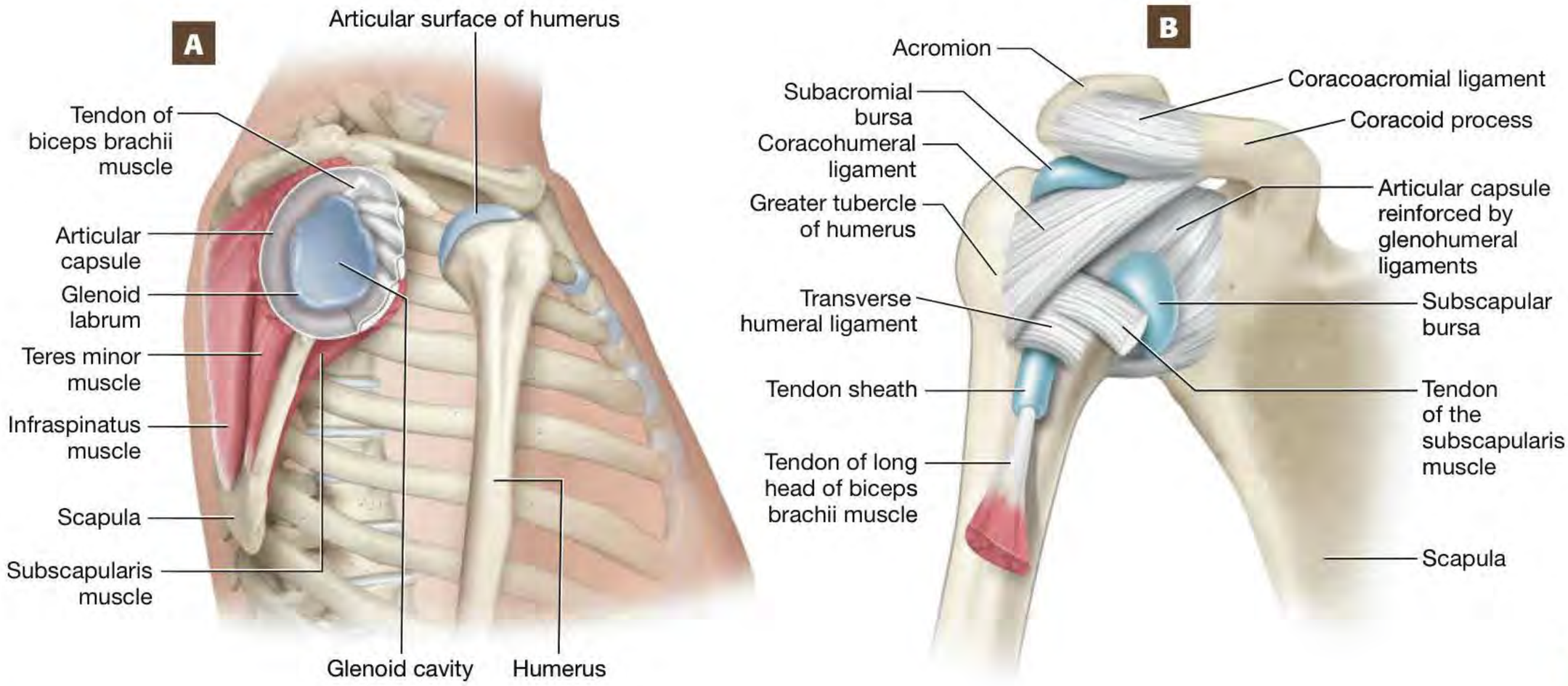


FIGURE **8.7** Right shoulder joint: (**A**) lateral view; (**B**) anterior view of joint capsule; (**C**) anterior view of musculature; (**D**) posterior view of musculature.

Procedure 6 Identifying Structures of the Shoulder Joint

Identify the following structures of the shoulder joint on anatomical models or fresh specimens. Check off each structure as you identify it. When you have completed the activity, answer Check Your Understanding question 7 (p 206).

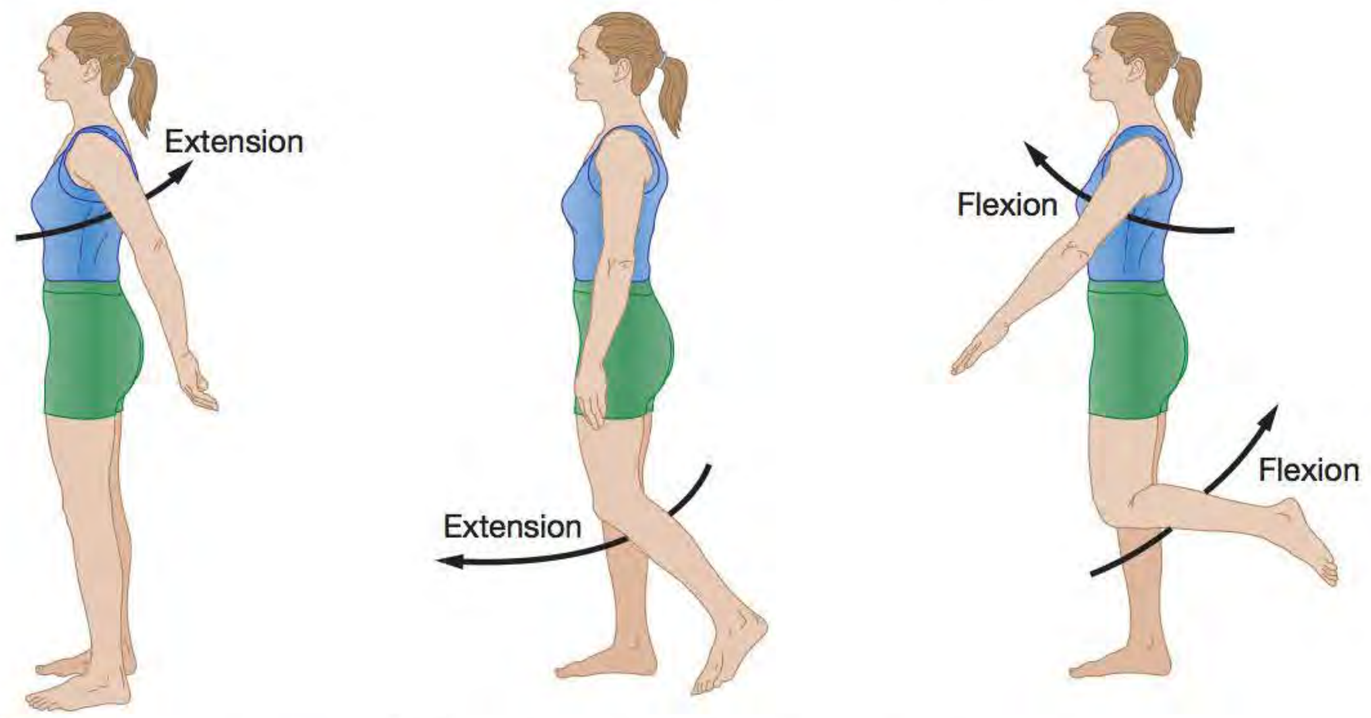
- ❑ **Humeral head**
- ❑ **Glenoid cavity**
  - Glenoid labrum
- ❑ **Ligaments**
  - Coracohumeral ligament
  - Glenohumeral ligaments
- ❑ **Biceps brachii tendon**
- ❑ **Rotator cuff muscles**
  - Supraspinatus muscle
  - Infraspinatus muscle
  - Teres minor muscle
  - Subscapularis muscle
- ❑ **Bursae**

Exercise 8-3

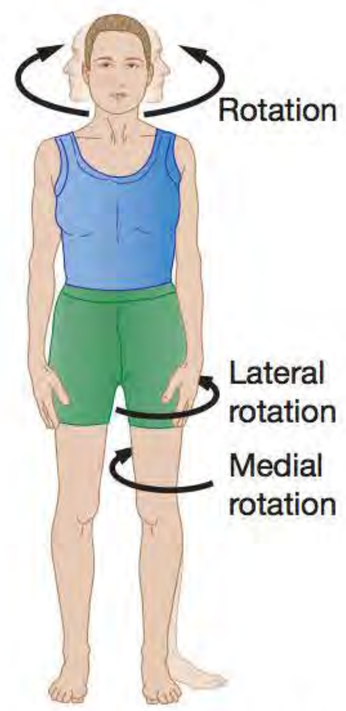
Motions of Synovial and Cartilaginous Joints

Each time you move your body in a seemingly routine fashion (such as walking or climbing stairs), you are producing motion at a tremendous number of joints. Many possible motions can occur at synovial and cartilaginous joints. These motions are illustrated in Figure 8.8.

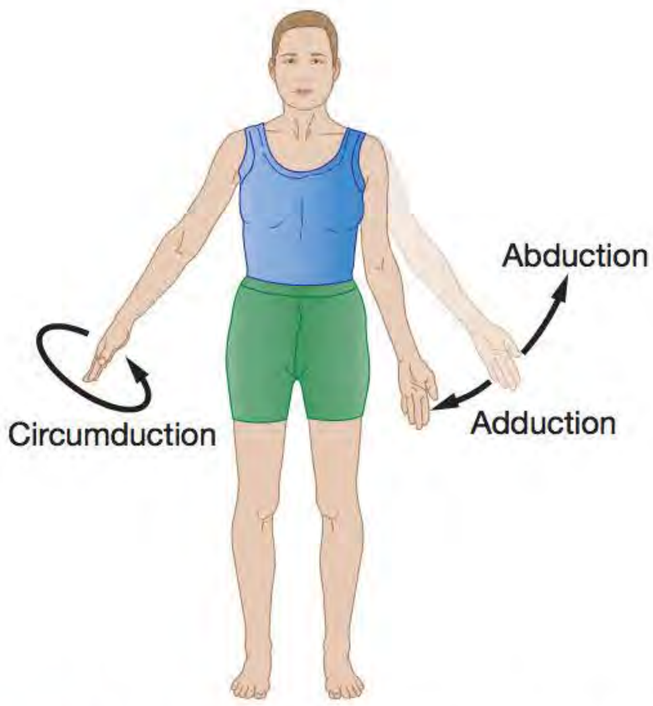
In the following procedure you will determine which joints you are moving with some commonly performed actions and which motions are occurring at each joint.



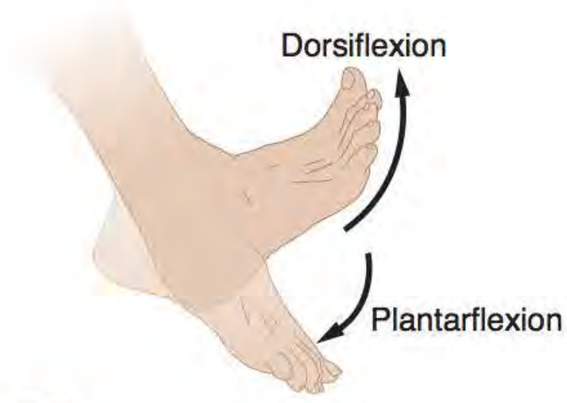
A Angular movements: Extension and flexion at the shoulder and knee



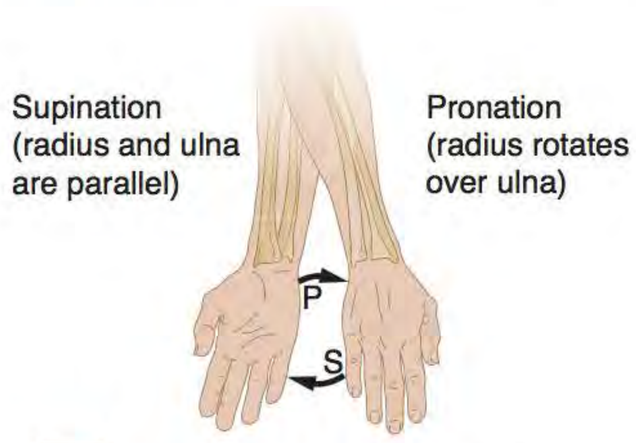
B Rotation of the head, neck, and lower limb



C Angular movements: adduction, abduction, and circumduction of the upper limb at the shoulder



D Dorsiflexion and plantarflexion



E Pronation (P) and supination (S)

FIGURE **8.8** Motions of synovial and cartilaginous joints.

Procedure 1 Identifying Joint Motions of Common Movements

Team up with a partner, and have your partner perform each of the following actions. Watch carefully as the actions are performed, and list the joints that are in motion.

Ask your instructor if he or she wants you to use the technical name or the common name for each joint (e.g., glenohumeral versus shoulder joint). Some of the joints, such as the hip joint and knee joint, will be obvious. Others, such as the radioulnar joint, the fingers and toes, and the intervertebral joints, are less obvious and easily overlooked.

Once you have listed the joints being used, determine which motions are occurring at each joint. Keep in mind the type and the range of motion of each joint as you answer each question.

1 Walking up stairs

Joints moving:

Motions occurring:

2 Doing jumping jacks

Joints moving:

Motions occurring:

3 Answering the telephone

Joints moving:

Motions occurring:

4 Jumping rope

Joints moving:

Motions occurring:

Name _____

Section _____ Date _____

Check Your Recall

1 **Joints that permit no motion are called**

a. synarthroses.
b. amphiarthroses.
c. cartilaginous joints.
d. diarthroses.

2 **Freely moveable joints are called**

a. cartilaginous joints.
b. synarthroses.
c. amphiarthroses.
d. fibrous joints.
e. diarthroses

3 **Most cartilaginous joints allow _____ and are _____ joints.**

a. no motion; synarthrotic
b. some motion; diarthrotic
c. no motion; amphiarthrotic
d. some motion; amphiarthrotic

4 **Synovial joints are filled with _____, which _____ the joint.**

a. serous fluid; lubricates
b. synovial fluid; lubricates
c. serous fluid; increases range of motion of
d. synovial fluid; increases range of motion of

5 ***Mark the following statements as true (T) or false (F).*** **If the statement is false, correct it so it is a true statement.**

_____ a. The articulating ends of the bones in a synovial joint are covered by a synovial membrane.

_____ b. Articular discs improve the fit between two bones in a synovial joint.

_____ c. The joint capsule of a synovial joint is lined with a synovial membrane.

_____ d. Ligaments provide a smooth, nearly frictionless surface for articulation.

_____ e. Fluid-filled sacs called bursae often lie between tendons and the joint capsule of a synovial joint.

_____ f. A multiaxial joint allows gliding motion between two bones only.

6 **Which of the following describes a plane joint correctly?**

a. The convex articular surface of one bone fits into a concave articular surface of another bone.
b. One bone rotates around another bone.
c. The flat articular surfaces of two bones glide past one another.
d. The rounded, ball-like end of one bone fits into a concave depression of another bone.

7 **Which of the following correctly describes a pivot joint?**

a. The convex articular surface of one bone fits into a concave articular surface of another bone.
b. One bone rotates around another bone.
c. The flat articular surfaces of two bones glide past one another.
d. The rounded, ball-like end of one bone fits into a concave depression of another bone.

8 **Label the following parts of the knee joint in Figure 8.9.**

- ❑ Anterior cruciate ligament
- ❑ Fibular collateral ligament
- ❑ Lateral meniscus
- ❑ Tibial collateral ligament
- ❑ Medial meniscus
- ❑ Patellar ligament
- ❑ Posterior cruciate ligament

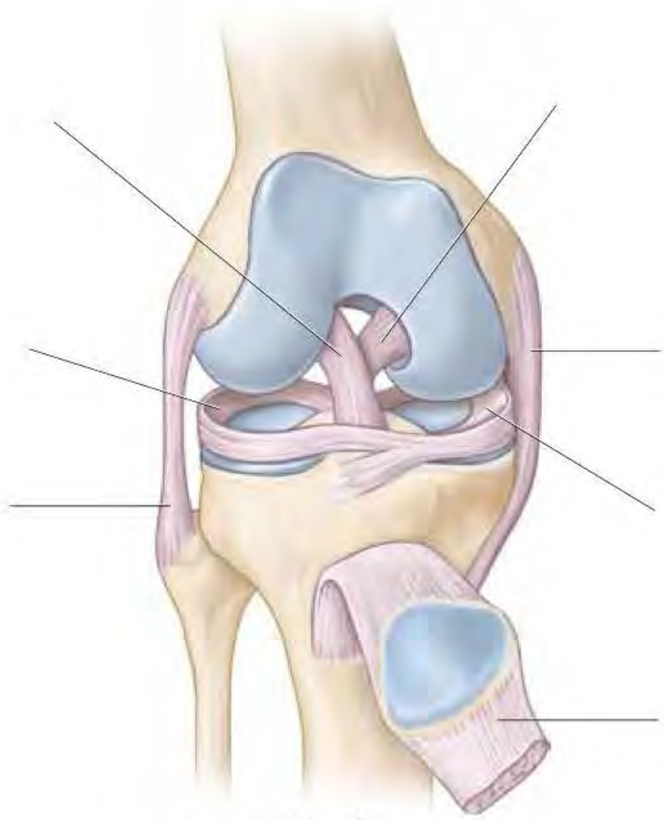


FIGURE **8.9** Knee joint.

9 **Label the following parts of the shoulder joint in Figure 8.10.**

- ❑ Biceps brachii tendon (long head)
- ❑ Coracohumeral ligament
- ❑ Subscapularis tendon
- ❑ Teres minor tendon
- ❑ Supraspinatus tendon
- ❑ Infraspinatus tendon
- ❑ Glenoid labrum
- ❑ Articular capsule

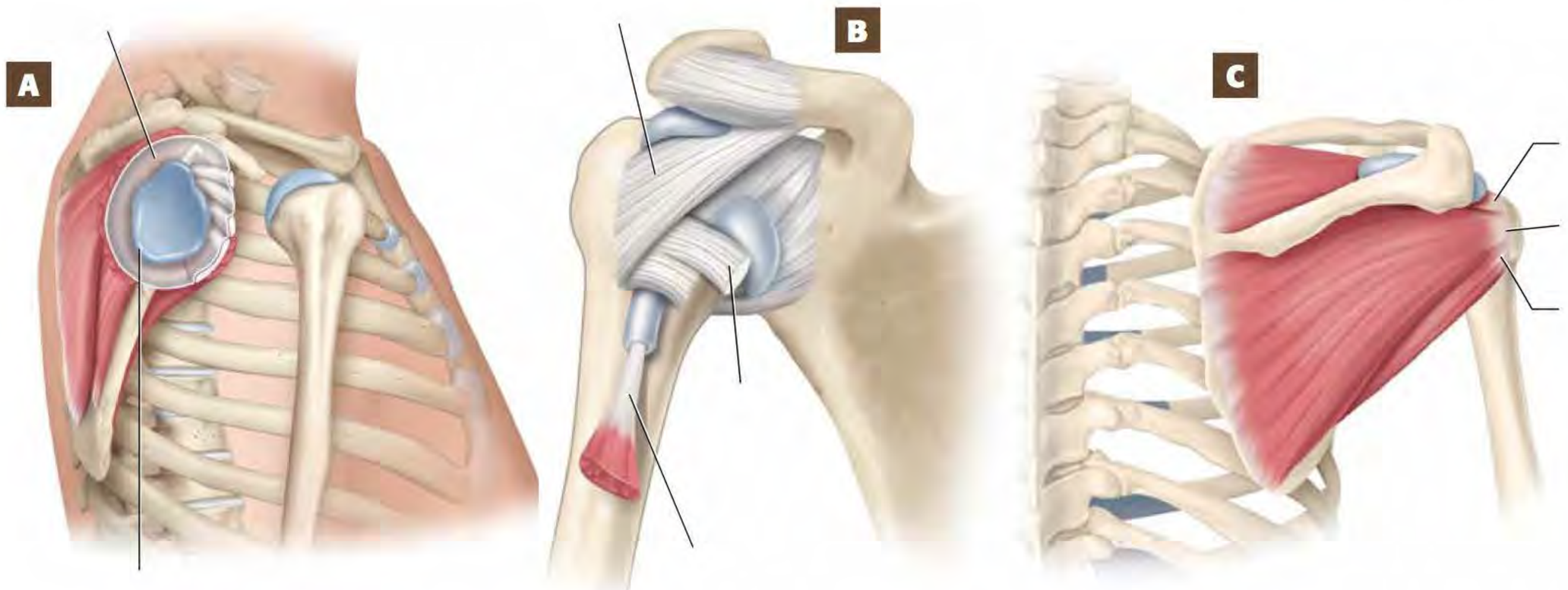


FIGURE **8.10** Shoulder joint: (**A**) lateral view: (**B**) anterior view of joint capsule; (**C**) posterior view of musculature.

10 ***Matching:*** **Match the following terms with the correct description.**

_____ Flexion
_____ Circumduction
_____ Adduction
_____ Extension
_____ Dorsiflexion
_____ Abduction
_____ Rotation
_____ Pronation

A. Movement of a body part toward the midline
B. Movement around a central axis
C. Turning the palm over to face down
D. Decreasing the angle between two bones
E. Movement of a body part away from the midline
F. Increasing the angle between two bones
G. Movement of the ankle that decreases the angle between the foot and leg
H. Movement in a circle

Name _____

Section _____ Date _____

Check Your Understanding

Critical Thinking and Application Questions

1 Would fibrous and cartilaginous joints be able to perform their functions if they had joint cavities? Explain.

2 Your father plans to visit an alternative medicine practitioner for "cranial therapy." You read the brochure for this proposed treatment and note that it involves the movement and manipulation of the cranial sutures, which the practitioner claims will cure nearly all diseases. What kind of joint is a cranial suture, both structurally and functionally? Given these facts, what do you think of the claims made about "cranial therapy"?

3 The term *double-jointed* describes individuals who have an abnormally large range of motion in a given joint. This excess range of motion is not because of the presence of a second joint but, instead, weakness of the ligaments surrounding the joint. Why would weakness of ligaments lead to a greater range of motion at a joint?

4 Compare the structure of the hip joint and the shoulder joint. Which joint do you think would be more likely to dislocate? Why?

5 Your friend is on the basketball court when she suddenly hears a loud popping sound and hyperextends her knee. What likely has happened? What results would you see from the anterior drawer test?

6 Meniscal tears are very common knee injuries. How could a torn meniscus affect the function of the knee joint?

7 When the shoulder joint dislocates, it most commonly dislocates posteriorly, meaning that the joint capsule tears on the posterior side and the head of the humerus pushes partly out through the capsule. Why do you think the posterior capsule tears more commonly? (*Hint:* Consider the structure of the capsule and look at the ligaments of the shoulder joint.)

Muscular System: Muscle Tissue and the Gross Anatomy of Muscles

9

OBJECTIVES

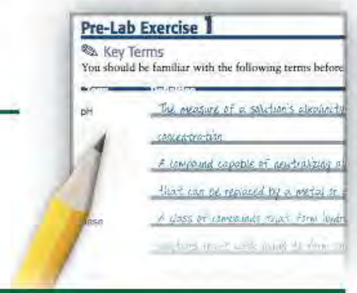
Once you have completed this unit, you should be able to:

1. Describe the microscopic anatomy of skeletal muscle fibers.
2. Identify structures of skeletal muscle fibers on anatomical models and microscope slides.
3. Identify structures associated with the neuromuscular junction on anatomical models and microscope slides.
4. Identify muscles of the upper and lower limbs, trunk, head, and neck.
5. Describe the origin, insertion, and action of selected muscles.
6. Describe the muscles required to perform common movements.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 9-1

✎ Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

General Skeletal Muscle Structures

Epimysium _____

_____

Fascicle _____

_____

Perimysium _____

_____

Muscle fiber _____

_____

Endomysium _____

_____

Structures of the Skeletal Muscle Fiber

Sarcolemma _____

_____

T-tubule _____

_____

Sarcoplasmic reticulum _____

_____

Terminal cisternae _____

_____

Myofibril _____

_____

Myofilament _____

_____

Thick filament _____

_____

Name _____ Section _____ Date _____

Thin filament _____

_____

Components of the Sarcomere

A band _____

_____

I band _____

_____

Z disc _____

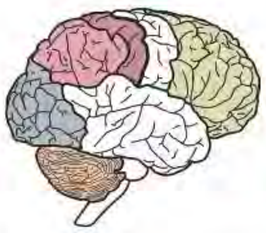
_____

H zone _____

_____

M line _____

_____



Pre-Lab Exercise 9-2

Muscle Fiber Microanatomy

Label and color the microscopic anatomy of the skeletal muscle fiber in Figures 9.1 and 9.2 with the terms from Exercise 9-1 (p. 217). Use your text and Exercise 9-1 in this unit for reference.

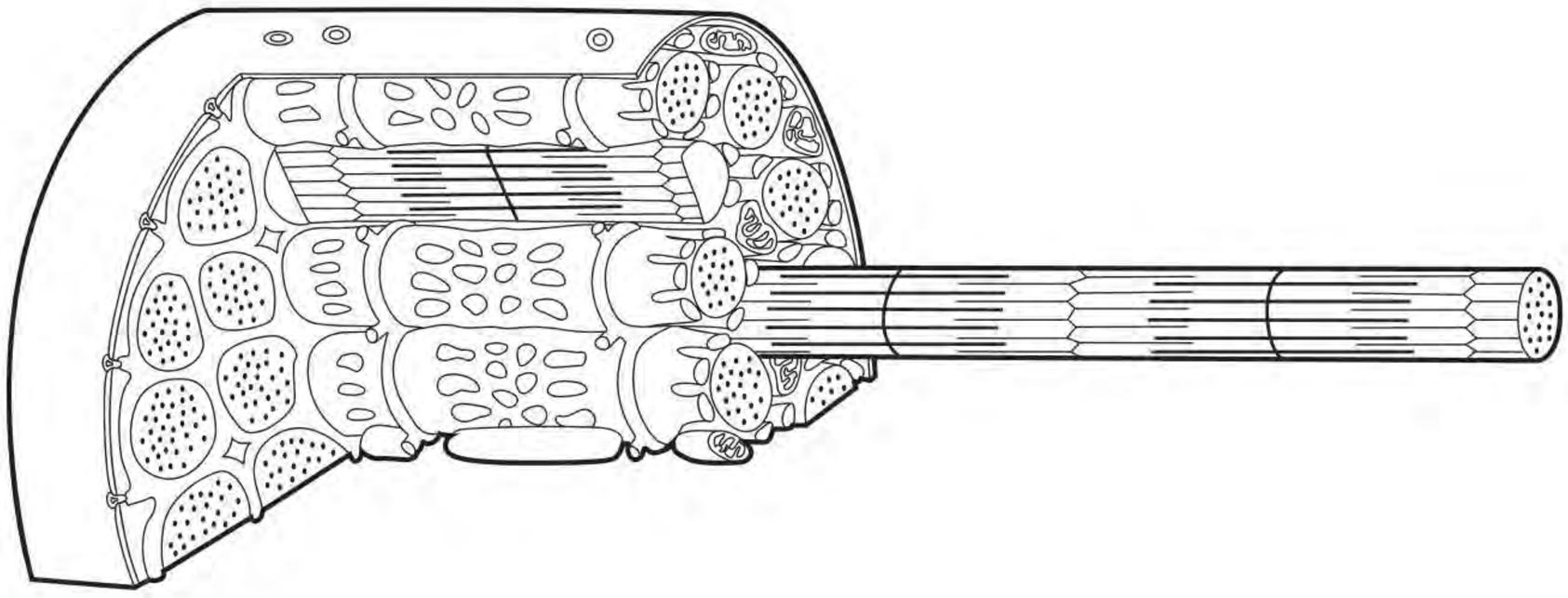


FIGURE **9.1** Skeletal muscle fiber.

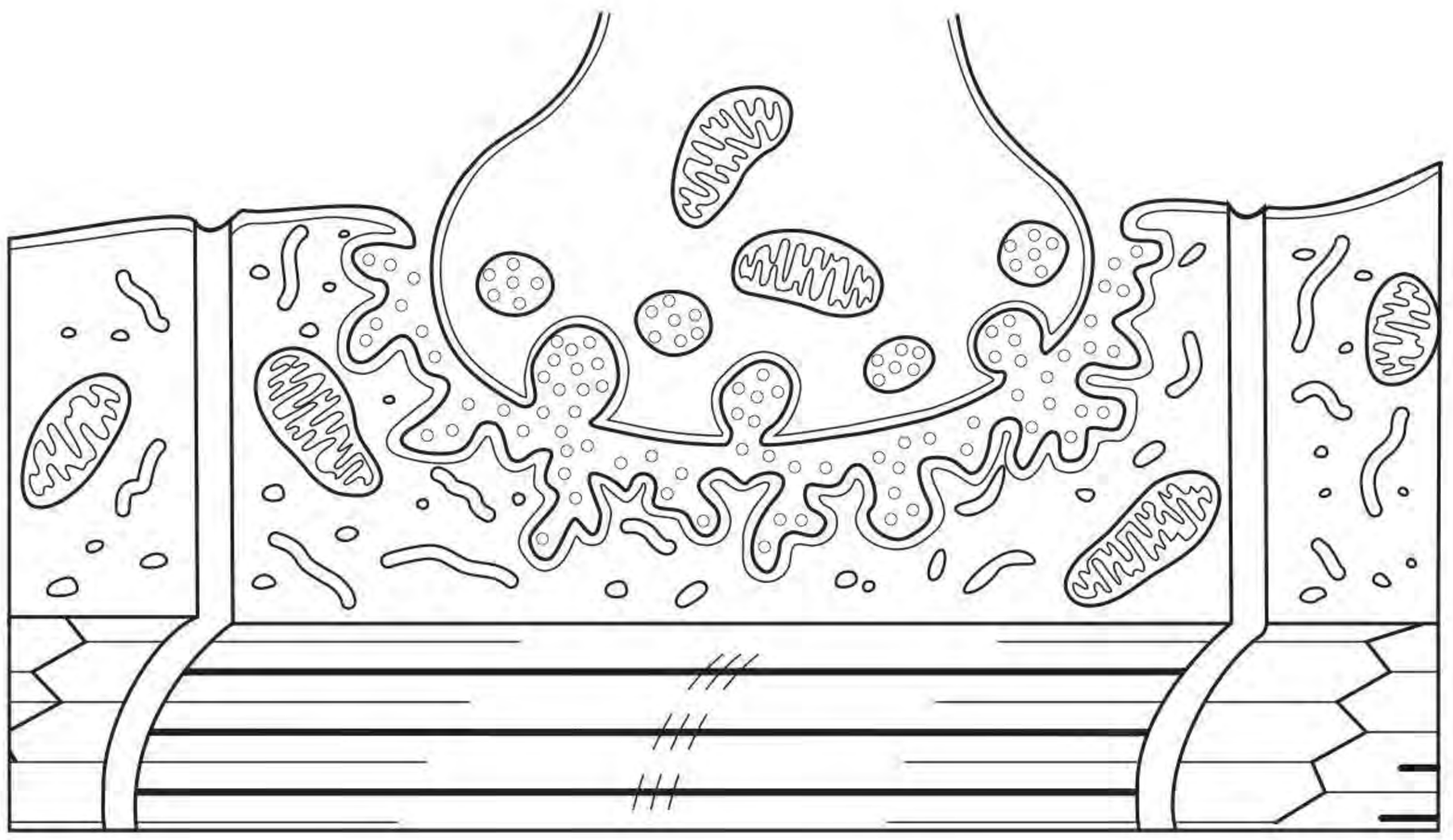
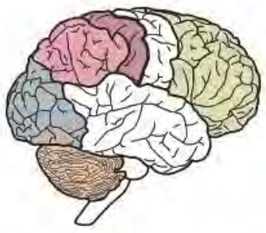


FIGURE **9.2** Neuromuscular junction.

Name _____ Section _____ Date _____



Pre-Lab Exercise 9-3

Skeletal Muscle Anatomy

Label and color the muscles in Figure 9.3 with the terms from Exercise 9-2 (p. 223). Use your text and Exercise 9-2 in this unit for reference.

A

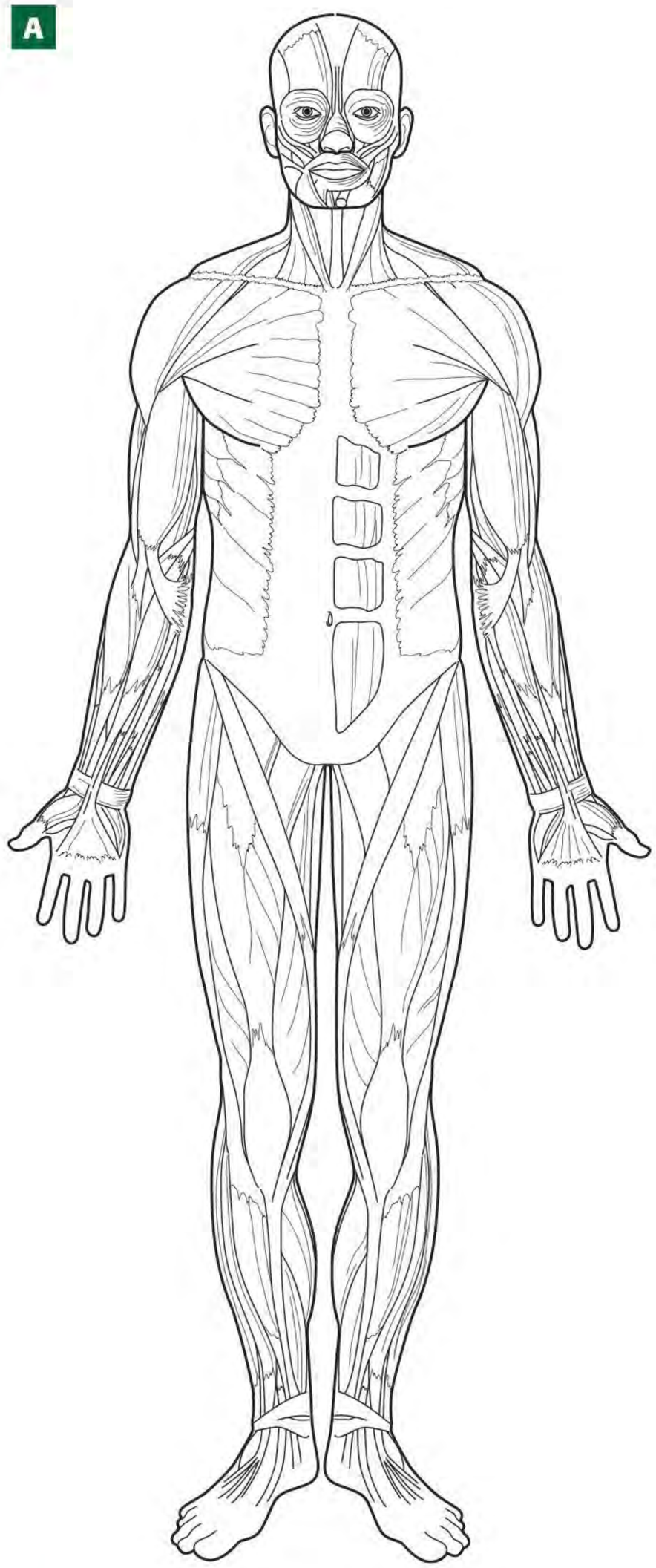


FIGURE **9.3** Human musculature: (**A**) anterior view *(continues)*

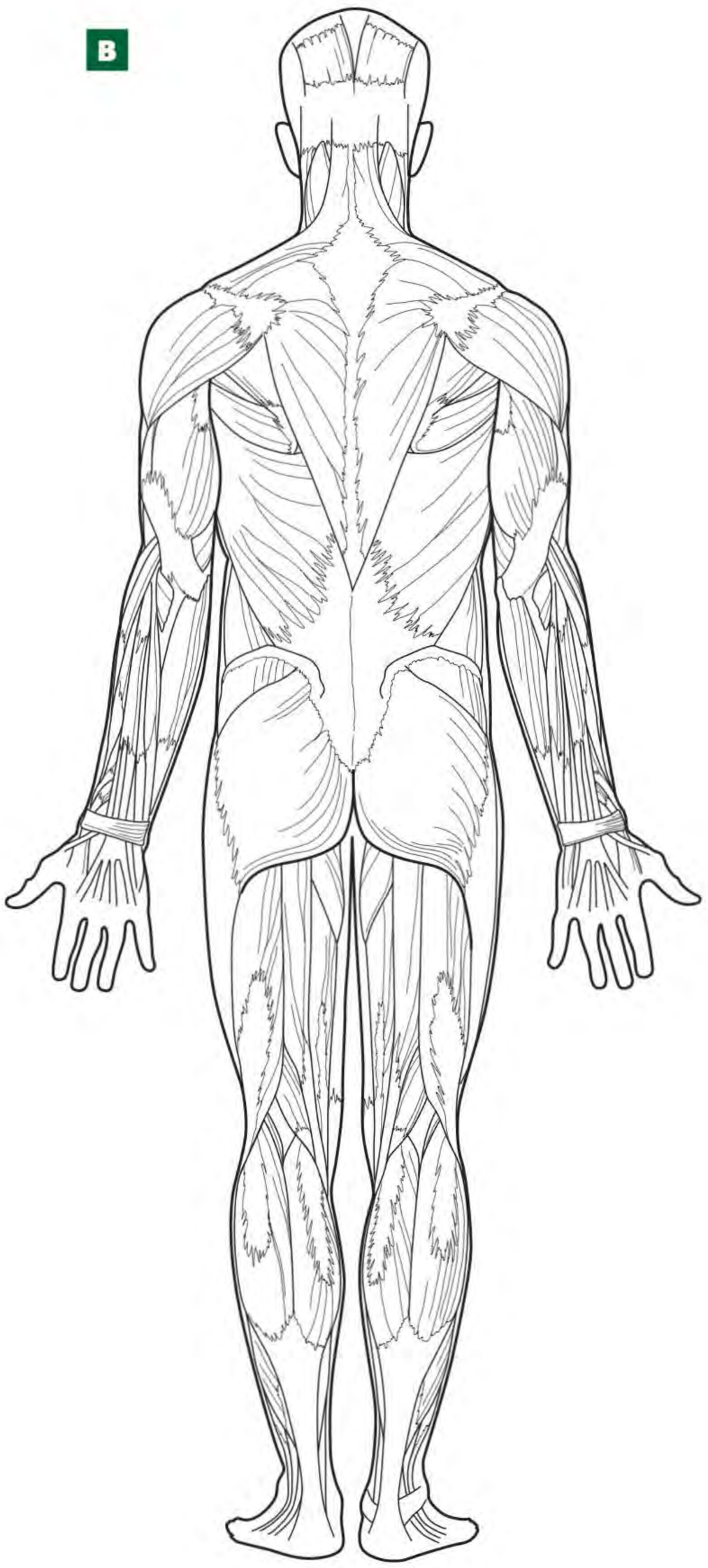


FIGURE **9.3** Human musculature *(cont.)*: **(B) posterior view** *(continues)*

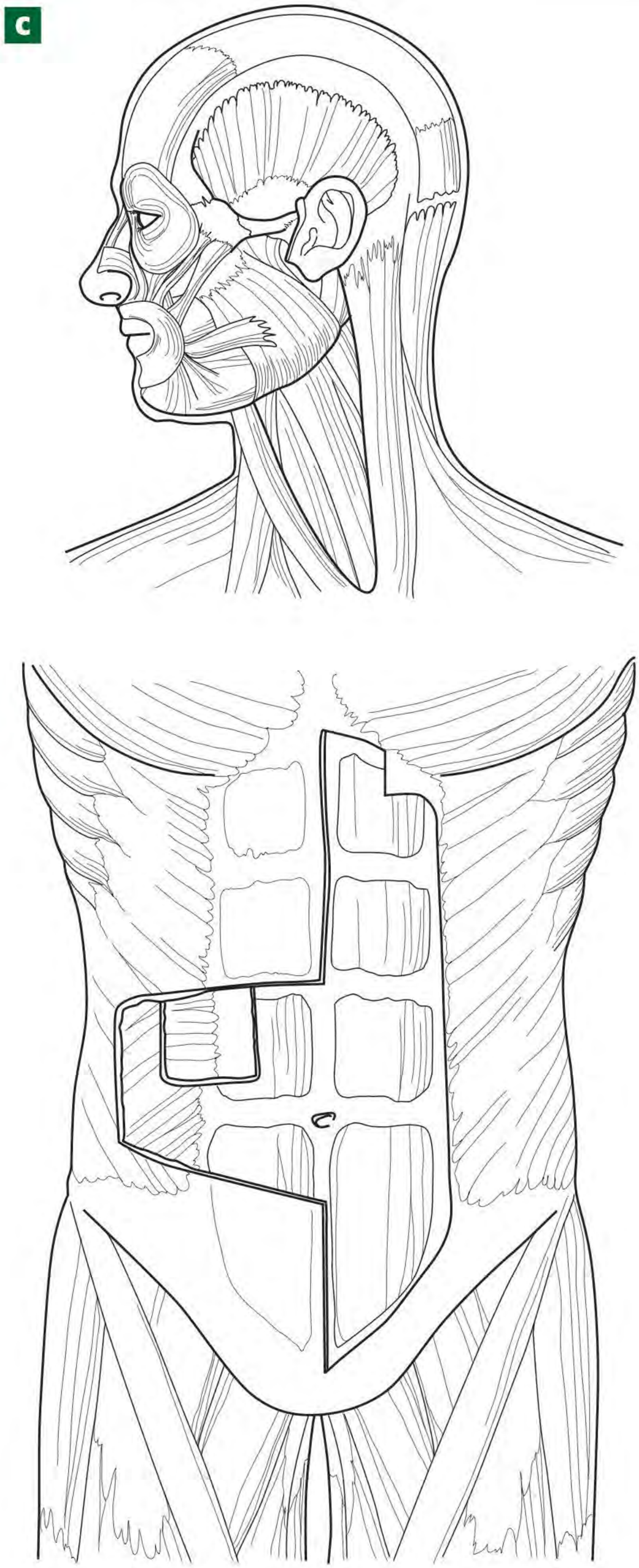


FIGURE **9.3** Human musculature *(cont.)*: (**C**) lateral view of the face; (**D**) abdominal muscles *(continues)*

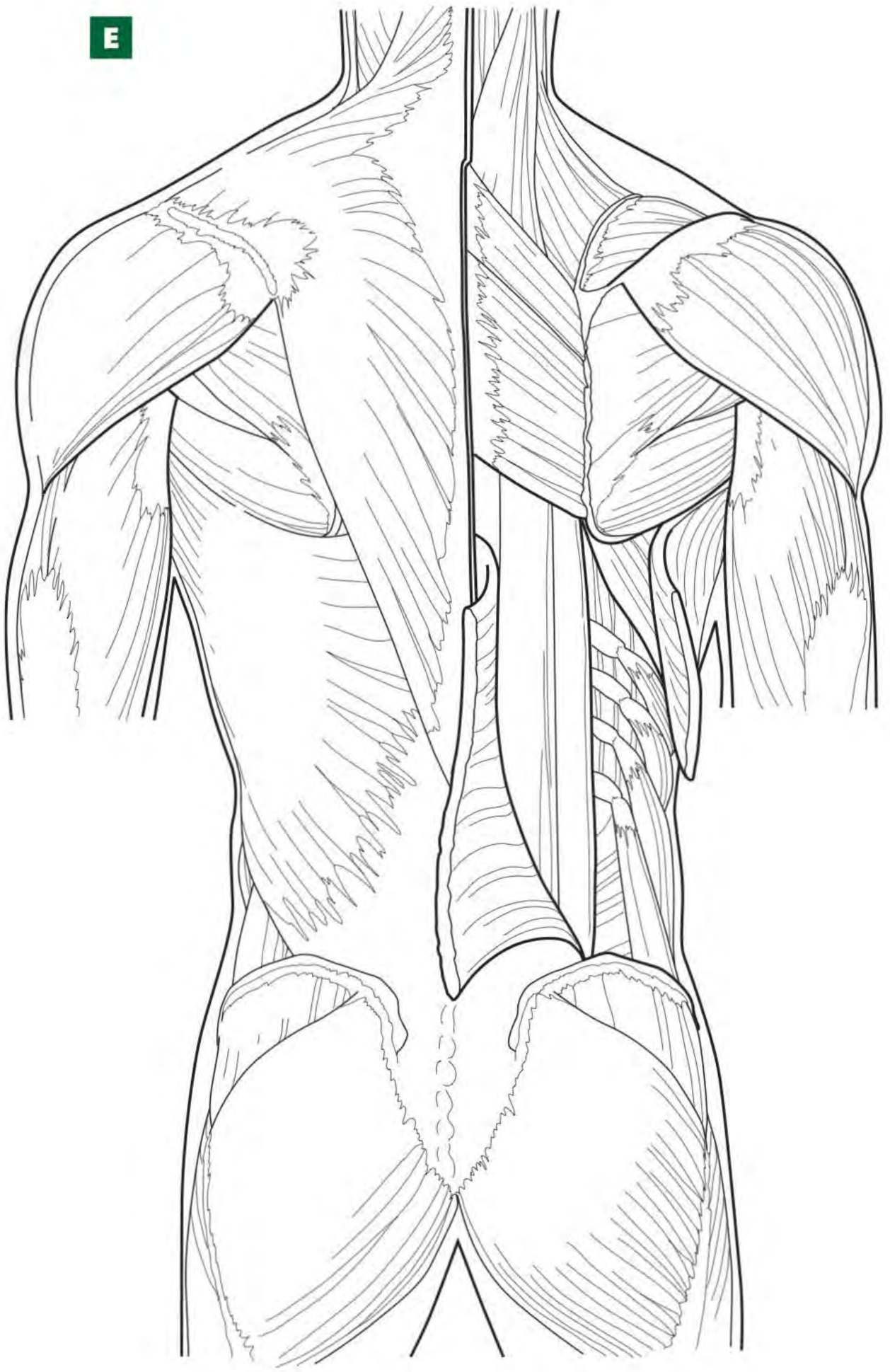
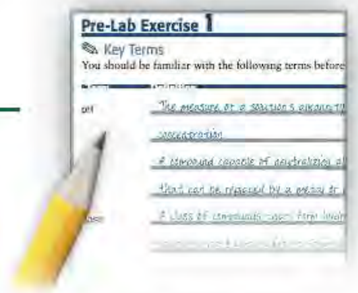


FIGURE **9.3** Human musculature *(cont.)*: **(E)** posterior torso.

Name _____ Section _____ Date _____

Pre-Lab Exercise 9-4

Muscle Origins, Insertions, and Actions



Complete Table 9.1 with the origins, insertions, and *main* actions for the listed muscles. You may notice in your textbook that the origin and insertion of a muscle often are extensive. For example, the latissimus dorsi muscle originates from T7–L5, the lower three or four ribs, the inferior angle of the scapula, and the thoracolumbar fascia. This obviously is quite a bit to write and to remember, so I suggest shortening it to something that makes sense to you (e.g., "inferior back and scapula"). You also will notice that most muscles have more than one action, which you may wish to simplify as well. If your instructor prefers that you learn the more technical version, learning a simplified version first may be helpful.

TABLE **9.1** Muscle Origins, Insertions, and Actions

Muscle	Origin	Insertion	Action(s)
Muscles of the Head and Neck			
Sternocleidomastoid			
Trapezius			
Muscles of the Thorax, Abdomen, and Back			
Rectus abdominis			
External oblique			
Internal oblique			
Erector spinae			
Deltoid			
Pectoralis major			
Latissimus dorsi			

(continues)

TABLE **9.1** Muscle Origins, Insertions, and Actions *(cont.)*

Muscle	Origin	Insertion	Action(s)
Muscles of the Upper Limb			
Biceps brachii			
Triceps brachii			
Brachioradialis			
Muscles of the Lower Limb			
Iliopsoas			
Gluteus maximus			
Sartorius			
Rectus femoris			
Adductor group			
Biceps femoris			
Semitendinosus			
Semimembranosus			
Gastrocnemius			
Tibialis anterior			

EXERCISES

The human body has nearly 700 skeletal muscles that range dramatically in size and shape from the large trapezius muscle to the tiny corrugator supercilii muscle. Luckily for you, we will be learning only about 70 muscles rather than the full 700.

A muscle begins at its origin, which is generally the more stationary part, and attaches to its insertion, which is generally the part that the muscle moves. We are most familiar with muscles that insert into and move bones. Many muscles, however, insert into structures other than bones. Examples include the diaphragm, which inserts into its own central tendon, and the muscles of facial expression, which insert into skin or other muscles.

The exercises in this unit help you become familiar with the main muscle groups and their component muscles. The first exercise reintroduces you to the microscopic anatomy of skeletal muscle tissue, the second exercise focuses on gross muscle anatomy, and the final two exercises examine skeletal muscle origins, insertions, and actions.

Exercise 9-1

Microscopic Anatomy of Skeletal Muscle Tissue

MATERIALS

- ❑ Skeletal muscle models
- ❑ Skeletal muscle fiber model
- ❑ Skeletal muscle tissue slide
- ❑ Neuromuscular junction models
- ❑ Neuromuscular junction slide
- ❑ Light microscope with oil-immersion objective
- ❑ Oil
- ❑ Colored pencils

You began to explore muscle tissue in Unit 4 (p. 82), where you were introduced to the three types of muscle tissue: skeletal muscle, smooth muscle, and cardiac muscle. Here we look more closely at the structure of skeletal muscle tissue. Recall that a skeletal muscle is composed of skeletal muscle cells, also called **muscle fibers**. Individual skeletal muscle fibers are surrounded by their extracellular matrix, known as the **endomysium** (in-doh-MY-see-um). Muscle fibers are arranged into groups called **fascicles** (FASS-ih-kullz; Figure 9.4). Each fascicle is surrounded by another connective tissue sheath called the **perimysium** (pehr-ee-MY-see-um). The muscle as a whole is covered by another connective tissue sheath called the **epimysium** (ep-ee-MY-see-um), which blends with the thick, superficial **fascia** (FASH-ah) that binds muscles into groups. The epimysium also blends with the fibers of tendons and aponeuroses, which connect the muscle to bones or soft tissue.

Skeletal muscle fibers are long, cylindrical cells wrapped by their plasma membrane, known as the **sarcolemma** (sar-koh-LEM-uh; Figure 9.5). About 80% of the skeletal muscle fiber's cytoplasm, also called its **sarcoplasm** (SAR-koh-plazm), is filled with small cylindrical organelles called **myofibrils** (my-oh-FY-brillz). The remainder of the sarcoplasm contains abundant mitochondria, multiple nuclei, and a modified endoplasmic reticulum called the **sarcoplasmic reticulum** (SAR-koh-plaz-mik reh-TIK-yoo-lum; **SR**) that wraps around the myofibrils.

One of the SR's unique functions is that it stores calcium ions required for a muscle fiber to contract. Notice in Figure 9.5 that at certain points along the myofibril, the SR swells to form **terminal cisternae** (sis-TER-nee). Running down the middle of each terminal cisterna is an inward extension of the sarcolemma known as a **T-tubule**. A group of two terminal cisternae and a T-tubule is called a **triad**; these structures are important for coordinating electrical stimulation of the muscle fiber with release of calcium ions from the SR and initiation of a muscle contraction.

Myofibrils are composed of protein subunits called **myofilaments**. The two types of myofilaments involved in contraction are: (a) **thick filaments**, composed of the contractile protein **myosin** (MY-oh-sin), and (b) **thin filaments**, composed of the contractile protein **actin** and the regulatory proteins **troponin** (troh-POH-nin) and **tropomyosin** (trohp-oh-MY-oh-sin). The arrangement of myofilaments within the myofibrils is what gives skeletal muscle its characteristic **striated** appearance. The dark regions of the striations, called **A bands**, are dark because this is where the thick and thin filaments overlap. The light regions, called **I bands**, appear light because they contain only thin filaments.

On closer inspection, there are more lines and bands than simply the A and I bands. For example, in the middle of the A band is a lighter region called the **H zone** where we find only thick filaments. Running down the middle of the H zone is the **M line**, which contains structural proteins that stabilize and support the thick filament. In the middle of each

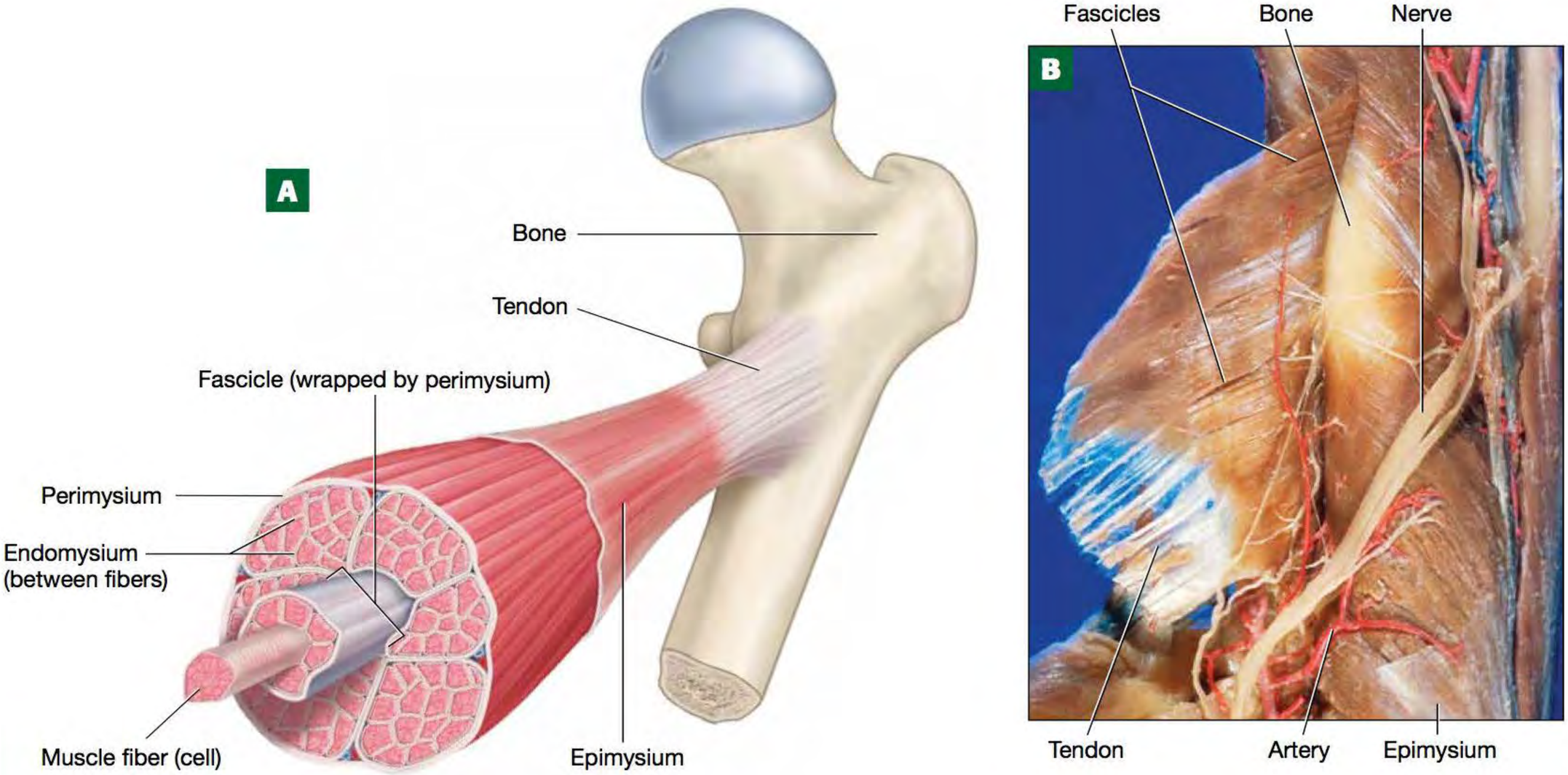


FIGURE **9.4** (A) Basic skeletal muscle structure; (B) dissected muscle.

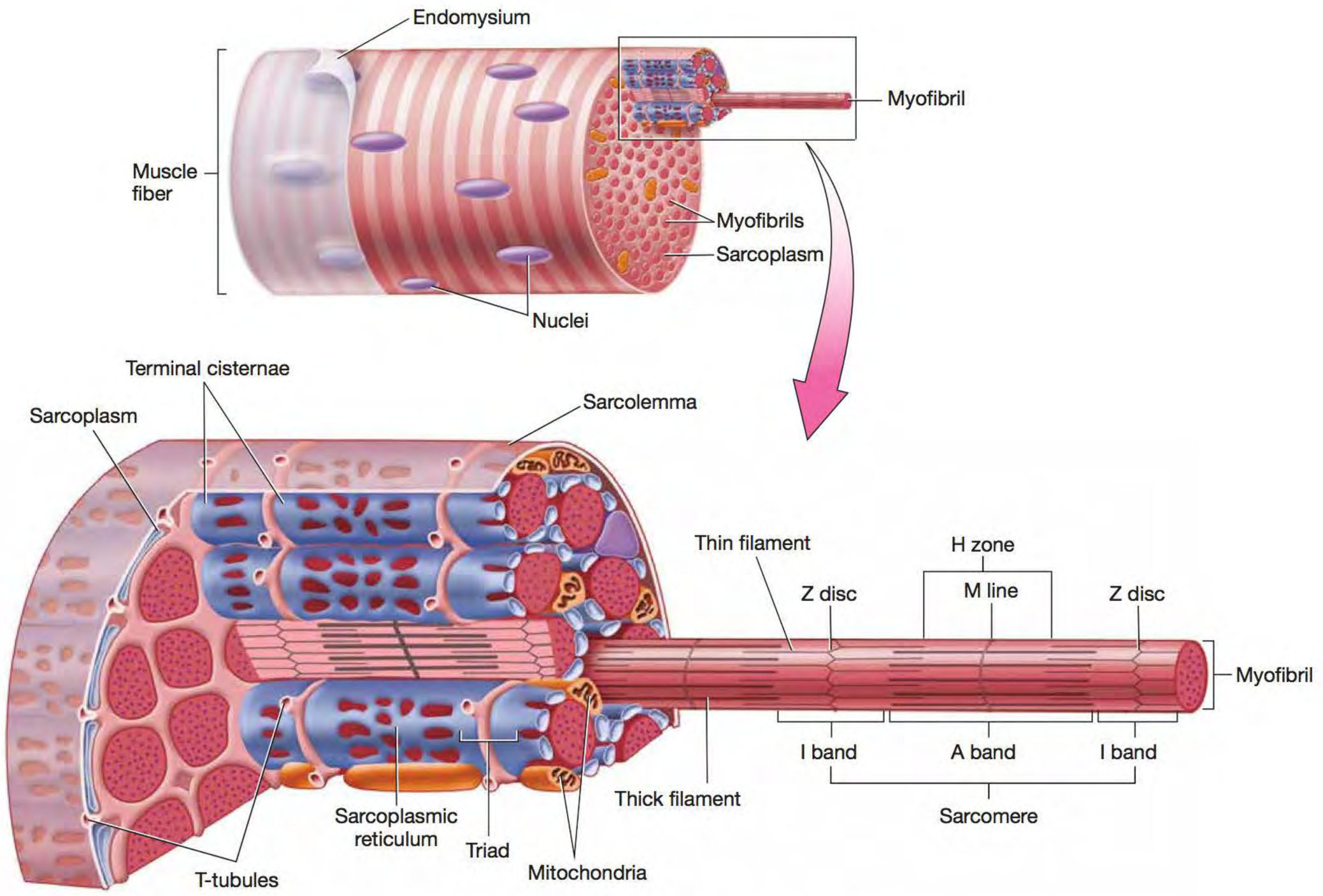


Figure **9.5** Skeletal muscle fiber.

I band is a dark line called the **Z disc**, which consists of structural proteins that support the thin filaments and stabilize the structure of the **myofibril**. Although this might sound like alphabet soup, these terms are actually quite important, as they are used to define the fundamental unit of contraction: the **sarcomere** (SAR-koh-meer). A sarcomere, defined as the space from one Z disc to the next Z disc, consists of a full A band and two half-I bands. This is the unit that generates tension during a contraction.

Procedure 1 Model Inventory for Skeletal Muscle and Skeletal Muscle Fibers

Identify the following structures of skeletal muscle and skeletal muscle fibers on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 9.2. When you have finished the activity, answer Check Your Understanding question 1 (p. 245).

Skeletal Muscle Anatomy

1. Connective tissue coverings
   a. Epimysium
   b. Perimysium
2. Fascicle
3. Muscle fiber (cell)
4. Tendon
5. Aponeurosis

Muscle Fiber Microanatomy

1. Sarcolemma
2. Sarcomere
   a. A band
   b. I band
   c. H zone
   d. Z disc
   e. M line
3. Transverse tubules
4. Sarcoplasmic reticulum
5. Terminal cisternae
6. Triad
7. Endomysium

Table **9.2** Model Inventory for Skeletal Muscle Anatomy and Microanatomy

Model/Diagram	Structures Identified

Procedure 2 Microscopy of Skeletal Muscle Tissue

View a prepared slide of skeletal muscle tissue.

1. First examine the slide with the low-power objective and advance to the high-power objective of your light microscope. See Figure 9.6A for reference.
2. Draw and color what you see, and label your drawing with the terms listed.
3. Then switch to an oil-immersion lens (your instructor may have one set up as a demonstration), and identify the structures of the sarcomere. See Figure 9.6B for reference.

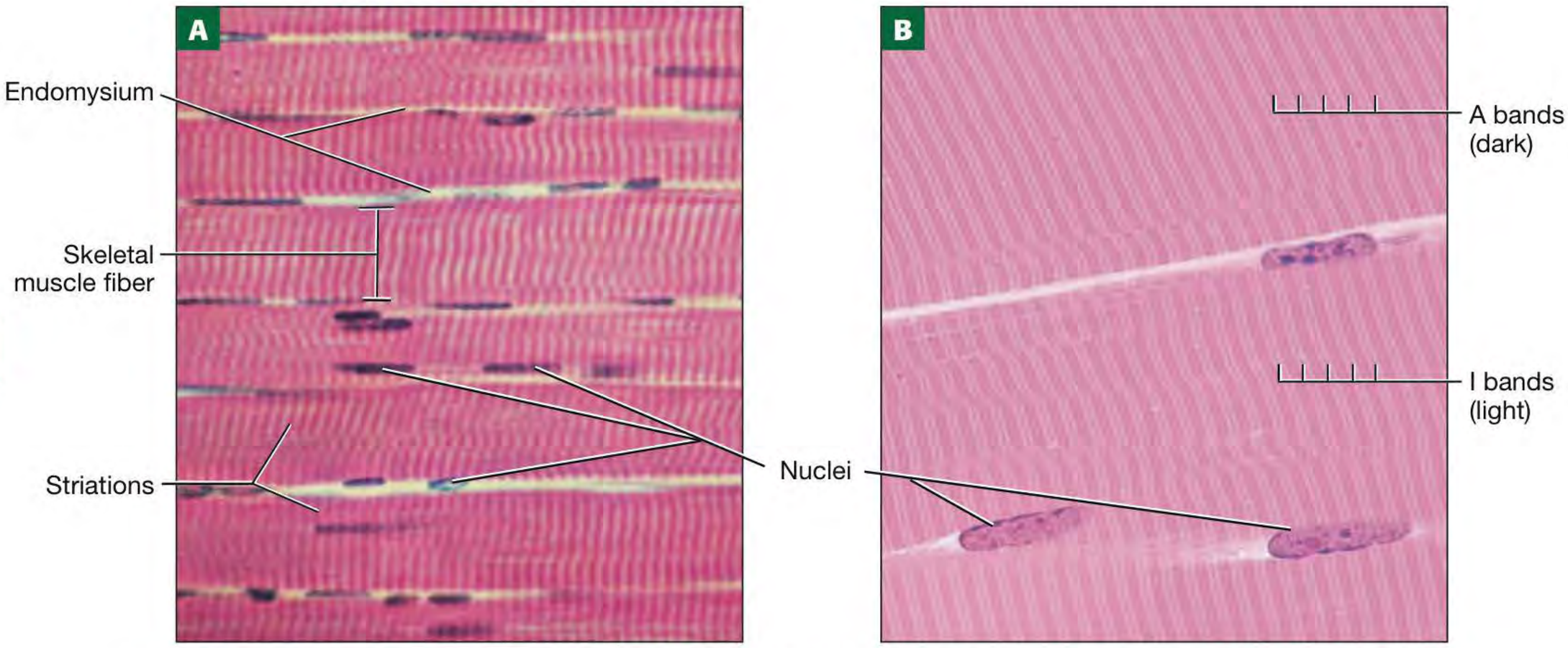


FIGURE **9.6** Skeletal muscle tissue, photomicrograph: (**A**) 40× objective; (**B**) 100× objective (oil immersion).

High-Power (40×) Objective

1. Striations
2. Sarcolemma
3. Nuclei
4. Endomysium

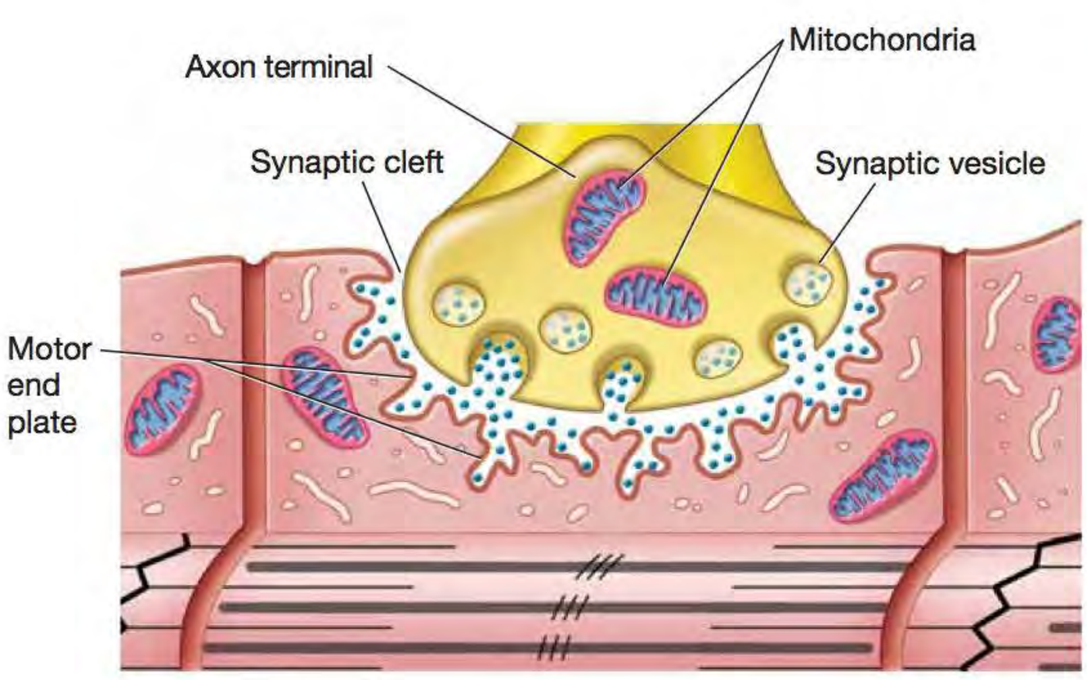
Oil-Immersion Lens

1. Sarcomere
2. A band
3. I band
4. Z disc
5. H zone
6. M line

The Neuromuscular Junction

Skeletal muscle fibers are voluntary, which means that they contract under the conscious control of the nervous system. Each skeletal muscle fiber has a **motor neuron** that triggers it to contract. The place where the nerve meets the muscle fiber is called the **neuromuscular junction** (NMJ) (Figure 9.7). The neuromuscular junction consists of three parts:

1. **Axon terminal.** Each motor neuron splits into many swollen **axon terminals,** each of which communicates with one muscle fiber. Each axon terminal has **synaptic vesicles** in its cytosol that contain the neurotransmitter **acetylcholine** (ah-SEE-til-koh-leen) **or ACh.**
2. **Synaptic cleft.** The axon terminal doesn't come into direct contact with the muscle fiber; instead, there is a space between the axon terminal and the muscle fiber called the **synaptic cleft.**
3. **Motor end plate.** The **motor end plate** is a specialized region of the sarcolemma that contains **acetylcholine receptors** to which ACh binds, beginning the events that will eventually lead to a muscle contraction.



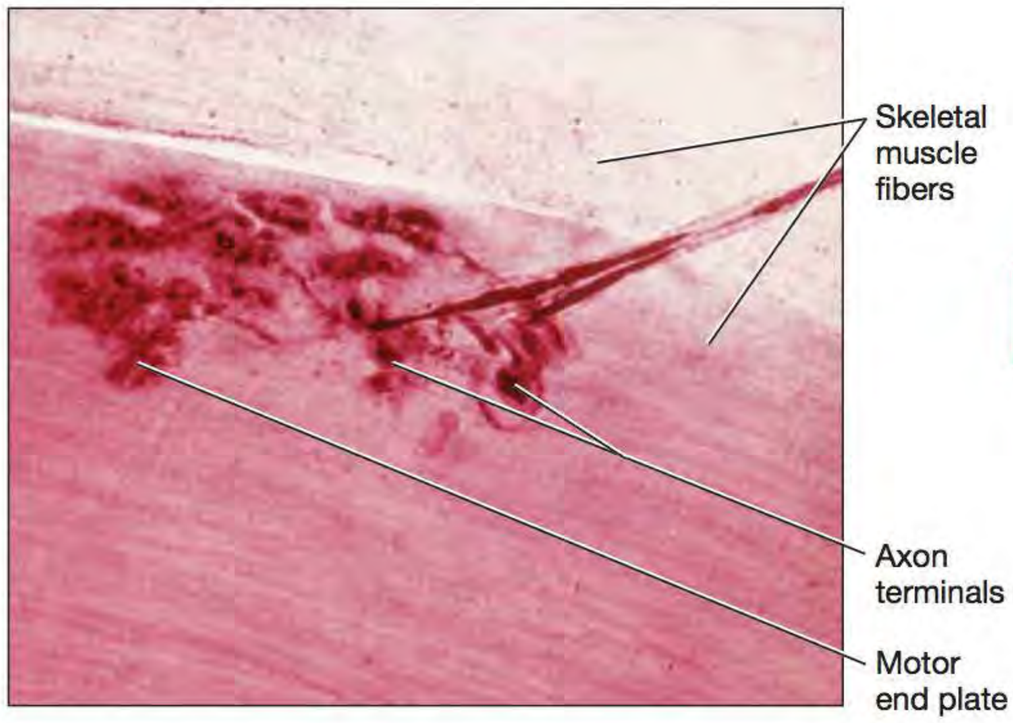


FIGURE **9.7** Neuromuscular junction.

Procedure 3 Model Inventory for the Neuromuscular Junction

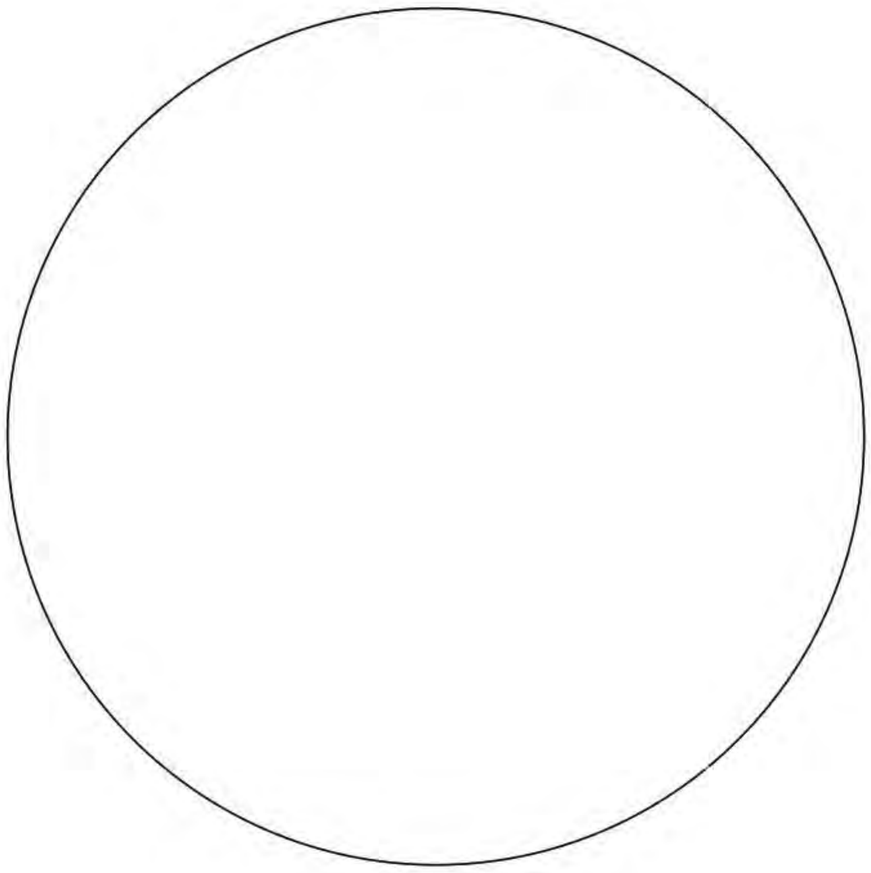
Identify the following structures of the neuromuscular junction on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 9.2 (note that this is the model inventory you used for the muscle fiber anatomy). When you have finished the activity, answer Check Your Understanding question 2 (p. 245).

- Motor neuron
- Axon terminal
- Synaptic vesicles
- Synaptic cleft
- Motor end plate
- Acetylcholine receptors

Procedure 4 Microscopy of the Neuromuscular Junction

Obtain a prepared slide of a neuromuscular junction. Use your colored pencils to draw what you see, and label your drawing with the following terms.

1. Motor neuron
2. Axon terminal
3. Skeletal muscle fiber
4. Striations



Exercise 9-2

Skeletal Muscles

MATERIALS

- ❑ Muscle models: upper limb, lower limb, trunk, head, neck

In this exercise, we divide skeletal muscles into muscle groups that have similar functions. For example, we classify the latissimus dorsi muscle with the muscles of the upper limb, rather than the muscles of the back or trunk, because it moves the upper limb. We will use the following groupings of skeletal muscles in this unit: muscles that move the head, neck, and face; muscles that move the trunk; muscles that move the shoulder; muscles that move the forearm and wrist; muscles that move the hip and knee; and muscles that move the ankle and foot.

1. **Muscles that move the head, neck, and face.** We can subdivide the muscles that move the head, neck, and face into the muscles of **facial expression**, the muscles of **mastication**, and the muscles that move the head and neck. The **muscles of facial expression** control the various facial expressions humans are capable of making, and they all insert into skin or other muscles. Examples include the **orbicularis oculi muscle** (ohr-bik-yoo-LEHR-iss AWK-yoo-lye), which closes and squints the eye, the **orbicularis oris muscle**, which purses the lips, and the **zygomaticus major** and **minor muscles**, which pull the corners of the mouth laterally during smiling. The other muscles of facial expression are illustrated in Figure 9.8. The **muscles of mastication** are involved in chewing. They include the **masseter muscle**, a thick muscle over the lateral jaw, and the fan-shaped **temporalis muscle**, which rests over the lateral skull.

   Several muscles move the head, including the **trapezius muscle** (trah-PEE-zee-uhs), which holds the head upright and hyperextends the neck (note that it also elevates the shoulders), and the **sternocleidomastoid muscle** (stern-oh-kly-doh-MASS-toyd), a strap-like muscle in the neck that flexes the head and neck, rotates the neck laterally, and flexes the neck laterally. In addition, two muscles called the **splenius capitis** (SPLEN-ee-us CAP-it-us) and **splenius cervicis** muscles (SIR-vih-sis) extend and hyperextend the head (Figure 9.9).

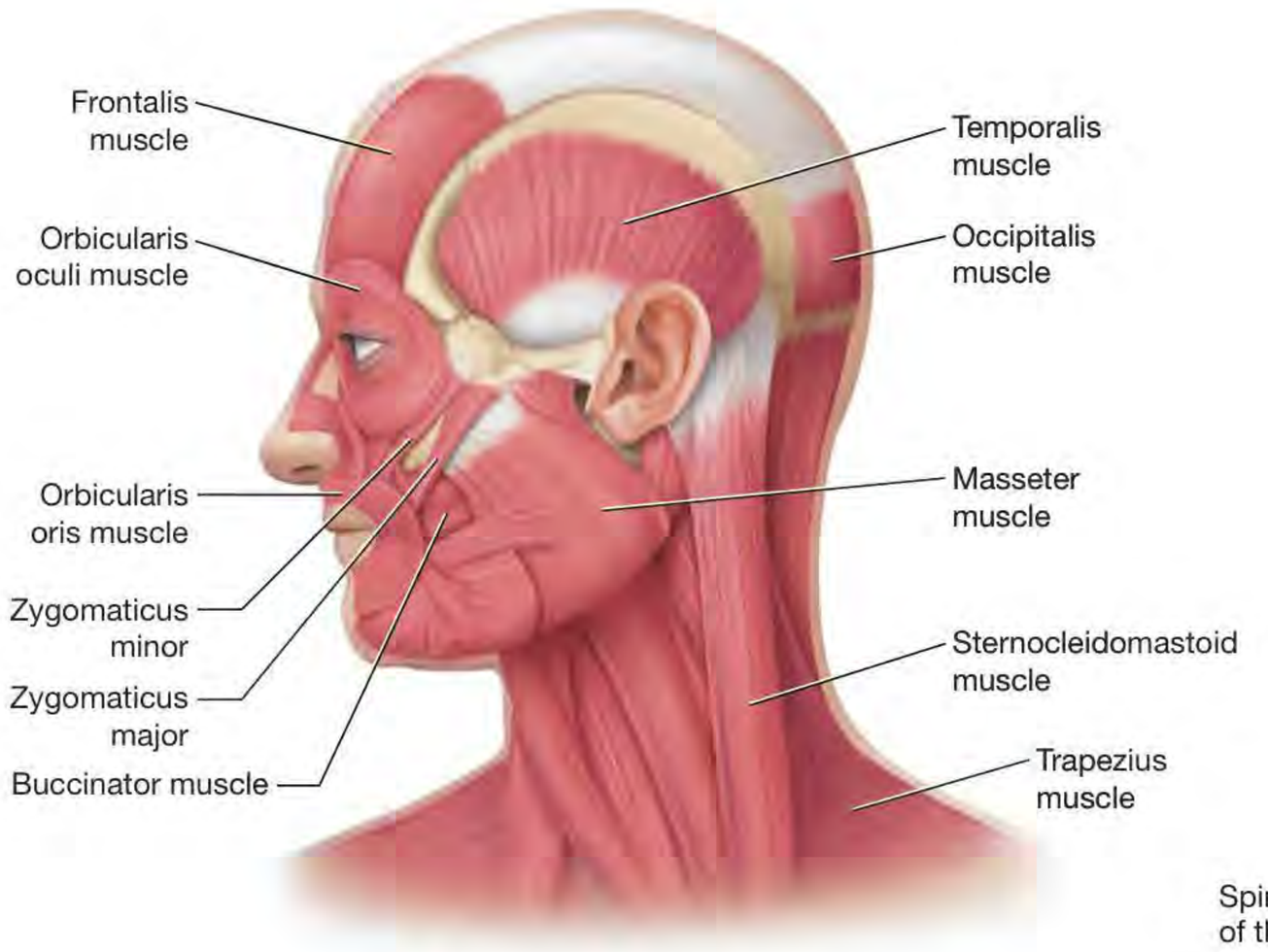


FIGURE **9.8** Facial musculature, lateral view.

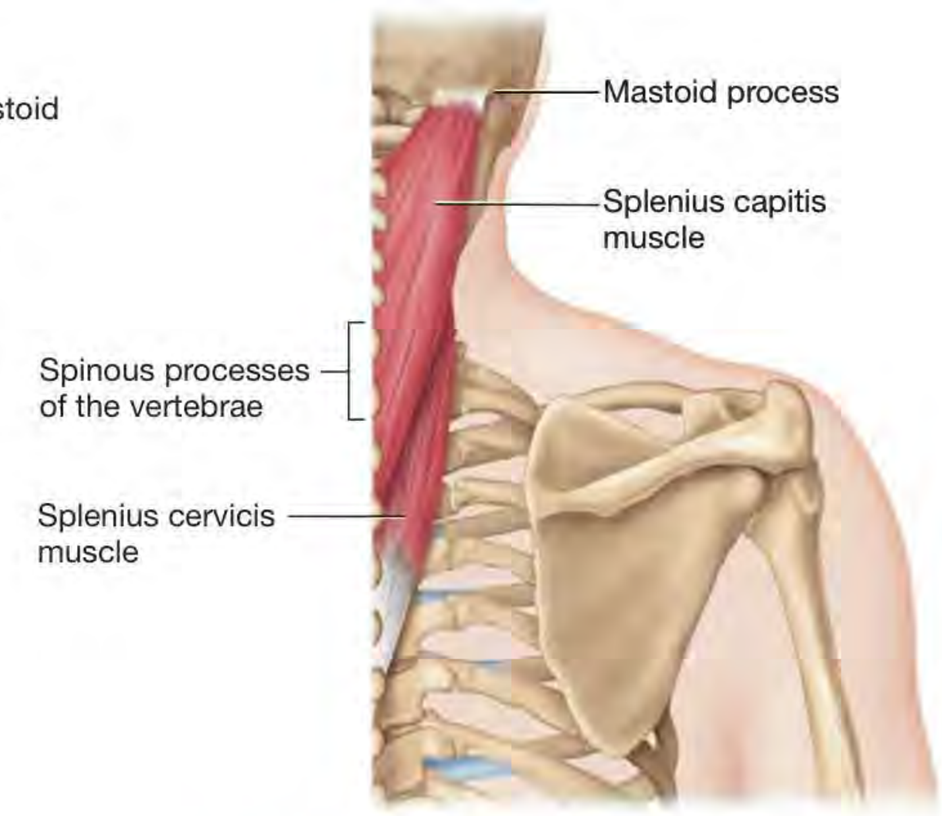


FIGURE **9.9** Splenius muscles of the neck.

2. **Muscles that move the trunk.** The muscles that move the trunk are the muscles of the thorax, muscles of the abdominal wall, and postural muscles of the back.
   a. The muscles of the thorax are generally involved in the muscle movements that produce ventilation. The **internal** and **external intercostal** muscles are located between the ribs and are involved in both quiet and forced inspiration and expiration (Figure 9.10); the circular **diaphragm** muscle (DY-uh-fram) produces the movements necessary for breathing; and the small **pectoralis minor** muscle draws the scapula anteriorly and the rib cage superiorly during forced inspiration and expiration (Figure 9.11).
   b. The abdominal muscles move the vertebral column and increase intra-abdominal pressure (Figure 9.12). The **rectus abdominis** muscle is the central and superficial muscle that flexes the vertebral column; the **internal** and **external oblique muscles** are located laterally and rotate the vertebral column; and the deep **transversus abdominis** muscle squeezes the abdominal contents like a belt to increase intra-abdominal pressure.
   c. The three main postural muscles of the back are part of a group known collectively as the **erector spinae** (eh-REK-tohr SPY-nee). The three components of the erector spinae include the lateral **iliocostalis** (ill-ee-oh-kawst-AL-iss), the middle **longissimus** (lawn-JISS-ih-muss), and the medial **spinalis muscles** (spy-NAL-iss) (Figure 9.13).

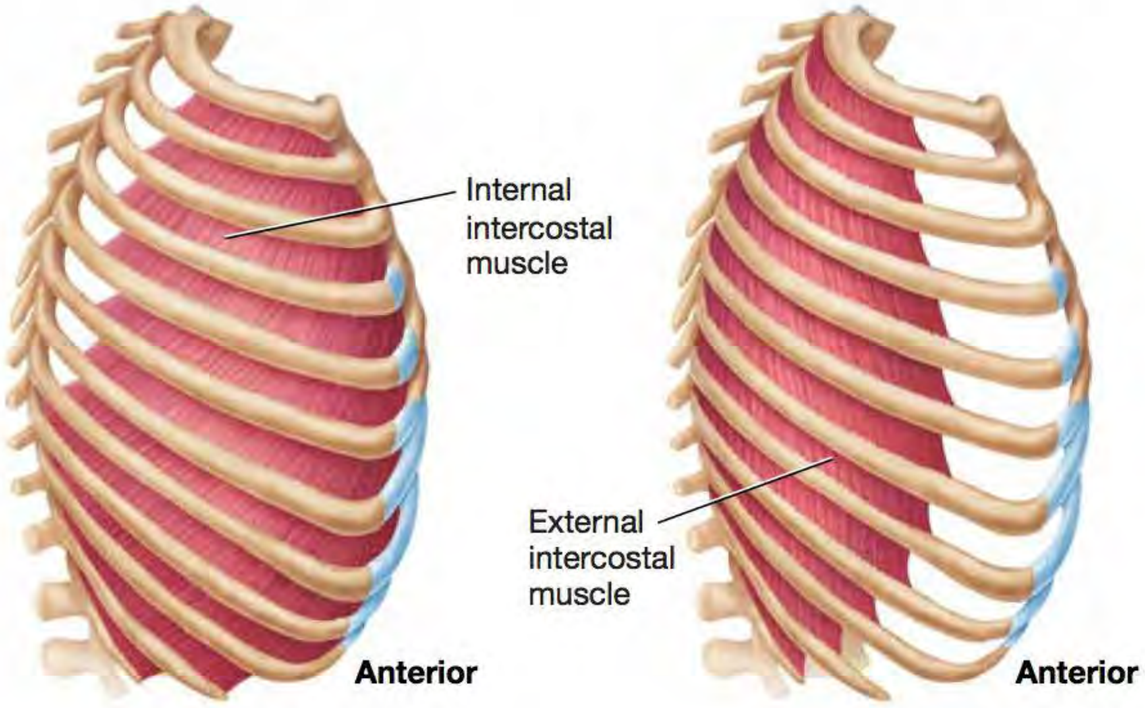


FIGURE **9.10** Internal and external intercostal muscles, lateral view.

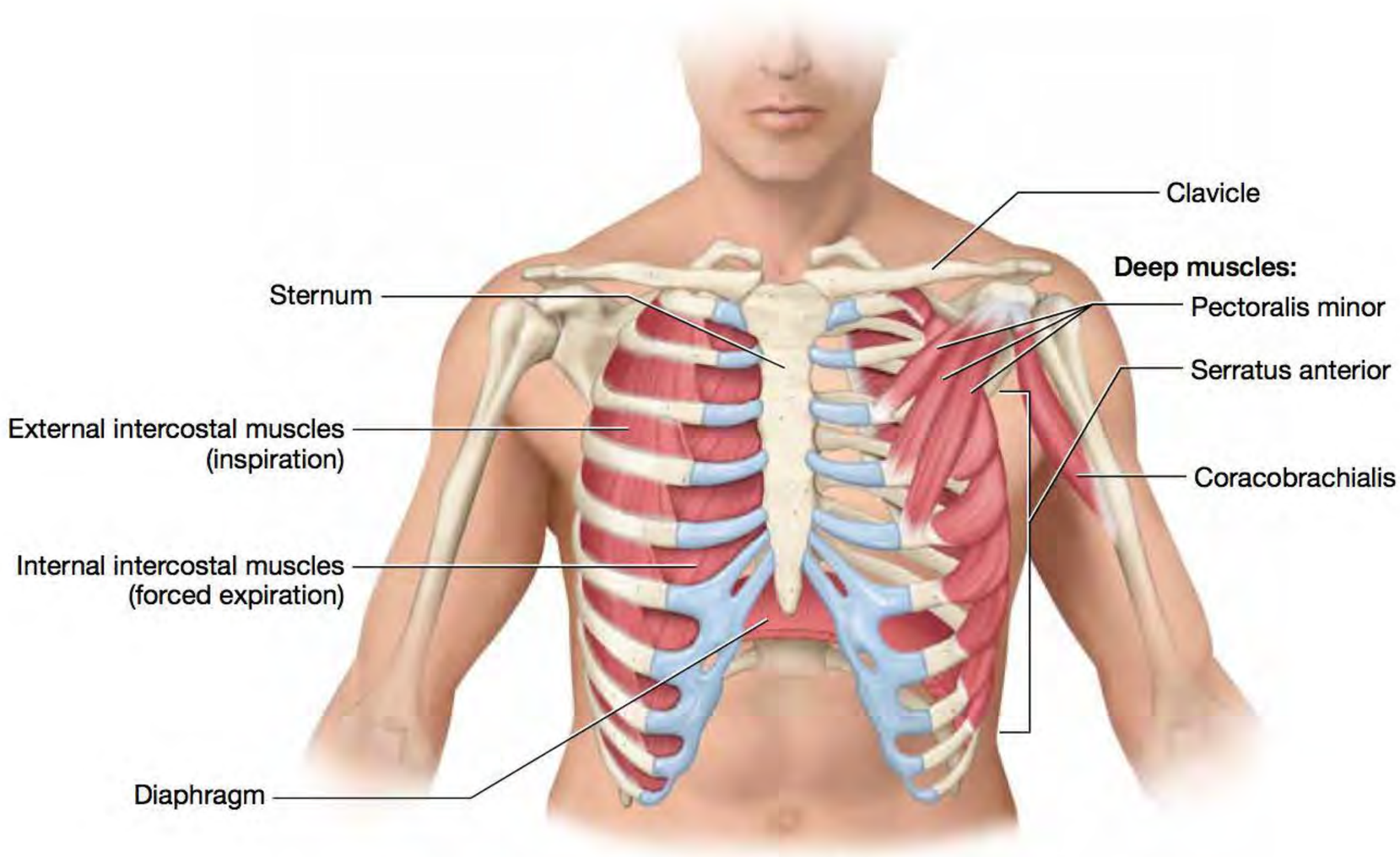


FIGURE **9.11** Deep muscles of the anterior thorax.

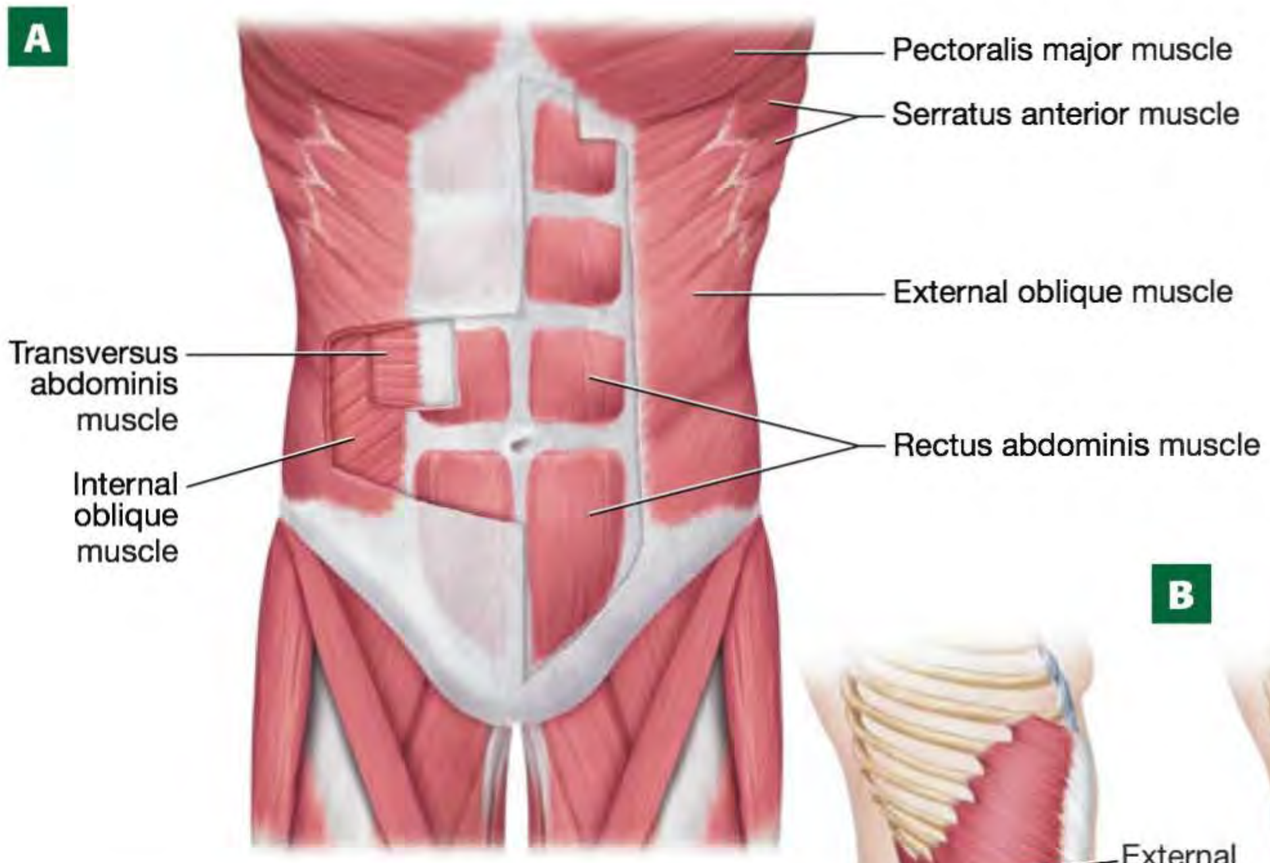


FIGURE **9.12** Muscles of the trunk: (**A**) anterior view of the abdomen; (**B**) lateral view of the individual abdominal muscles.

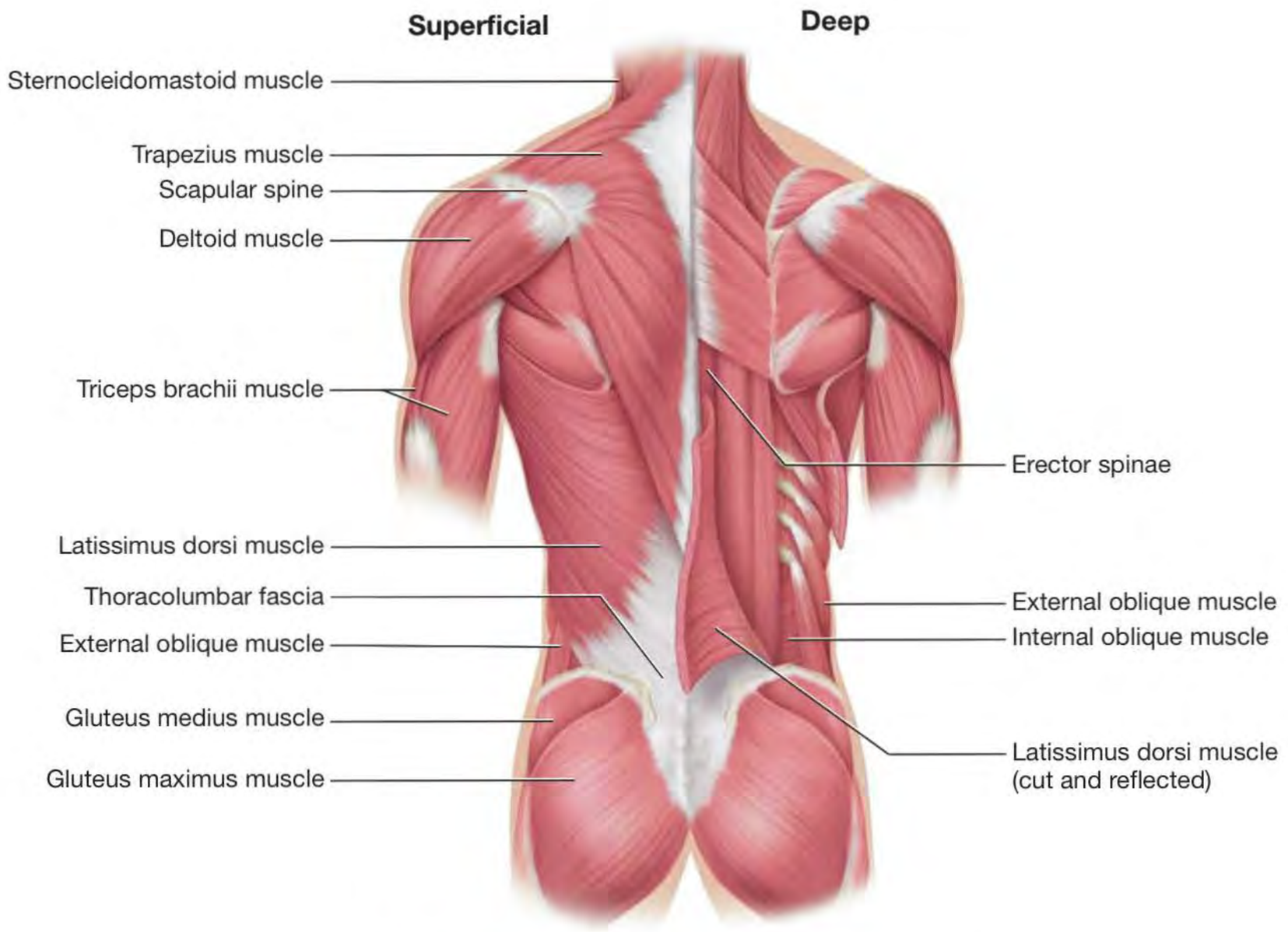


FIGURE **9.13** Muscles of the trunk, posterior view.

3. **Muscles that move the shoulder.** Only three muscles are "prime movers" of the shoulder: the posterior **latissimus dorsi muscle** (lah-TISS-ih-muss DOHR-sye), the prime muscle of shoulder extension (Figure 9.13); the **pectoralis major muscle**, or "chest muscle," the prime muscle of shoulder flexion; and the **deltoid muscle**, or "shoulder muscle," the prime abductor of the shoulder. The **serratus anterior muscle** (ser-AY-tus), located deep to the pectoralis major, acts mainly on the scapula, pulling it anteriorly, protracting it (as in when throwing a punch), and rotating it superiorly (as in when doing a bench press) (Figure 9.14). The other shoulder muscles, the **rotator cuff muscles**, are visible in Figure 9.15. They include the **infraspinatus** (in-frah-spin-AY-tus), **teres minor** (THER-eez), **supraspinatus** (soo-prah-spin-AY-tus), and **subscapularis muscles** (sub-skap-yoo-LEHR-us; note that the subscapularis is on the anterior scapula and is not visible in Figure 9.15). The tendons of these muscles unite with the articular capsule of the shoulder joint where they reinforce the capsule to prevent dislocation of the humerus from the scapula.
4. **Muscles that move the forearm and wrist.** The four main muscles that move the forearm are the anterior **biceps brachii** (BRAY-kee-aye), the anterior and deep **brachialis** (bray-kee-AL-iss), the anterior and lateral **brachioradialis** (bray-kee-oh-ray-dee-AL-iss), and the posterior **triceps brachii** muscles (Figures 9.16 and 9.17). The first three muscles play a role in forearm flexion, and the triceps brachii extends the forearm. The remainder of the muscles of the upper limb act on the wrist, the hand, and the digits. Muscles that flex the wrist and the digits, located on the anterior forearm, are the **flexor carpi radialis** (KARP-eye RAY-dee-al-iss), **flexor carpi ulnaris** (ul-NEHR-iss), **flexor digitorum**

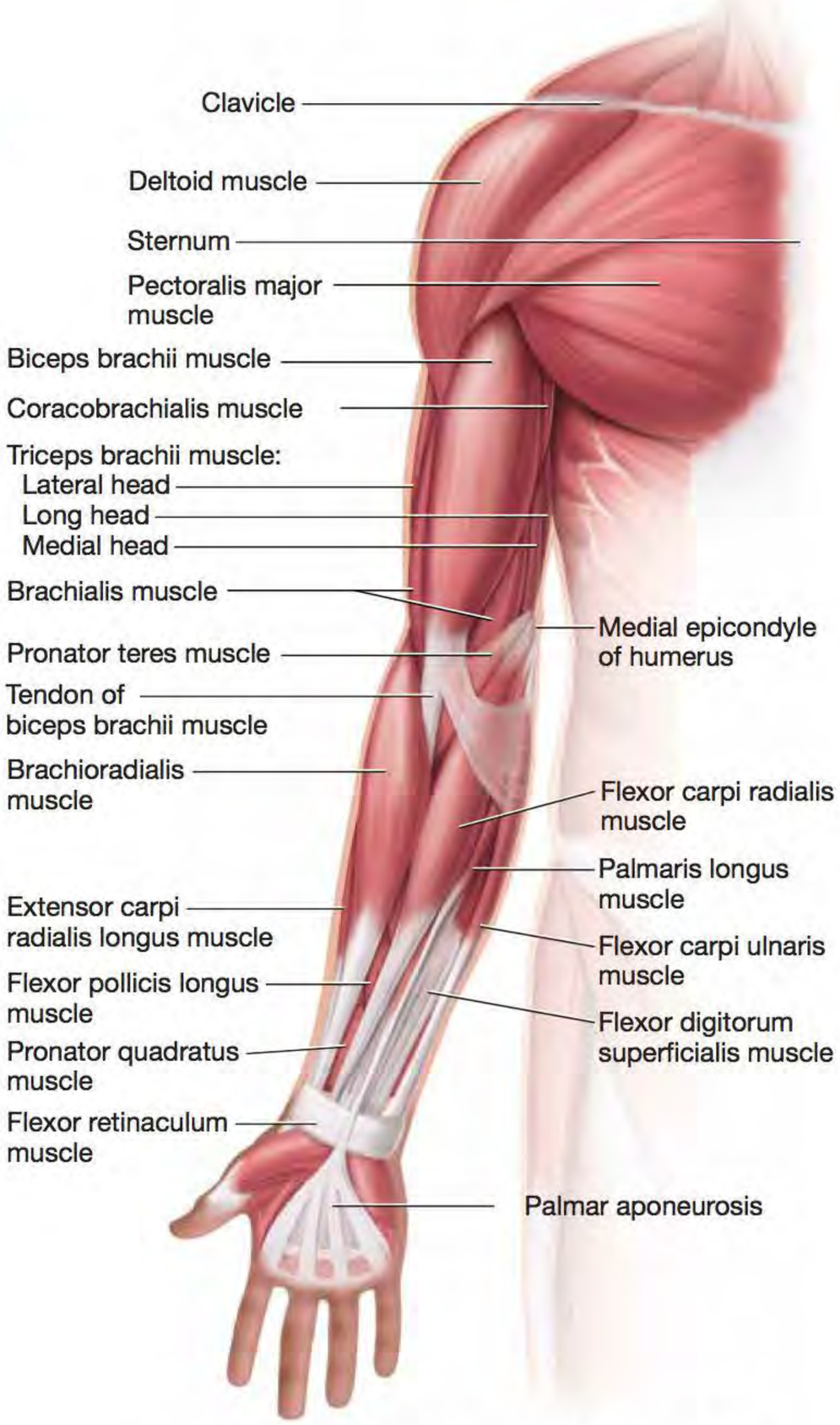


FIGURE **9.14** Anterior view of the muscles of the right upper limb.

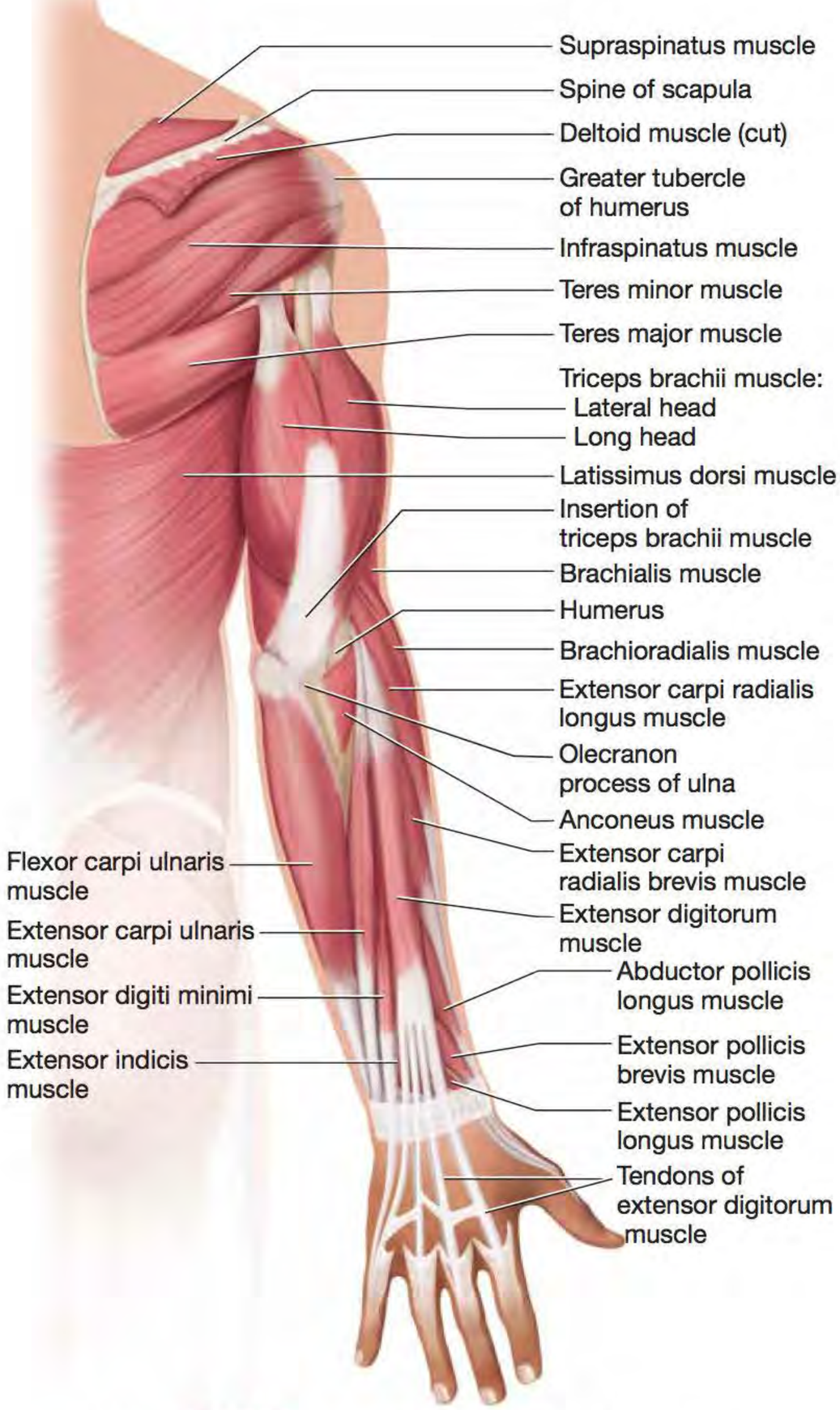


FIGURE **9.15** Posterior view of the muscles of the right upper limb.

superficialis, and **flexor digitorum profundus** muscles (Figure 9.16). Muscles that extend the wrist and the digits, located on the posterior forearm, are the **extensor carpi radialis longus, extensor digitorum,** and **extensor carpi ulnaris** muscles (Figure 9.17).

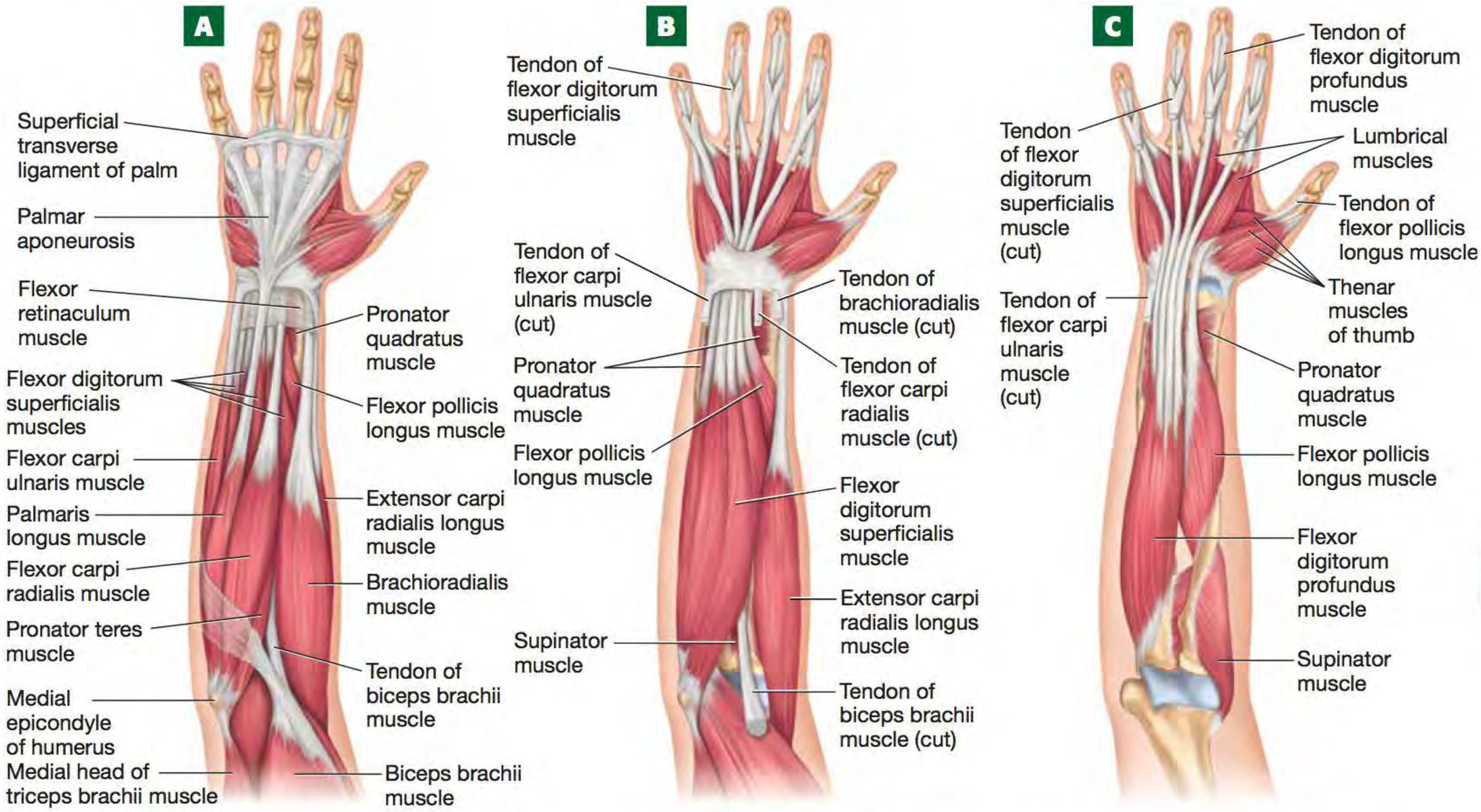


FIGURE **9.16** Muscles of the anterior right forearm: (**A**) superficial muscles; (**B**) intermediate muscles; (**C**) deep muscles.

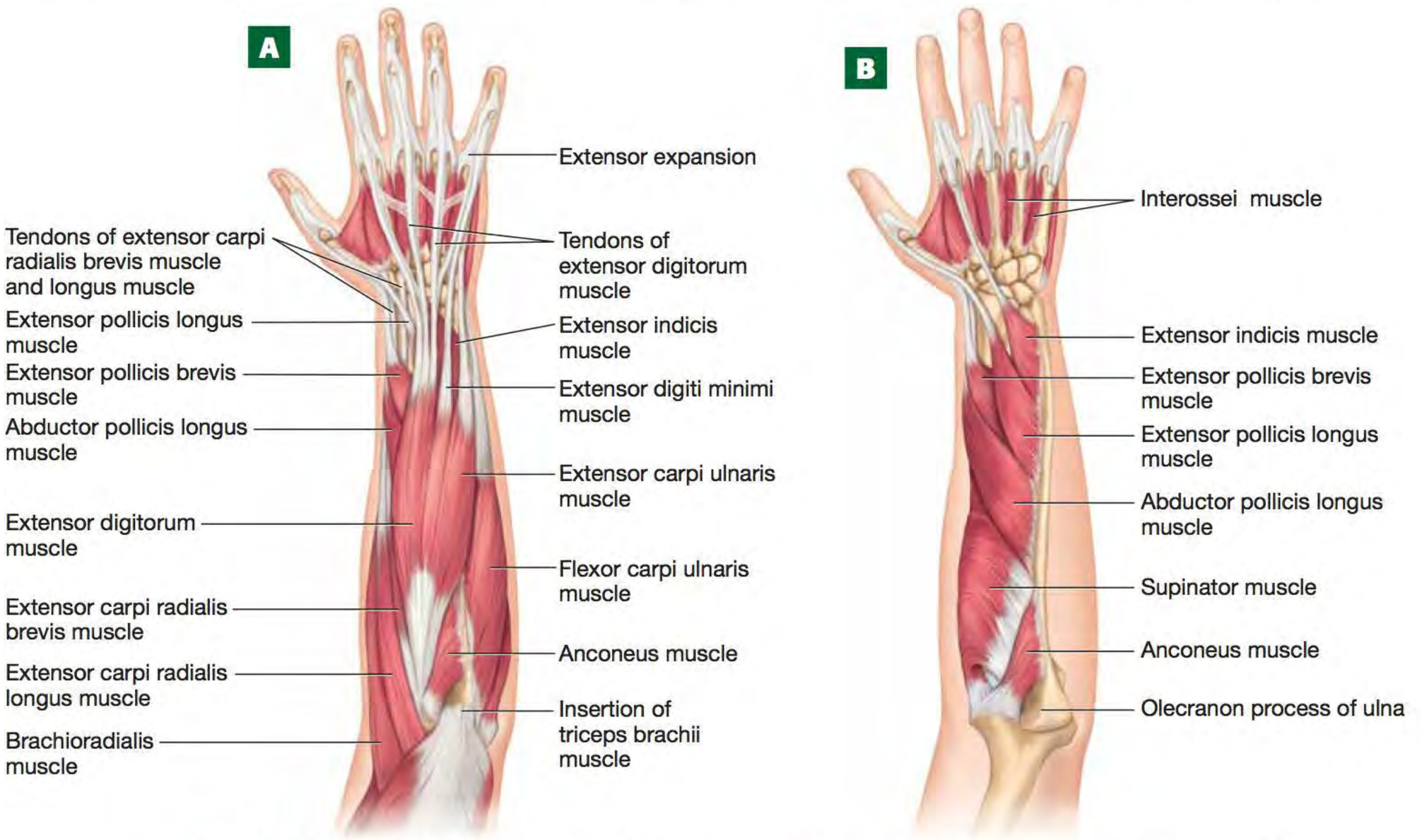


FIGURE **9.17** Muscles of the posterior right forearm: (**A**) superficial muscles; (**B**) deep muscles.

5. **Muscles that move the hip and knee.** Muscles that move the hip joint exclusively include the deep **iliopsoas** (ill-ee-oh-SOH-uhs), the anterior **pectineus** (pek-TIN-ee-uhs), the anterior **adductor group**, and the posterior **gluteus maximus** and **gluteus medius** (MEE-dee-us) muscles (Figures 9.18 and 9.19). The iliopsoas muscle is the prime flexor of the hip joint and is assisted by the pectineus muscle. As implied by their names, the muscles in the adductor group are the prime adductors of the hip joint. The gluteus maximus muscle is the prime extensor of the hip joint, and the gluteus medius muscle is a major abductor of the hip joint. Other posterior muscles are illustrated in Figure 9.19.

   The remainder of the thigh muscles may move both the hip and knee or just the knee joint. One of the most prominent groups of thigh muscles is the anterior thigh and known as the **quadriceps femoris group**. It includes the **rectus femoris, vastus lateralis, vastus intermedius,** and **vastus medialis** muscles. These four muscles converge to form the common patellar tendon, which envelops the patella. Note that the vastus intermedius muscle is deep to the rectus femoris muscle and so is not visible in Figure 9.18. Other prominent muscles include the strap-like **sartorius muscle** (sar-TORH-ee-us), which crosses from lateral to medial across the thigh, and the medial **gracilis muscle** (grah-SILL-iss).

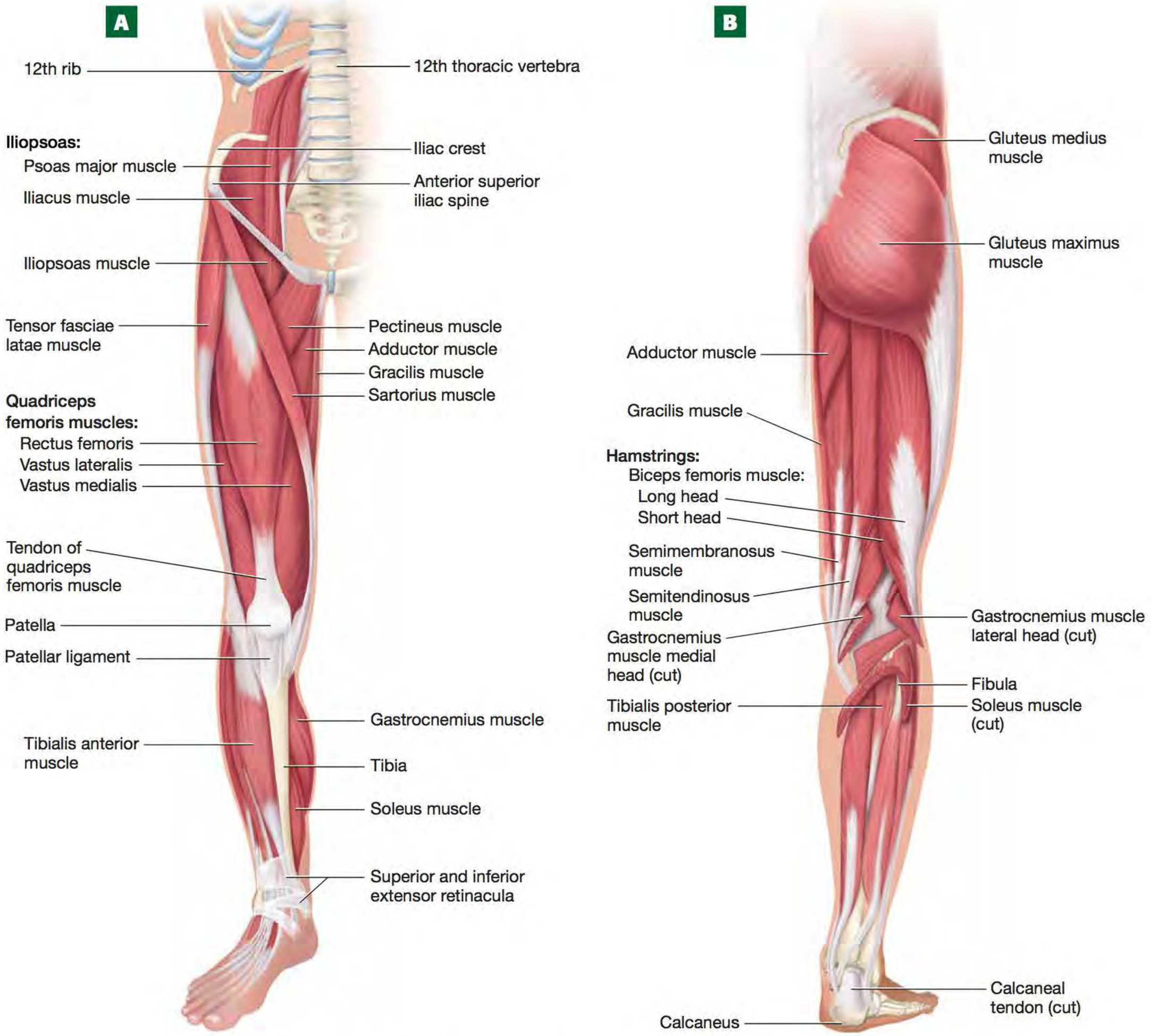


FIGURE **9.18** Muscles of the right lower limb: (**A**) anterior lower limb; (**B**) posterior lower limb.

Most of these muscles have the dual function of flexion at the hip joint and extension at the knee joint; the exception is the vastus muscle group, which only extends the knee joint. The posterior thigh muscles include the three muscles of the **hamstrings group**: the lateral **biceps femoris** and the medial **semitendinosus** (sem-eye-ten-din-OH-sus) and **semimembranosus** (sem-eye-mem-brah-NOH-sus) muscles. These three muscles produce both extension at the hip joint and flexion at the knee joint.

6. **Muscles that move the ankle and foot.** The most obvious muscle of the posterior leg is the large **gastrocnemius** muscle (gas-trawk-NEE-mee-us), also known as the "calf muscle." This two-headed muscle originates on the distal femur and inserts into the posterior calcaneus via the **calcaneal tendon** (kal-KAY-nee-uhl), more commonly called the **Achilles tendon.** Deep to the gastrocnemius is the **soleus** muscle (SOHL-ee-us), which unites with the gastrocnemius and contributes to the calcaneal tendon. Together these two muscles are the prime muscles that produce plantarflexion at the ankle joint. The gastrocnemius also produces some flexion at the knee joint. Deep to these two muscles are muscles that plantarflex the foot and the digits, as well as the **tibialis posterior muscle** (tib-ee-AL-is), the main inverter of the foot. On the lateral leg we find two muscles, the **fibularis longus** (fib-yoo-LEHR-iss) and **fibularis brevis muscles,** the main everters of the foot. Anteriorly are the extensors such as the **extensor digitorum longus,** which extends the toes, and the **tibialis anterior,** which dorsiflexes the foot and the ankle joint. The muscles of the leg are best seen in Figures 9.18 and 9.20.

Figures 9.21 and 9.22 provide whole-body views of many of the muscles we have just discussed.

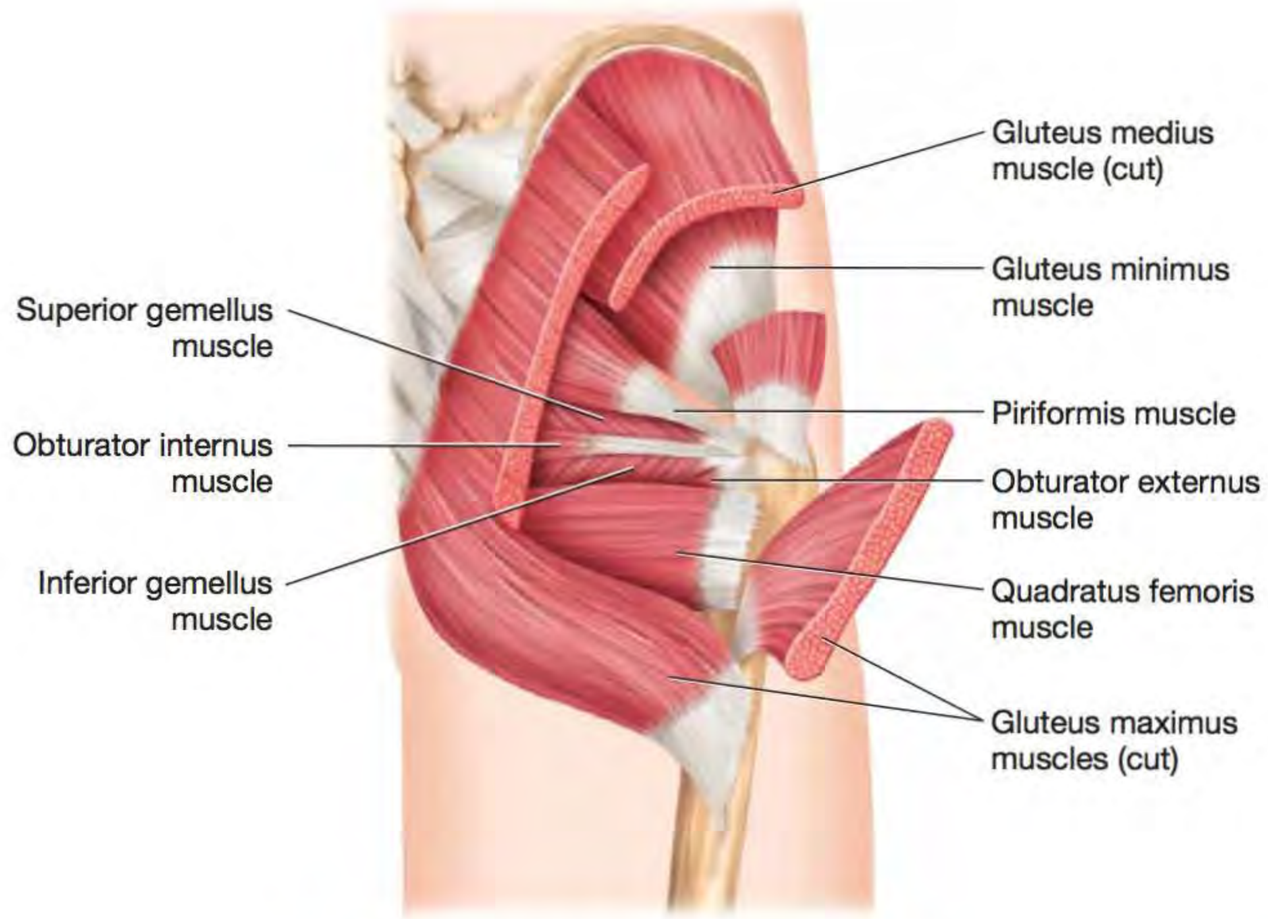


FIGURE **9.19** Deeper muscles of the gluteal region.

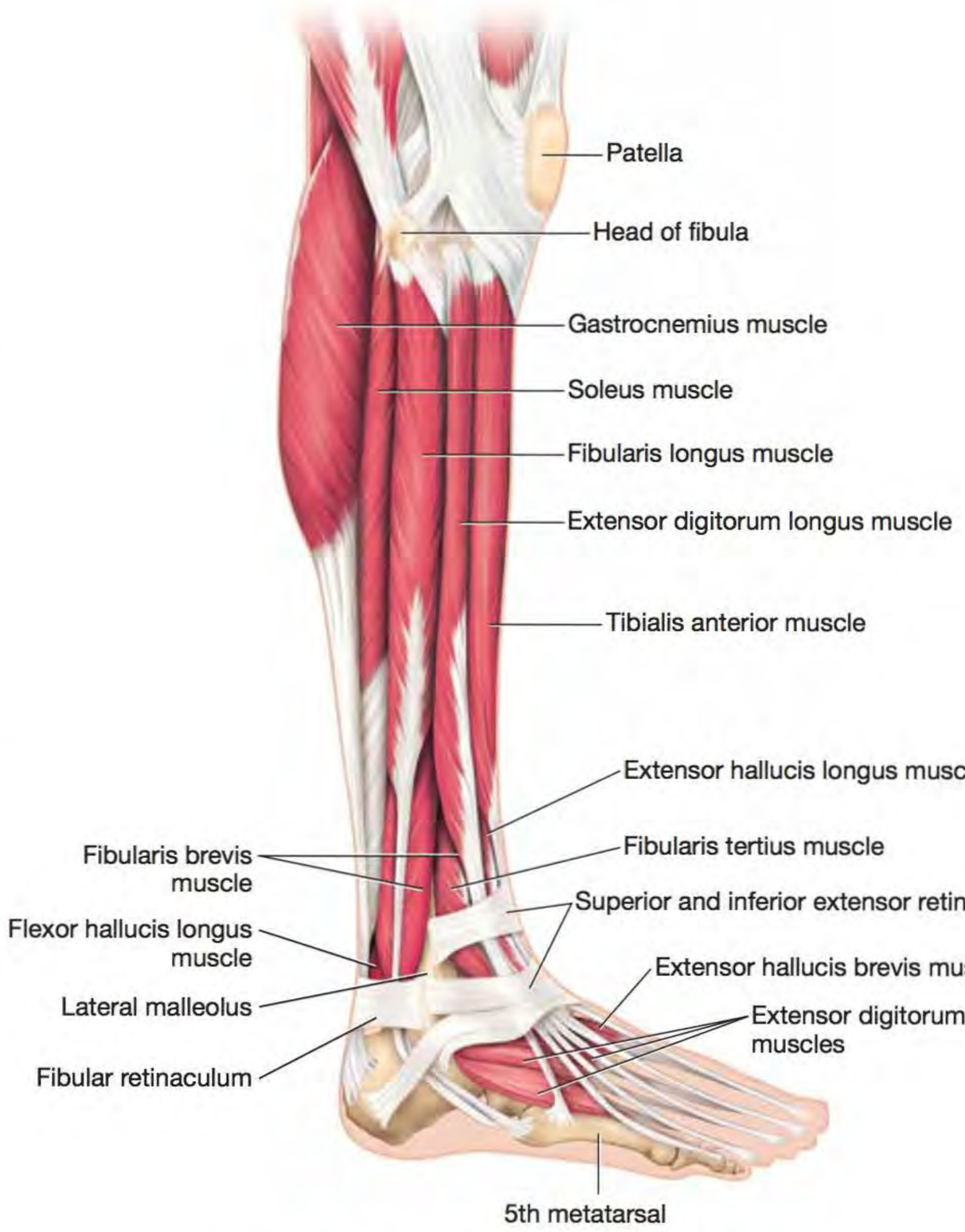


FIGURE **9.20** Lateral view of muscles of the leg.

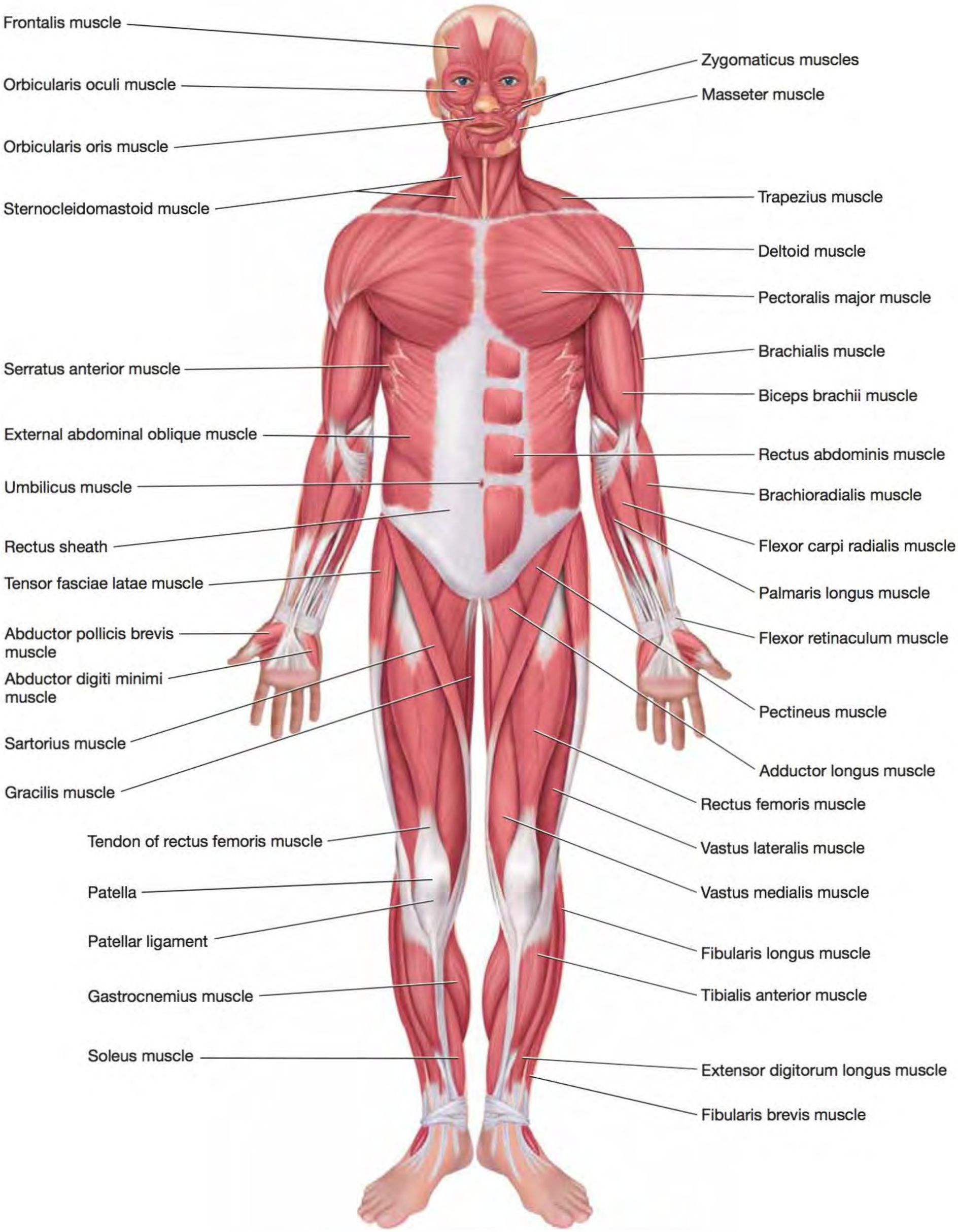


FIGURE **9.21** Muscles of the body, anterior view.

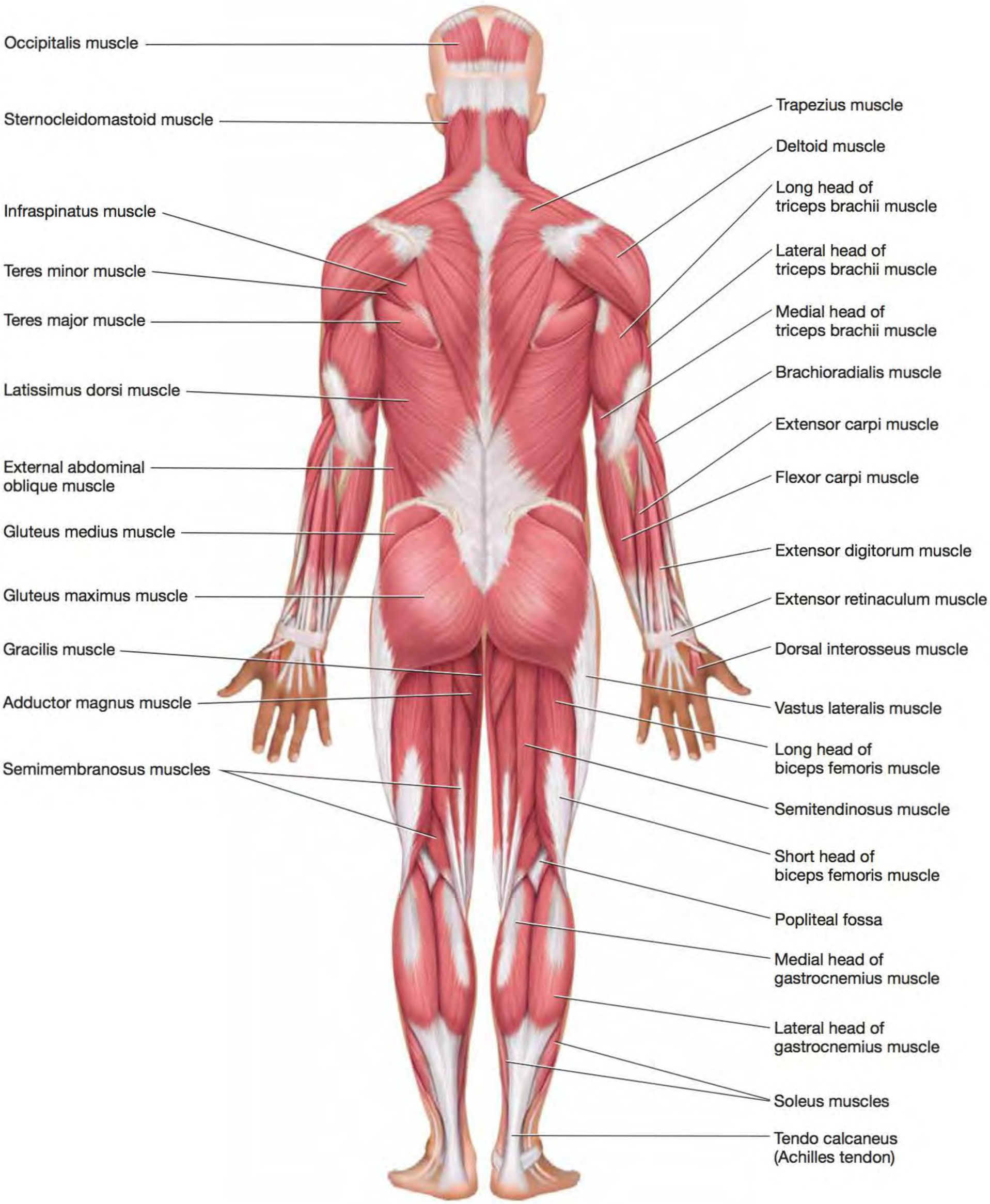


FIGURE **9.22** Muscles of the body, posterior view.

Procedure 1 Model Inventory for the Skeletal Muscles

Identify the following muscles on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 9.3. When you have completed the activity, answer Check Your Understanding question 3 (p. 245).

Muscles That Move the Head, Neck, and Face

1. Muscles of facial expression
   a. Epicranius (frontalis and occipitalis) m.
   b. Orbicularis oculi m.
   c. Zygomaticus major and minor mm.
   d. Buccinator m.
   e. Orbicularis oris m.
2. Muscles of mastication
   a. Temporalis m.
   b. Masseter m.
3. Muscles of head and neck
   a. Platysma m.
   b. Sternocleidomastoid m.
   c. Trapezius m.
   d. Splenius capitis m.
   e. Splenius cervicis m.

Muscles That Move the Shoulder

1. Muscles of the shoulder
   a. Deltoid m.
   b. Pectoralis major m.
   c. Latissimus dorsi m.
   d. Serratus anterior m.
2. Rotator cuff muscles
   a. Infraspinatus m.
   b. Subscapularis m.
   c. Supraspinatus m.
   d. Teres minor m.

Muscles That Move the Hip and Knee

1. Muscles of the pelvic girdle
   a. Iliopsoas m.
   b. Gluteus maximus m.
   c. Gluteus medius m.
2. Muscles of the thigh
   a. Pectineus m.
   b. Adductor group
      (1) Adductor magnus m.
      (2) Adductor longus m.
      (3) Adductor brevis m.

Muscles That Move the Trunk

1. Muscles of the thorax
   a. Pectoralis minor m.
   b. External intercostal mm.
   c. Internal intercostal mm.
   d. Diaphragm m.
2. Muscles of the abdominal wall
   a. Rectus abdominis m.
   b. External oblique m.
   c. Internal oblique m.
   d. Transversus abdominis m.
3. Postural muscles of the back
   a. Erector spinae m.
      (1) Iliocostalis m.
      (2) Longissimus m.
      (3) Spinalis m.

Muscles That Move the Forearm and Wrist

1. Muscles of the arm
   a. Biceps brachii m.
   b. Triceps brachii m.
   c. Brachialis m.
   d. Brachioradialis m.
2. Flexors of the forearm
   a. Flexor carpi radialis m.
   b. Flexor carpi ulnaris m.
   c. Flexor digitorum superficialis m.
   d. Flexor digitorum profundus m.
3. Extensors of the forearm
   a. Extensor carpi radialis longus m.
   b. Extensor digitorum m.
   c. Extensor carpi ulnaris m.

c. Quadriceps femoris group
   (1) Rectus femoris m.
   (2) Vastus medialis m.
   (3) Vastus intermedius m.
   (4) Vastus lateralis m.
d. Sartorius m.
e. Gracilis m.
f. Hamstring muscles
   (1) Biceps femoris m.
   (2) Semimembranosus m.
   (3) Semitendinosus m.

Muscles That Move the Ankle and Foot

1. Gastrocnemius m.
2. Soleus m.
3. Flexor digitorum longus m.
4. Fibularis (peroneus) longus m.
5. Fibularis (peroneus) brevis m.
6. Tibialis posterior m.
7. Tibialis anterior m.
8. Extensor digitorum longus m.

Your instructor may wish to omit certain muscles included above or add muscles not included in these lists. List any additional structures below:

Table **9.3** Model Inventory for Skeletal Muscles

Model/Diagram	Structures Identified

Exercise 9-3

Muscle Origins, Insertions, and Actions

MATERIALS

- ❑ Small skeletons
- ❑ Modeling clay in five colors

Before you can fully understand a muscle's actions, you must understand a muscle's origin and insertion. As we discussed in the introduction to this unit, the origin of a muscle is the part from which it originates, which generally is the more stationary part, and the muscle typically inserts into the part that it moves. For example, you can see in Figure 9.23 that the biceps brachii muscle originates on the coracoid process of the scapula and crosses the elbow joint, where it inserts into the radial tuberosity. Notice also that the triceps brachii muscle originates from the humerus and the inferior scapula and crosses the elbow joint to insert into the olecranon process.

Once you determine a muscle's origin and insertion, figuring out its actions becomes easy. Let's examine the biceps brachii and triceps brachii muscles again. The biceps brachii muscle inserts into the radial tuberosity, so we know it will move the forearm. Given how it crosses the anterior elbow joint, we can conclude it will cause forearm *flexion* at the elbow joint. The triceps brachii muscle inserts into the olecranon process, so we know it also will move the forearm. Given how it crosses the posterior elbow joint, we can conclude that it will cause forearm *extension* at the elbow joint. Now wasn't that easy? So you don't need to actually memorize most muscle actions—all you need to do is look at a muscle's origin and insertion and use some basic logic to figure out its actions. We practice doing this in the next two procedures.

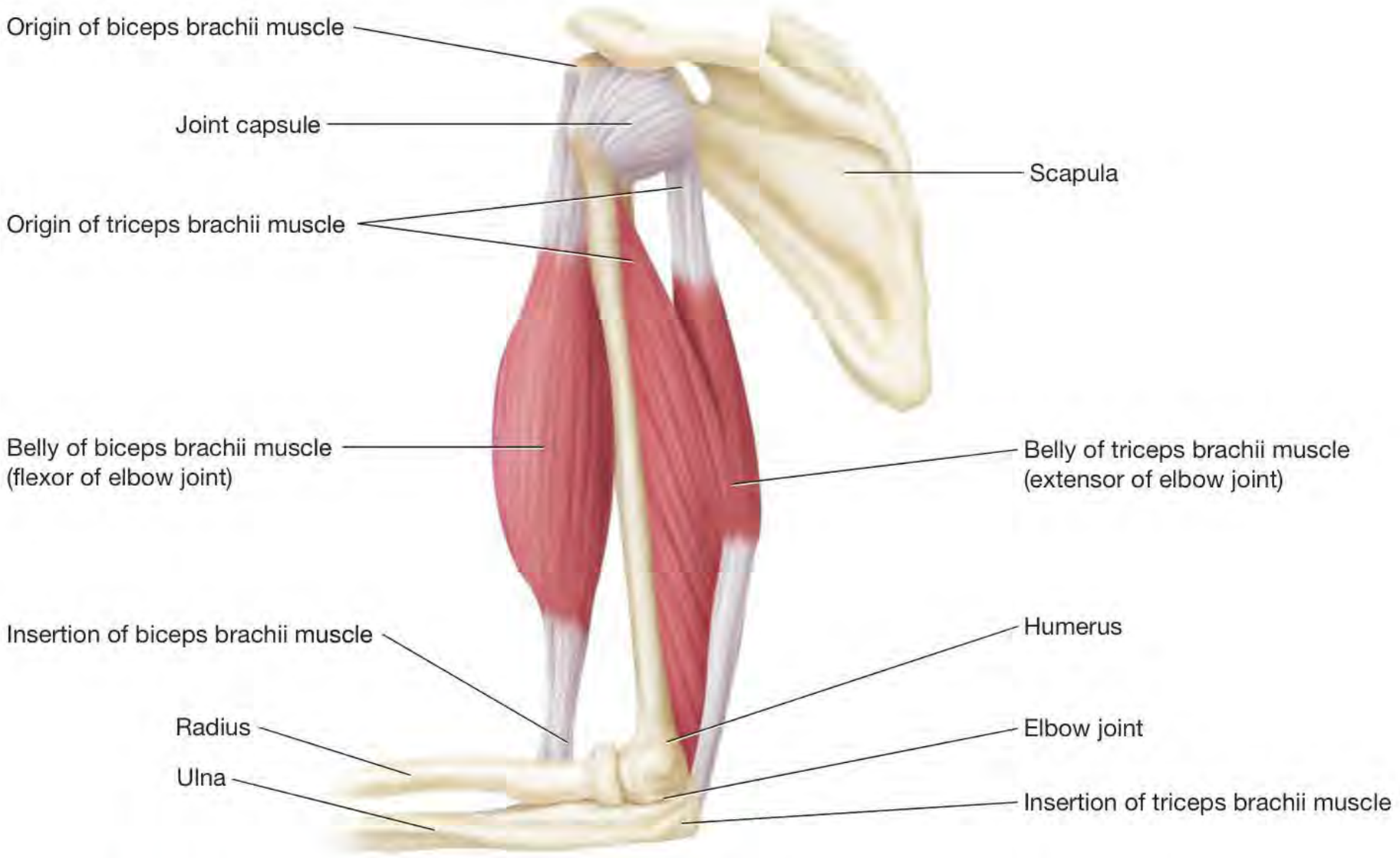


FIGURE **9.23** Origin and insertion of the biceps brachii and triceps brachii muscles, posterior view.

Procedure 1 Build Muscles

In this exercise you will use small skeletons and modeling clay to build specific muscle groups. This may sound easy, but there is a catch: You must determine the actions of the muscle by looking only at the origin and insertion of each muscle you build. Use Pre-Lab Exercise 9-4 (p. 215) as a guide to each muscle's origin and insertion. When you have finished the activity, answer Check Your Understanding questions 4 through 7.

1. Obtain a small skeleton and five colors of modeling clay.
2. Build the indicated muscles, using a different color of clay for each muscle. As you build, pay careful attention to the origin and insertion of each muscle.
3. Determine the primary actions for each muscle you have built by looking *only* at the origin and insertion. Record this information in Tables 9.4–9.6.

TABLE **9.4** Muscles and Actions for Group 1

Muscle	Actions
Biceps femoris m.	
Rectus femoris m.	
Gluteus medius m.	
Adductor group	

TABLE **9.5** Muscles and Actions for Group 2

Muscle	Actions
Biceps brachii m.	
Triceps brachii m.	
Deltoid m.	
Pectoralis major m.	

TABLE **9.6** Muscles and Actions for Group 3

Muscle	Actions
Gastrocnemius m.	
Tibialis anterior m.	
Rectus abdominis m.	
Trapezius m.	

Procedure 2 Identifying Muscle Actions of Common Movements

This exercise should look familiar, because you did a similar exercise in Unit 8 (Articulations, p. 200). As before, you will be performing various activities to demonstrate which joints are moving with each activity. In this exercise, however, rather than focusing on the motions that occur at each joint, you will be determining *which muscles* are causing the motions at each joint. Following is an example:

Walking in Place

Part 1

First list all motions occurring at each joint (as before, the joints are listed with their common names, and the lists are certainly *not* all-inclusive):

- Vertebral column and neck: extension
- Shoulder: flexion/extension
- Elbow: flexion
- Hip: flexion/extension, abduction/adduction
- Knee: flexion/extension
- Ankle: dorsiflexion/plantarflexion, inversion/eversion

Part 2

Now refer to Table 9.1 in Pre-Lab Exercise 9-4 (p. 215) to determine which muscles are causing each joint to move. Please note that these lists are far from complete. With nearly 700 muscles in the human body, a complete list could take all day!

- Vertebral column and neck
  - Extension: erector spinae and trapezius muscles
- Shoulder
  - Flexion: pectoralis major muscle
  - Extension: latissimus dorsi muscle
- Elbow
  - Flexion: biceps brachii, brachialis, and brachioradialis muscles
- Hip
  - Flexion: iliopsoas, sartorius muscles
  - Extension: biceps femoris, semitendinosus, semimembranosus, and gluteus maximus muscles
  - Abduction: tensor fasciae latae, sartorius, and gluteus medius muscles
  - Adduction: gracilis and adductor muscles
- Knee
  - Flexion: biceps femoris, semitendinosus, semimembranosus, and gastrocnemius muscles
  - Extension: rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis muscles
- Ankle
  - Dorsiflexion: tibialis anterior muscle
  - Plantarflexion: gastrocnemius and soleus muscles
  - Inversion: tibialis anterior and tibialis posterior muscles
  - Eversion: fibularis brevis and fibularis longus muscles

Okay, so now you're thinking, "Wow, that's a lot of work!" Following are a few hints that will make this task less daunting:

- You will notice that the following activities are the same as the activities from Exercise 8-3 in Unit 8 (p. 200). To save yourself some work, reference that exercise to complete Part 1 of this exercise.
- As before, perform the indicated activity. If you don't, you'll miss some things!

- Unless your instructor asks you to do otherwise, try to keep it simple. List only the main muscles for each action. For example, when listing the muscles to flex the hip, we easily could include 10 different muscles. To make it simpler, list only those muscles we discussed that flex the hip as their primary action (as in the example on page 236).

Ready to give it a try? Determine the joints being moved for Part 1, and then determine the muscles moving the joints for Part 2. Refer to Unit 8 (p. 185) for help.

1 Walking up the stairs

Part 1:

Part 2:

2 Doing jumping jacks

Part 1:

Part 2:

3 Answering the telephone

Part 1:

Part 2:

4 Jumping rope

Part 1:

Part 2:

Name _____

Section _____ Date _____

UNIT 9 REVIEW

Check Your Recall

1 Label the following terms on Figure 9.24.

- ❑ A band
- ❑ I band
- ❑ Myofibril
- ❑ Nucleus
- ❑ Sarcolemma
- ❑ Sarcomere
- ❑ Sarcoplasmic reticulum
- ❑ T-tubule
- ❑ Z disc

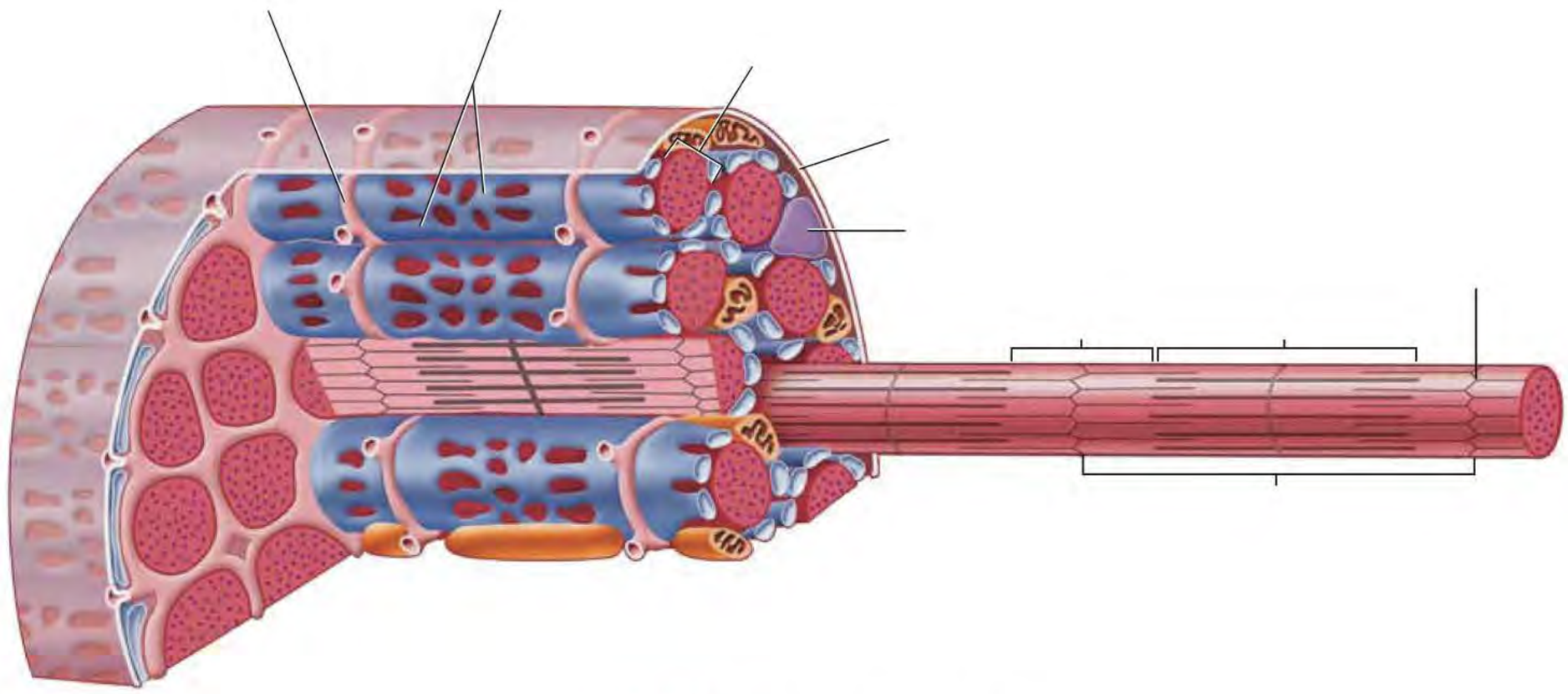


FIGURE **9.24** Skeletal muscle fiber.

2 **The striations in skeletal muscle fibers are attributable to**

a. light and dark pigments found in the sarcoplasm.
b. the arrangement of thick and thin filaments in the myofibril.
c. overlapping Z discs.
d. overlapping adjacent skeletal muscle fibers.

3 **Which of the following is *not* a part of the neuromuscular junction?**

a. Axon terminal
b. Dendritic receptor
c. Synaptic cleft
d. Motor end plate

4 Label the following muscles on Figure 9.25.

- ❑ Buccinator m.
- ❑ Frontalis m.
- ❑ Masseter m.
- ❑ Occipitalis m.
- ❑ Orbicularis oculi m.
- ❑ Orbicularis oris m.
- ❑ Sternocleidomastoid m.
- ❑ Temporalis m.
- ❑ Zygomaticus major and minor mm.

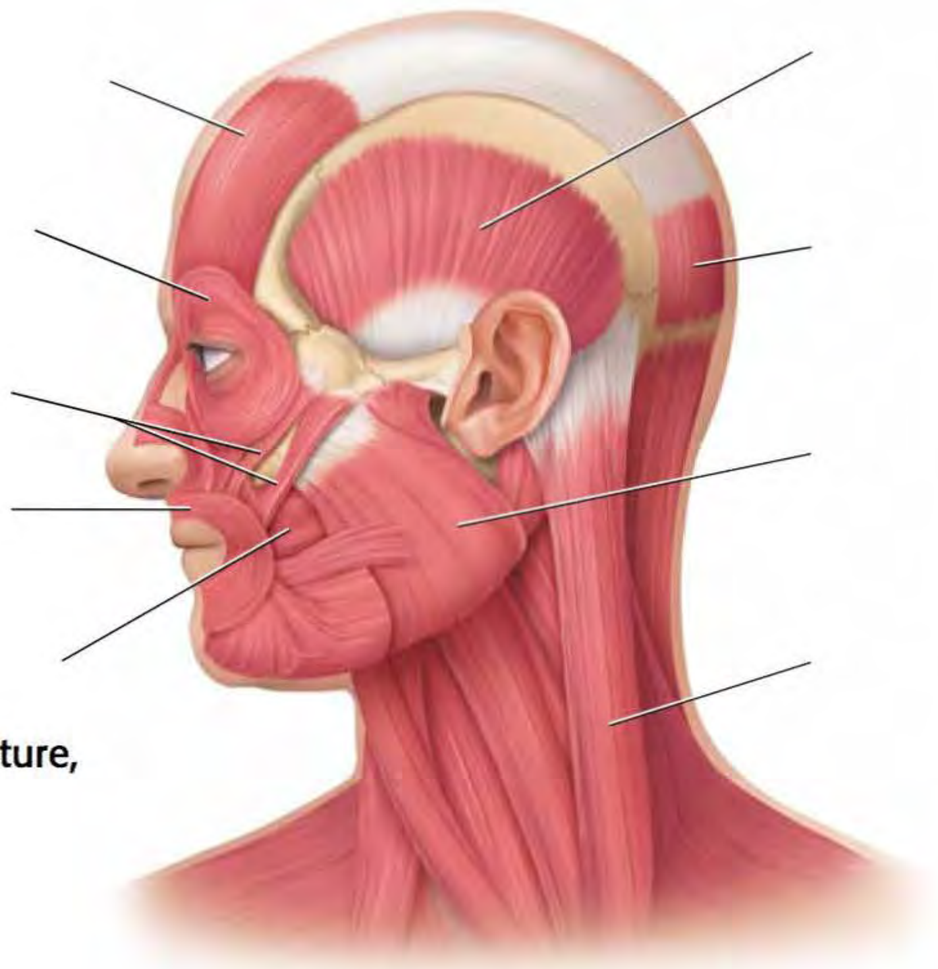


FIGURE **9.25** Facial musculature, lateral view.

5 Label the following muscles on Figure 9.26.

- ❑ External oblique m.
- ❑ Internal oblique m.
- ❑ Rectus abdominis m.
- ❑ Serratus anterior m.
- ❑ Transversus abdominis m.

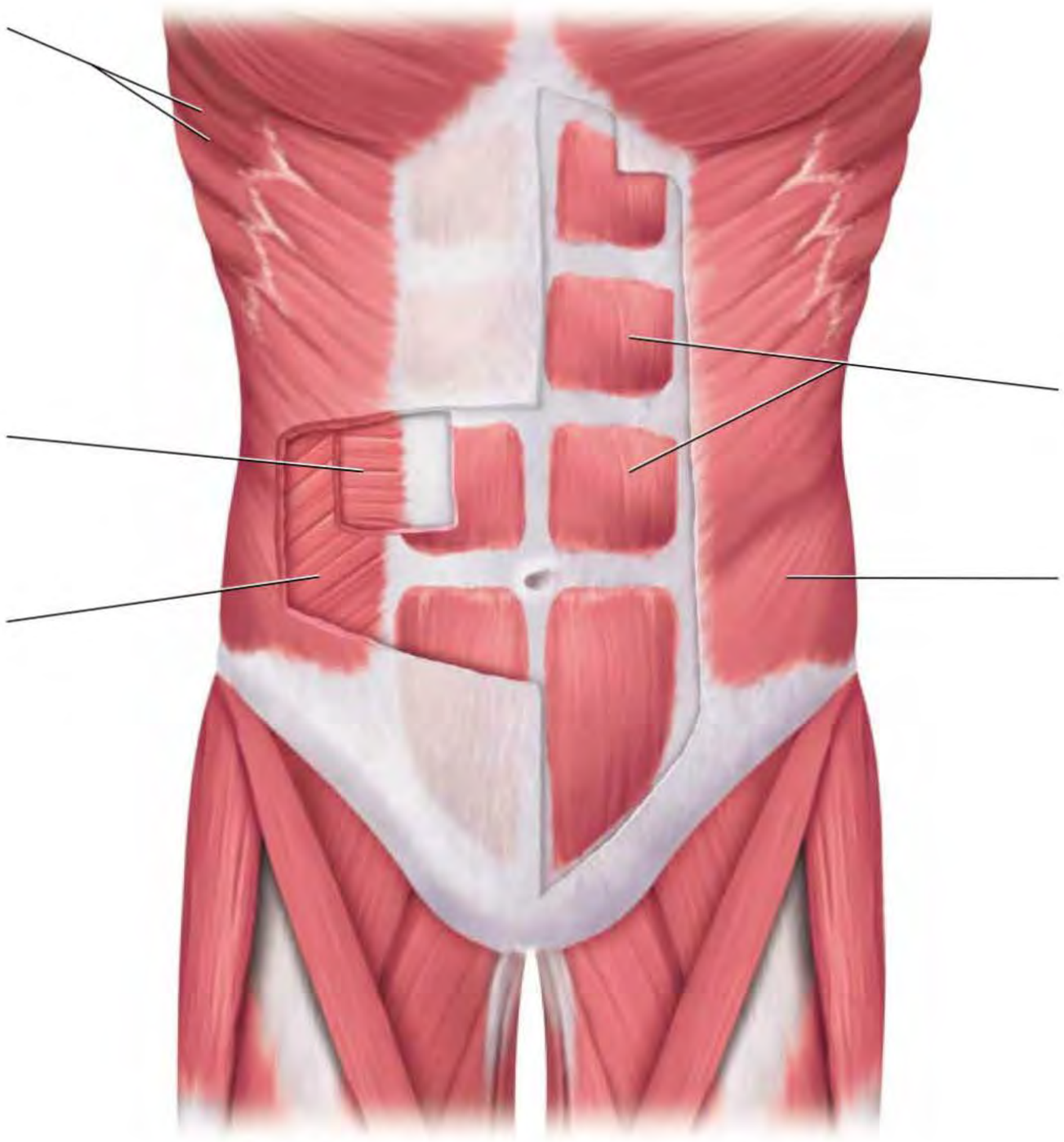
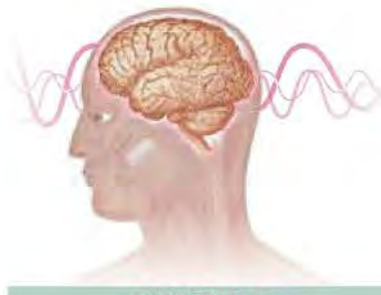


FIGURE **9.26** Muscles of the trunk, anterior view.

Name _____

Section _____ Date _____



6 Label the following muscles on Figure 9.27.

- ❑ Deltoid m.
- ❑ Erector spinae m.
- ❑ Gluteus maximus m.
- ❑ Gluteus medius m.
- ❑ Infraspinatus m.
- ❑ Latissimus dorsi m.
- ❑ Supraspinatus m.
- ❑ Trapezius m.
- ❑ Triceps brachii m.

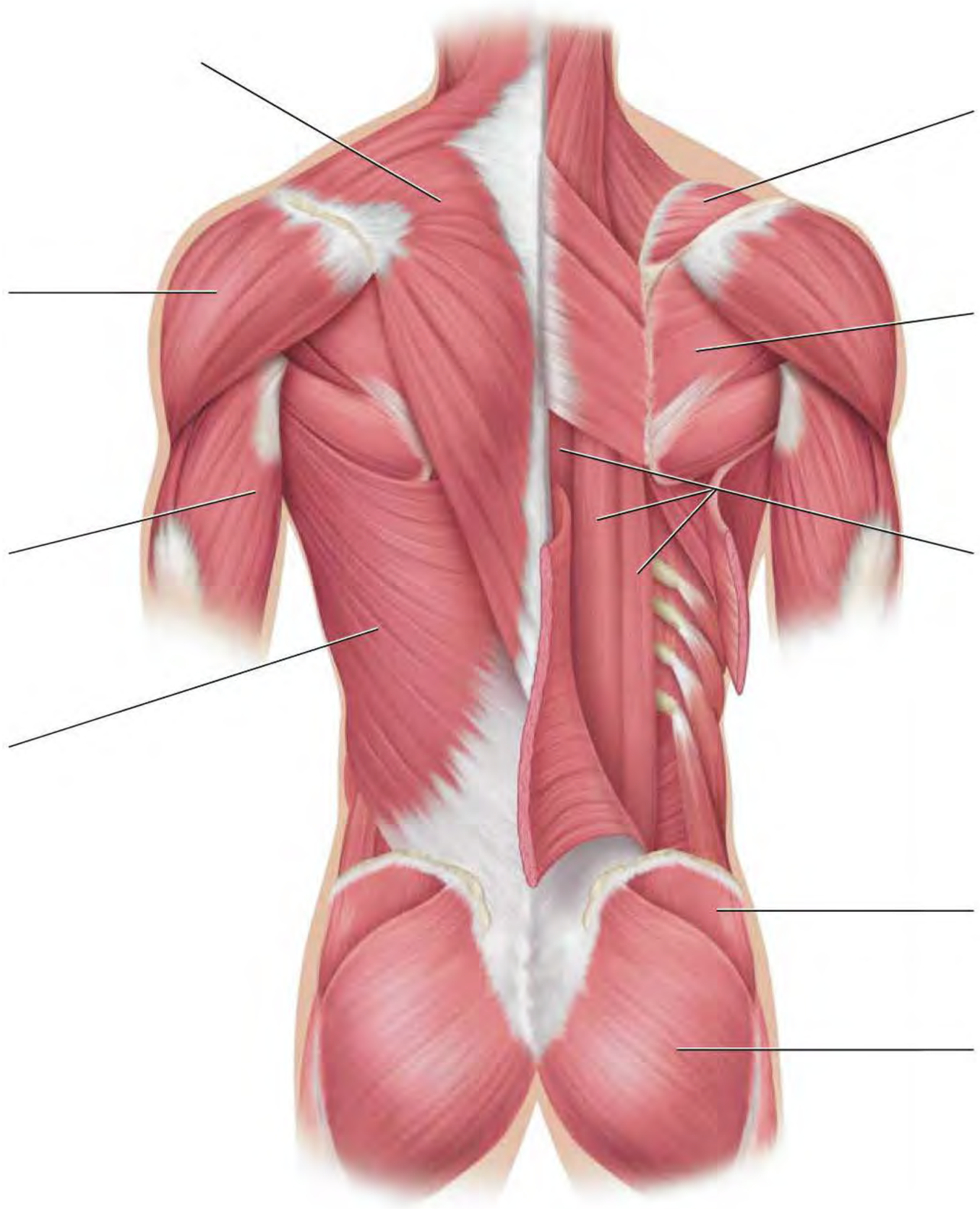


FIGURE **9.27** Muscles of the trunk, posterior view.

7 Label the following muscles on Figure 9.28.

- ❑ Biceps brachii m.
- ❑ Brachioradialis m.
- ❑ Gracilis m.
- ❑ Pectoralis major m.
- ❑ Rectus femoris m.
- ❑ Sartorius m.
- ❑ Tibialis anterior m.
- ❑ Vastus lateralis m.
- ❑ Vastus medialis m.

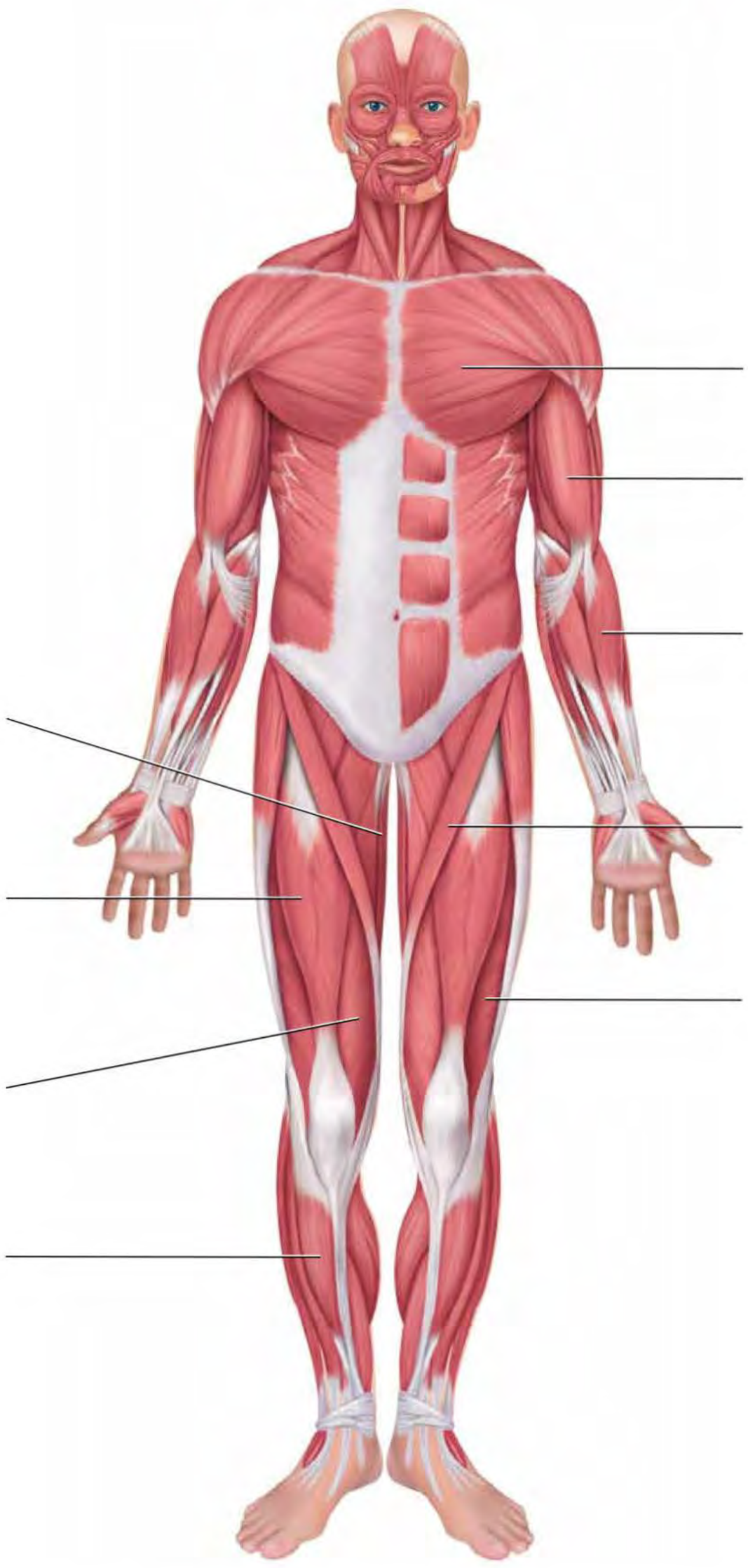


FIGURE **9.28** Muscles of the body, anterior view.

Name _____

Section _____ Date _____

8 Label the following muscles on Figure 9.29.

- ❑ Biceps femoris m.
- ❑ Gastrocnemius m.
- ❑ Gluteus maximus m.
- ❑ Semimembranosus m.
- ❑ Semitendinosus m.
- ❑ Soleus m.
- ❑ Triceps brachii m.

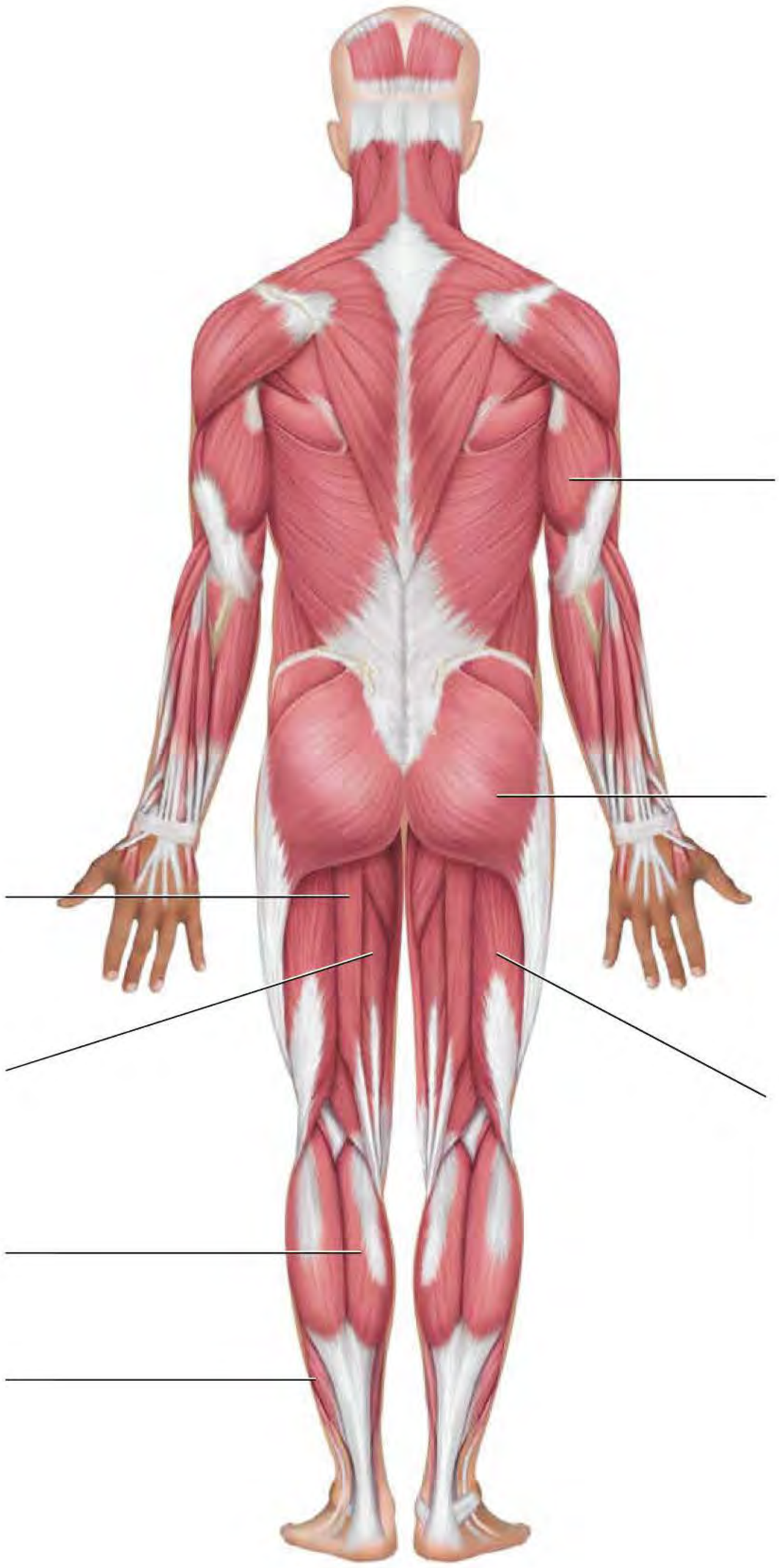


FIGURE **9.29** Muscles of the body, posterior view.

9 *Fill in the blanks:* A muscle's _____ is generally the more stationary part, and a muscle _____ into the part that it moves.

10 Which of the following muscles is *not* a forearm flexor at the elbow?

a. Brachioradialis m.
b. Triceps brachii m.
c. Biceps brachii m.
d. Brachialis m.

11 Which of the following muscles does *not* extend the hip and flex the knee?

a. Sartorius m.
b. Biceps femoris m.
c. Semimembranosus m.
d. Semitendinosus m.

12 Which of the following muscles is the prime abductor of the arm at the shoulder joint?

a. Pectoralis major m.
b. Latissimus dorsi m.
c. Pectoralis minor m.
d. Deltoid m.

Name _____

Section _____ Date _____

UNIT 9 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Would a muscle cell be able to produce a functional contraction if it lacked T-tubules? Explain.

2 *Myasthenia gravis* is an autoimmune disease in which the immune system produces antibodies that attack the acetylcholine receptor on the motor end plate. What symptoms would you expect with this disease? Explain.

3 Muscle strain, or "pulling a muscle," may result from overuse injuries or from trauma. Typically muscle strain results in pain around the muscle with movement and with pressure. Predict which muscle or muscles may be strained from pain in each of the following locations.

a Lateral thigh _____

b Posterior arm _____

c Lateral neck _____

d Abdomen just lateral to the midline _____

e Anterolateral leg _____

f Thoracic region just lateral to the vertebral column _____

4 A stroke, caused by a clot in a blood vessel of the brain, may lead to a loss of function of certain muscles. Which motions would an individual be unable to perform if the following muscles lost function?

a Orbicularis oculi m. _____

b Sternocleidomastoid m. _____

c Gluteus maximus m. _____

5 Neuromuscular diseases may lead to a condition called *drop foot*, in which a patient is unable to dorsiflex his or her foot. Which muscle(s) do you think is/are involved in this condition? Which muscles may have to compensate for lack of dorsiflexion during walking? Explain.

6 The pectoralis minor muscle normally originates on the third to fifth ribs and inserts into the coracoid process of the scapula. Predict its action from this information.

7 When a person is in respiratory distress, the origin and insertion of the pectoralis minor muscle actually switch, and the part of the muscle attached to the coracoid process acts as the origin. How will this change the muscle's action?

Introduction to the Nervous System

10

OBJECTIVES

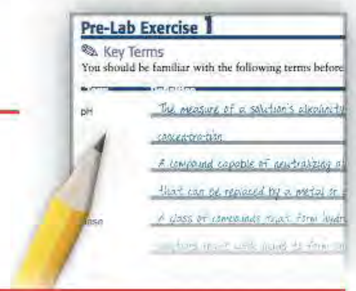
Once you have completed this unit, you should be able to:

1. Describe the microanatomy of nervous tissue and the parts of a synapse.
2. Identify structures of the neuron and neuroglial cells on anatomical models and microscope slides.
3. Identify structures of a peripheral nerve.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 10-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Parts of the Neuron

Neuron _____

Cell body _____

Axon _____

Dendrite _____

Myelin sheath _____

Node of Ranvier _____

Structures of the Synapse

Synapse _____

Axon terminal _____

Synaptic vesicle _____

Synaptic cleft _____

Presynaptic neuron _____

Postsynaptic neuron _____

Name _____ Section _____ Date _____

Parts of a Peripheral Nerve

Fascicle _____

_____

Axon _____

_____

Epineurium _____

_____

Perineurium _____

_____

Endoneurium _____

Pre-Lab Exercise 10-2

Nervous Tissue Microanatomy

Label and color the microscopic anatomy of nervous tissue in Figure 10.1 with the terms from Exercise 10-1 (p. 251). Use your text and Exercise 10-1 in this unit for reference.

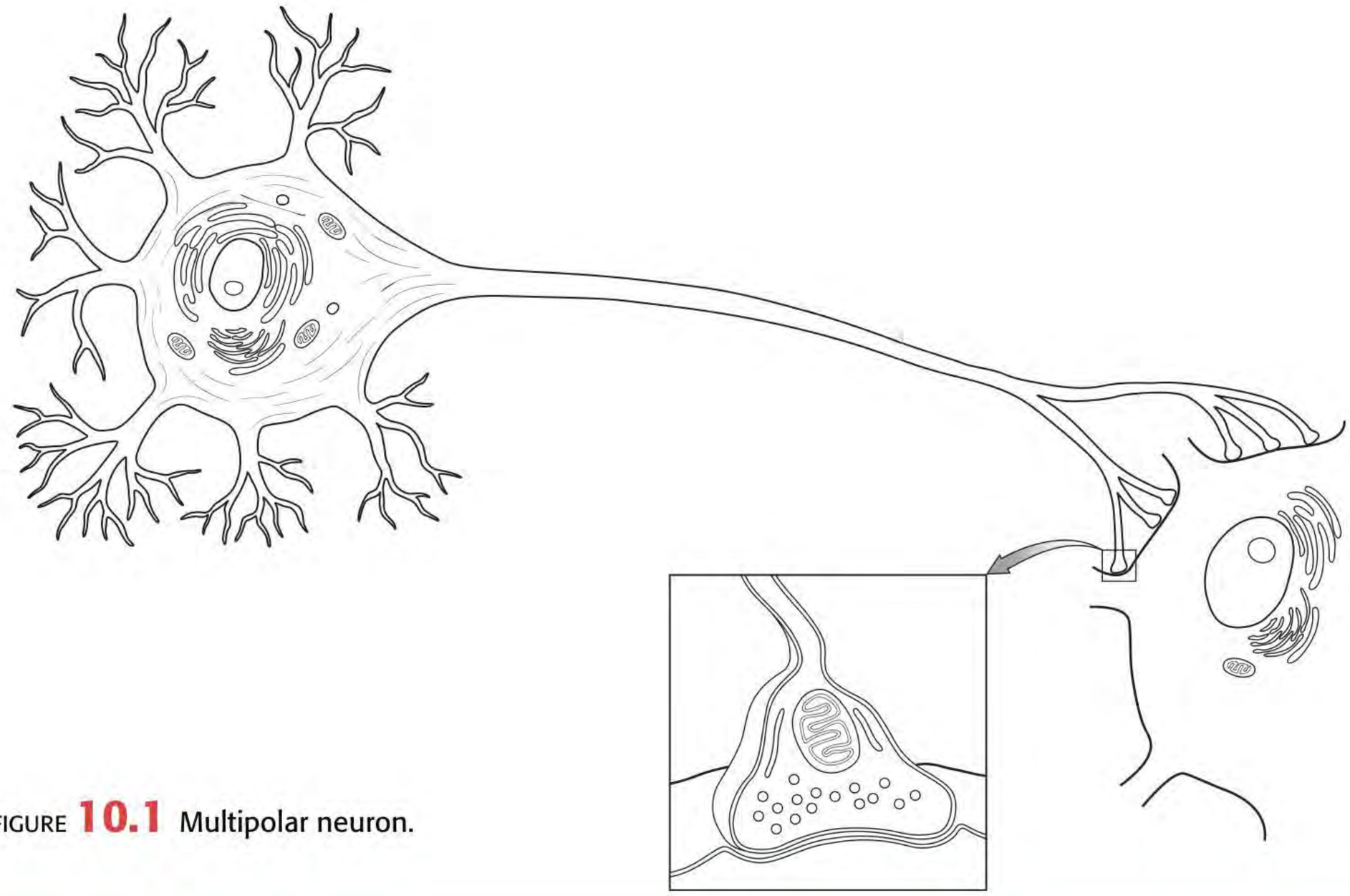
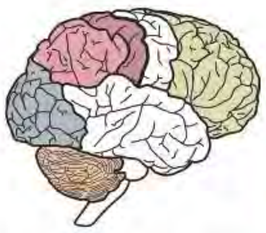


FIGURE 10.1 Multipolar neuron.



Pre-Lab Exercise 10-3

Peripheral Nerve Anatomy

Label and color the peripheral nerve diagram in Figure 10.2 with the terms from Exercise 10-2 (p. 258). Use your text and Exercise 10-2 in this unit for reference.

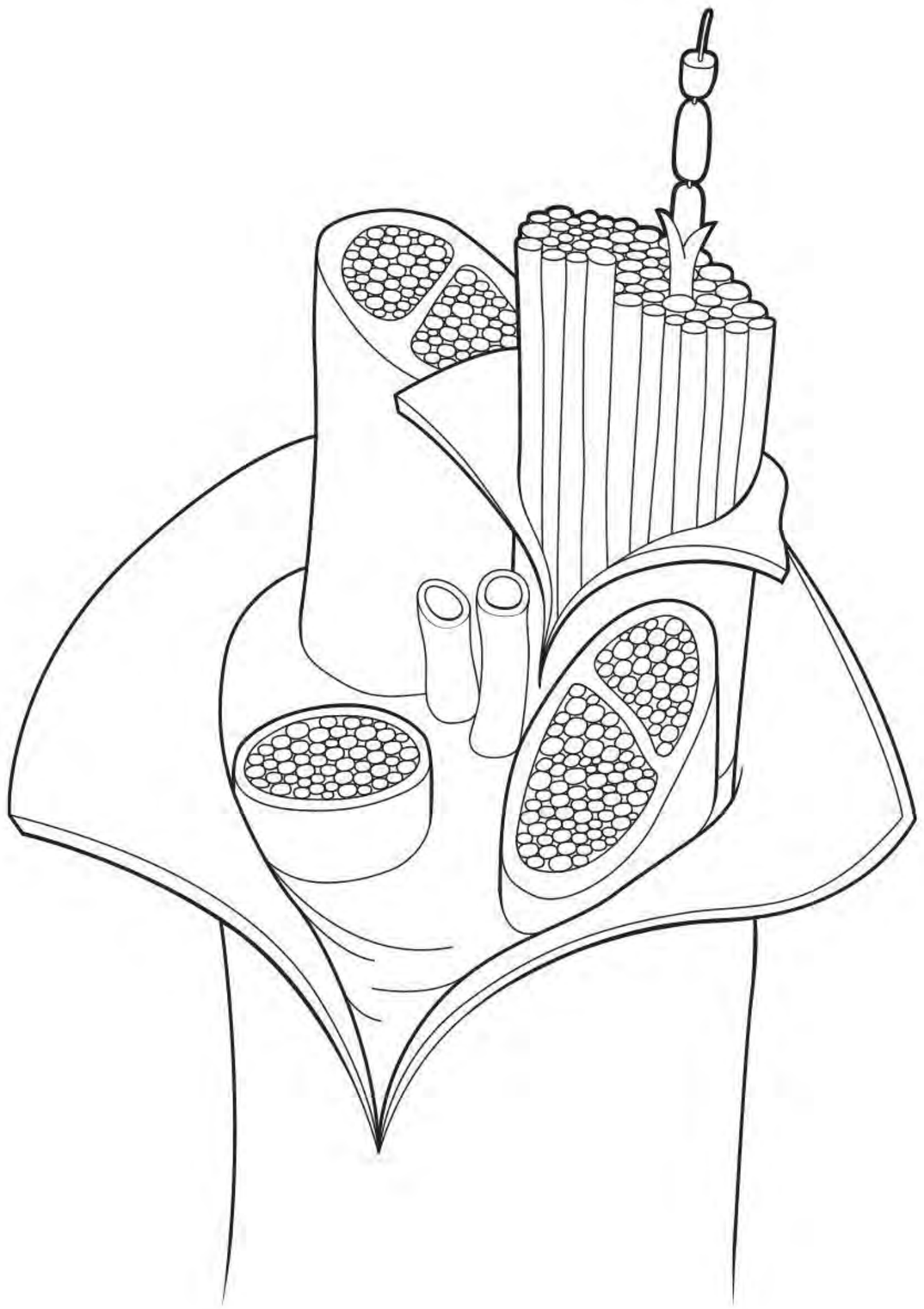


FIGURE **10.2** Anatomy of a peripheral nerve.

EXERCISES

We begin our study of the nervous system in this unit, and we will explore it further over the next three units. The **nervous system** consists of the *brain*, *spinal cord*, and *peripheral nerves*. Its main function is to maintain homeostasis by regulating the activity of other cells. The organs of nervous tissue are composed of cells called *neurons* that maintain homeostasis in the body by regulating the function of other cells. They accomplish this by sending nerve impulses, also known as **action potentials**, to their target cells. Neurons are supported by a variety of smaller cells collectively called *neuroglial cells*, and these two cell types, along with a specialized extracellular matrix, make up **nervous tissue**.

In the following exercises you will examine the cells and structure of nervous tissue. Then we will examine how neurons and other tissues make up one of the organs of the nervous system: *peripheral nerves*.

Exercise 10-1

Neurons and Neuroglia

MATERIALS

- ❑ Neuron models
- ❑ Synapse models
- ❑ Modeling clay in four colors
- ❑ Nervous tissue slide
- ❑ Myelin sheath slide
- ❑ Light microscope
- ❑ Colored pencils

There are two types of cells within nervous tissue: **neurons** and **neuroglial cells** (Figure 10.3). **Neurons** (NOOR-ahnz) are large cells that transmit and generate messages in the form of nerve impulses, or **neuronal action potentials**. Although they vary widely in size and structure, most have the following features in common (Figure 10.4):

1. **Cell body.** The **cell body** is the biosynthetic center of the neuron, containing the nucleus and many of the organelles. Its cytoskeleton consists of densely packed microtubules and **neurofilaments** that compartmentalize the rough endoplasmic reticulum into dark-staining structures called **Nissl bodies**. Cell bodies are often found in clusters. In the central nervous system (CNS), which consists of the brain and the spinal cord, clusters of cell bodies are called **nuclei**. In the peripheral nervous system (PNS), which consists of the cranial and spinal nerves, such clusters are called **ganglia** (GAYNG-lee-uh).
2. **Axon.** A single **axon** exits the cell body at the **axon hillock** to transmit messages in the form of action potentials to other neurons, muscles, and glands. An axon generates action potentials across its plasma membrane, known as the **axolemma** (aks-oh-LEM-ah). The action potential spreads down the entire length of the axon and then down its multiple terminal branches, called **telodendria** (tee-loh-DEN-dree-uh). At the end of each telodendrion is an **axon terminal**. Recall from Unit 9 that the axon terminal contains synaptic vesicles with neurotransmitters that communicate with the axon's target cell.
3. **Dendrites.** Most neurons have one or more branching processes called **dendrites** (DEN-drytz) that receive messages from other neurons. They can transmit these messages to the neuron's cell body, but they are not capable of generating action potentials.

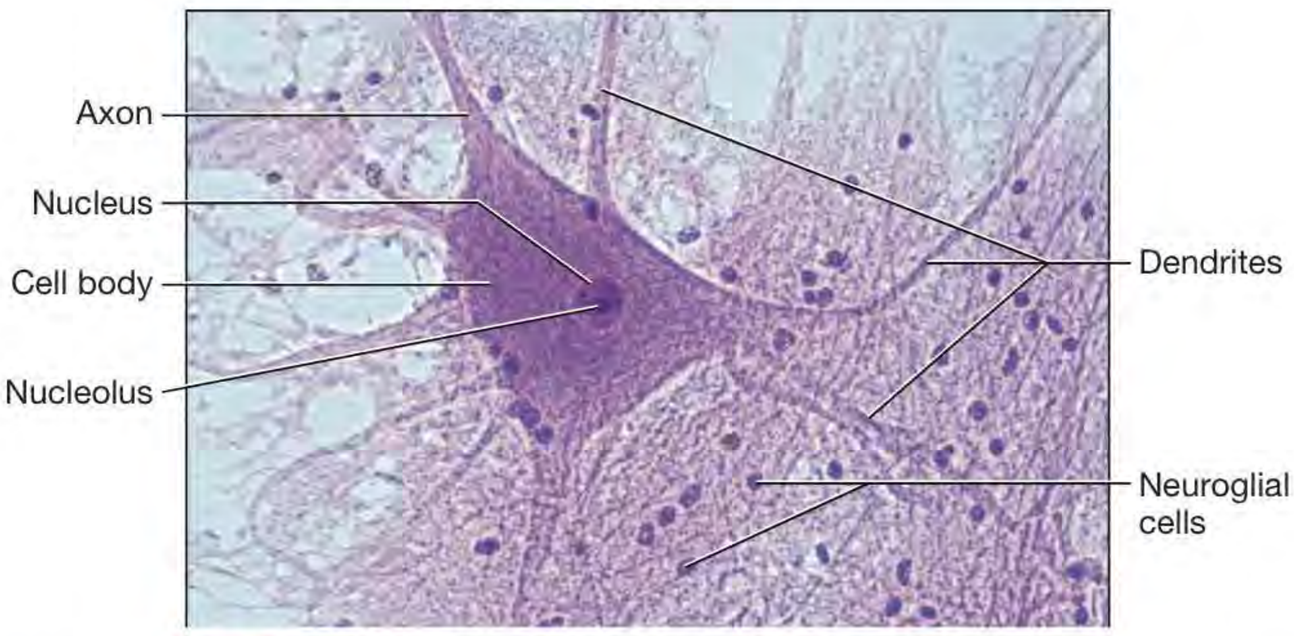


FIGURE **10.3** Nervous tissue, photomicrograph (motor neuron smear).

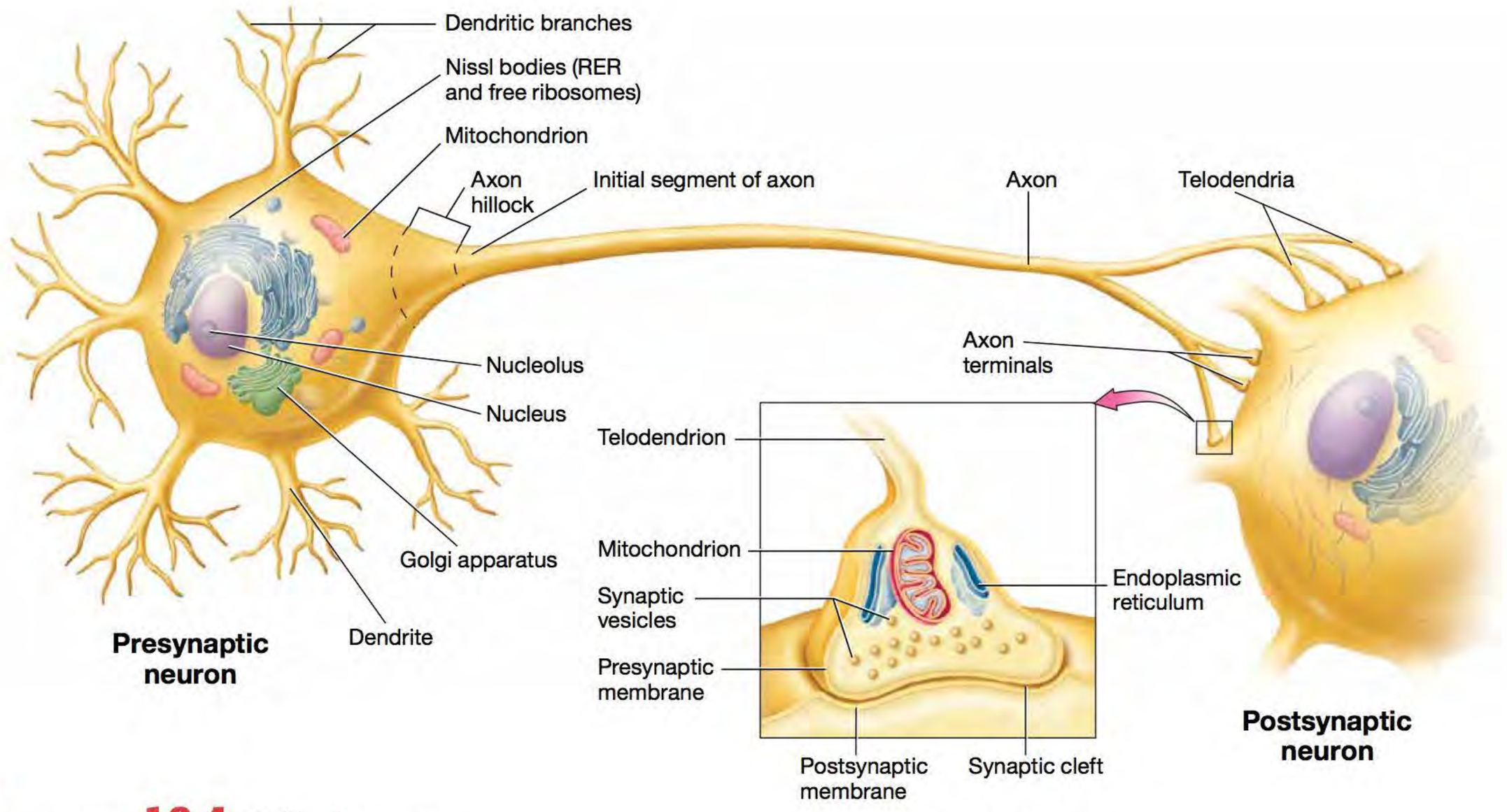


FIGURE **10.4** Multipolar neuron.

Neurons are classified structurally on the basis of the number of processes extending from the cell body (Figure 10.5). The most common type of neuron is the large **multipolar neuron,** which has three or more processes—specifically, one axon and two or more dendrites. Most multipolar neurons resemble highly branched trees and have hundreds to thousands of dendrites.

Both **bipolar neurons** and **pseudounipolar neurons** are rarer than multipolar neurons and are associated with the senses. **Bipolar neurons** have one axon and one dendrite and are found in special sense organs such as the olfactory epithelium and the retina of the eye. **Pseudounipolar neurons** have only one process and are found in the skin, where they detect and transmit sensations such as pain and temperature. A short distance from the cell body, the process branches like a "T" into a **central process,** which travels from the cell body to the spinal cord, and a **peripheral process,** which travels from a sensory receptor to the cell body. Both the central process and the peripheral process can generate action potentials and are therefore axons.

Neurons communicate with one another and with their target cells at a junction called a **synapse** (SIN-apz). In Unit 9 you learned about a type of synapse called the *neuromuscular junction* (NMJ). The synapse between two neurons is similar to the NMJ and consists of three parts:

1. **Presynaptic neuron.** The neuron that sends the message is called the **presynaptic neuron.** It contains neurotransmitters packaged in synaptic vesicles in its axon terminals.
2. **Synaptic cleft.** As we saw with the NMJ, the two neurons in a neuronal synapse are also separated by a small space. This space, called the **synaptic cleft,** is filled with extracellular fluid through which the neurotransmitters diffuse when they are released from the synaptic vesicles.

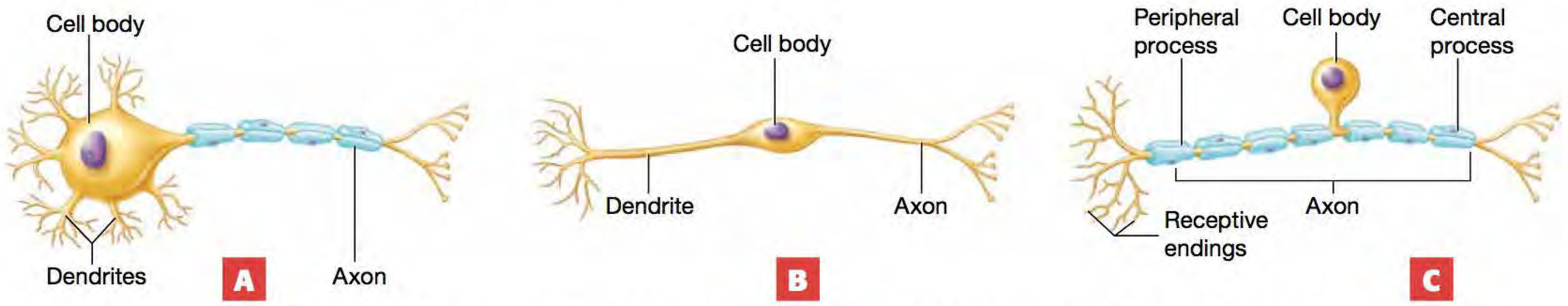


FIGURE **10.5** Types of neurons: (A) multipolar neuron; (B) bipolar neuron; (C) pseudounipolar neuron.

3. **Postsynaptic neuron.** The neuron that receives the message is the **postsynaptic neuron.** Its plasma membrane contains receptors for neurotransmitters. When the neurotransmitters bind to these receptors, the membrane potential of the postsynaptic neuron changes, which either stimulates or inhibits the neuron.

Neuroglial cells (noor-oh-GLEE-uhl) are much smaller than neurons, and they outnumber neurons about 50 to 1—no small feat considering that the nervous system contains about a trillion neurons. Following are the neuroglial cells of the central nervous system (CNS; brain and spinal cord) and the peripheral nervous system (PNS; cranial and spinal nerves). The neuroglia are shown in Figure 10.6, but note that this figure shows only neuroglial cells of the CNS.

1. **Astrocytes. Astrocytes** are the most numerous neuroglial cell type in the CNS. These star-shaped cells have many functions, including anchoring neurons and blood vessels in place with processes called **perivascular feet** and regulating the extracellular environment of the brain. In addition, they facilitate the formation of the **blood-brain barrier,** created by tight junctions in the brain capillaries that prevent many substances in the blood from entering the brain tissue.
2. **Oligodendrocytes. Oligodendrocytes** (oh-lig-oh-DEN-droh-syt'z) have long extensions that wrap around the axons of certain neurons in the CNS to form a structure called the *myelin sheath*. Note that one oligodendrocyte can myelinate several axons.
3. **Microglial cells.** The small **microglial cells** (my-kroh-GLEE-ul) are very active phagocytes that clean up debris surrounding neurons. Microglia also degrade and ingest damaged or dead neurons.
4. **Ependymal cells.** The ciliated **ependymal cells** (eh-PEN-dih-mul) line the hollow spaces of the brain and spinal cord. They assist in forming the fluid that bathes the brain and spinal cord, called **cerebrospinal fluid,** and circulate it with their cilia.
5. **Schwann cells. Schwann cells** form the **myelin sheath** around the axons of certain neurons in the PNS. Schwann cells can myelinate only one axon.
6. **Satellite cells. Satellite cells** surround the cell bodies of neurons in the PNS. These cells are believed to enclose and support the cell bodies, although their precise function is unknown.

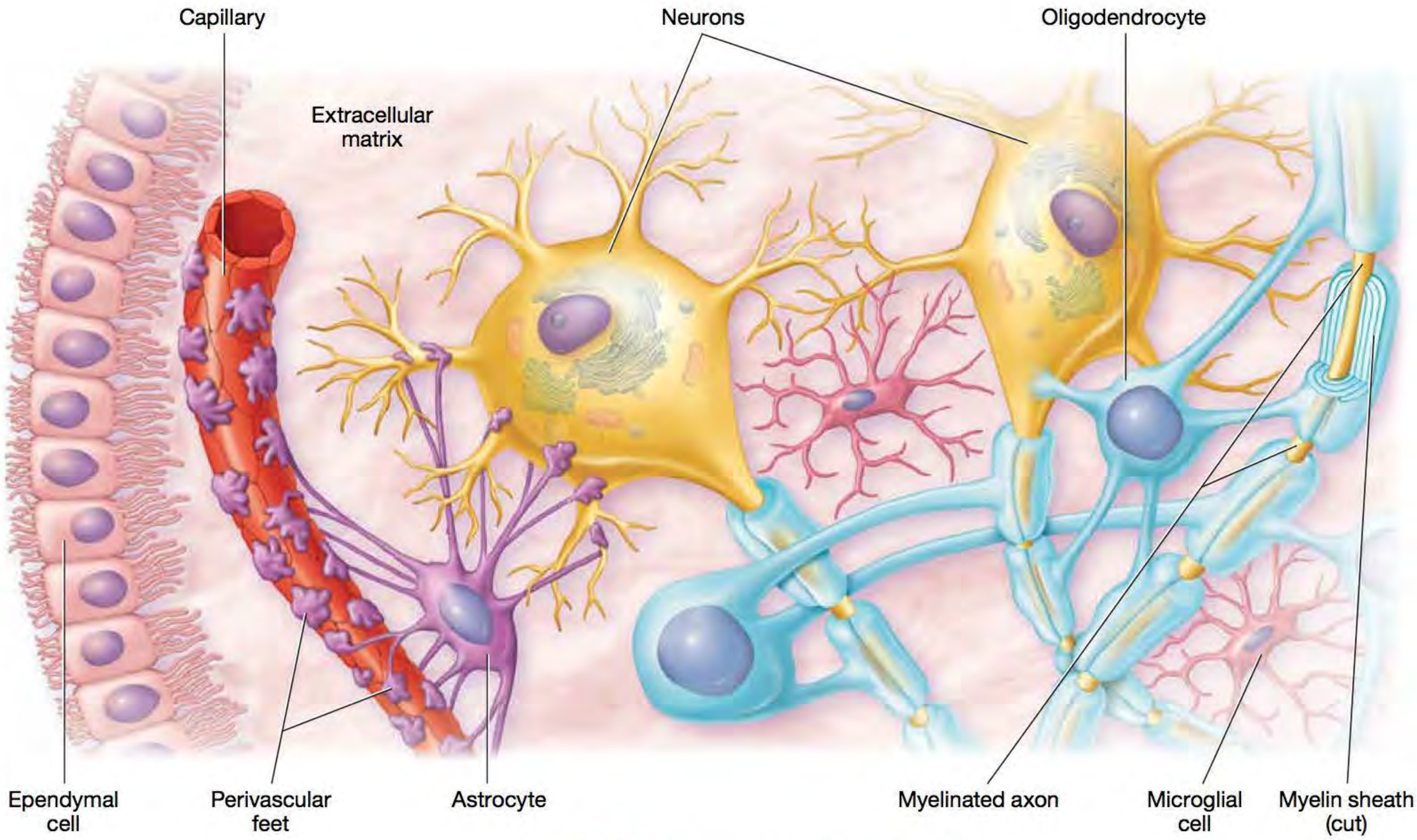


FIGURE **10.6** Neuroglial cells of the CNS.

The **myelin sheath** (MY-lin) is composed of many layers of the plasma membrane of the oligodendrocyte or Schwann cell wrapped around an axon. It performs critical functions within the nervous system, including protecting and insulating the axons and speeding up conduction of action potentials. As you can see in Figure 10.7, Schwann cells and oligodendrocytes myelinate axons differently. Schwann cells, which myelinate only a single axon, wrap clockwise around the axon (Figure 10.7A). The outer edge of the Schwann cell, called the **neurilemma** (noor-ih-LEM-ah), contains most of its cytoplasm and the nucleus. Oligodendrocytes, on the other hand, wrap multiple axons in a counterclockwise direction (Figure 10.7B).

Notice that there are small gaps in the myelin sheath between each oligodendrocyte arm or Schwann cell where the plasma membrane of the axon is exposed. These gaps are called **nodes of Ranvier** (rahn-vee-ay), and the myelin-covered segments between the nodes are called **internodes**. You can see these nodes of Ranvier and internodes in Figures 10.7 and 10.8.

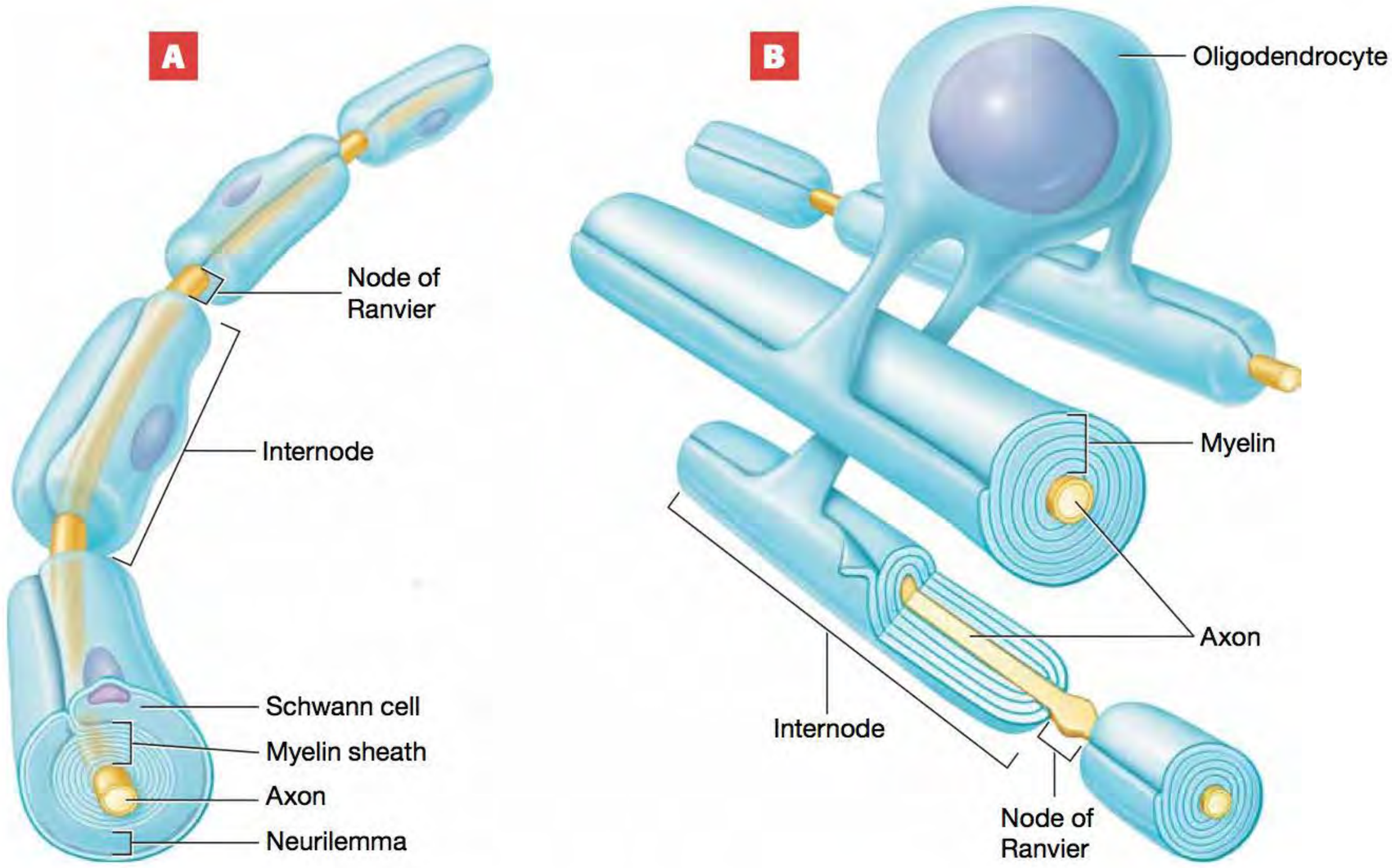


FIGURE **10.7** Myelin sheath: (A) Schwann cells around a PNS axon; (B) an oligodendrocyte around multiple CNS axons.

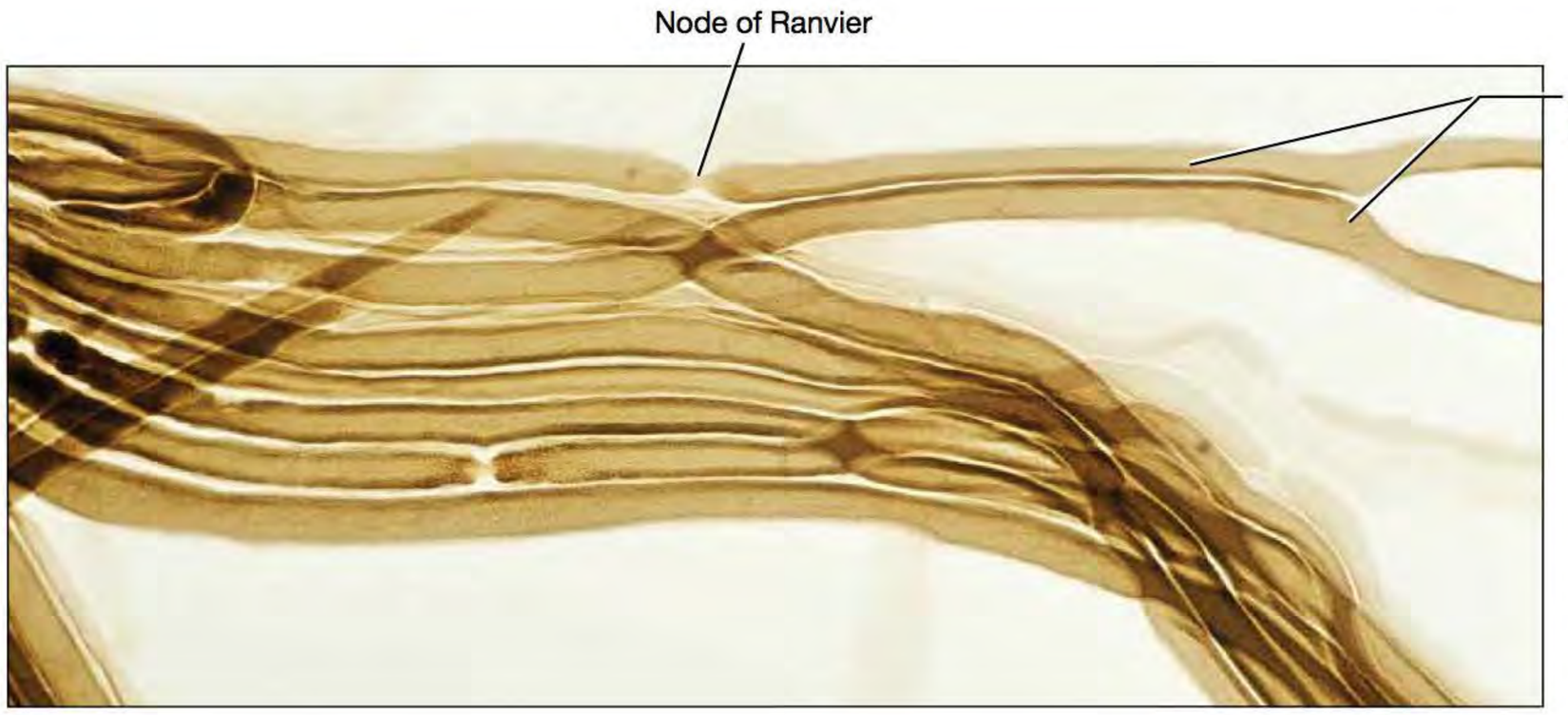


FIGURE **10.8** Myelin sheath, photomicrograph.

Procedure 1 Model Inventory for Nervous Tissue

Identify the following structures of nervous tissue on models and diagrams using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 10.1. When you have completed the activity, answer Check Your Understanding questions 1 through 4 (p. 263).

1. Neuron
   a. Cell body (soma)
      (1) Neurofilaments
      (2) Nissl bodies
      (3) Nuclei
      (4) Ganglia
   b. Axon
      (1) Axon hillock
      (2) Axolemma
      (3) Telodendria
   c. Dendrite(s)
2. Multipolar neuron
3. Bipolar neuron
4. Pseudounipolar neuron
5. Parts of the synapse
   a. Presynaptic neuron
   b. Axon terminal
   c. Synaptic vesicle
   d. Synaptic cleft
   e. Postsynaptic neuron
   f. Neurotransmitter receptors
6. Neuroglial cells
   a. Astrocytes
   b. Oligodendrocytes
   c. Microglial cells
   d. Ependymal cells
   e. Schwann cells
   f. Satellite cells
7. Other structures
   a. Myelin sheath
   b. Neurilemma
   c. Node of Ranvier
   d. Internode

TABLE **10.1** Model Inventory for Nervous Tissue

Model/Diagram	Structures Identified

Procedure 2 Building a Myelin Sheath

In this exercise you will demonstrate the difference between the methods by which Schwann cells and oligodendrocytes myelinate the axons of neurons in the peripheral nervous system and the central nervous system, respectively. When you have completed the activity, answer Check Your Understanding question 5 (p. 264).

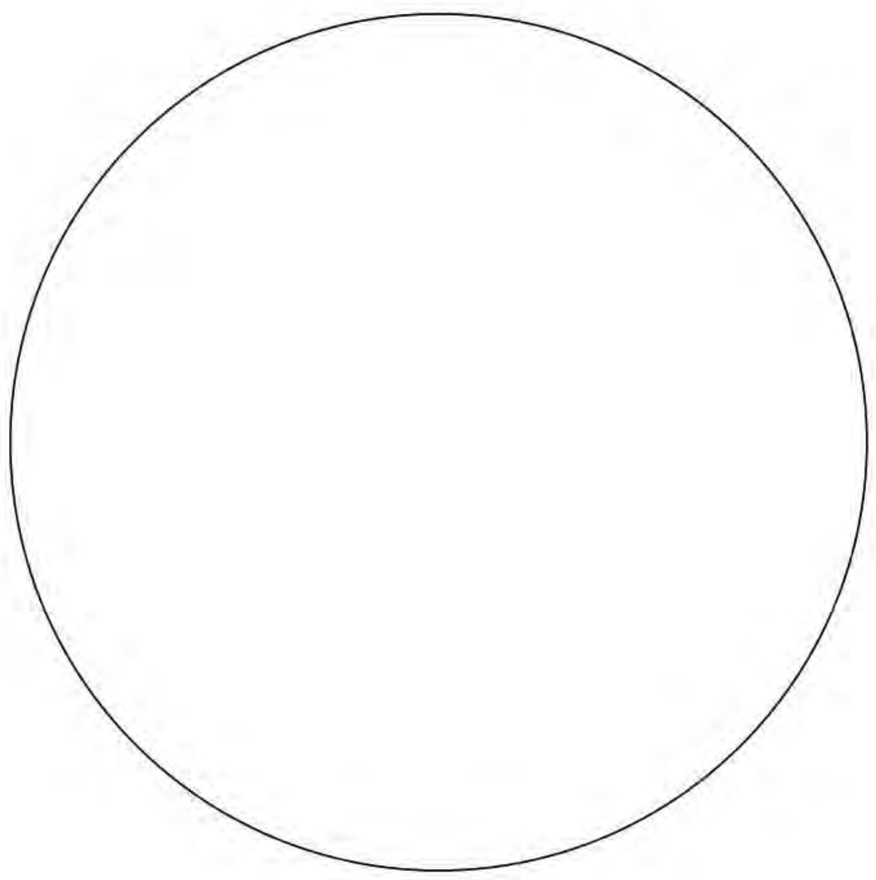
1. Obtain four colors of modeling clay (blue, green, yellow, and red, if available).
2. Use the following color code to build three central nervous system (CNS) axons, one peripheral nervous system (PNS) axon, one oligodendrocyte, and two Schwann cells:
   a. CNS axons: blue
   b. PNS axon: green
   c. Oligodendrocyte: yellow
   d. Schwann cells: red
3. Build your oligodendrocyte so it reaches out to myelinate the three CNS axons.
4. Build your Schwann cells so they myelinate the single PNS axon, making sure to leave a gap for the node of Ranvier. Be sure to pay attention to the direction in which oligodendrocytes and Schwann cells myelinate their axons (clockwise or counterclockwise).

Procedure 3 Microscopy of Nervous Tissue

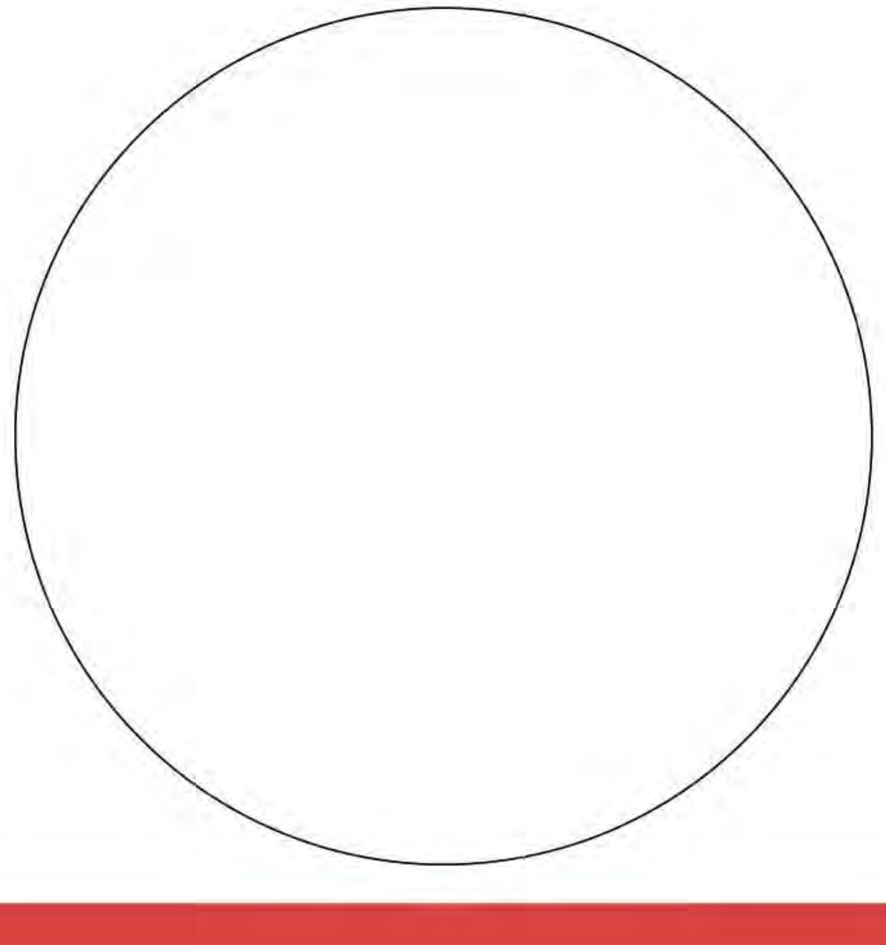
Let's now identify some of the structures from the previous procedures on microscope slides. You will examine two tissue sections:

1. **Motor neuron smear.** On this slide you should see many multipolar neurons surrounded by many, much smaller, neuroglial cells (they may look like purple dots; refer to Figure 10.3). As you scan the slide with the low-power objective, find a well-stained neuron, and move the objective lens to high power. Look for Nissl bodies, and try to identify the single axon and the axon hillock. (This may be difficult, so don't get discouraged if all of the processes look similar.)
2. **Myelin sheath.** A longitudinal section of axons stained with a stain specific for the components of myelin (often osmium) is useful for seeing the sheath itself and also the nodes of Ranvier (refer back to Figure 10.8). You will likely need to use the high-power objective to see the nodes.
3. Obtain prepared slides of a motor neuron smear and the myelin sheath. Use your colored pencils to draw what you see, and label your drawing with the following terms.

1. Nervous Tissue
   a. Cell body
   b. Axon
   c. Dendrites
   d. Neuroglial cells



2. Myelin Sheath
   a. Axon with myelin sheath
   b. Node of Ranvier



Procedure 4 Time to Draw

In the space below, draw, color, and label one of the neuron models that you examined. In addition, write the function of each structure that you label.

Exercise 10-2

Peripheral Nerve Anatomy

MATERIALS

- ❑ Peripheral nerve models or charts
- ❑ Peripheral nerve slide
- ❑ Light microscope with three objectives
- ❑ Colored pencils

One of the main organs of the nervous system is known as a **peripheral nerve** or simply a **nerve.** Each nerve consists of myelinated and unmyelinated axons (also known as *nerve fibers*), blood vessels, lymphatic vessels, and connective tissue sheaths (Figure 10.9). Each individual axon is covered by its axolemma (plasma membrane), superficial to which we find a connective tissue sheath called the **endoneurium** (en-doh-NOOR-ee-um). Axons are grouped into bundles called **fascicles** (FASS-ih-kullz), which are in turn covered with another connective tissue sheath called the **perineurium** (pehr-ih-NOOR-ee-um). Groups of fascicles, blood vessels, and lymphatic vessels are surrounded by the most superficial connective tissue sheath: the **epineurium** (ep-ih-NOOR-ee-um).

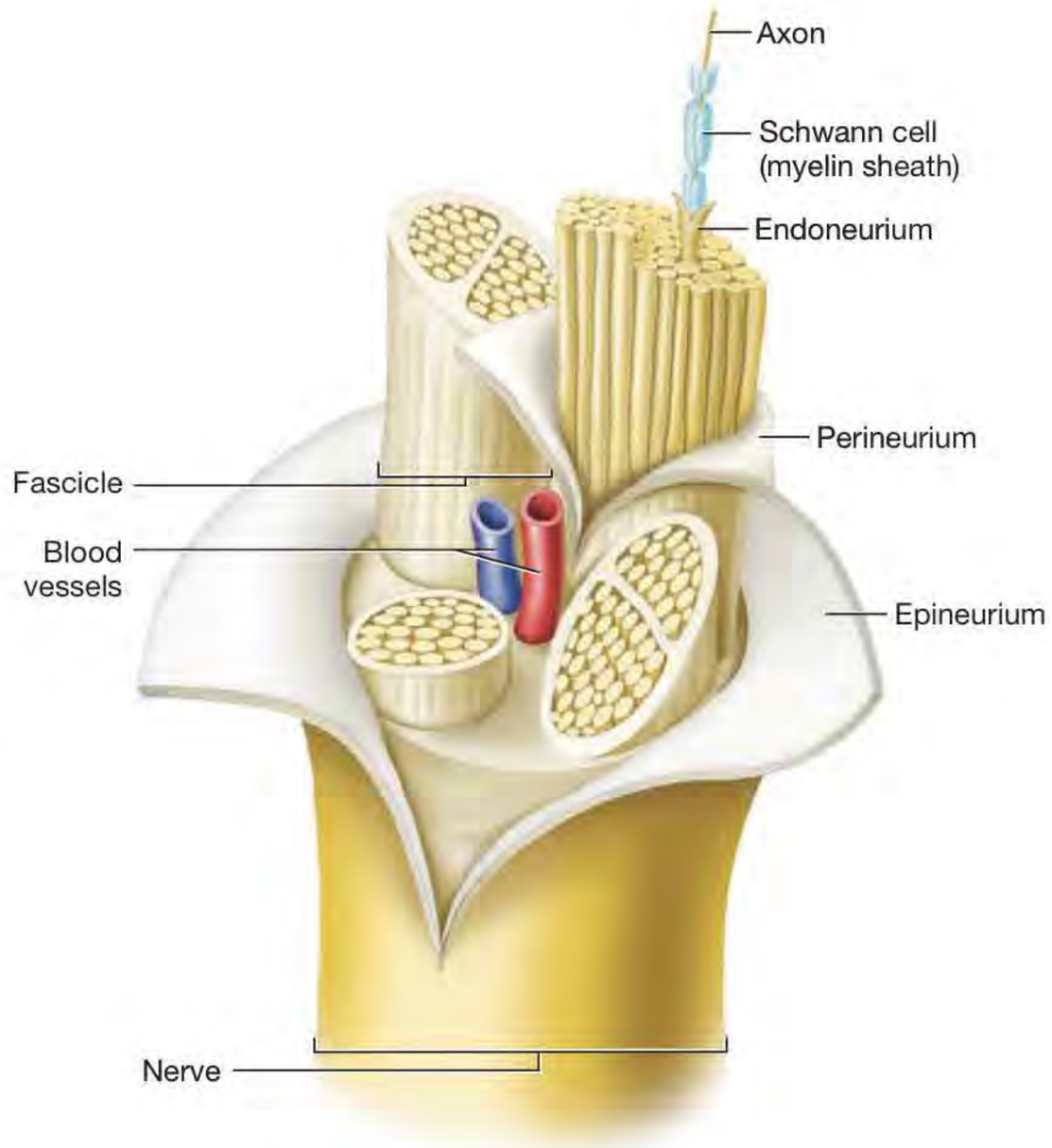
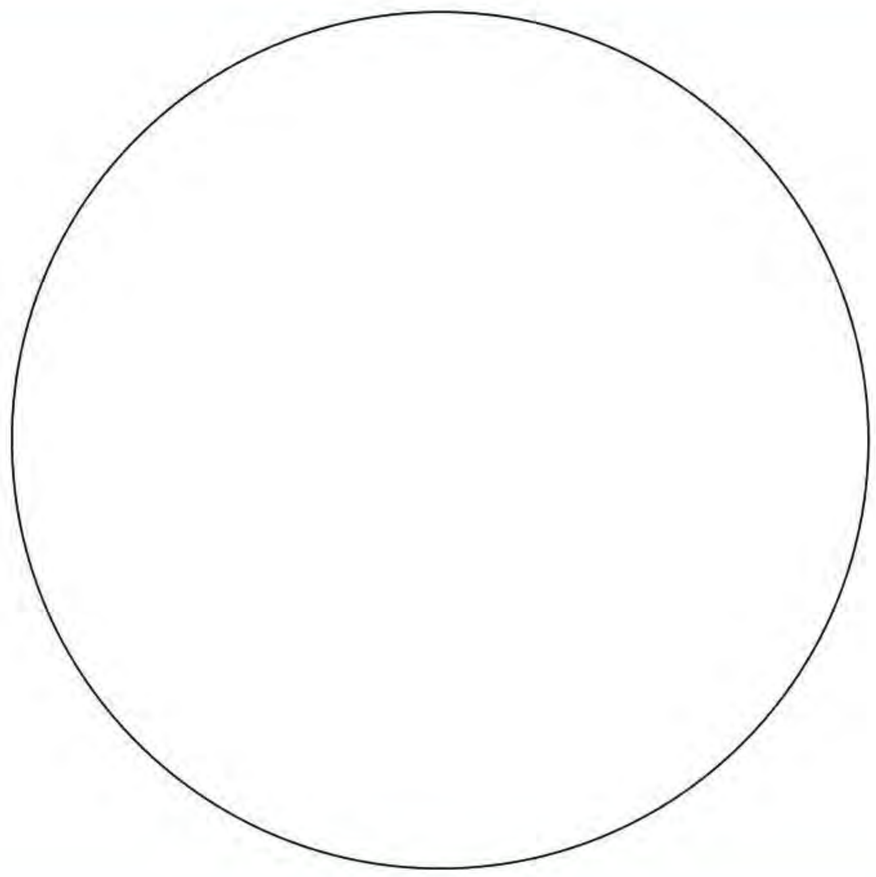


FIGURE **10.9** Anatomy of a peripheral nerve.

Procedure 1 Microscopy

Examine a prepared slide of a sectioned peripheral nerve. Start on low power, then advance to higher powers to see more details. Draw what you see, and label your drawing with the following terms. When you have finished the procedure, answer Check Your Understanding question 6 (p. 264).

1. Nerve
2. Fascicle
3. Axon (nerve fiber)
4. Blood vessels
5. Nerve sheaths
   a. Epineurium
   b. Perineurium
   c. Endoneurium
   d. Myelin sheath



Name _____

Section _____ Date _____

UNIT 10 REVIEW

Check Your Recall

1 Label the following structures on Figure 10.10.

- ❑ Axon
- ❑ Axon hillock
- ❑ Axon terminals
- ❑ Cell body
- ❑ Dendrites
- ❑ Synaptic cleft
- ❑ Synaptic vesicles
- ❑ Telodendria

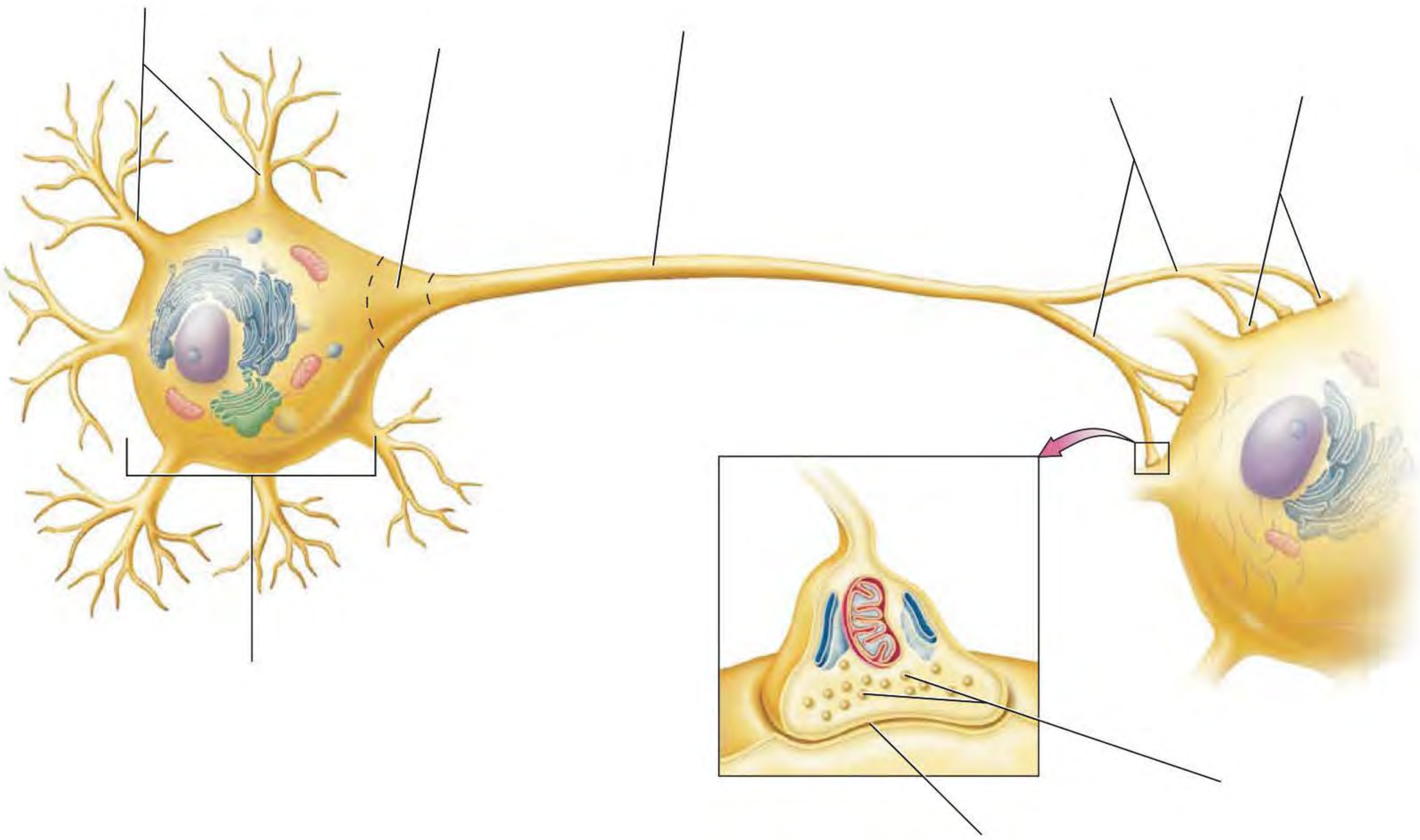


FIGURE **10.10** Neuron.

2 The neuron pictured in Figure 10.10 is a

a. pseudounipolar neuron.
b. bipolar neuron.
c. multipolar neuron.
d. unipolar neuron.

3 **The function of most dendrites is to**

a. receive messages from an axon.
b. send messages to an axon.
c. send messages to another dendrite.
d. receive messages from a cell body.

4 **What are the three parts of the synapse, and what are their functions?**

5 **Where are synaptic vesicles located?**

a. Axon terminals
b. Dendrites
c. Cell body
d. Both a and b are correct.
e. All of the above.

6 ***Matching:*** **Match the neuroglial cell with its correct function.**

_____ Oligodendrocytes
_____ Astrocytes
_____ Microglial cells
_____ Schwann cells
_____ Satellite cells
_____ Ependymal cells

A. Create the myelin sheath in the PNS
B. Ciliated cells in the CNS that form and circulate cerebrospinal fluid
C. Surround the cell bodies of neurons in the PNS
D. Anchor neurons and blood vessels, maintain extracellular environment around neurons, assist in the formation of the blood-brain barrier
E. Phagocytic cells of the CNS
F. Form the myelin sheath in the CNS

7 **What is the function of the myelin sheath?**

Name _____

Section _____ Date _____

UNIT 10

8 Label the following structures on Figure 10.11.

- ❑ Internode
- ❑ Myelin
- ❑ Neurilemma
- ❑ Node of Ranvier
- ❑ Oligodendrocyte
- ❑ Schwann cell

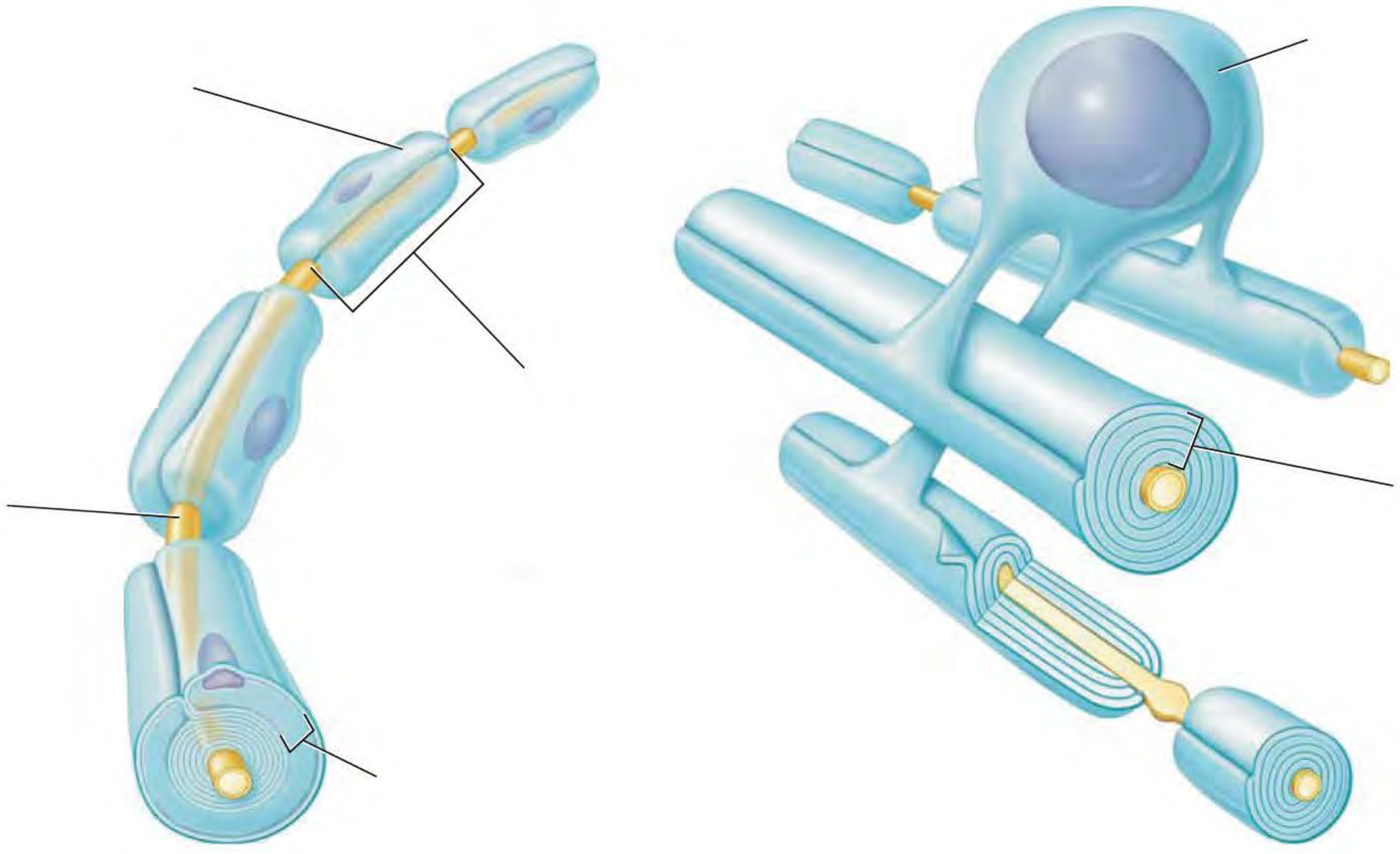


FIGURE **10.11** Myelin sheath.

10

9 Label the following structures on Figure 10.12.

- ❑ Axon
- ❑ Endoneurium
- ❑ Epineurium
- ❑ Fascicle
- ❑ Myelin sheath
- ❑ Nerve
- ❑ Perineurium

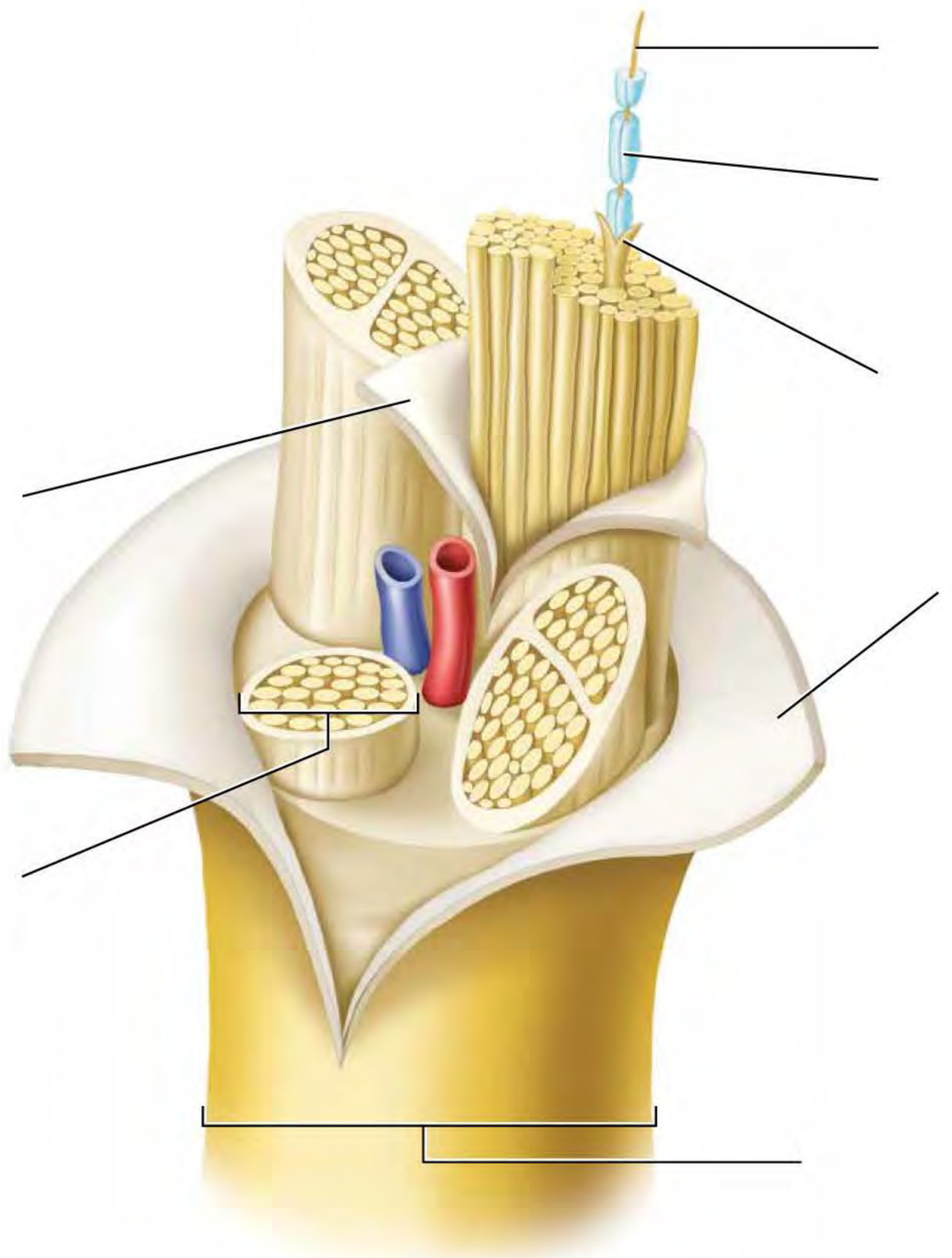


FIGURE **10.12** Peripheral nerve.

10 Another name for an axon is

a. myelin sheath.
b. endoneurium.
c. nerve fiber.
d. peripheral nerve.

Name _____

Section _____ Date _____

UNIT 10 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Neurons are amitotic, which means that after a certain stage, they do not divide further. Most tumor cells are characterized by a rapid rate of mitosis. Considering this, of which cell types (neurons or neuroglia) must brain tumors be composed? Why?

2 You are examining a neuronal process and you find that it generates action potentials. Is this an axon or a dendrite? How can you tell?

3 You are examining another neuron, and find that it has two processes, both of which generate action potentials. What is the structural class of this neuron? How did you come to this conclusion?

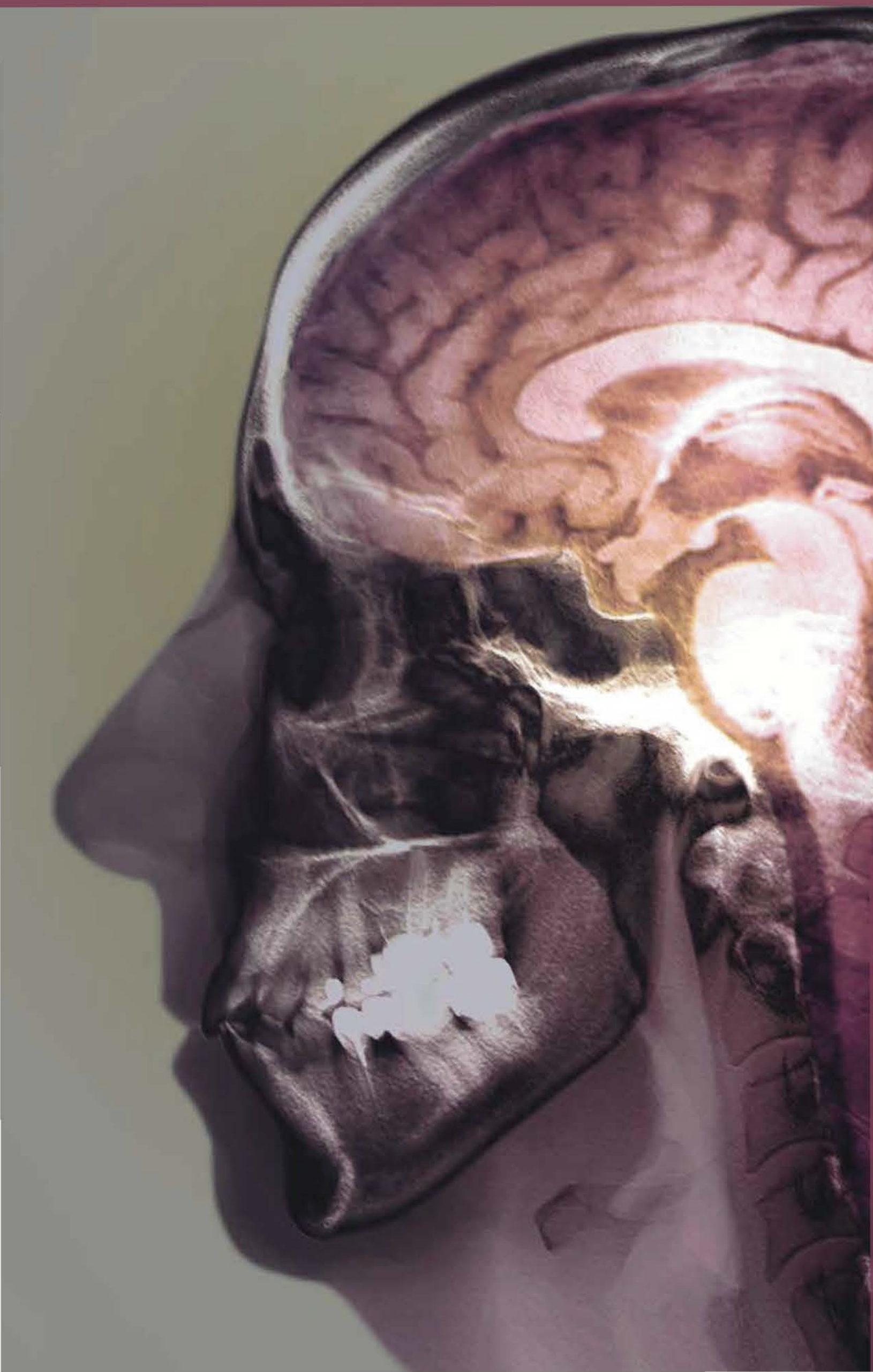
4 A traumatic brain injury may result in a large number of damaged or dying neurons. In such a case, which neuroglial cell would you expect to be present in large numbers? Explain.

5 Multiple sclerosis is a demyelinating disease, in which the patient's immune system attacks and destroys the cells that form the myelin sheath in the central nervous system. What types of symptoms would you expect from such a disease? Why? Would Schwann cells or oligodendrocytes be affected? Explain.

6 Often the terms "nerve" and "neuron" are mistakenly used interchangeably. Explain the difference between the two structures.

The Brain and Cranial Nerves

11



OBJECTIVES

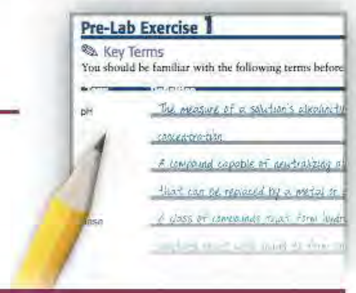
Once you have completed this unit, you should be able to:

1. Describe the gross anatomy of the brain.
2. Identify structures of the brain.
3. Identify, describe, and demonstrate functions of cranial nerves.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 11-1

✎ Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition
Structures of the Brain	
Cerebral hemispheres	
Cerebral cortex	
Basal nuclei	
Corpus callosum	
Diencephalon	
Thalamus	
Hypothalamus	
Midbrain	
Pons	
Medulla oblongata	
Cerebellum	
Dura mater	

Name _____ Section _____ Date _____

Arachnoid mater _____

_____

Pia mater _____

_____

Ventricles _____

_____

Dural sinuses _____

_____

Pre-Lab Exercise 11-2

Brain Anatomy

Label and color the diagrams of the brain in Figures 11.1–11.4 with the terms from Exercise 11-1 (p. 271). Use your text and Exercise 11-1 in this unit for reference.

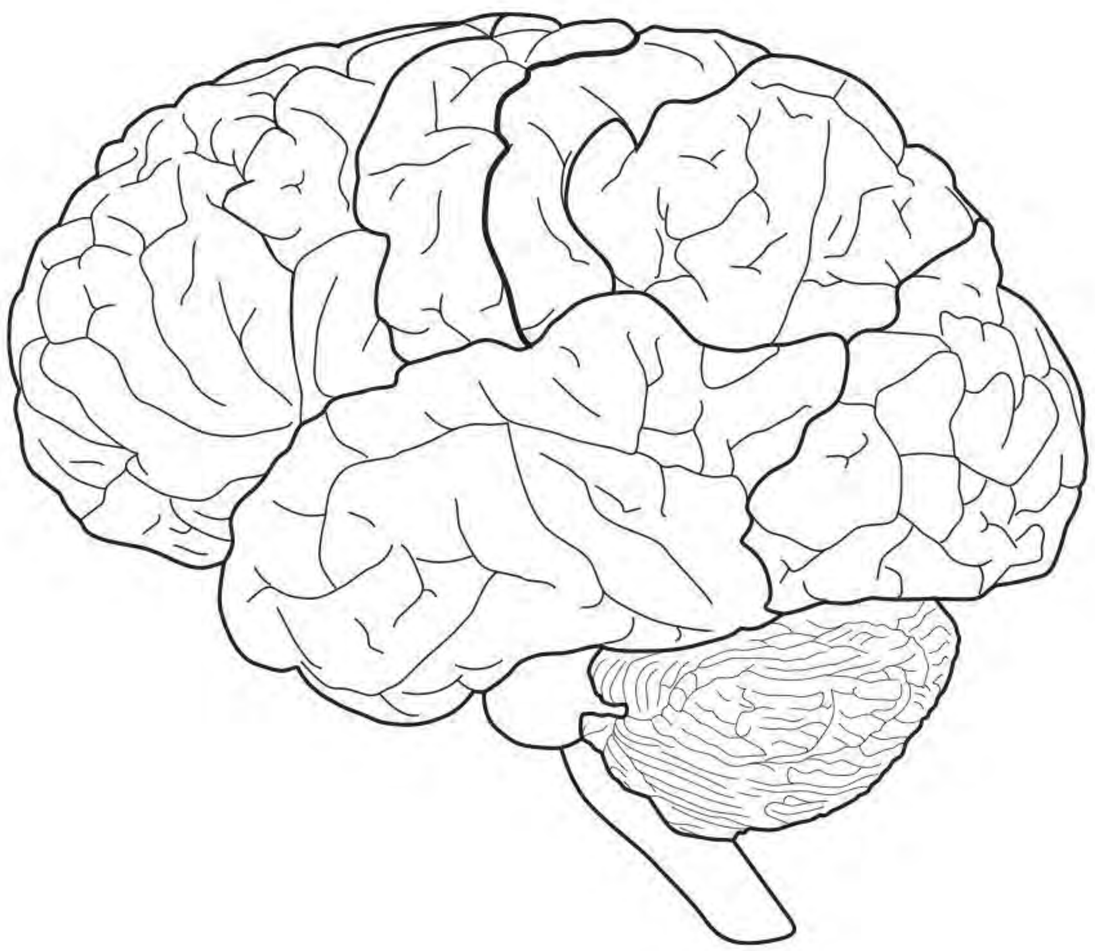


FIGURE **11.1** Brain, lateral view.

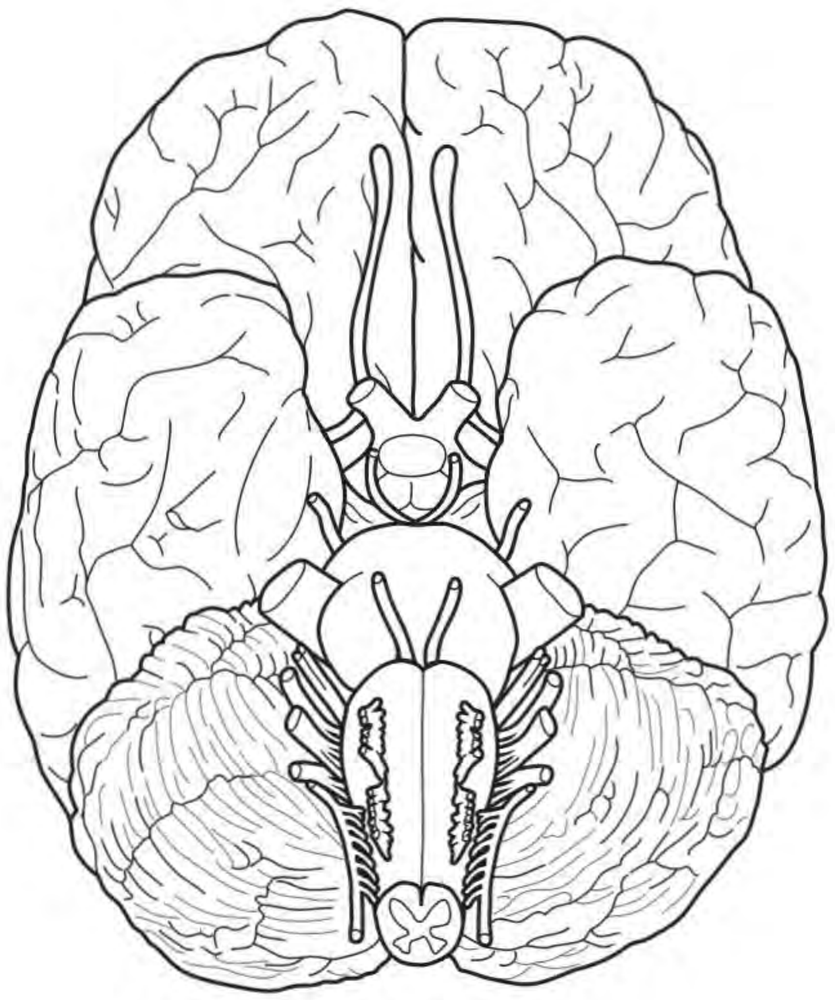


FIGURE **11.2** Brain, inferior view.

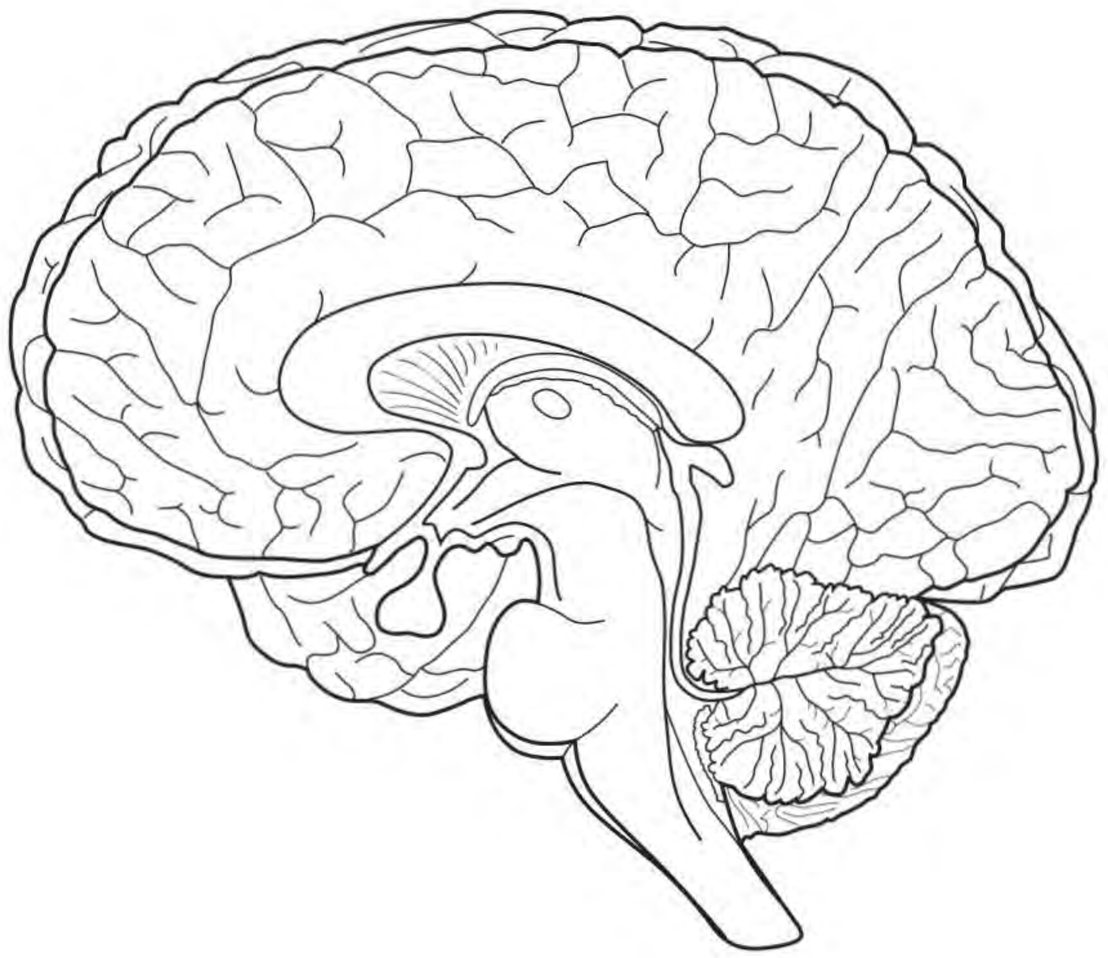


FIGURE **11.3** Brain, midsagittal section.

Name _____ Section _____ Date _____

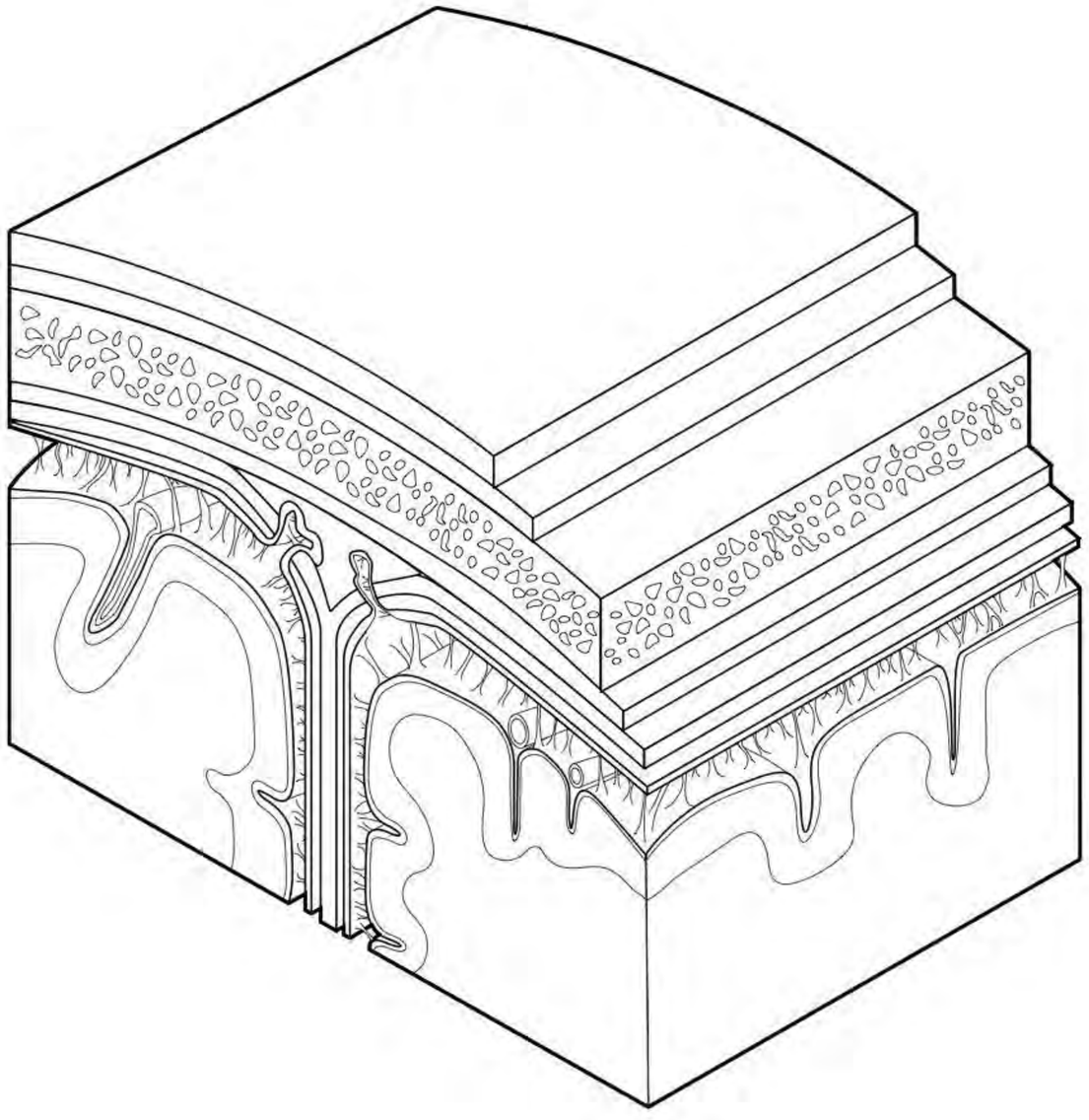
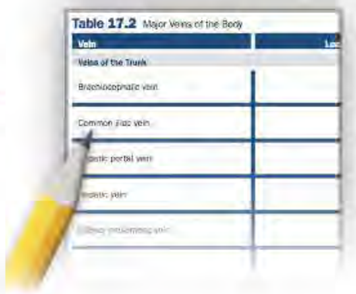


FIGURE **11.4** Brain and meninges, frontal and parasagittal section.

Pre-Lab Exercise 11-3

Cranial Nerve Locations and Functions



Complete Table 11.1 with the functions of each pair of cranial nerves, and indicate whether the nerve is motor, sensory, or mixed.

TABLE **11.1** The Cranial Nerves

Cranial Nerve	Functions	Motor, Sensory, or Mixed
CN I: Olfactory nerve		
CN II: Optic nerve		
CN III: Oculomotor nerve		
CN IV: Trochlear nerve		
CN V: Trigeminal nerve		
CN VI: Abducens nerve		
CN VII: Facial nerve		
CN VIII: Vestibulocochlear nerve		
CN IX: Glossopharyngeal nerve		
CN X: Vagus nerve		
CN XI: Accessory nerve		
CN XII: Hypoglossal nerve		

EXERCISES

The **brain** is the most complex organ of the nervous system, consisting of a folded, hollow, whitish-gray mass of nervous, epithelial, and connective tissues. Traveling to and from the brain are peripheral nerves called **cranial nerves**, most of which supply structures of the head and the neck. Together the brain and cranial nerves control many of our homeostatic functions, our sensation, our movement, and our higher brain functions. The anatomy of both structures will be explored in the exercises in this unit.

Exercise 11-1

Anatomy of the Brain

MATERIALS

- ❑ Brain models: whole and sectioned
- ❑ Ventricle models
- ❑ Brainstem models
- ❑ Dural sinus model
- ❑ Sheep brain
- ❑ Hammer and chisel (if the brain is still in the skull)
- ❑ Dissection equipment and trays

The brain is divided into four regions: the **cerebral hemispheres** (collectively called the **cerebrum**), the **diencephalon**, the **brainstem**, and the **cerebellum**. The brain contains hollow spaces called **ventricles** that are filled with a fluid similar to plasma called **cerebrospinal fluid** (seh-ree-broh-SPY-nul; CSF). As you can see in Figure 11.5, the largest of the ventricles, called the **lateral ventricles**, are located in the right and left cerebral hemispheres. Note in Figure 11.5A that the lateral ventricles resemble rams' horns when viewed from the anterior side. The smaller **third ventricle** is housed within the diencephalon. It is continuous with the **fourth ventricle**, found in the brainstem, via a small canal called the **cerebral aqueduct**. The fourth ventricle is continuous with a canal that runs down the central spinal cord called the **central canal**.

Within each of the four ventricles we find collections of blood vessels known as **choroid plexuses** (KOHR-oyd). As blood flows through the choroid plexuses, fluid filters out into the ventricles, and at that point is called CSF. The largest choroid plexuses are within the lateral ventricles. Recall from Unit 10 that the ventricles are lined by neuroglial cells called ependymal cells, whose cilia beat to circulate CSF. One of the main functions of CSF is to reduce brain weight, as the brain is buoyant in the CSF. Without CSF, your brain literally would crush itself under its own weight.

The **cerebrum** (seh-REE-brum) is the most superior portion of the brain and is responsible for the brain's cognitive functions, including learning and language, conscious interpretation of sensory information, conscious planning of

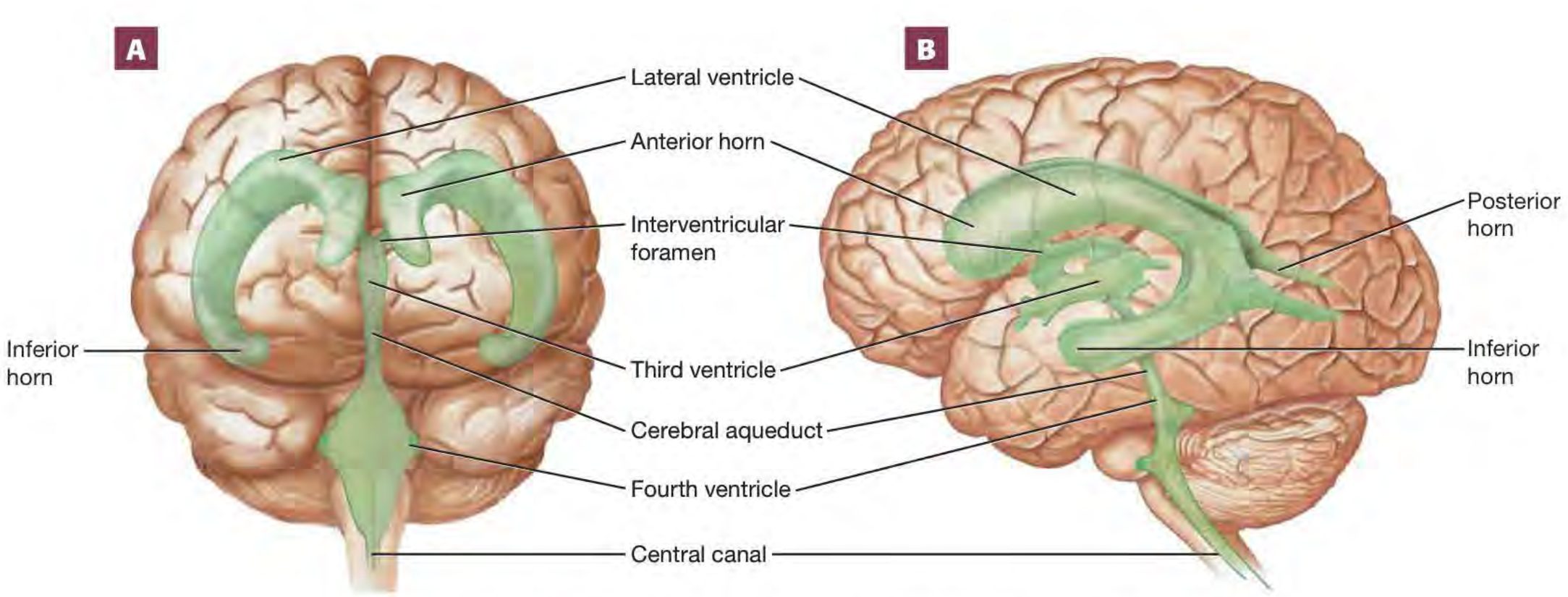


FIGURE **11.5** Ventricles: (**A**) anterior view; (**B**) lateral view.

movement, and personality (Figure 11.6). Its surface consists of elevated ridges called **gyri** (JY-ree) and shallow grooves called **sulci** (SUL-kee). Deep grooves, called **fissures**, separate major regions of the cerebral hemispheres. For example, the **longitudinal fissure** separates the right and left hemispheres. The cerebrum consists of five lobes: the **frontal, parietal, temporal, occipital,** and deep **insula** lobes (remember this last one by the mnemonic "the *insula* is *insula*ted"). A major sulcus called the **central sulcus** separates the frontal and parietal lobes. Anterior to the central sulcus is the **precentral gyrus,** which houses the primary motor cortex, and posterior to the central sulcus is the **postcentral gyrus,** which houses the primary somatosensory cortex.

The cell bodies and unmyelinated axons and dendrites of the cerebral neurons lie in the cerebrum's outer 2 millimeters in a region called the **cerebral cortex.** These portions of the neurons are unmyelinated, which gives the cerebral cortex a gray color, and for this reason it is called **gray matter.** The cell bodies and processes of the cerebral cortex communicate with other parts of the nervous system by bundles of myelinated axons called **white matter.** The largest tract of cerebral white matter is called the **corpus callosum** (KOHR-pus kal-OH-sum), which connects the right and left cerebral hemispheres (Figure 11.7). Another prominent tract of white matter visible inferior to the corpus callosum is the **fornix.**

Gray matter isn't confined to the cerebral cortex. Clusters of cell bodies called **nuclei** are found throughout the white matter of the cerebrum. An important group of nuclei, the **basal nuclei,** monitors voluntary motor functions. The neurons of these nuclei are connected to other parts of the nervous system by various tracts of cerebral white matter.

Deep to the cerebral hemispheres in the central core of the brain we find the **diencephalon** (dy-en-SEF-ah-lahn), which is composed of three main parts (Figure 11.7):

1. **Thalamus.** The **thalamus** (THAL-uh-muss) is the large, central, egg-shaped mass of gray and white matter that makes up 80% of the diencephalon. It is a major integration and relay center that edits and sorts information going into the cerebrum. It essentially functions as the "gateway" into the cerebrum.
2. **Hypothalamus.** The **hypothalamus** (hy-poh-THAL-uh-muss) is located on the anterior and inferior aspect of the diencephalon. It is a deceptively small structure that contains the nuclei whose neurons carry out many of the body's homeostatic functions. These include helping to regulate the endocrine system; monitoring the sleep-wake cycle; controlling thirst, hunger, and body temperature; and helping to monitor the autonomic nervous system (good things do come in small packages, after all). An endocrine organ called the **pituitary gland** (pih-TOO-ih-tehr-ee) is connected to the hypothalamus by a stalk called the **infundibulum** (in-fun-DIB-yoo-lum).
3. **Epithalamus.** The **epithalamus** is located on the posterior and superior aspect of the diencephalon. It contains an endocrine organ called the **pineal gland** (pin-EE-ul) that secretes the hormone **melatonin** (mel-uh-TOH-nin), which helps to regulate the sleep-wake cycle.

The third major portion of the brain, the **brainstem,** influences the automatic functions of the body, such as the rhythm for breathing, heart rate, blood pressure, and certain reflexes. The most superior portion of the brainstem is

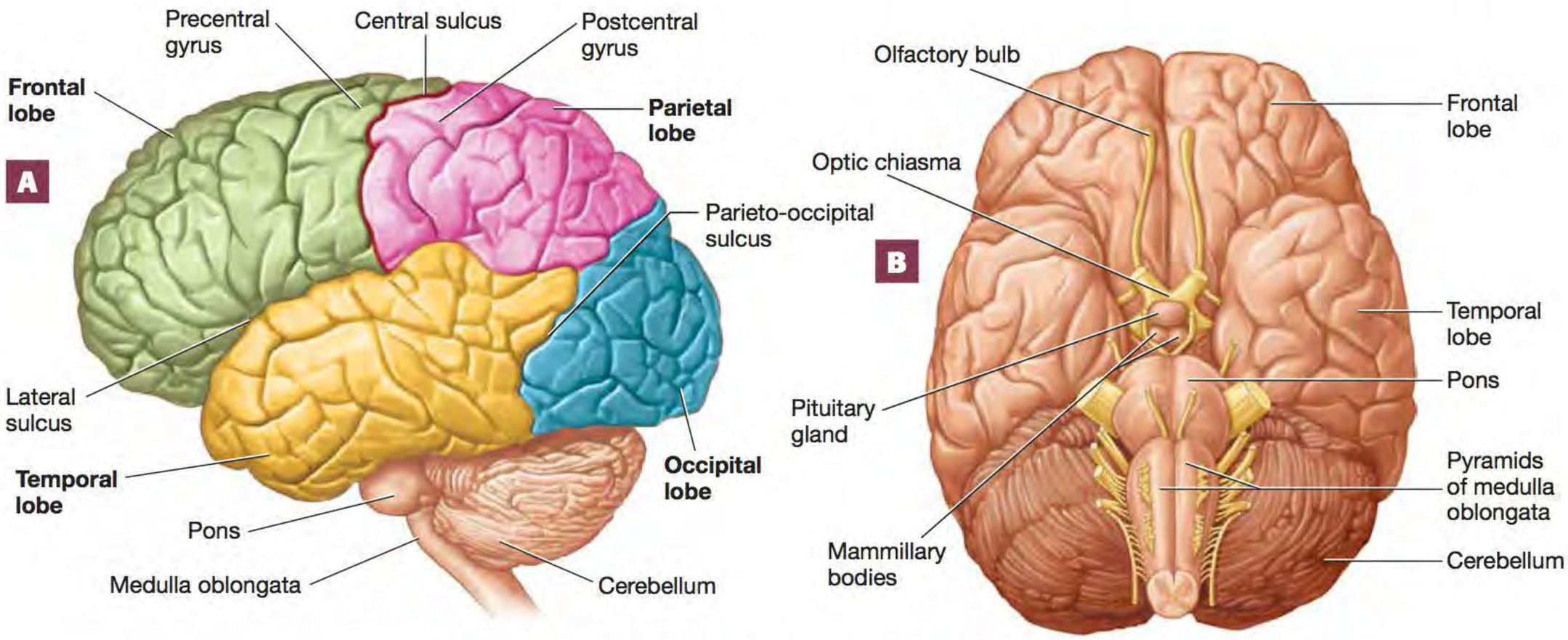


FIGURE **11.6** Brain: (A) lateral view; (B) inferior view.

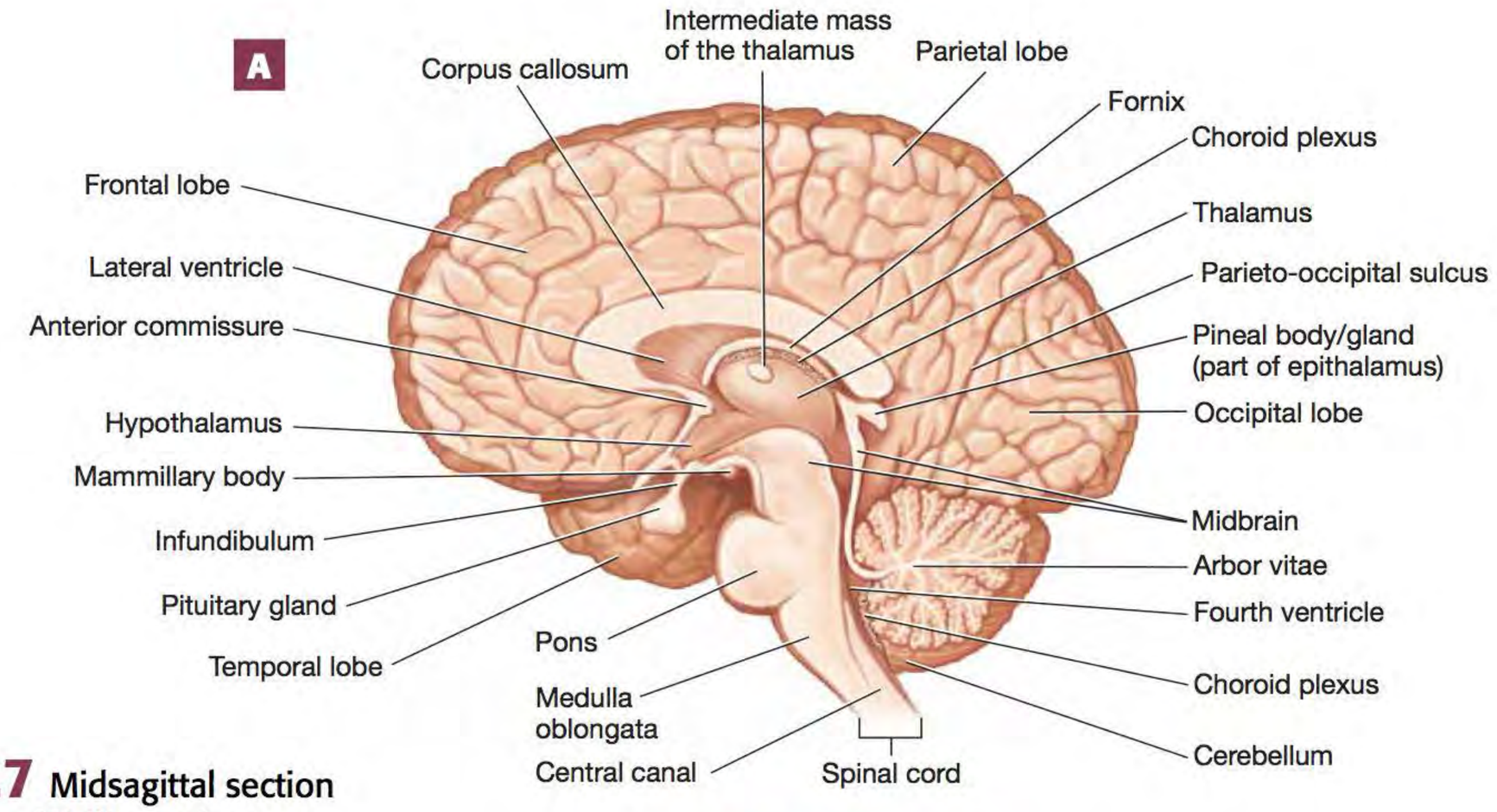


FIGURE 11.7 Midsagittal section of the brain: (A) illustration; (B) photograph.

the **midbrain,** and inferior to it we find the rounded **pons,** which bulges anteriorly. The last segment of the brainstem, the **medulla oblongata** (or simply *medulla*), is continuous inferiorly with the spinal cord.

The fourth major component of the brain is the large posterior **cerebellum** (sehr-eh-BELL-um). It consists of two highly convoluted lobes connected by a piece called the **vermis** (VER-miss). Like the cerebral hemispheres, the cerebellum has an outer **cerebellar cortex** composed of gray matter and inner white matter. The cerebellar white matter is called the **arbor vitae** (AR-bohr VEE-tay) because of its resemblance to the branches of a tree. The cerebellum coordinates and plans ongoing motor activities and is critical in reducing and preventing motor error with movement.

Note in Figure 11.8 that a set of three membranes, collectively called the **meninges** (meh-NIN-jeez; singular: *meninx*), surrounds the brain. The meninges include the following:

1. **Dura mater.** The outermost meninx is the thick, leathery, double-layered **dura mater** (DOO-rah MAH-ter). The superficial *periosteal layer* is fused to the skull, and the deeper *meningeal layer* is continuous with the dura mater of the spinal cord. The two layers of the dura are fused, but in three regions the meningeal layer separates from the periosteal layer and dives into the brain to form three structures:
   a. the **falx cerebri** (FALS seh-REE-bree), which forms a partition between the right and left cerebral hemispheres,
   b. the **falx cerebelli** (sehr-eh-BELL-ee), which separates the two cerebellar hemispheres, and
   c. the **tentorium cerebelli,** which separates the cerebrum from the cerebellum.

   At these locations there are spaces between the two dural layers collectively called the **dural sinuses** (see Figure 16.11, p. 406). All deoxygenated blood from the brain drains into the dural sinuses, which in turn drain into veins exiting the head and neck.

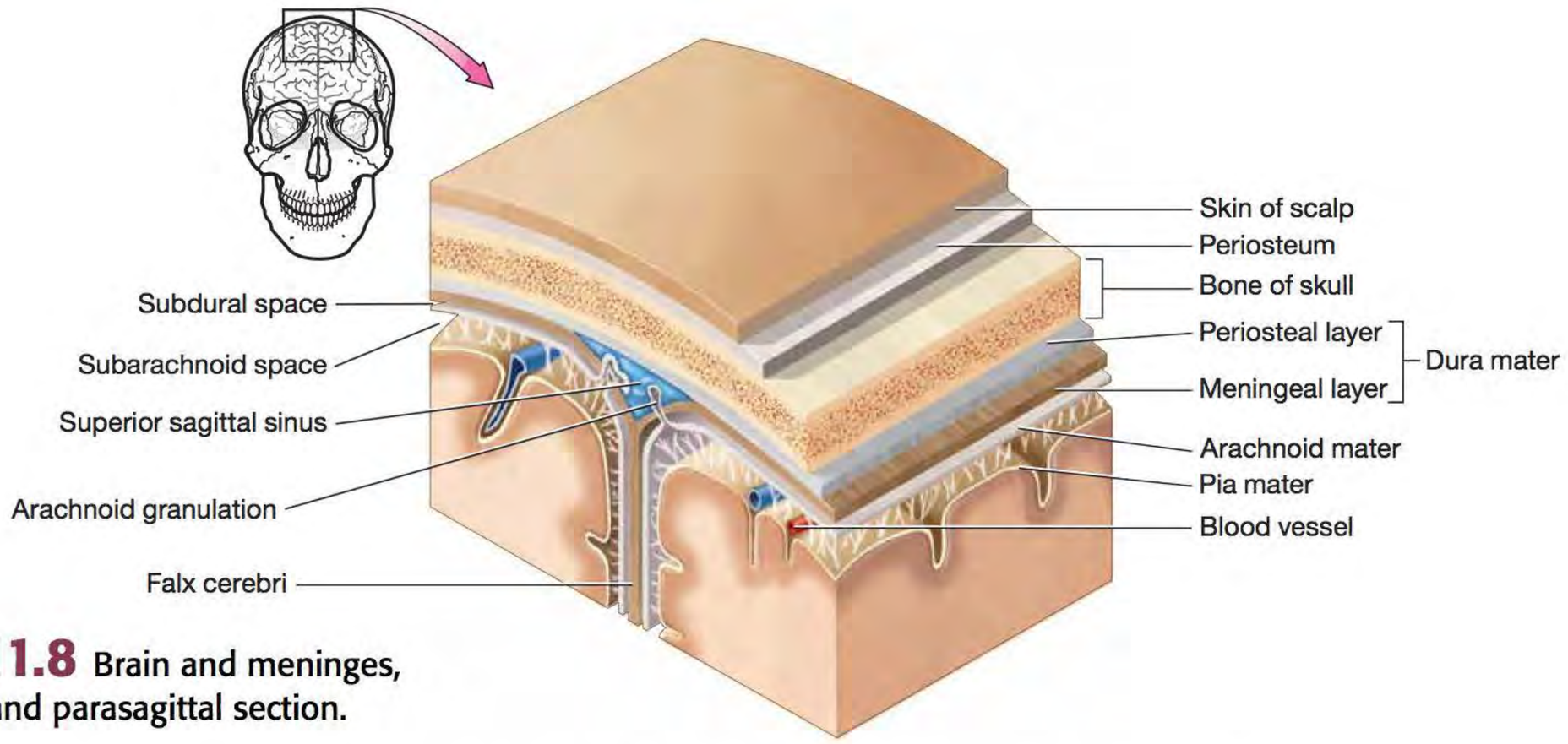
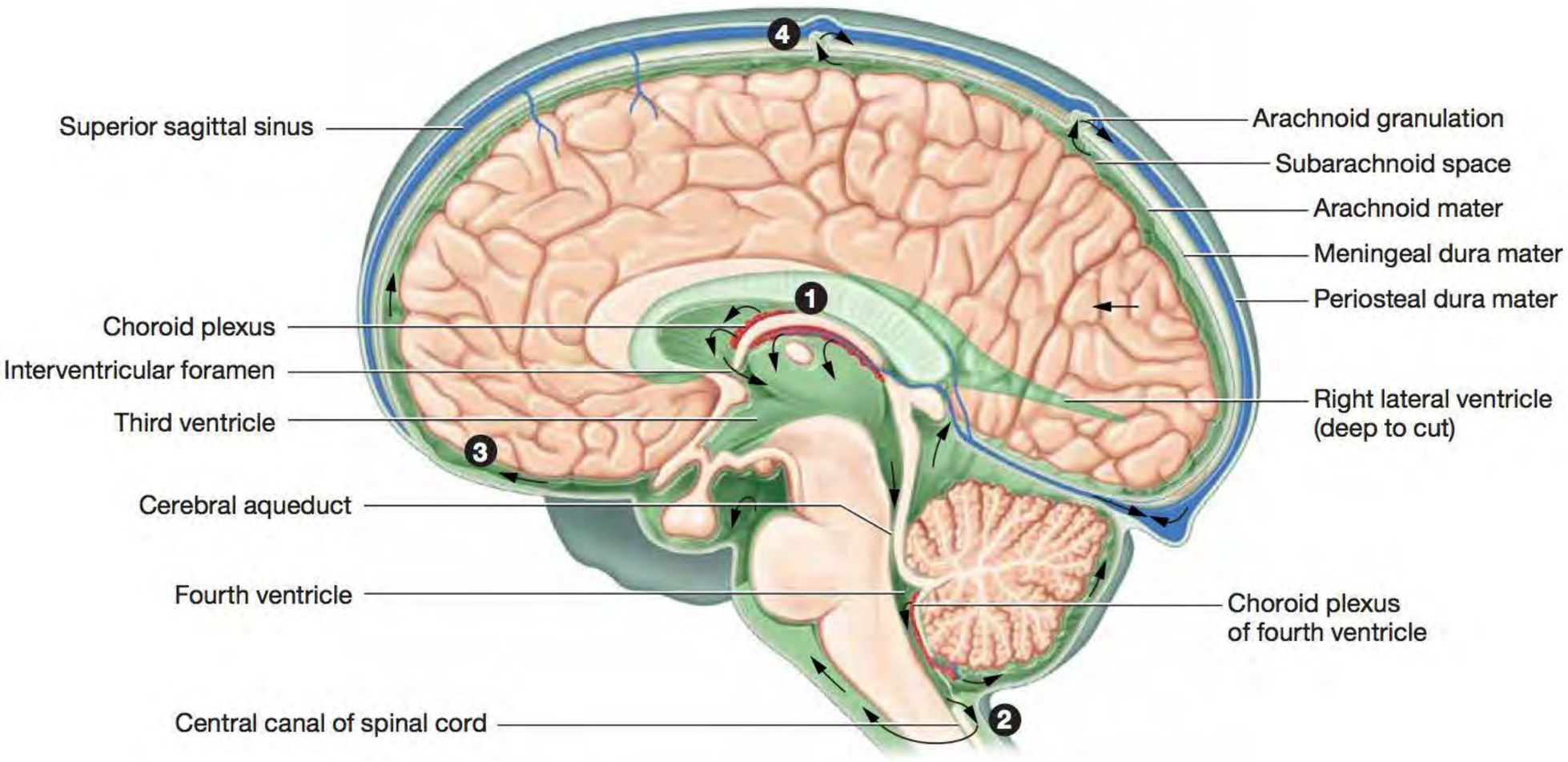


FIGURE **11.8** Brain and meninges, frontal and parasagittal section.

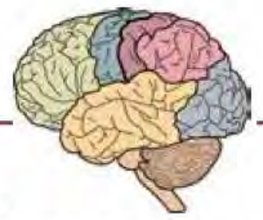
2. **Arachnoid mater.** The middle meninx, the **arachnoid mater** (ah-RAK-noyd), is separated from the dura by a space called the **subdural space.** Small bundles of the arachnoid mater called the **arachnoid granulations (or arachnoid villi)** project into the dural sinuses and allow CSF to reenter the blood. You can see the pattern of CSF circulation from its formation by the choroid plexuses to its return to the blood in Figure 11.9.
3. **Pia mater.** The thinnest, innermost meninx is the **pia mater** (PEE-ah). The pia mater clings to the surface of the cerebral hemispheres and follows the contours of the sulci and gyri. It is richly supplied with blood vessels. A space between the pia mater and the arachnoid mater, called the **subarachnoid space,** is filled with CSF.



1. CSF is produced by the choroid plexus of each ventricle.
2. CSF flows through the ventricles and into the subarachnoid space. Some CSF flows through the central canal of the spinal cord.
3. CSF flows through the subarachnoid space.
4. CSF is absorbed into the dural venous sinuses via the arachnoid granulations.

FIGURE **11.9** Circulation of CSF through the brain and spinal cord.

Procedure 1 Model Inventory for the Brain



Identify the following structures of the brain on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 11.2. The brain's structure is fairly complex, and it's best to examine models in as many different planes of section as possible. When you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 289).

1. Ventricles
   a. Lateral ventricles
   b. Third ventricle
   c. Fourth ventricle
   d. Cerebral aqueduct
   e. Choroid plexuses
2. Cerebrum
   a. Cerebral hemispheres
   b. Lobes of the cerebrum
      (1) Frontal lobe
      (2) Parietal lobe
      (3) Occipital lobe
      (4) Temporal lobe
      (5) Insula lobe
   c. Fissures
      (1) Longitudinal fissure
      (2) Transverse fissure
   d. Sulci
      (1) Central sulcus
         (a) Precentral gyrus
         (b) Postcentral gyrus
      (2) Lateral sulcus
      (3) Parieto-occipital sulcus
   e. Corpus callosum (cerebral white matter)
   f. Cerebral cortex (gray matter)
   g. Basal nuclei (these will only be visible on certain sections of the brain)
   h. Fornix
3. Diencephalon
   a. Thalamus
   b. Hypothalamus
      (1) Infundibulum
      (2) Pituitary gland
   c. Epithalamus
      (1) Pineal gland
4. Brainstem
   a. Midbrain
   b. Pons
   c. Medulla oblongata
5. Cerebellum
   a. Vermis
   b. Arbor vitae
6. Brain coverings
   a. Dura mater
      (1) Subdural space
      (2) Falx cerebri
      (3) Falx cerebelli
      (4) Tentorium cerebelli
      (5) Dural sinuses
   b. Arachnoid mater
      (1) Subarachnoid space
      (2) Arachnoid granulations
   c. Pia mater

TABLE **11.2** Model Inventory for the Brain

Model/Diagram	Structures Identified

Procedure 2 Brain Dissection

Often structures of the brain and spinal cord are difficult to see on anatomical models. This exercise will allow you to examine these structures more closely by dissecting a preserved sheep brain. You will note that certain structures, such as the frontal lobes of the cerebral hemispheres, are proportionally smaller in the sheep than in the human brain. Note that the process of preservation makes many structures of the brain much tougher than they would be in a fresh specimen.

1 If the brain is still encased in the skull, you have your work cut out for you. The best way to approach extracting it from the skull is to take a hammer and chisel and gently (at least as gently as one can with a hammer and chisel) remove it piece by piece.

Safety Note

Goggles and gloves are required!

2 As you remove the skull, you will note a thick membrane holding the skull in place. This is the dura mater, and it can make removal of the skull somewhat difficult. Ideally, you would like to preserve the dura, but you may end up cutting through it as you remove the brain.

3 Once you have removed most of the skull, gently lift out the brain. (If you're careful, you may be able to get the brain out with the pituitary gland still attached.) You may have to loosen the remaining attachments of the dura with your finger.

4 Once the brain is out, note the thick part of the dura covering the longitudinal fissure. If you cut through this with scissors, you will enter the superior sagittal sinus.

5 Next remove the dura to reveal the thin membrane on top of the brain. This is the arachnoid mater.

6 Remove an area of the arachnoid mater to see the shiny inner membrane—the pia mater—directly touching the surface of the brain. Note that the pia mater follows the convolutions of the gyri and sulci.

7 Examine the surface anatomy of both the superior and the inferior surfaces of the sheep brain (Figures 11.10 and 11.11).

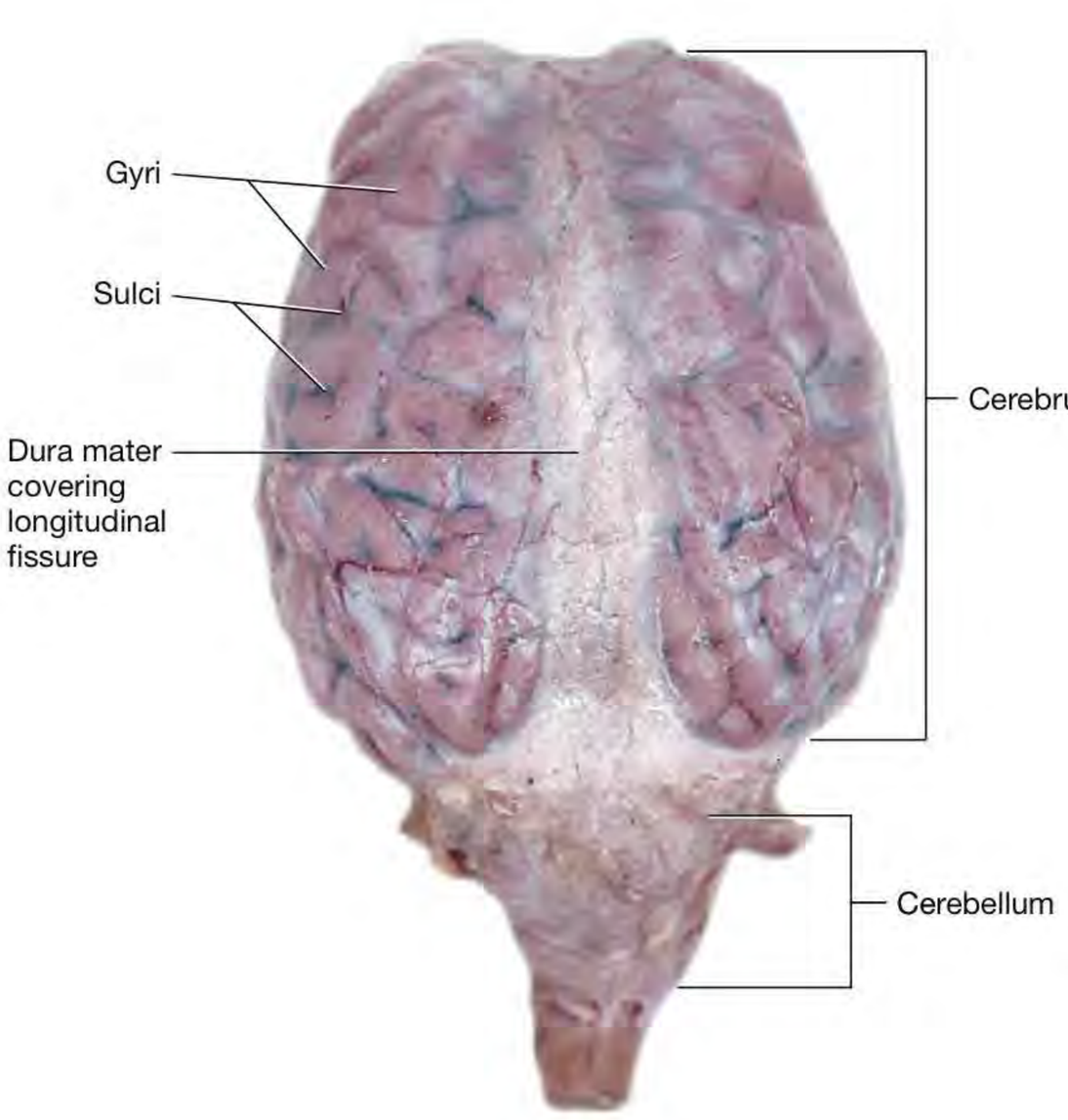


FIGURE **11.10** Superior view of the sheep brain.

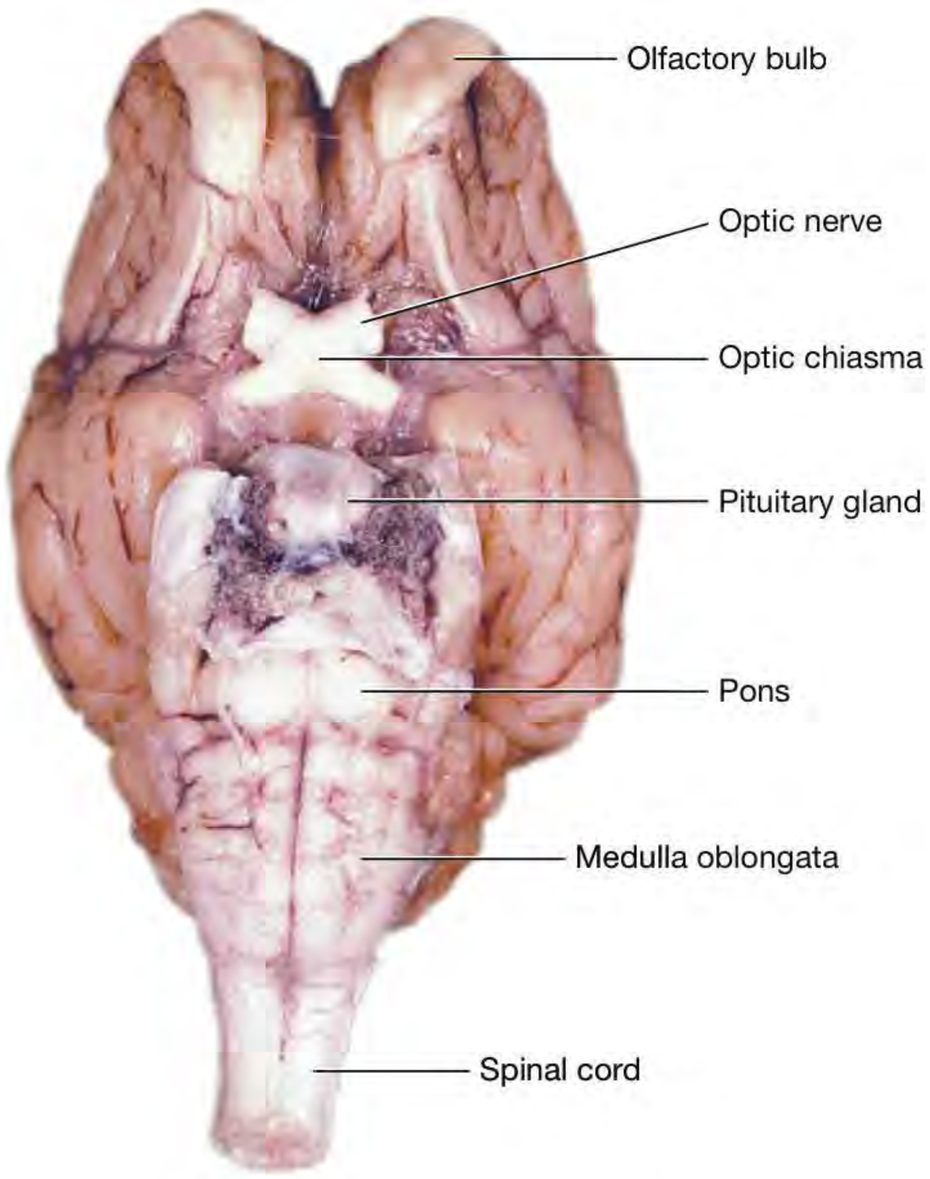


FIGURE **11.11** Inferior view of the sheep brain.

8 In the space provided, draw what you see on both surfaces, and label your drawing with the following structures:

- ❑ Arachnoid mater
- ❑ Cerebellum
- ❑ Cerebrum
- ❑ Dura mater
- ❑ Gyri
- ❑ Longitudinal fissure
- ❑ Medulla oblongata
- ❑ Olfactory bulb
- ❑ Optic chiasma
- ❑ Pituitary gland
- ❑ Pons
- ❑ Sulci

9 Note the size of the olfactory bulbs. Are they larger or smaller than those you observed in the human brain? Why do you think this is so?

10 Spread the two cerebral hemispheres, and identify the corpus callosum.

11 Make a cut down the brain's midsagittal plane to separate the two cerebral hemispheres.

12 Examine the brain's internal anatomy (Figure 11.12), and stick your finger in the lateral ventricle. You will see (or feel) that it is much larger than it appears.

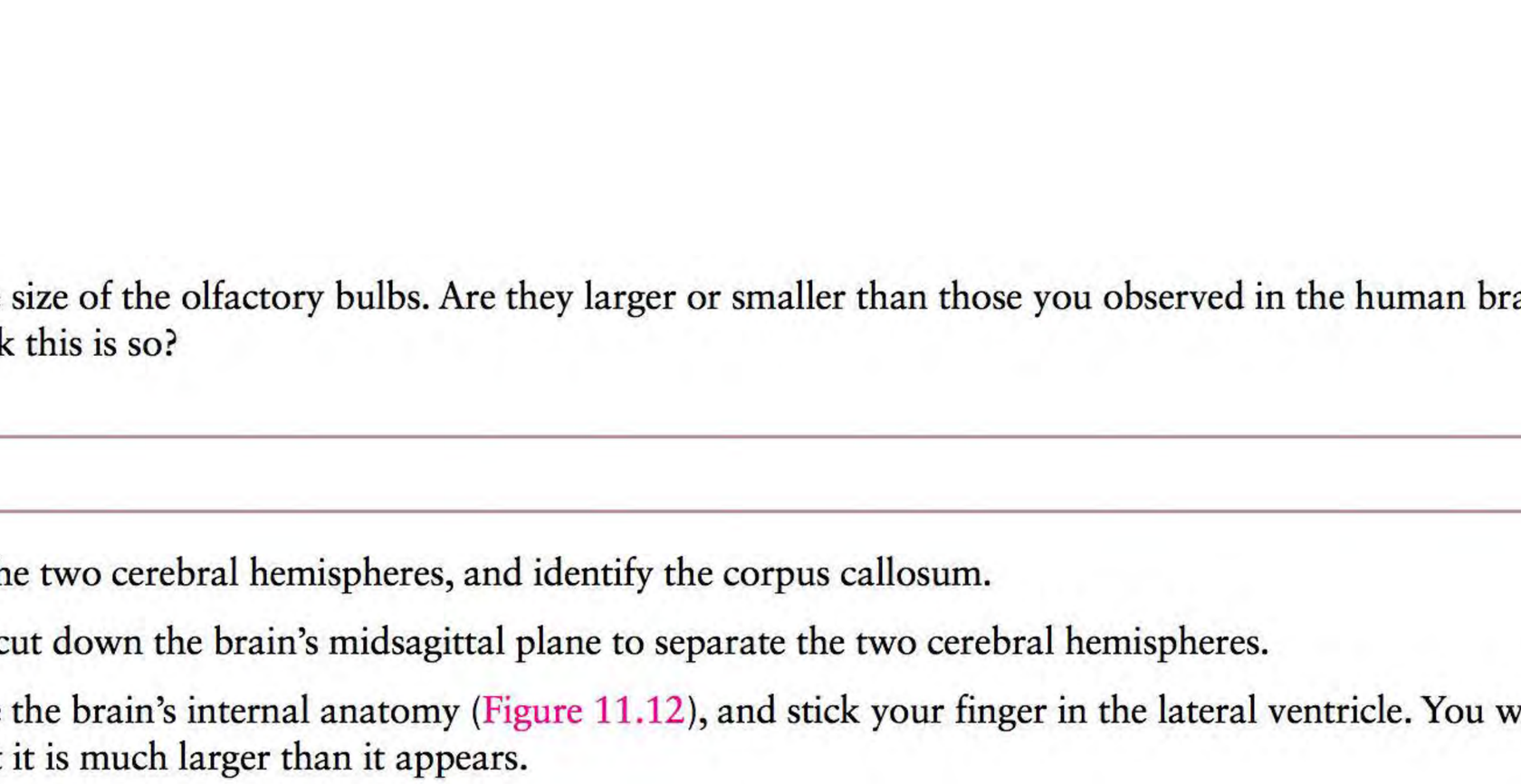


FIGURE **11.12** Lateral view of the sheep brain; midsagittal section.

13 Draw what you see in the space provided, and label your drawing with the following structures:

- ❑ Arbor vitae
- ❑ Choroid plexus
- ❑ Corpus callosum
- ❑ Fornix
- ❑ Hypothalamus
- ❑ Lateral ventricle
- ❑ Medulla oblongata
- ❑ Midbrain
- ❑ Pineal gland
- ❑ Pons
- ❑ Thalamus

14 Section one of the halves of the brain in the frontal plane, approximately along the central sulcus. Note the outer cerebral cortex (the gray matter) and the inner white matter. From this view you also can see the lateral and third ventricles. Again draw what you see in the space provided and label your drawing with the following structures:

- ❑ Cerebral cortex
- ❑ Cerebral white matter
- ❑ Falx cerebri
- ❑ Lateral ventricle
- ❑ Thalamus
- ❑ Third ventricle

Exercise 11-2

The Cranial Nerves

MATERIALS

- ❑ Brain models
- ❑ Preserved brain specimens
- ❑ Penlight
- ❑ Snellen vision chart
- ❑ Tuning fork
- ❑ Unknown samples to smell
- ❑ PTC, thiourea, and sodium benzoate tasting papers

The 12 pairs of **cranial nerves** originate from or bring information to the brain (Figure 11.13). Each nerve is given two names: (1) a sequential Roman numeral in order of its attachment to the brain, and (2) a name that describes the nerve's location or function. For example, cranial nerve III is the third cranial nerve to arise from the brain. It is also called the oculomotor nerve because one of its functions is to provide motor fibers to some of the muscles that move the eyeball.

All cranial nerves innervate structures of the head and neck. Three cranial nerves are **sensory nerves** whose fibers have purely sensory functions, four are **mixed nerves** that contain both sensory and motor fibers, and five are **motor nerves** that contain primarily motor fibers. Following is an overview of the main functions of each cranial nerve (note that CN = "cranial nerve"):

1. **CN I: Olfactory Nerve.** The **olfactory nerve** is a purely sensory nerve that innervates the olfactory mucosa in the superior nasal cavity, where it provides for the sense of smell.
2. **CN II: Optic Nerve.** The **optic nerve** is also a purely sensory nerve that provides for the sense of vision. Its fibers emerge from the retina of the eye and meet at the **optic chiasma** (ky-AZ-mah), where the nerves partially exchange fibers before diverging to form the **optic tracts.**
3. **CN III: Oculomotor Nerve.** The **oculomotor nerve** (awk-yoo-loh-MOH-tohr) is a motor cranial nerve. It innervates four of the six extrinsic eye muscles that move the eyeball, the muscle that opens the eyelid, the muscle that constricts the pupil, and the muscle that changes the shape of the lens for near vision, an adjustment called **accommodation.**
4. **CN IV: Trochlear Nerve.** The **trochlear nerve** (TROH-klee-ur) is a small motor nerve that innervates one of the six extrinsic eye muscles that moves the eyeball (the *superior oblique muscle*).
5. **CN V: Trigeminal Nerve.** The **trigeminal nerve** is a large mixed nerve named for the three branches that provide sensory innervation to the face and motor innervation to the muscles of mastication (chewing).

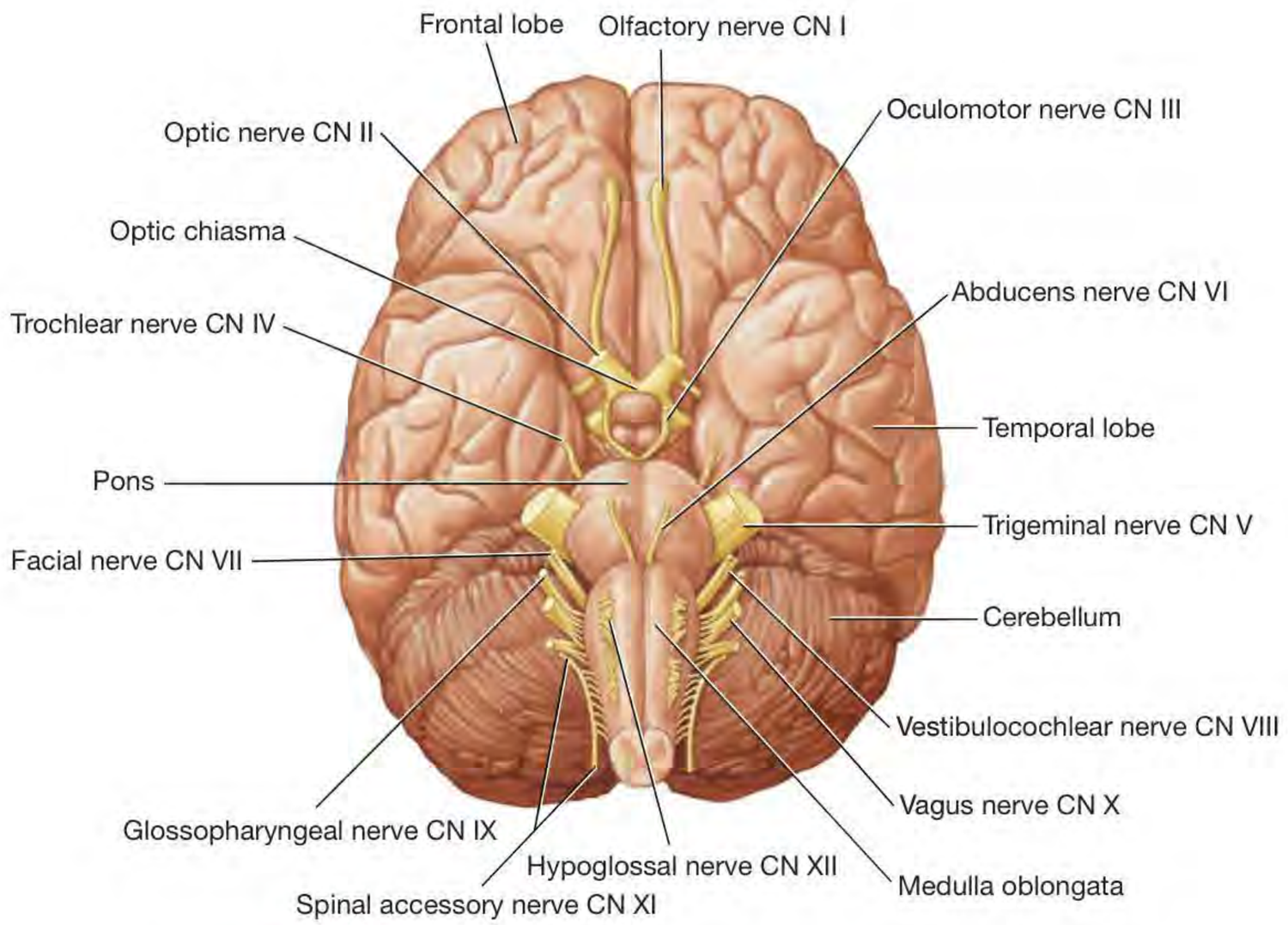


FIGURE **11.13** Inferior view of the brain with the cranial nerves.

6. **CN VI: Abducens Nerve.** The **abducens nerve** (ab-DOO-senz) is a small motor nerve that innervates the final extrinsic eye muscle (the *lateral rectus muscle*).
7. **CN VII: Facial Nerve.** The mixed fibers of the **facial nerve** innervate many structures and provide for the following: motor to the muscles of facial expression; taste to the anterior two-thirds of the tongue; motor to the glands that produce tears (the lacrimal glands), mucus, and saliva; and sensory to part of the face and mouth.
8. **CN VIII: Vestibulocochlear Nerve.** The final sensory nerve, the **vestibulocochlear nerve** (ves-tib-yoo-loh-KOHK-lee-ur), innervates the structures of the inner ear and provides for the senses of hearing and equilibrium.
9. **CN IX: Glossopharyngeal Nerve.** The small mixed **glossopharyngeal nerve** (glah-soh-fehr-IN-jee-ul) provides motor fibers to the muscles of the pharynx (throat) involved in swallowing and sensory fibers to the posterior one-third of the tongue for taste sensation.
10. **CN X: Vagus Nerve.** The mixed **vagus nerve** (VAY-gus) is the only cranial nerve that "wanders" outside of the head and neck ("vagus" means "wanderer"). In the head and the neck it provides some sensory fibers to the skin of the head and the pharynx, motor fibers to muscles involved in speech and swallowing, and motor fibers to certain salivary glands. Outside the head and the neck it innervates most of the thoracic and abdominal viscera as the main nerve of the parasympathetic nervous system.
11. **CN XI: Accessory Nerve.** The **accessory nerve** is the only cranial nerve that has both a cranial component originating from the brainstem and a spinal component originating from the spinal cord. Its motor fibers innervate the muscles that move the head and the neck, such as the trapezius and sternocleidomastoid muscles.
12. **CN XII: Hypoglossal Nerve.** The **hypoglossal nerve** is a small motor nerve that innervates the muscles that move the tongue. Note that the hypoglossal nerve *moves* the tongue but does not provide any taste sensation to the tongue.

HINTS & TIPS

Remembering the Order of the Cranial Nerves

Many cranial nerve mnemonics have been created over the years to help students remember their correct order. Following is one of my favorite mnemonics, but if this one doesn't stick for you, try making up your own or doing an Internet search for "cranial nerve mnemonics":

Oh (Olfactory)
Once (Optic)
One (Oculomotor)
Takes (Trochlear)
The (Trigeminal)
Anatomy (Abducens)
Final (Facial)
Very (Vestibulocochlear)
Good (Glossopharyngeal)
Vacations (Vagus)
Are (Accessory)
Happening (Hypoglossal)

You also can help yourself remember the olfactory and optic nerves by reminding yourself that you have one nose (CN I, the *olfactory* nerve) and two eyes (CN II, the *optic* nerve).

Procedure 1 Model Inventory for Cranial Nerves I–XII

Identify cranial nerves I–XII and associated structures on anatomical models and/or preserved specimens of the brain. List in Table 11.2 in Exercise 11-1 (p. 000) the nerves and structures you identify.

1. Olfactory nerves
   a. Olfactory bulbs
2. Optic nerves
   a. Optic chiasma
   b. Optic tract
3. Oculomotor nerves
4. Trochlear nerves
5. Trigeminal nerves
6. Abducens nerves
7. Facial nerves
8. Vestibulocochlear nerves
9. Glossopharyngeal nerves
10. Vagus nerves
11. Accessory nerves
12. Hypoglossal nerves

Procedure 2 Testing the Cranial Nerves

A component of every complete physical examination performed by healthcare professionals is the cranial nerve exam. In this exercise you will put on your "doctor hat," and perform the same tests of the cranial nerves done during a physical examination. Pair up with another student, and take turns performing the following tests. For each test, first document your observations (in many cases, this will be "able to perform" or "unable to perform"). Then state which cranial nerve(s) you have checked with each test. Keep in mind that some tests check more than one cranial nerve, some cranial nerves are tested more than once, and each nerve is tested in this exercise at least once. When you have completed the activity, answer Check Your Understanding questions 4 through 6 (p. 312).

1 Have your partner perform the following actions individually (not all at once—your partner may have difficulty smiling and frowning at the same time): smile, frown, raise his or her eyebrows, and puff his or her cheeks.

Observations: _____

_____

_____

CN(s) tested: _____

2 Have your partner open and close his or her jaw and clench his or her teeth.

Observations: _____

_____

_____

CN(s) tested: _____

3 Have your partner elevate and depress his or her shoulders and turn his or her head to the right and the left.

Observations: _____

_____

_____

CN(s) tested: _____

4 Draw a large, imaginary "Z" in the air with your finger. Have your partner follow your finger with his or her eyes without moving his or her head. Repeat the procedure, this time drawing the letter "H" in the air with your finger.

Observations: _____

_____

_____

CN(s) tested: _____

5 Test pupillary response:

- **a** Dim the lights in the room about halfway.
- **b** Place your hand vertically against the bridge of your partner's nose as illustrated in Figure 11.14. This forms a light shield to separate the right and left visual fields.
- **c** Shine the penlight indirectly into the left eye from an angle as illustrated in Figure 11.14. Watch what happens to the pupil in the left eye.
- **d** Move the penlight away, and watch what happens to the left pupil.
- **e** Shine the light into the left eye again, and watch what happens to the pupil in the right eye. Move the penlight away, and watch what happens to the right pupil.
- **f** Repeat this process with the right eye.
- **g** Record your results in Table 11.3.

FIGURE **11.14** Method for testing the pupillary response.

CN(s) tested: _____

_____

TABLE **11.3** Pupillary Response Results

Action	Response of Left Pupil	Response of Right Pupil
Light shined into left eye		
Light removed from left eye		
Light shined into right eye		
Light removed from right eye		

6 Have your partner focus on an object on the far side of the room (e.g., the chalkboard or a chart) for 1 minute. Then have your partner switch his or her focus to an object in your hand (e.g., a pencil). Watch your partner's pupils carefully as the point of focus is changed from far to near.

Observations: _____

_____

_____

_____

_____

CN(s) tested: _____

7 Place your hand lightly on your partner's throat, and have him or her swallow and speak. Feel for symmetrical movement of the larynx (throat).

Observations: _____

_____

_____

CN(s) tested: _____

8 Have your partner protrude his or her tongue. Check for abnormal deviation or movement (e.g., does the tongue move straight forward or does it move to one side?).

Observations: _____

_____

_____

CN(s) tested: _____

9 Test your partner's vision by having him or her stand 20 feet from a Snellen chart and read the chart, starting at the largest line and progressing to the smallest line he or she is able to see clearly. Record the ratio (e.g., 20/30) next to the smallest line your partner can read.

Observations: _____

_____

_____

CN(s) tested: _____

10 Hold a tuning fork by its handle, and strike the tines with a rubber mallet (or just tap it lightly on the lab table). Touch the stem to the top of your partner's head along the midsagittal line in the manner shown in Figure 11.15. This is called the Weber test. Ask your partner if he or she hears the vibration better in one ear, or if he or she hears the sound equally well in both ears.

Observations: _____

_____

_____

_____

_____

CN(s) tested: _____

_____

FIGURE **11.15** Weber test for hearing.

11 Have your partner stand with his or her eyes closed and arms at his or her sides for several seconds. Evaluate his or her ability to remain balanced.

Observations: _____

_____

_____

CN(s) tested: _____

12 Hold an unknown sample near your partner's nose, and fan the odor toward him or her by waving your hand over the container. Have him or her identify the substance by its scent.

Observations: _____

_____

_____

CN(s) tested: _____

13 Evaluate your partner's ability to taste using tasting papers. Have your partner place a piece of PTC paper on his or her tongue and determine if he or she can taste it (the ability to taste PTC is genetically determined; about half of the population can taste it). If your partner cannot taste the PTC, try the thiourea paper instead (a word of warning—thiourea tastes bad). If your partner cannot taste either of these papers, try the sodium benzoate paper.

Observations: _____

_____

_____

CN(s) tested: _____

Name _____

Section _____ Date _____

UNIT 11 REVIEW

Check Your Recall

1 Label the following parts of the brain in Figures 11.16 and 11.17.

- ❑ Central sulcus
- ❑ Cerebellum
- ❑ Corpus callosum
- ❑ Frontal lobe
- ❑ Hypothalamus
- ❑ Lateral sulcus
- ❑ Medulla oblongata
- ❑ Midbrain
- ❑ Occipital lobe
- ❑ Parietal lobe
- ❑ Pineal gland
- ❑ Pons
- ❑ Postcentral gyrus
- ❑ Precentral gyrus
- ❑ Temporal lobe
- ❑ Thalamus

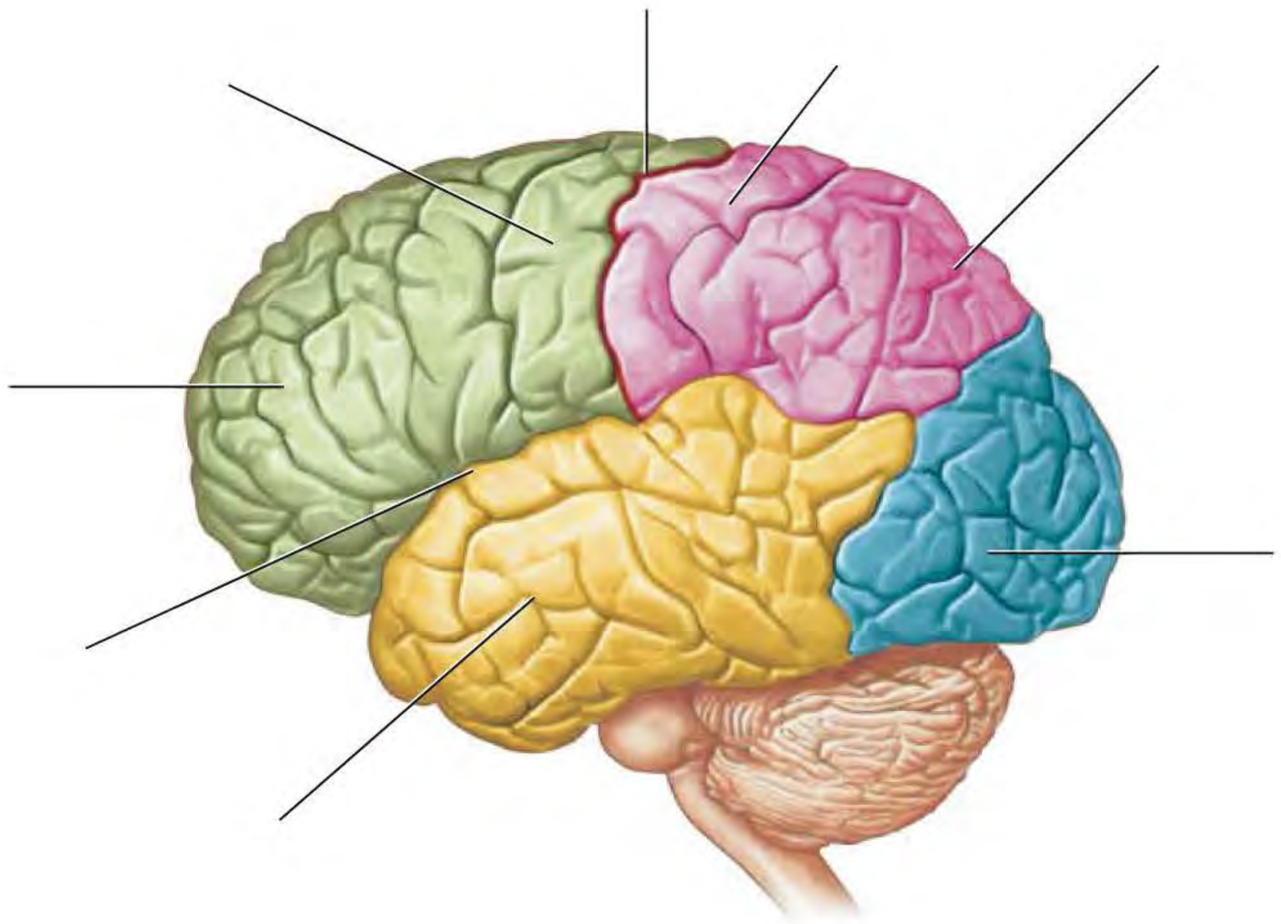


FIGURE **11.16** Brain, lateral view.

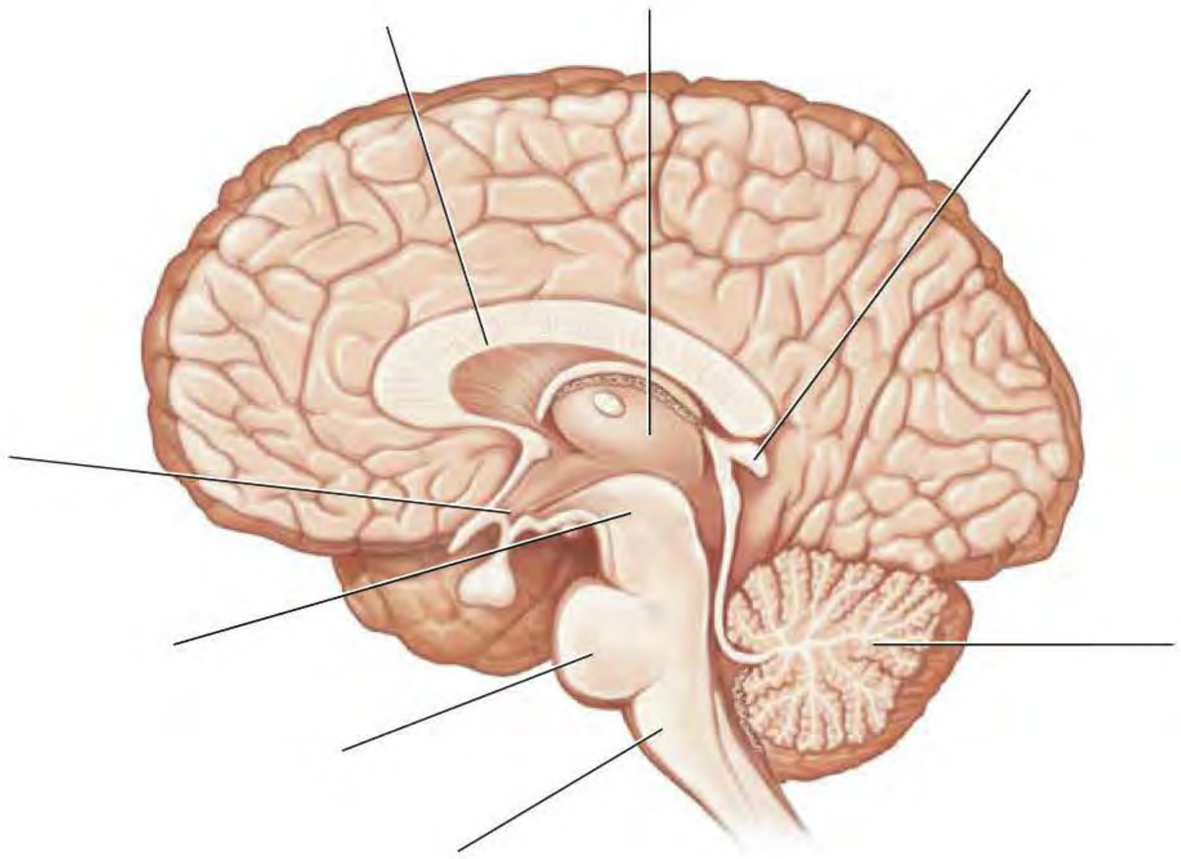


FIGURE **11.17** Brain, midsagittal section.

2 Identify the following structures in Figure 11.18.

- ❑ Central canal
- ❑ Cerebral aqueduct
- ❑ Fourth ventricle
- ❑ Lateral ventricle
- ❑ Third ventricle

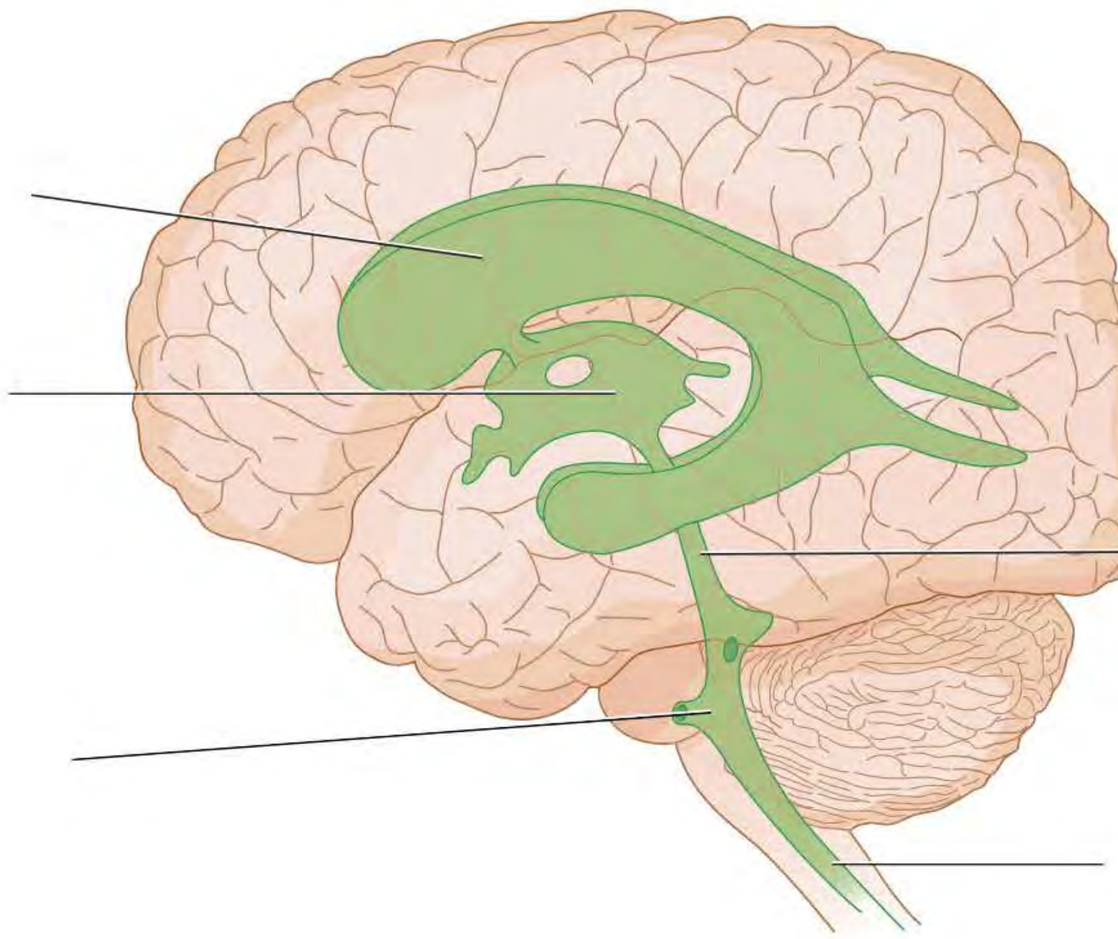


FIGURE **11.18** Brain, left lateral view.

3 Which of the following is *not* one of the four main regions of the brain?

a. Cerebral hemispheres
b. Brainstem
c. Cerebral aqueduct
d. Cerebellum
e. Diencephalon

4 Where is the cerebral cortex located, and what is located here?

5 White matter consists of

a. unmyelinated cell bodies, dendrites, and axons.
b. myelinated axons.
c. unmyelinated axons.
d. myelinated cell bodies, dendrites, and axons.

6 Which of the following cranial nerves is not a purely sensory nerve?

a. Optic nerve
b. Vestibulocochlear nerve
c. Hypoglossal nerve
d. Olfactory nerve

Name _____

Section _____ Date _____

UNIT 11

7 ***Matching:*** **Match the following terms with the correct definition.**

_____ Thalamus

_____ Pia mater

_____ Medulla oblongata

_____ Epithalamus

_____ Cerebellum

_____ Hypothalamus

_____ Dura mater

_____ Pons

_____ Midbrain

_____ Arachnoid mater

A. Most inferior portion of the brainstem

B. Posterior part of the brain that controls and monitors ongoing movement

C. Innermost and thinnest meninx

D. Most superior part of the brainstem

E. Largest, egg-shaped component of the diencephalon; edits and sorts information coming into the cerebrum

F. Middle part of the brainstem that bulges anteriorly

G. Middle meninx

H. Inferior part of the diencephalon that controls many aspects of homeostasis

I. Contains the pineal gland and secretes the hormone melatonin

J. Outermost and thickest meninx

8 ***Fill in the blanks:*** **Write the name of each cranial nerve next to its Roman numeral below.**

CN I _____

CN II _____

CN III _____

CN IV _____

CN V _____

CN VI _____

CN VII _____

CN VIII _____

CN IX _____

CN X _____

CN XI _____

CN XII _____

11

9 ***Matching:*** **Match the cranial nerve with its main functions.**

_____ CN I

_____ CN II

_____ CN III

_____ CN IV

_____ CN V

_____ CN VI

_____ CN VII

_____ CN VIII

_____ CN IX

_____ CN X

_____ CN XI

_____ CN XII

A. Sensory to the face, motor to the muscles of mastication

B. Motor to the trapezius and sternocleidomastoid muscles

C. Hearing and equilibrium

D. Olfaction (smell)

E. Motor to the muscles of swallowing; taste to the posterior one-third of the tongue

F. Motor to one-sixth extraocular muscles (superior oblique muscle)

G. Motor to the tongue

H. Vision

I. Motor to the muscles of facial expression, taste to the anterior two-thirds of the tongue

J. Motor to four-sixths extraocular muscles, dilates the pupil, opens the eye, changes the shape of the lens

K. Motor to the muscles of swallowing and speaking, motor to the thoracic and abdominal viscera

L. Motor to one-sixth extraocular muscles (lateral rectus muscle)

10 **Which of the following cranial nerves is not classified as a mixed nerve?**

a. Trochlear nerve
b. Facial nerve
c. Vagus nerve
d. Trigeminal nerve

11

Name _____

Section _____ Date _____

REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Traumatic brain injuries may result in damage to the blood vessels in the spaces between the meninges. These damaged blood vessels leak blood into either the subdural or subarachnoid spaces—a potentially deadly condition called a *subdural* or *subarachnoid hemorrhage*. Why do you think this condition is so dangerous?

_____

_____

_____

_____

_____

2 Predict the effects of injuries to the following areas.

a Cerebral cortex _____

_____

b Brainstem _____

_____

c Cerebellum _____

_____

d Hypothalamus _____

_____

3 Which of the injuries from question 2 do you think would be the most damaging to survival? Why?

_____

_____

_____

_____

_____

_____

4 **Damage to which cranial nerve(s) might produce the following results?**

a Inability to move the tongue _____

_____

b Inability to taste _____

_____

c Inability to move the eyes in any direction _____

_____

d Inability to shrug the shoulders _____

_____

e Inability to swallow _____

_____

5 Dave was playing a hockey game when he was hit in the face by a puck. He suffered a broken nose during the injury and now finds that his sense of smell has diminished. What is likely causing this?

_____

_____

_____

_____

6 Your patient, Mr. Pratchett, is unable to open his eyelid. On examination, you find that his pupil is dilated, and he is unable to move his affected eye in any direction except laterally and downward, indicating that only his lateral rectus and superior oblique extrinsic eye muscles are functioning. Based on this information, which cranial nerve do you think is involved in his condition? Explain your reasoning.

_____

_____

_____

_____

_____

Spinal Cord and Spinal Nerves

12

OBJECTIVES

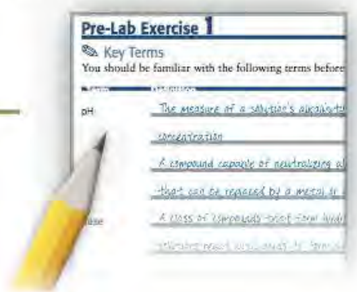
Once you have completed this unit, you should be able to:

1. Identify structures of the spinal cord and describe its anatomical organization.
2. Describe the organization of spinal nerve plexuses and identify select nerves of the plexuses.
3. Explain the process of a simple spinal reflex arc, and test the effects of mental concentration on the patellar tendon (knee-jerk) reflex.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 12-1

Key Terms

You should be familiar with the following terms before coming to lab. Please note that the individual spinal nerves are covered in Pre-Lab Exercises 12-3 (p. 295) and 12-4 (p. 296).

Term	Definition

Structures of the Spinal Cord

Gray matter horns (anterior, posterior, lateral) _____

Funiculi (anterior, posterior, lateral) _____

Conus medullaris _____

Filum terminale _____

Cauda equina _____

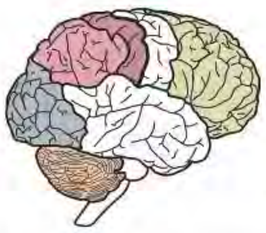
Spinal Nerve Plexuses

Cervical plexus _____

Brachial plexus _____

Lumbar plexus _____

Sacral plexus _____



Pre-Lab Exercise 12-2

Spinal Cord Anatomy

Label and color the diagrams of the spinal cord in Figures 12.1 and 12.2 with the terms from Exercise 12-1 (p. 297). Use your text and Exercise 12-1 in this unit for reference.

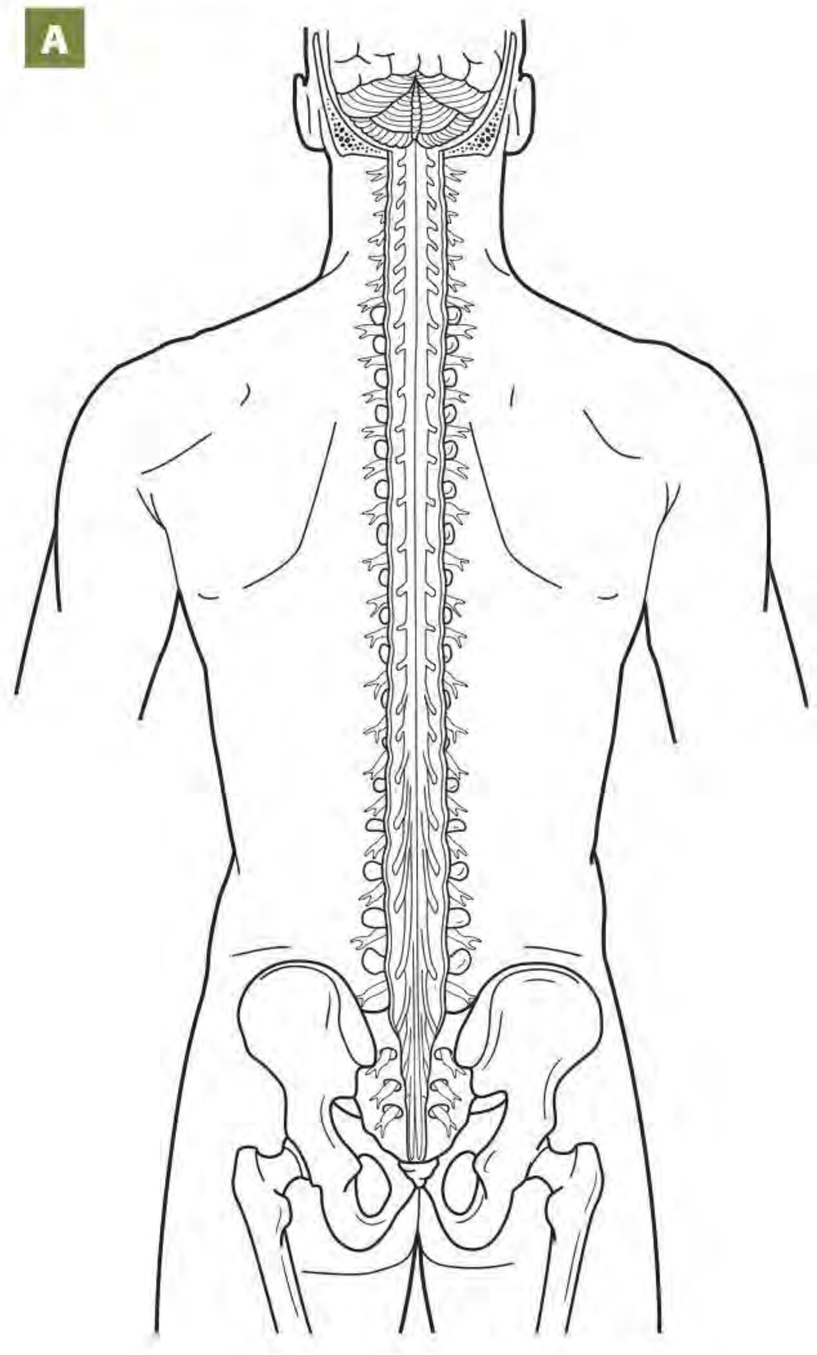
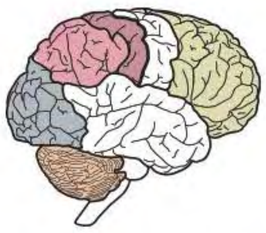


FIGURE 12.1 Spinal cord: (A) brain and spinal cord, posterior view; (B) spinal cord, transverse section.

Name _____ Section _____ Date _____



Pre-Lab Exercise 12-3

Nerve Plexus and Nerve Anatomy

Label the diagram of the nerve plexuses and their main nerves in Figure 12.2 with the terms from Exercise 12-2 (p. 301). Use your text and Exercise 12-2 in this unit for reference. Note that this diagram is presented in color to make identification of the nerves easier.

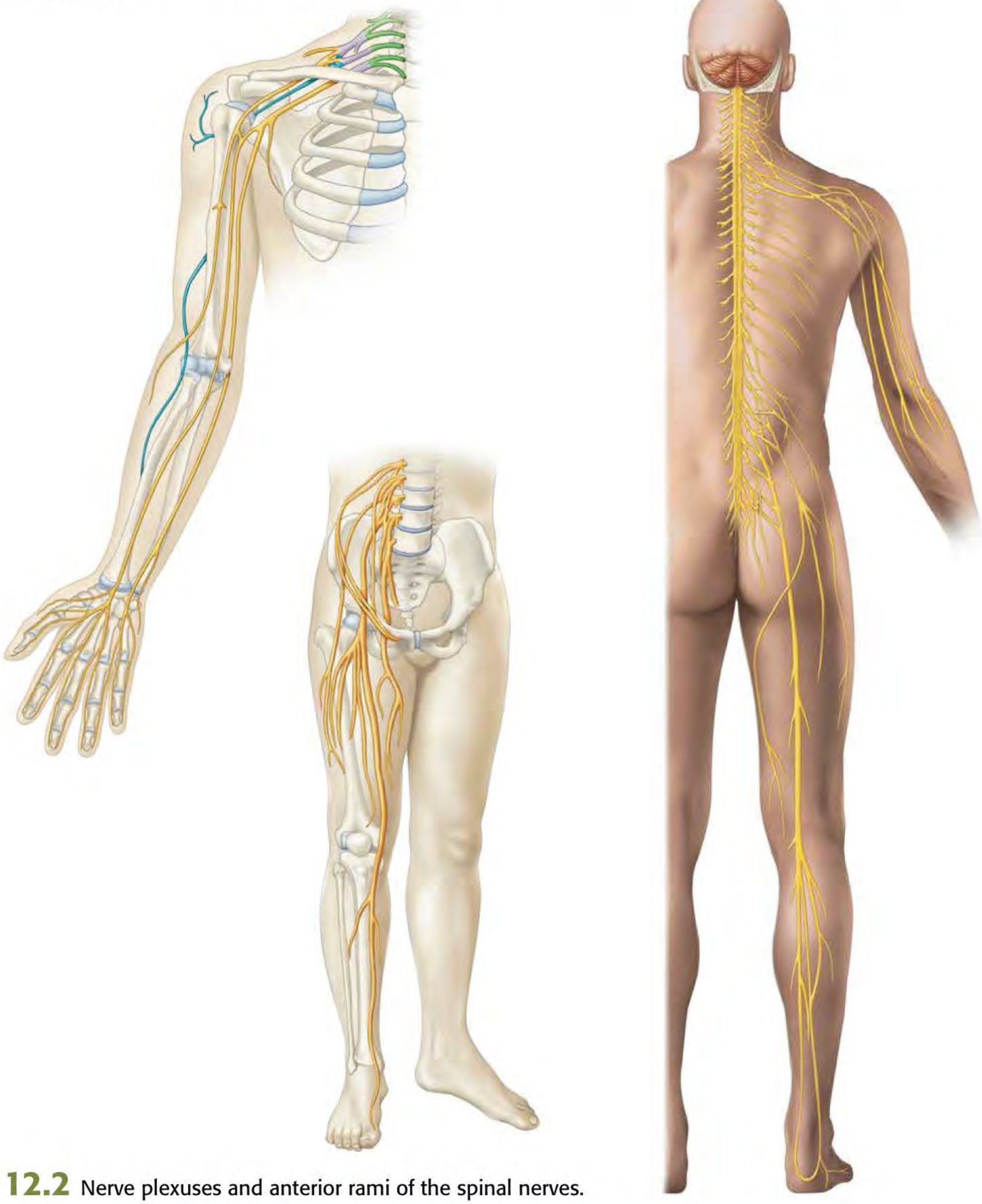


FIGURE **12.2** Nerve plexuses and anterior rami of the spinal nerves.

Pre-Lab Exercise 12-4

Anterior Rami of the Spinal Nerves: Locations and Functions

The anterior rami of the spinal nerves (with the exception of the intercostal nerves) can be traced to the specific nerve plexus from which they originate. Fill in Table 12.1 with the nerve plexus from which each nerve originates and the functions of each nerve.

TABLE **12.1** Selected Anterior Rami of the Spinal Nerves

Spinal Nerve	Nerve Plexus	Functions
Phrenic nerve		
Musculocutaneous nerve		
Ulnar nerve		
Median nerve		
Femoral nerve		
Sciatic nerve		
Tibial nerve		
Common peroneal (fibular) nerve		

EXERCISES

In Unit 11 we discussed the brain and cranial nerves, and now we turn to the other organs of the nervous system—the spinal cord and spinal nerves. The **spinal cord** is the portion of the central nervous system (CNS) that resides within the vertebral cavity. It connects the CNS with the peripheral nervous system (PNS) and also controls many *reflex* functions, which are programmed, automatic responses that are generally below the level of conscious control.

Connecting to the spinal cord are short nerves known as **spinal nerves**. Shortly after they form, spinal nerves branch to supply nearly all structures of the body below the head and the neck.

In the following exercises, you will examine the structure and functions of the spinal cord and spinal nerves. Then, you will take a look at how these organs work together to carry out spinal reflexes.

Exercise 12-1

The Spinal Cord

MATERIALS

- ❑ Spinal cord models: whole and sectioned

The medulla oblongata passes through the foramen magnum of the occipital bone and becomes the **spinal cord** (Figure 12.3). Note in Figure 12.3A that the spinal cord does not extend the entire length of the vertebral column; rather, it ends between the first and second lumbar vertebrae. At this point it tapers to form the end of the spinal cord, called the **conus medullaris** (KOHN-us med-yoo-LEHR-us), which gives off a tuft of nerve roots called the **cauda equina** (KOW-dah eh-KWY-nah; "horse's tail"). The cauda equina fills the remainder of the vertebral column to the sacrum and exits out of the appropriate foramina to become spinal nerves.

The external surface of the spinal cord features two indentations. Anteriorly, we find the relatively wide **anterior median fissure**, and posteriorly is the much narrower **posterior median sulcus**. We can also see two notable bulges along the length of the spinal cord, which are visible in Figure 12.3A. These are known as the **cervical** and **lumbar enlargements**. The spinal cord is larger in these areas due to the high number of nerve roots that attach at these locations coming to and from the upper and lower limbs.

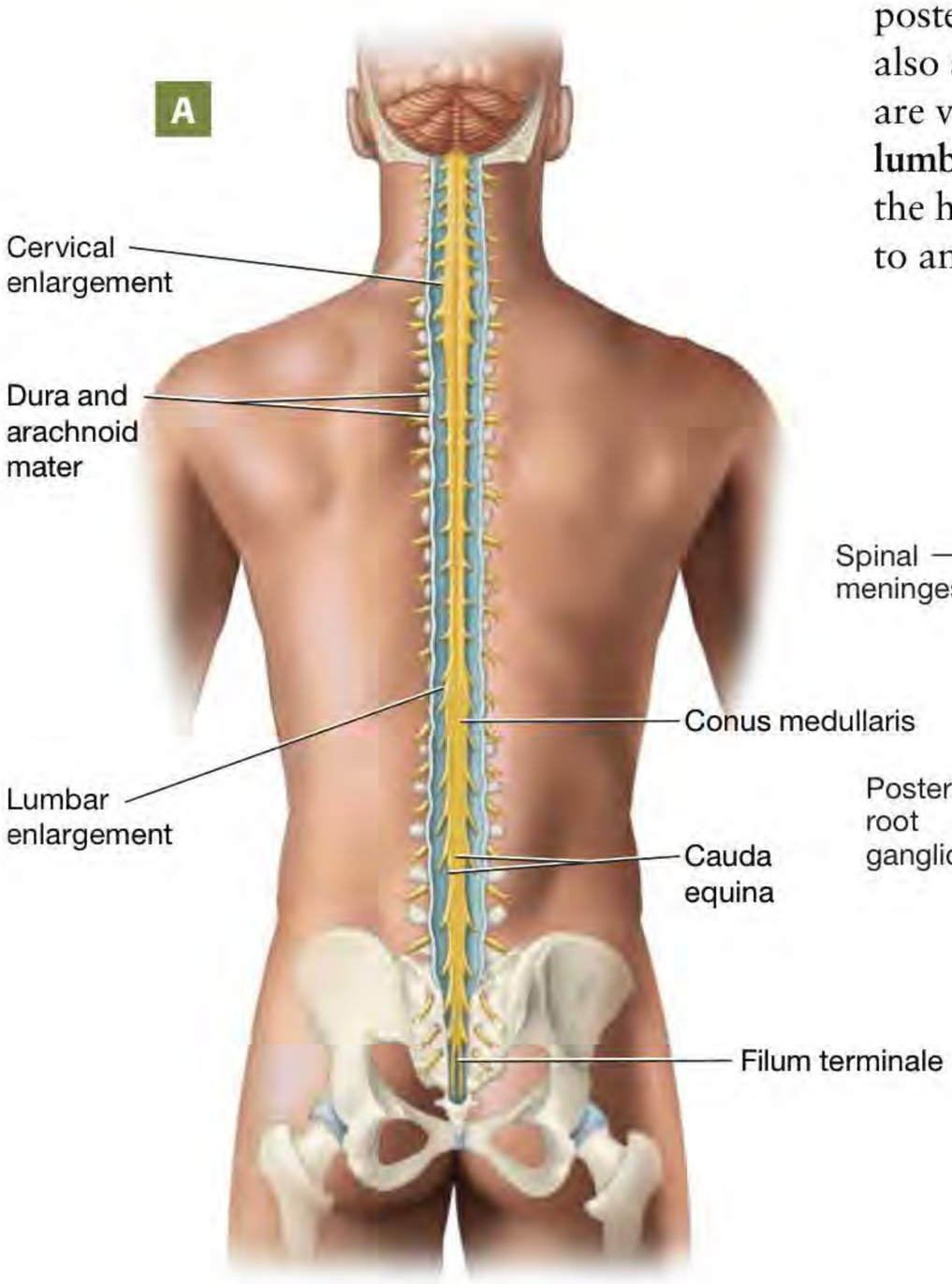


FIGURE **12.3** Spinal cord: (**A**) posterior view in the vertebral column; (**B**) transverse section of the spinal cord in the vertebral column *(continues)*

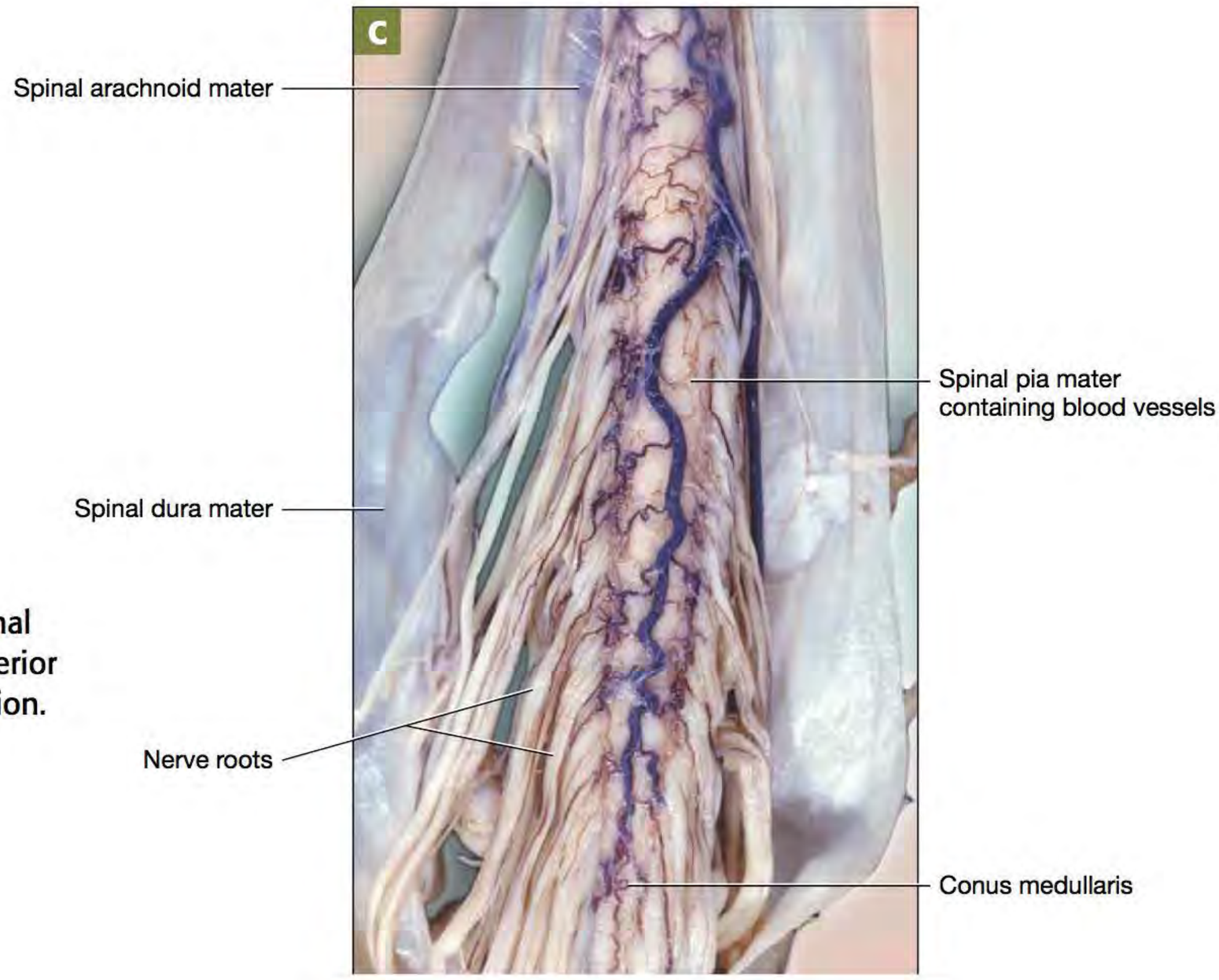


FIGURE 12.3 Spinal cord *(cont.)*: (C) inferior spinal cord dissection.

Like the brain, the spinal cord is protected by a set of **spinal meninges.** The cranial meninges are continuous with spinal meninges and are similar in name and structure (Figures 12.3B and 12.4). The CSF that surrounds the brain and fills the spaces between the cranial meninges also fills the spaces between the spinal meninges. But there are a few notable differences between the cranial and spinal meninges. For one, the spinal dura mater consists of only *one* layer rather than two like the cranial dura. This single dural layer does not attach to the vertebral column, which creates a space between the spinal dura and the interior vertebral foramen called the **epidural space** (ep-ih-DOO-rul). There is no epidural space around the brain because the periosteal layer of the cranial dura is fused to the skull.

Another difference between the cranial and spinal meninges is the presence of small extensions of pia mater in the spinal cord called **denticulate ligaments** (den-TIK-yoo-lit). These tiny ligaments secure the spinal cord to the vertebral column. In addition, the pia mater continues long after the spinal cord ends and forms a long, fibrous extension called the **filum terminale** (FY-lum ter-mee-NAL-ay) that eventually attaches to the coccyx.

Internally, the spinal cord consists of a butterfly-shaped core of gray matter that surrounds the CSF-filled **central canal** (Figure 12.4). The gray matter is divided into regions, or **horns.** Anteriorly are the **anterior horns,** which contain the cell bodies of motor neurons. The axons of the neurons of the anterior horn exit the spinal cord and form the **anterior root,** which eventually becomes part of a spinal nerve. On the posterior side we find the **posterior horn.** Here we find cell bodies of sensory neurons that receive input from sensory neurons in the PNS. The axons of neurons that synapse on the cell bodies of the posterior horn enter the spinal cord via the **posterior root.** The posterior root's cell bodies are located just lateral to the spinal cord in a swollen knob called the **posterior root ganglion.** In the thoracic and lumbar regions of the spinal cord are the **lateral horns,** which contain the cell bodies of autonomic neurons.

As you can see in Figure 12.4, it is possible to tell the anterior and posterior spinal cord apart by looking at the shapes of the anterior and posterior horns. The anterior horns are broad and flat on the ends, whereas the posterior horns are more tapered, and they extend farther out toward the edge.

Surrounding the spinal gray matter is the spinal white matter, which can be divided into three **funiculi** (fun-IK-yoo-lye; also known as *columns*): the **anterior, posterior,** and **lateral funiculi.** Each funiculus contains myelinated axons grouped into bundles called **tracts.** Tracts contain axons that have the same beginning and end points and the same general function. **Ascending tracts** carry sensory information from sensory neurons to the brain, and **descending tracts** carry motor information from the brain to motor neurons.

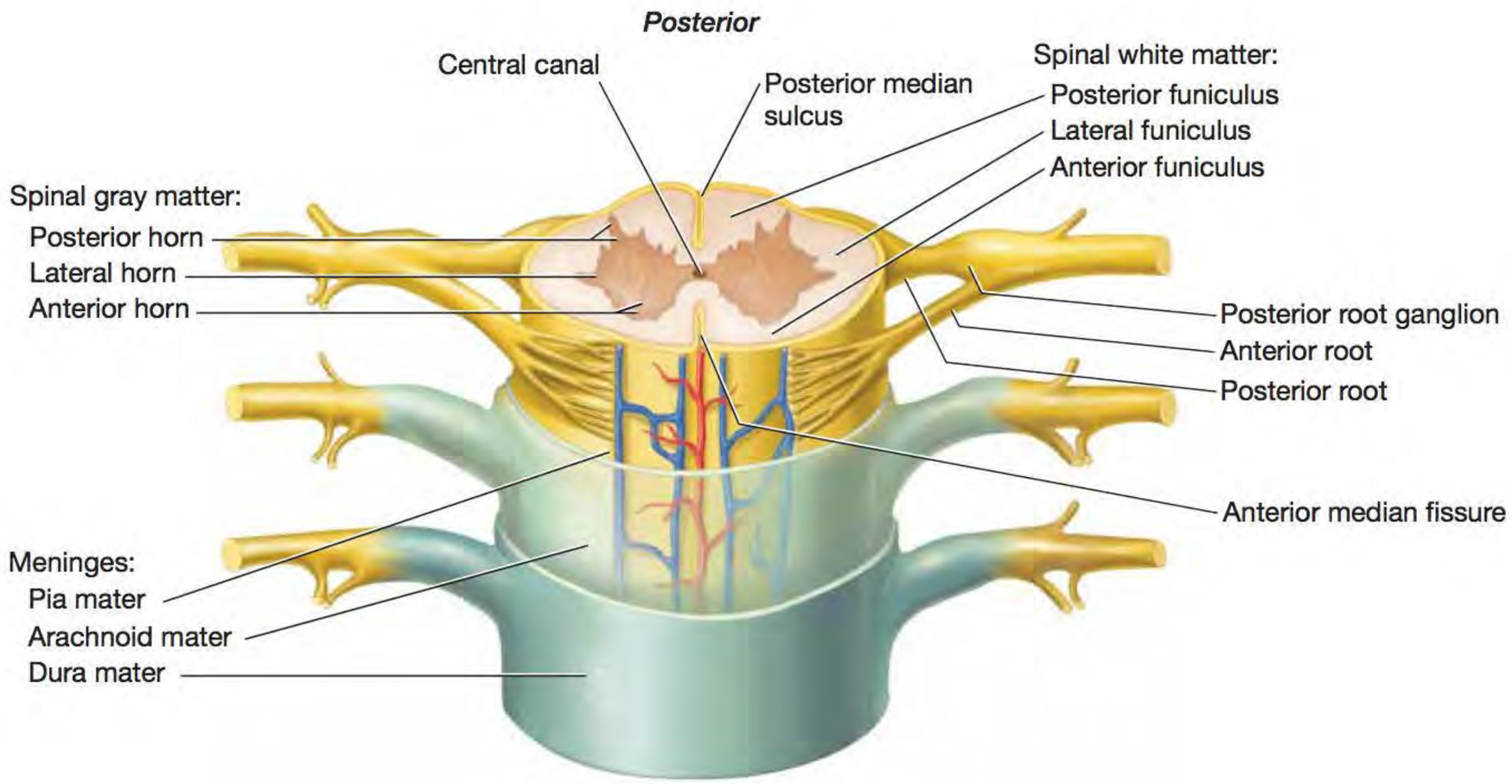


FIGURE **12.4** Transverse section of the spinal cord.

Procedure 1 Model Inventory for the Spinal Cord

Identify the following structures of the spinal cord on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 12.2. When you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 311).

1. Conus medullaris
2. Cauda equina
3. Anterior median fissure
4. Posterior median sulcus
5. Cervical enlargement
6. Lumbar enlargement
7. Meninges
   a. Dura mater
      (1) Epidural space
   b. Arachnoid mater
   c. Pia mater
      (1) Denticulate ligaments
      (2) Filum terminale
8. Central canal
9. Spinal gray matter
   a. Anterior horn
   b. Posterior horn
   c. Lateral horn
10. Spinal nerve roots
    b. Anterior root
    a. Posterior root
       (1) Posterior root ganglion
11. Spinal white matter
    a. Anterior funiculus
    b. Lateral funiculus
    c. Posterior funiculus

TABLE **12.2** Model Inventory for the Spinal Cord

Model	Structures Identified

12

Procedure 2 Time to Draw

In the space below, draw, color, and label one of the transverse sections of the spinal cord models that you examined. In addition, write the function of each structure that you label.

Exercise 12-2

Spinal Nerves and Reflexes

MATERIALS

- ❑ Model of the spinal nerves
- ❑ Reflex hammer

Each of the 31 pairs of **spinal nerves** forms from the fusion of the anterior and posterior roots of the spinal cord. Recall that the anterior roots carry motor fibers emerging from the spinal cord, and the posterior roots carry sensory fibers to the spinal cord. Each spinal nerve carries both motor and sensory fibers, so all spinal nerves are mixed nerves.

Shortly after the anterior and posterior roots fuse to form the spinal nerve, it splits into three branches: a **posterior ramus**, an anterior **ramus**, and a small **meningeal branch**. The **posterior rami** serve the skin, joints, and musculature of the posterior trunk. The **meningeal branches** reenter the vertebral canal to innervate spinal structures. The larger **anterior rami** travel anteriorly to supply the muscles of the upper and lower limbs, the anterior thorax and abdomen, and part of the back. The distribution of the anterior rami is illustrated in Figure 12.5.

The anterior rami of the thoracic spinal nerves travel anteriorly as 11 separate pairs of **intercostal nerves** that innervate the intercostal muscles, the abdominal muscles, and the skin of the chest and abdomen. The anterior rami of the cervical, lumbar, and sacral nerves combine to form four large **plexuses**, or networks, of nerves: the **cervical, brachial, lumbar,** and **sacral plexuses**. The major nerves of the cervical, brachial, thoracic, lumbar, and sacral plexuses are as follows:

1. **Cervical plexuses.** The **cervical plexuses** consist of the anterior rami of C1–C4 with small contributions from C5. The branches of each cervical plexus serve the skin of the head and the neck and certain neck muscles. The major branch is the **phrenic nerve** (FREN-ik; C3–C5), which serves the diaphragm.
2. **Brachial plexuses.** The complicated-looking **brachial plexuses** consist of the anterior rami of C5–T1 (Figure 12.6). The first

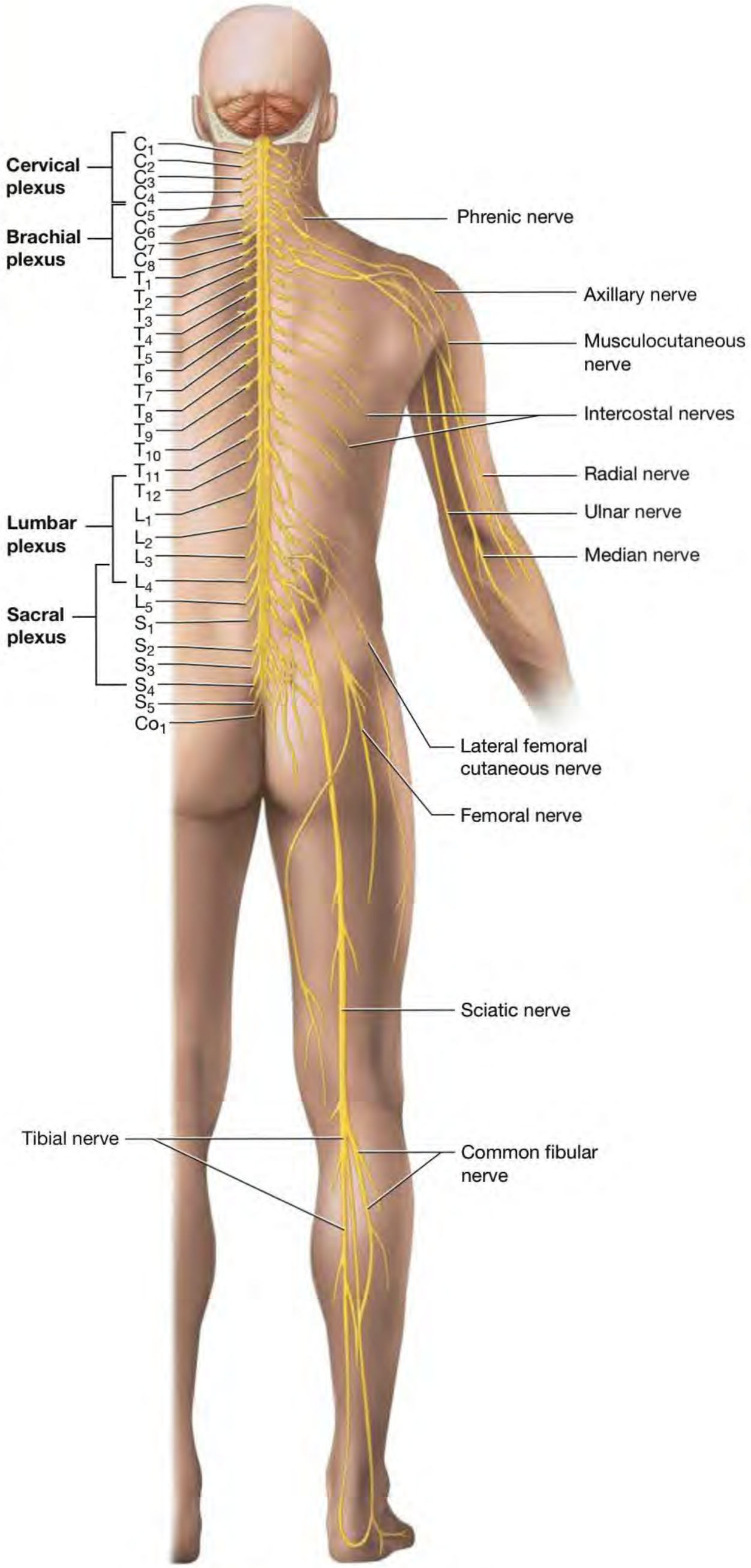


FIGURE **12.5** Nerve plexuses and anterior rami of the spinal nerves.

structures formed in each brachial plexus are its large **trunks.** Typically, C5 and C6 unite to form the *superior trunk*, C7 forms the *middle trunk*, and C8 and T1 unite to form the *inferior trunk*. Each trunk splits into an anterior division and a posterior division that become the plexus's **cords.** The anterior division of the inferior trunk forms the *medial cord*, which descends in the medial arm. The anterior divisions of the superior and middle trunks unite to form the *lateral cord*, which descends in the lateral arm. The posterior divisions of each trunk unite to form the *posterior cord*, which is located in the posterior arm. Several nerves originate from the brachial plexuses' cords and trunks, including the following:

a. **Axillary nerve.** The **axillary nerve** is a branch of the posterior cord and serves structures near the axilla, including the deltoid and teres minor muscles and the skin around this region.

b. **Musculocutaneous nerve.** The **musculocutaneous nerve** (musk-yoo-loh-kyoo-TAY-nee-us) is the distal continuation of the lateral cord. It is located in the lateral arm and serves the anterior arm muscles (such as the biceps brachii) and the skin of the lateral forearm.

c. **Radial nerve.** The **radial nerve** is the distal continuation of the posterior cord and is located in the posterior arm. It serves the posterior arm muscles and the forearm extensors as well as the skin in the lateral hand.

d. **Ulnar nerve,** which you likely know as the "funny bone nerve," is the distal continuation of the medial cord. It begins posteriorly but then crosses over to the anterior side of the arm as it curves around the medial epicondyle of the humerus. At this point the nerve is superficial and is easily injured when you smack your elbow on something. The ulnar nerve supplies certain forearm flexors, most of the intrinsic muscles of the hand, and the skin over the medial hand.

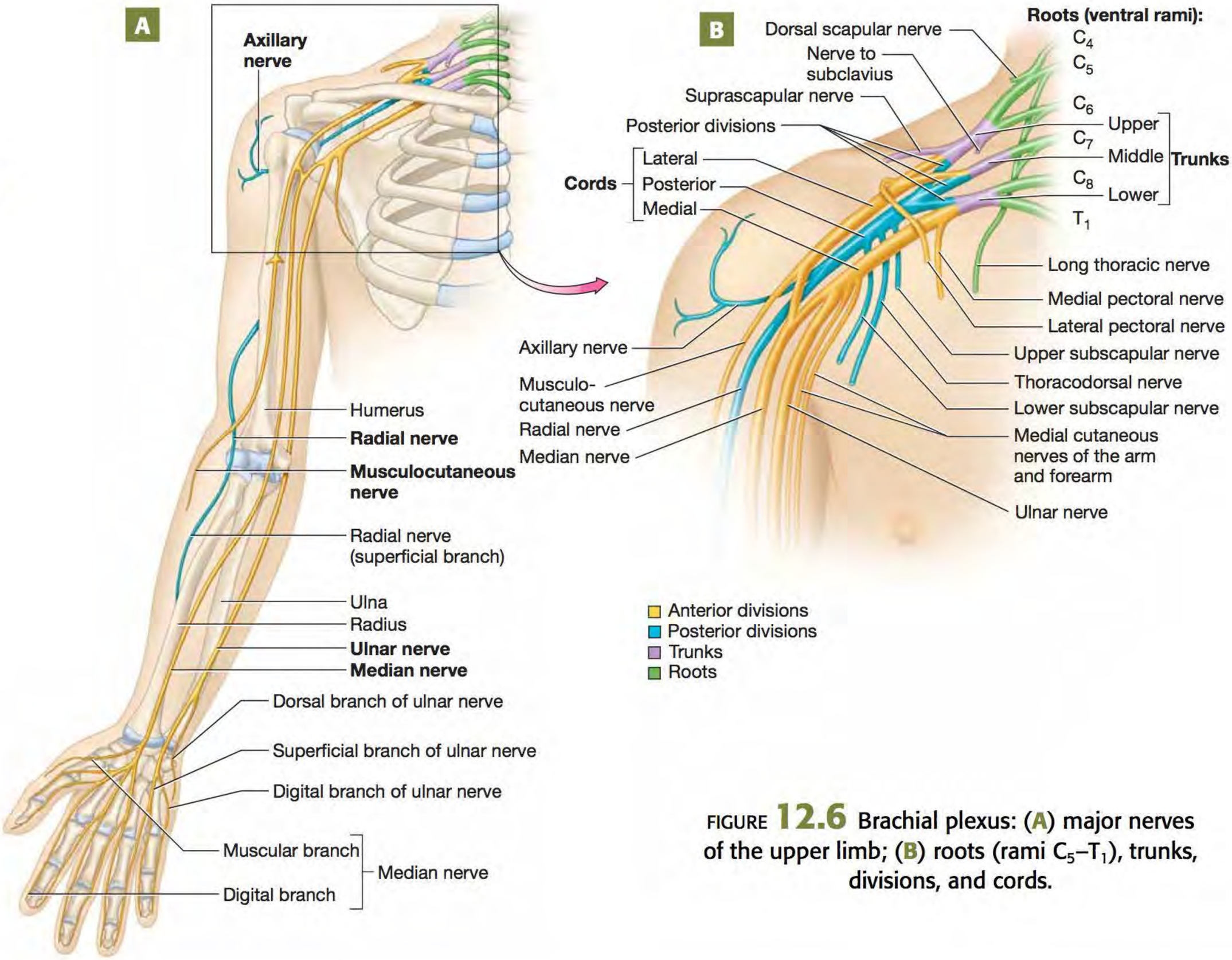


FIGURE **12.6** Brachial plexus: (**A**) major nerves of the upper limb; (**B**) roots (rami C_5–T_1), trunks, divisions, and cords.

e. **Median nerve.** The **median nerve** results from the fusion of portions of the medial and lateral cords. It is named as such because it travels approximately down the middle of the arm and forearm. It supplies most of the forearm flexors, certain intrinsic hand muscles, and the skin over the anterior and lateral hand. As the median nerve enters the wrist, it travels under a band of connective tissue called the *flexor retinaculum*. Occasionally the median nerve becomes trapped and inflamed under the flexor retinaculum, which results in **carpal tunnel syndrome.**

3. **Lumbar plexuses.** Each **lumbar plexus** consists of the anterior rami of L1–L4 with a small contribution from T12 (Figure 12.7A). The largest nerve of this plexus is the **femoral nerve,** which provides motor innervation to most of the anterior thigh muscles and sensory innervation to the skin of the anterior and medial thigh, the leg, and the foot. A smaller branch is the **lateral femoral cutaneous nerve,** which provides mainly sensory innervation to the anterolateral thigh.

4. **Sacral plexuses.** Each **sacral plexus** forms from anterior rami of L4–S4 (Figure 12.7B). Its largest nerve, and indeed the largest nerve in the body, is the **sciatic nerve** (sy-AEH-tik). The sciatic nerve travels in the posterior thigh, where it splits into two branches: the **tibial nerve** and the **common fibular nerve.** The tibial nerve provides motor innervation to the posterior muscles of the thigh, posterior leg, and foot, and sensory innervation to the posterior leg and foot. The common fibular nerve provides motor and sensory innervation to the anterolateral leg and the foot. A smaller branch of the sacral plexus is the **pudendal nerve** (poo-DEN-dal), which innervates the muscles of the pelvic floor and anogenital sphincters.

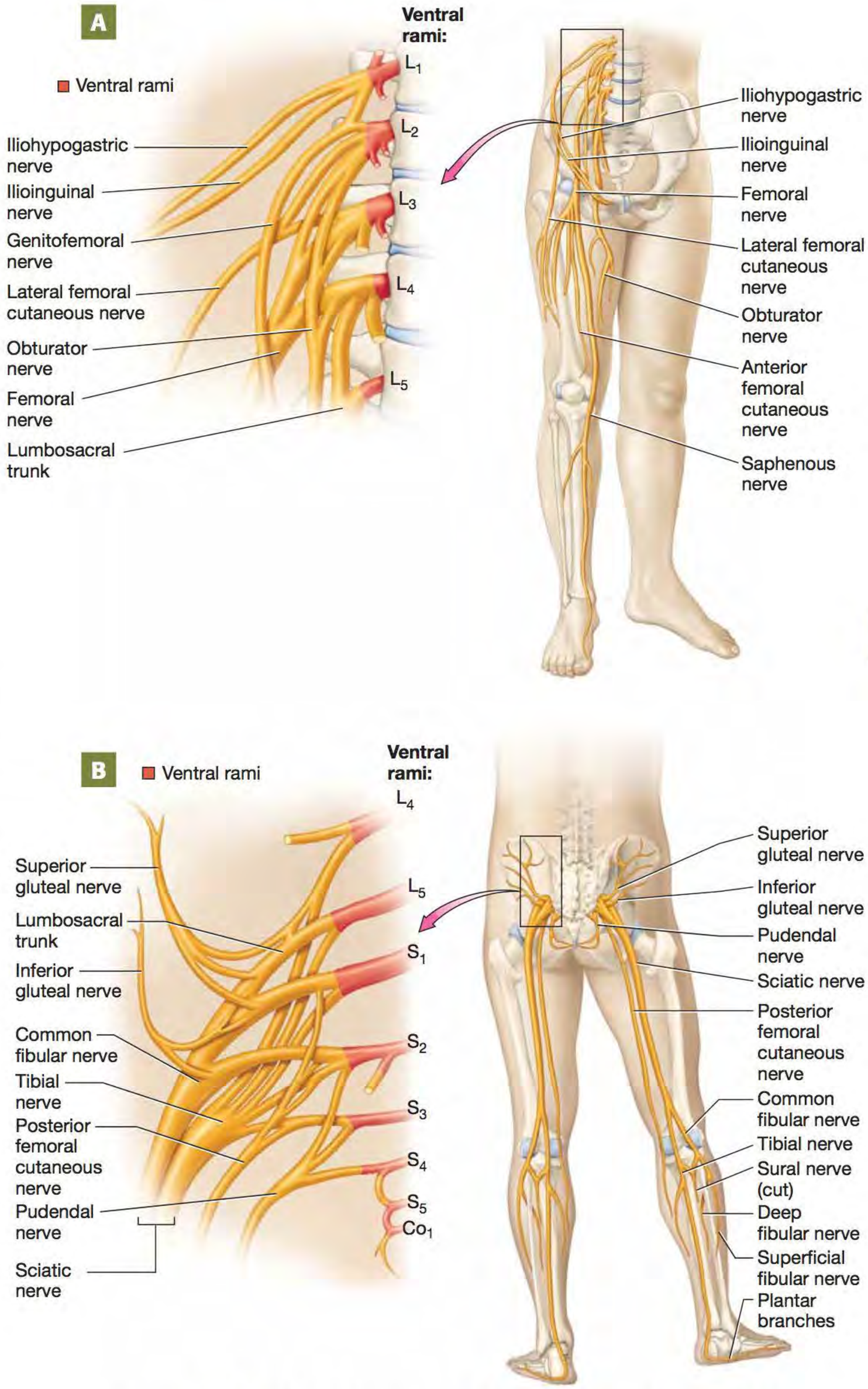


FIGURE **12.7** Nerve plexuses: (A) lumbar plexus; (B) sacral plexus.

Procedure 1 Model Inventory for Nerves and Nerve Plexuses

Identify the following nerves and nerve plexuses on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 12.3. Note that you also used this model inventory for the cranial nerves in Exercise 12-2. When you have completed the activity, answer Check Your Understanding questions 4 and 5 (p. 312).

1. Cervical plexus
   a. Phrenic nerve
2. Brachial plexus
   a. Axillary nerve
   b. Radial nerve
   c. Musculocutaneous nerve
   d. Ulnar nerve
   e. Median nerve
3. Thoracic (intercostal) nerves
4. Lumbar plexus
   a. Femoral nerve
   b. Lateral femoral cutaneous nerve
5. Sacral plexus
   a. Sciatic nerve
      (1) Tibial nerve
      (2) Common fibular nerve
   b. Pudendal nerve

TABLE **12.3** Model Inventory for Cranial Nerve and Spinal Nerve Anatomy

Model	Structures Identified

Procedure 2 Testing Spinal Reflexes

A **reflex** is an involuntary, predictable motor response to a stimulus. The pathway through which information travels, shown below and in Figure 12.8, is called a **reflex arc:**

sensory receptor detects the stimulus → sensory neurons bring the stimulus to the CNS → the CNS processes and integrates the information → the CNS sends its output via motor neurons to an effector → the effector performs the triggered action

The human body has many different reflex arcs, one of the simplest of which is the **stretch reflex**. Stretch reflexes are important in maintaining posture and equilibrium and are initiated when a muscle is stretched. The stretch is detected by **muscle spindles**, specialized stretch receptors in the muscles, and this information is sent via sensory neurons to the CNS. The CNS then sends impulses down the motor neurons to the muscle that trigger a muscle contraction to counter the stretch.

You can demonstrate the stretch reflex easily: Sit down with your knees bent and relaxed, and palpate (feel) the musculature of your posterior thigh. How do the muscles feel (taut or soft)? Now stand up, and bend over to touch your toes. Palpate the muscles of your posterior thigh again. How do they feel? The reason they feel different in this position is that you stretched the hamstring muscles when you bent over to touch your toes. This triggered a stretch reflex that resulted in shortening (or tightening) of those muscles.

Technically, this reflex can be carried out without the help of the cerebral cortex and can be mediated solely by the spinal cord. We will see shortly, however, that the cortex is involved in even the simplest example of a stretch reflex—the patellar tendon (knee-jerk) reflex, shown in Figure 12.9. When you have completed the following activity, answer Check Your Understanding question 6 (p. 312).

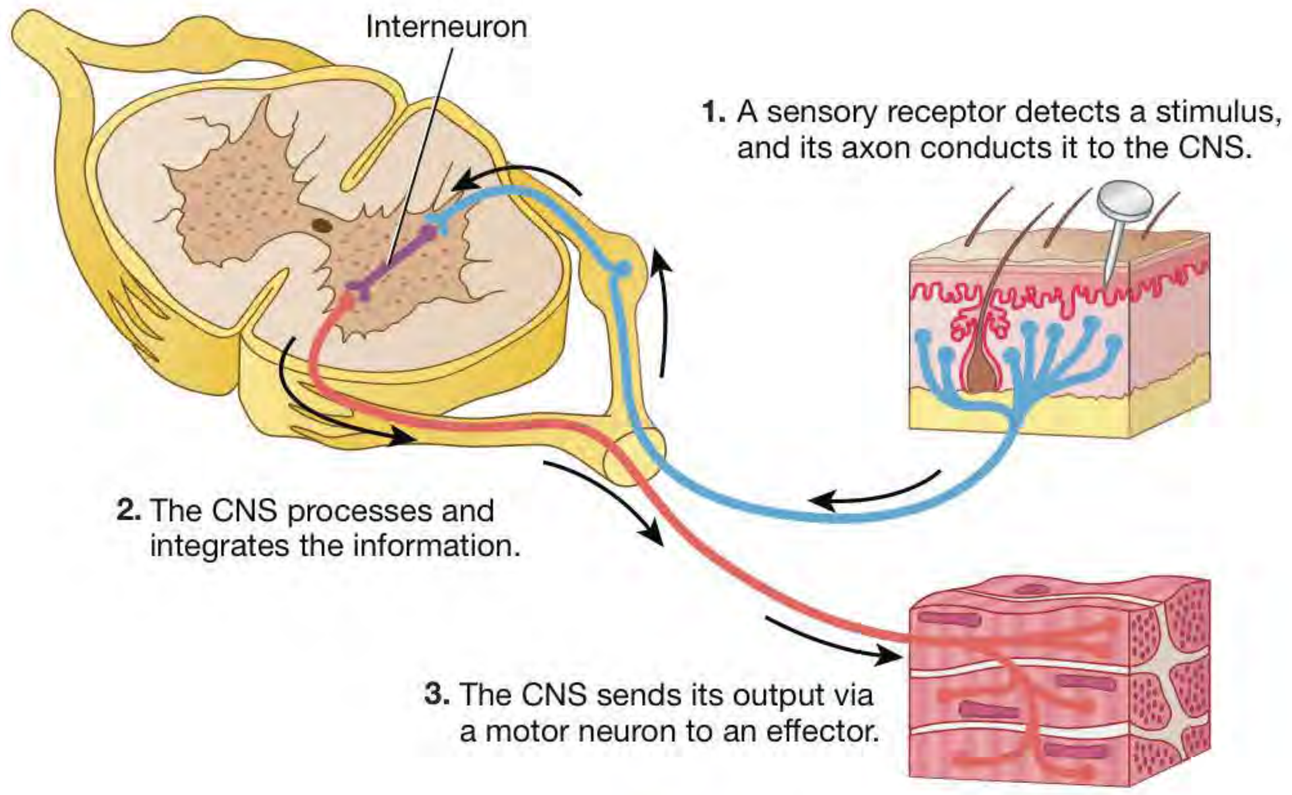


FIGURE **12.8** Reflex arc.

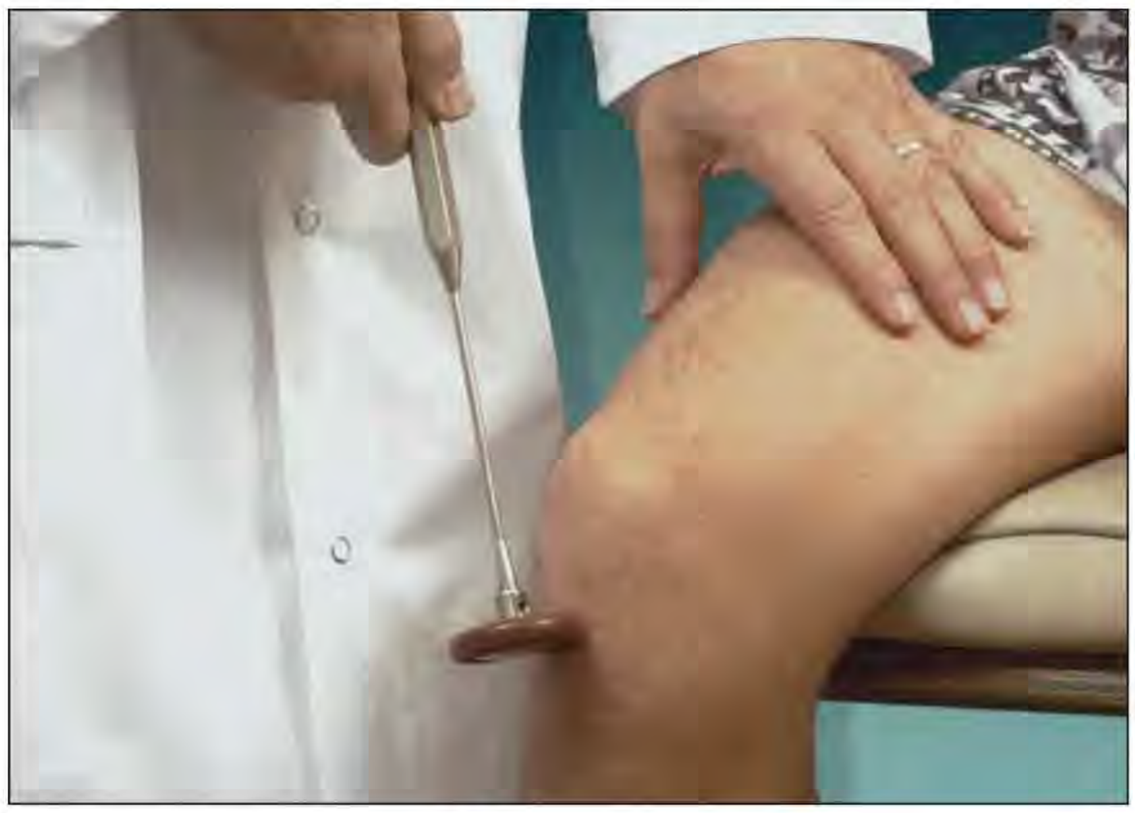


FIGURE **12.9** Patellar reflex.

1. Have your lab partner sit in a chair with their legs dangling freely.
2. Palpate your partner's patellar tendon between the tibial tuberosity and the patella.
3. Tap this area with the flat end of a reflex hammer (sometimes a few taps are necessary to hit the right spot). What is the result?

4 Now give your partner a difficult math problem to work (long division with decimals usually does the trick). As your partner works the problem, tap the tendon again. Is this response different from the original response? If yes, how, and why?

12

Name _____

Section _____ Date _____

UNIT 12 REVIEW

Check Your Recall

1 Label the following parts of the spinal cord in Figure 12.10.

- ❑ Anterior funiculus
- ❑ Anterior horn
- ❑ Anterior median fissure
- ❑ Lateral funiculus
- ❑ Lateral horn
- ❑ Posterior funiculus
- ❑ Posterior horn
- ❑ Posterior median sulcus

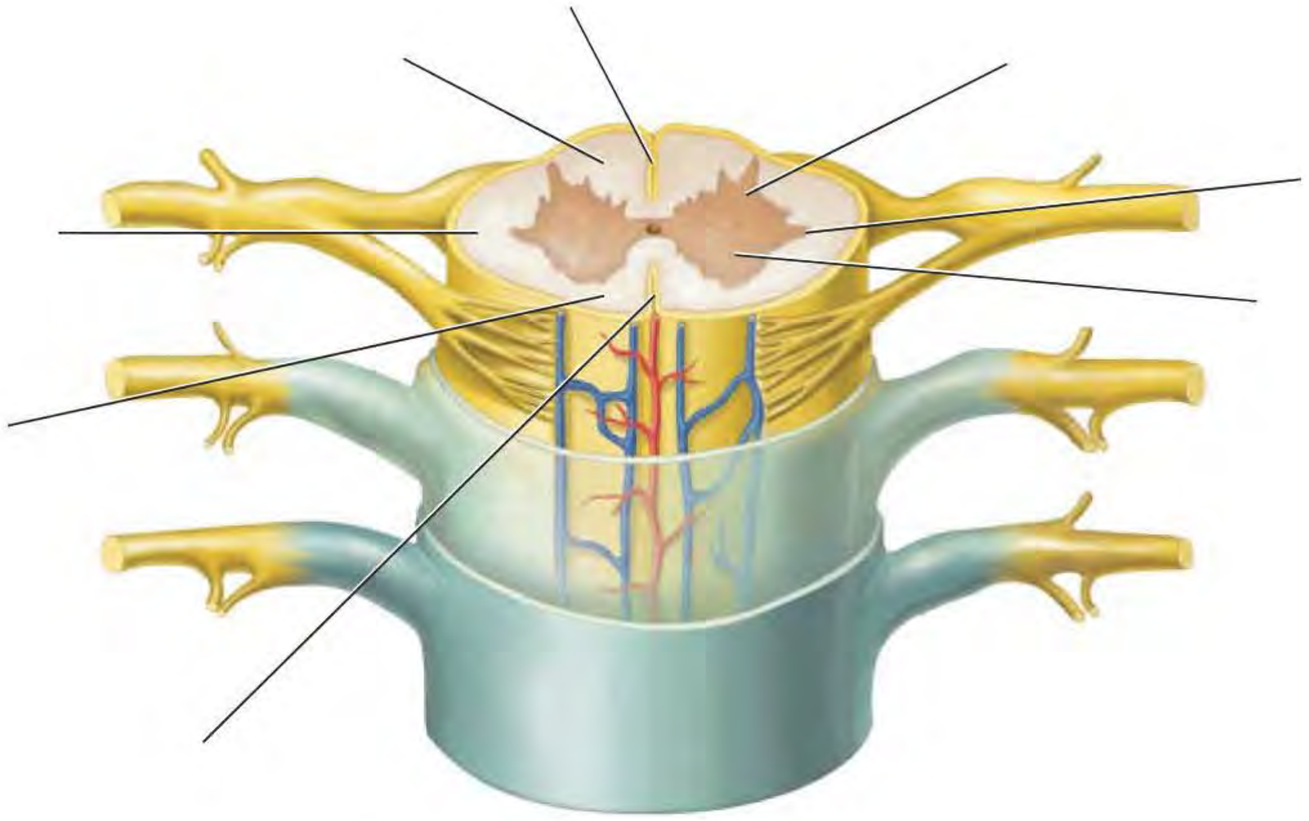


FIGURE **12.10** Spinal cord, transverse section.

2 Label the following parts of the spinal cord in Figure 12.11.

- ❑ Dura mater
- ❑ Arachnoid mater
- ❑ Epidural space
- ❑ Subdural space
- ❑ Subarachnoid space
- ❑ Central canal
- ❑ Pia mater

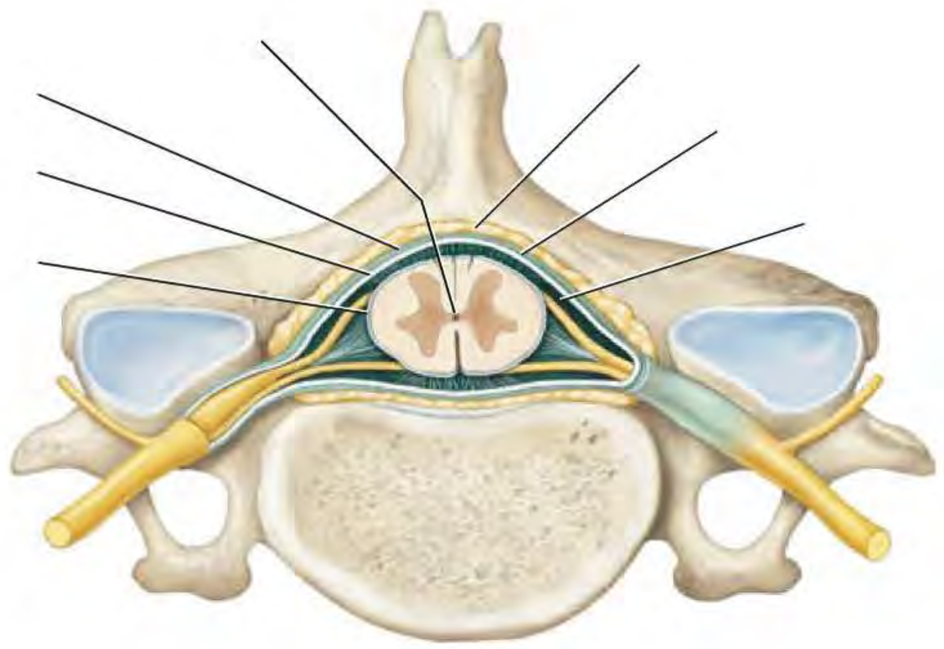


FIGURE **12.11** Transverse section of the spinal cord in the vertebral column.

3 *Fill in the blanks:* The spinal cord extends from the _____ of the occipital bone to the _____ vertebra. It terminates as the _____ and gives off a bundle of nerve roots called the _____.

4 Which of the following spaces is found around the spinal cord but *not* around the brain?

a. Epidural space
b. Subdural space
c. Subarachnoid space
d. Suprarachnoid space

5 The _____ of the spinal cord contains the cell bodies of motor neurons, whereas the _____ of the spinal cord contains the cell bodies of neurons that receive information from sensory neurons.

a. lateral horn; anterior horn
b. lateral horn; posterior horn
c. anterior horn; lateral horn
d. anterior horn; posterior horn

6 What are the three branches given off by a spinal nerve, and where do they travel?

_____

_____

_____

7 *Matching:* Match each spinal nerve with the main structures it supplies.

_____ Phrenic nerve
_____ Median nerve
_____ Tibial nerve
_____ Radial nerve
_____ Femoral nerve
_____ Ulnar nerve
_____ Common fibular nerve
_____ Musculocutaneous nerve

A. Anterior and lateral leg muscles and skin
B. Posterior thigh and leg muscles, foot
C. Diaphragm
D. Some forearm flexors, most intrinsic hand muscles, skin on medial hand
E. Posterior arm muscles, forearm extensors, skin on lateral hand
F. Anterior arm muscles, skin on lateral forearm
G. Most forearm flexors, skin on anterior and lateral hand
H. Anterior thigh muscles, skin on anterior and medial thigh and leg

8 Number the events of a reflex arc from 1 (first event) through 5 (last event).

_____ CNS sends output via motor neurons to an effector.
_____ Sensory neurons bring the stimulus to the CNS.
_____ The muscle contracts.
_____ CNS processes and integrates the information.
_____ Sensory receptor detects the stimulus.

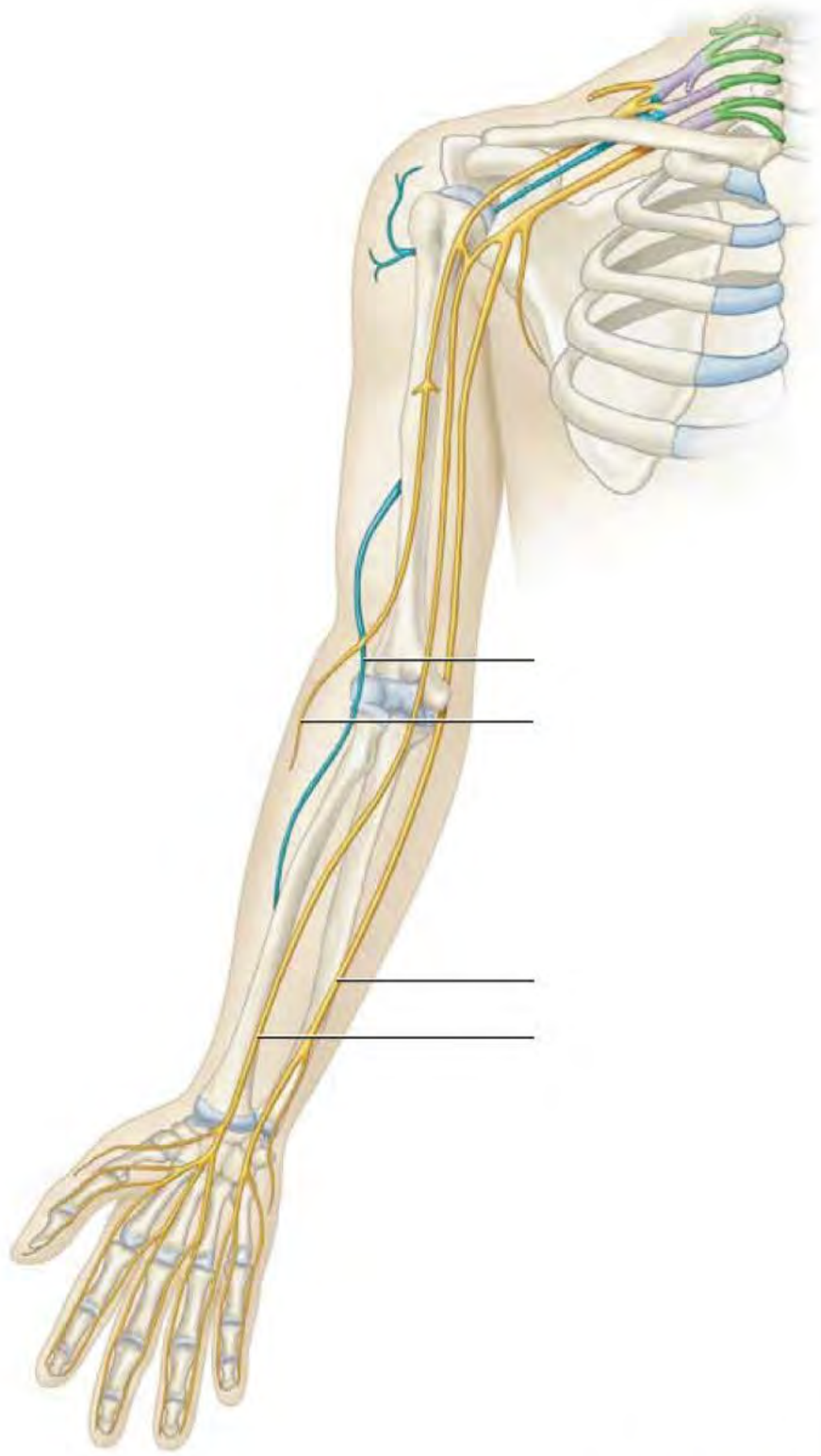
Name _____

Section _____ Date _____

UNIT 12

9 Label the following nerves and plexuses on Figure 12.12.

- ❑ Brachial plexus
- ❑ Cervical plexus
- ❑ Femoral nerve
- ❑ Lumbar plexus
- ❑ Median nerve
- ❑ Musculocutaneous nerve
- ❑ Radial nerve
- ❑ Sacral plexus
- ❑ Sciatic nerve
- ❑ Ulnar nerve



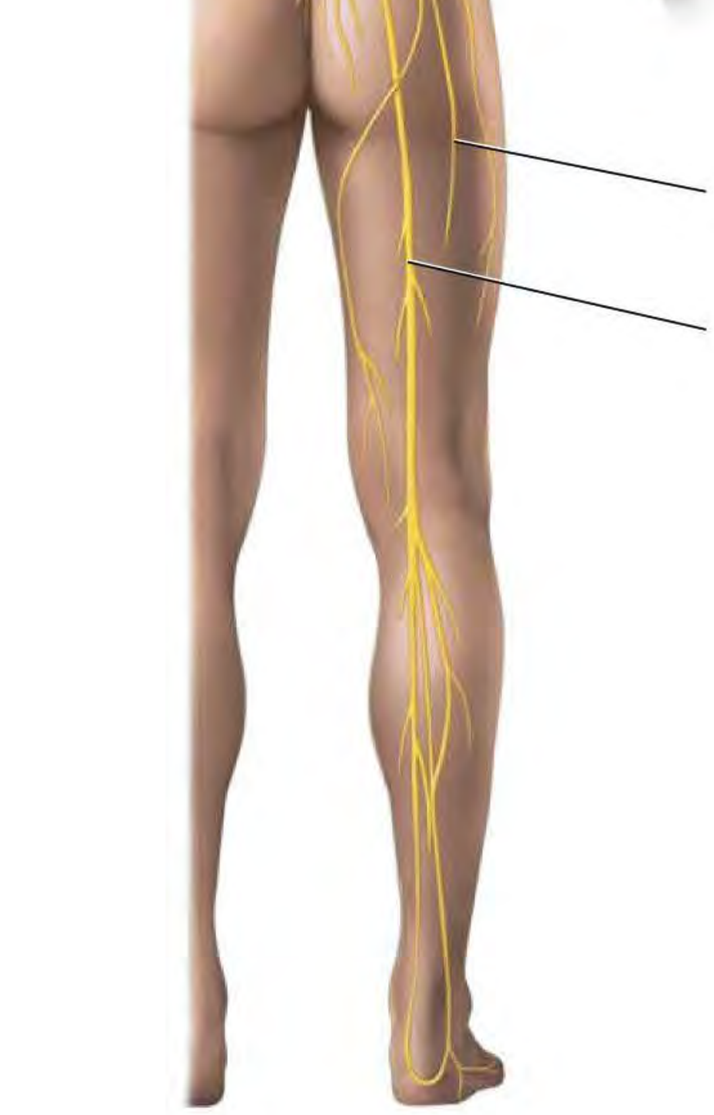


FIGURE **12.12** Nerve plexuses and anterior rami of the spinal nerves.

10 **The receptor that detects the stretch in a stretch reflex is called a(an)**

a. mitotic spindle.
b. muscle spindle.
c. capsular receptor.
d. efferent neuron.

12

Name _____

Section _____ Date _____

Check Your Understanding

Critical Thinking and Application Questions

1 A common way to deliver anesthesia for surgery and childbirth is to inject the anesthetic agent into the epidural space (*epidural anesthesia*). A possible complication of this procedure is a tear in the dura mater that causes CSF to leak out of the central nervous system. Why would a loss of cerebrospinal fluid be problematic? What symptoms do you predict with this condition? (*Hint*: Think about the function of cerebrospinal fluid.)

2 During a procedure called a *lumbar puncture*, CSF surrounding the meninges is withdrawn with a needle. This procedure generally is performed between L3 and L5. Why do you think the fluid is withdrawn here rather than from higher up in the vertebral column (e.g., the cervical vertebrae)? Often, the sampled CSF is tested for bacteria or viruses if a brain infection is suspected. Why would CSF sampled from the spinal cord give you information about the condition of the brain?

3 An individual sustains injuries to only the descending tracts of the spinal cord. Will this person experience deficits in movement, sensation, both, or neither? Explain.

4 **Damage to which spinal nerve(s) might produce the following physical findings?**

a Inability to flex the forearm (with the biceps brachii muscle)

b Inability to breathe

c Inability to flex the hip and extend the knee with the anterior thigh muscles

d Inability to extend the hip and flex the knee with the posterior thigh muscles

e Inability to move the hand or feel the skin over the medial hand

12

5 **Marta is an editor and she spends a great deal of time typing on her computer. She begins to feel numbness and tingling in her anterior and lateral hands and weakness in her forearm flexors. What nerve is likely involved in her problem, and what do you think has happened? Explain her symptoms.**

6 **Sometimes the reflex response is diminished or absent—a phenomenon termed *hyporeflexia*. Do you think hyporeflexia would be caused by disorders of the central nervous system or of the peripheral nervous system? Explain your reasoning.**

General and Special Senses

13

OBJECTIVES

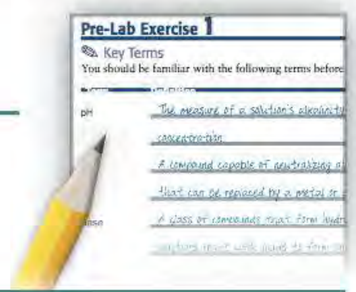
Once you have completed this unit, you should be able to:

1. Identify structures of the eye.
2. Describe the extrinsic eye muscles that move the eyeball.
3. Compare the functions of the rods and cones.
4. Identify structures of the ear.
5. Perform tests of hearing and equilibrium.
6. Identify structures of the olfactory and taste senses.
7. Determine the relative concentration of cutaneous sensory receptors in different regions of the body.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 13-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Structures of the Eye

Conjunctiva _____

Lacrimal gland _____

Sclera _____

Cornea _____

Iris _____

Pupil _____

Lens _____

Ciliary body _____

Choroid _____

Retina _____

Rods _____

Cones _____

Name _____ Section _____ Date _____

Structures of the Ear

Auricle _____

_____

External auditory canal _____

_____

Tympanic membrane _____

_____

Auditory ossicles _____

_____

Pharyngotympanic tube _____

_____

Semicircular canals _____

_____

Cochlea _____

_____

Structures of Taste and Smell

Chemosenses _____

_____

Olfactory epithelium _____

_____

Tongue papillae _____

_____

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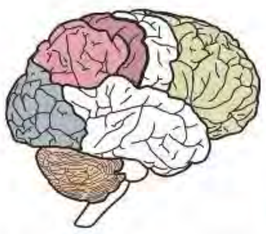


Pre-Lab Exercise 13-2

Anatomy of the Eye

Label and color the structures of the eye in Figures 13.1 and 13.2 with the terms from Exercise 13-1 (p. 319). Use your text and Exercise 13-1 in this unit for reference.

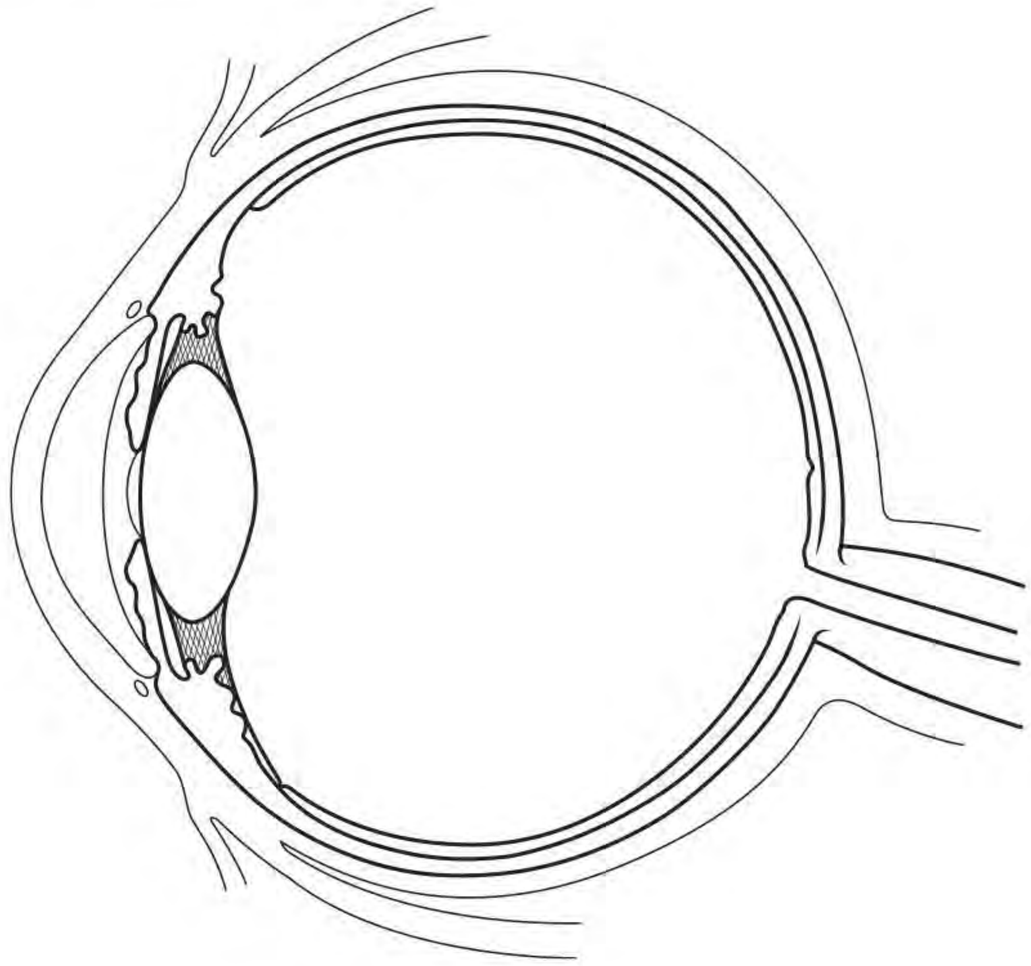


FIGURE **13.1** Eyeball, sagittal section.

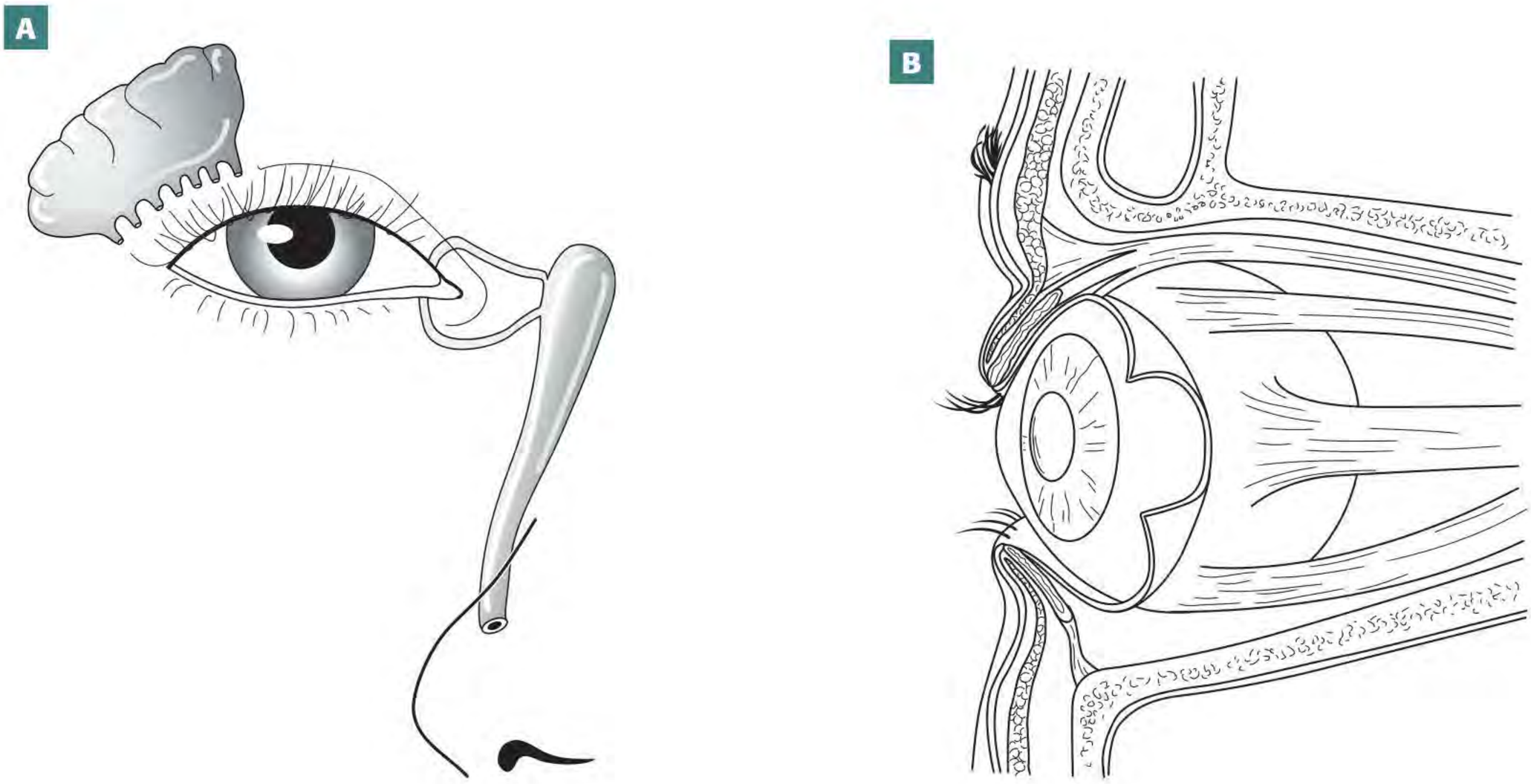
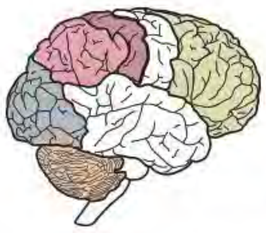


FIGURE **13.2** External and accessory structures of the eye: (**A**) anterior view; (**B**) lateral view.

Name _____ Section _____ Date _____



Pre-Lab Exercise 13-3

Extrinsic Eye Muscles

The six muscles that move the eyeball are called **extrinsic eye muscles**. First, label and color the extrinsic eye muscles illustrated in Figure 13.3. Then, fill in Table 13.1 with the location, action, and cranial nerve innervation for each of the extrinsic eye muscles.

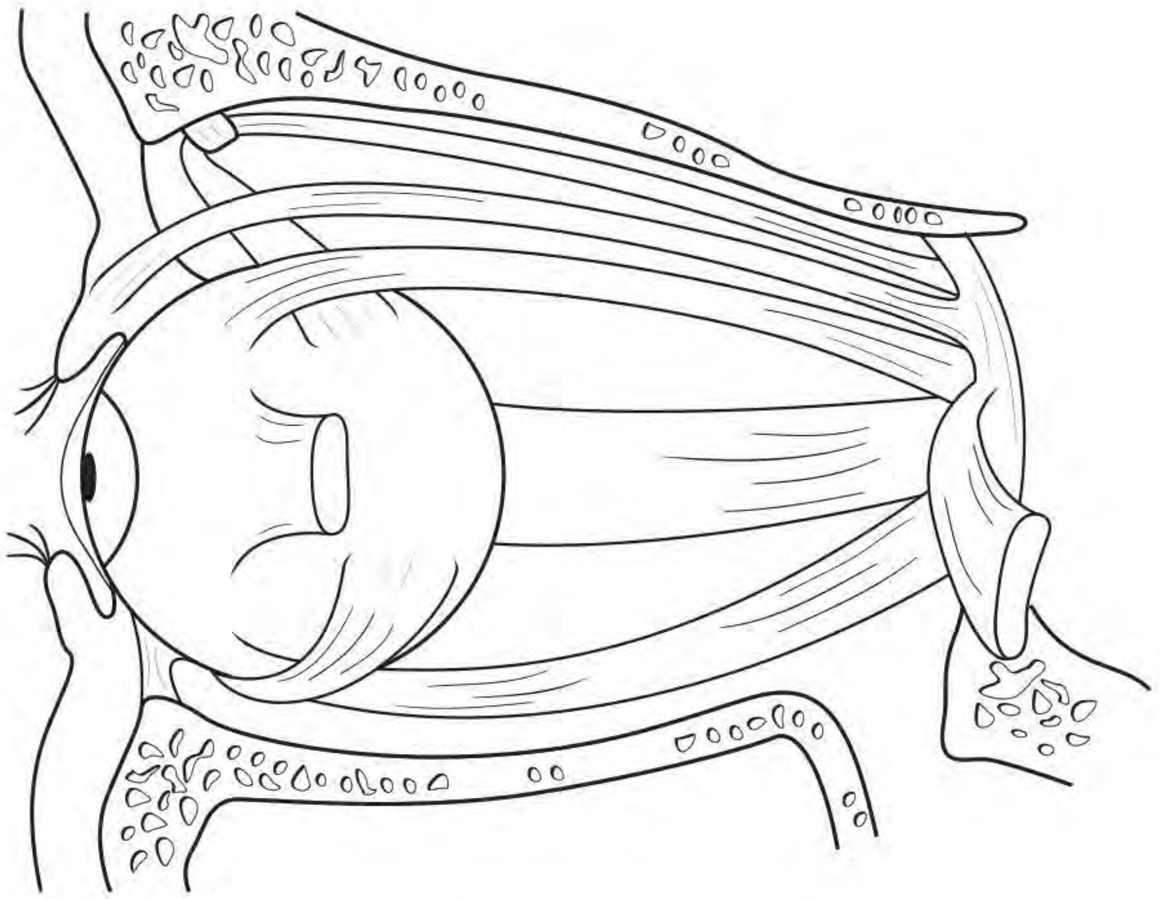
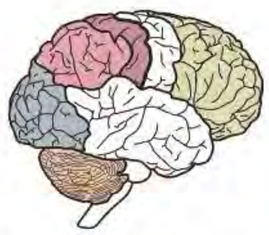


FIGURE **13.3** Extrinsic eye muscles.

13

TABLE **13.1** Extrinsic Eye Muscles

Muscle	Location	Action	Cranial Nerve Innervation
Superior rectus muscle			
Inferior rectus muscle			
Medial rectus muscle			
Lateral rectus muscle			
Superior oblique muscle			
Inferior oblique muscle			



Pre-Lab Exercise 13-4

Anatomy of the Ear

Label and color the structures of the ear in Figure 13.4 with the terms from Exercise 13-2 (p. 327).

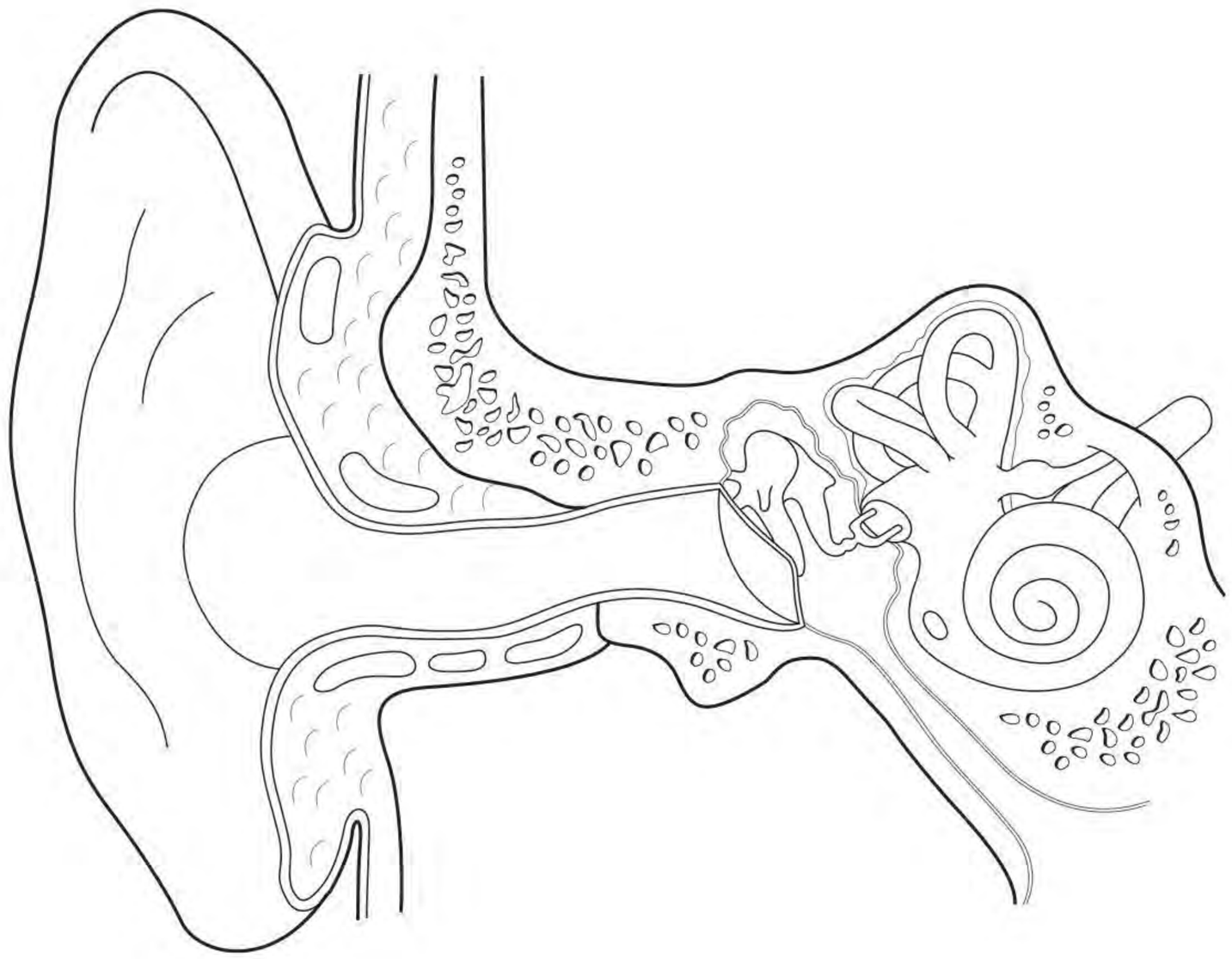


FIGURE 13.4 Ear.

EXERCISES

Sensation is broadly defined as the detection of changes in the internal and external environments. Sensation may be conscious or subconscious, depending on the destination of the sensory information. For example, certain blood vessels have receptors that detect blood pressure. This information is taken to the brainstem, which makes changes as necessary to ensure that blood pressure adjusts to meet the body's needs. This information never makes it to the cerebral cortex, so you are not consciously aware of it. However, information eventually taken to the cerebral cortex for integration and interpretation (e.g., the taste of your food or the level of light in a room) is something of which you are consciously aware. This is called **perception**, and it is the focus of this unit.

The following exercises ask you to examine the anatomy and physiology of the **special senses**: vision, hearing and equilibrium, taste, and smell. You also will examine the **general senses** in this unit, which include the senses of touch, pain, and temperature.

Exercise 13-1

Anatomy of the Eye and Vision

MATERIALS

- ❑ Eye models
- ❑ Preserved eyeballs
- ❑ Dissection equipment
- ❑ Dissection trays
- ❑ Snellen vision chart
- ❑ Dark green or blue paper
- ❑ Ruler

The eye is a complex organ consisting of three components:

1. External structures such as the **eyelids**,
2. Accessory structures such as the **lacrimal gland** and the extrinsic eye muscles, and
3. The **eyeball** (see Figure 13.7).

Many of the external and accessory structures of the eye protect the delicate eyeball.

Anteriorly, the eye is covered by the eyelids, or **palpebrae** (pal-PEE-bray; Figure 13.5A). The eyelids meet medially and laterally at the **medial** and **lateral commissures**, respectively. There are several structures in and around the eyelids that contain sebaceous or mucous glands to lubricate the eyelids and anterior surface of the eyeball. At the medial commissure is a structure called the **lacrimal caruncle** (LAK-rih-mul kar-UN-kul), and within the eyelids are another set of sebaceous glands called **tarsal glands** (Figure 13.5B). Additionally, the internal surface of the eyelids and much of the anterior eyeball are covered with a thin mucous membrane called the **conjunctiva** (kon-junk-TY-vah).

13

One of the most prominent accessory structures of the eye is the **lacrimal apparatus**, which produces and drains tears. The lacrimal apparatus consists of the **lacrimal gland**, located in the superolateral orbit, and the ducts that drain the tears it produces. As you can see in Figure 13.5A, tears drain into small **lacrimal canals** near the medial commissure, which then drain into the **lacrimal sac**, which is found in a depression in the lacrimal bone. From here, tears travel through the **nasolacrimal duct**, and finally empty into the nasal cavity just inferior to the inferior nasal concha (which is why your nose runs when you cry).

The other major accessory structures are the **extrinsic eye muscles**, which move the eyeball. As you learned in Unit 11, there are six extrinsic eye muscles (Figure 13.6):

1. **Lateral rectus**, which moves the eyeball laterally
2. **Medial rectus**, which moves the eyeball medially
3. **Superior rectus**, which moves the eyeball superiorly
4. **Inferior rectus**, which moves the eyeball inferiorly
5. **Superior oblique**, which moves the eyeball inferiorly and laterally
6. **Inferior oblique**, which moves the eyeball superiorly and laterally.

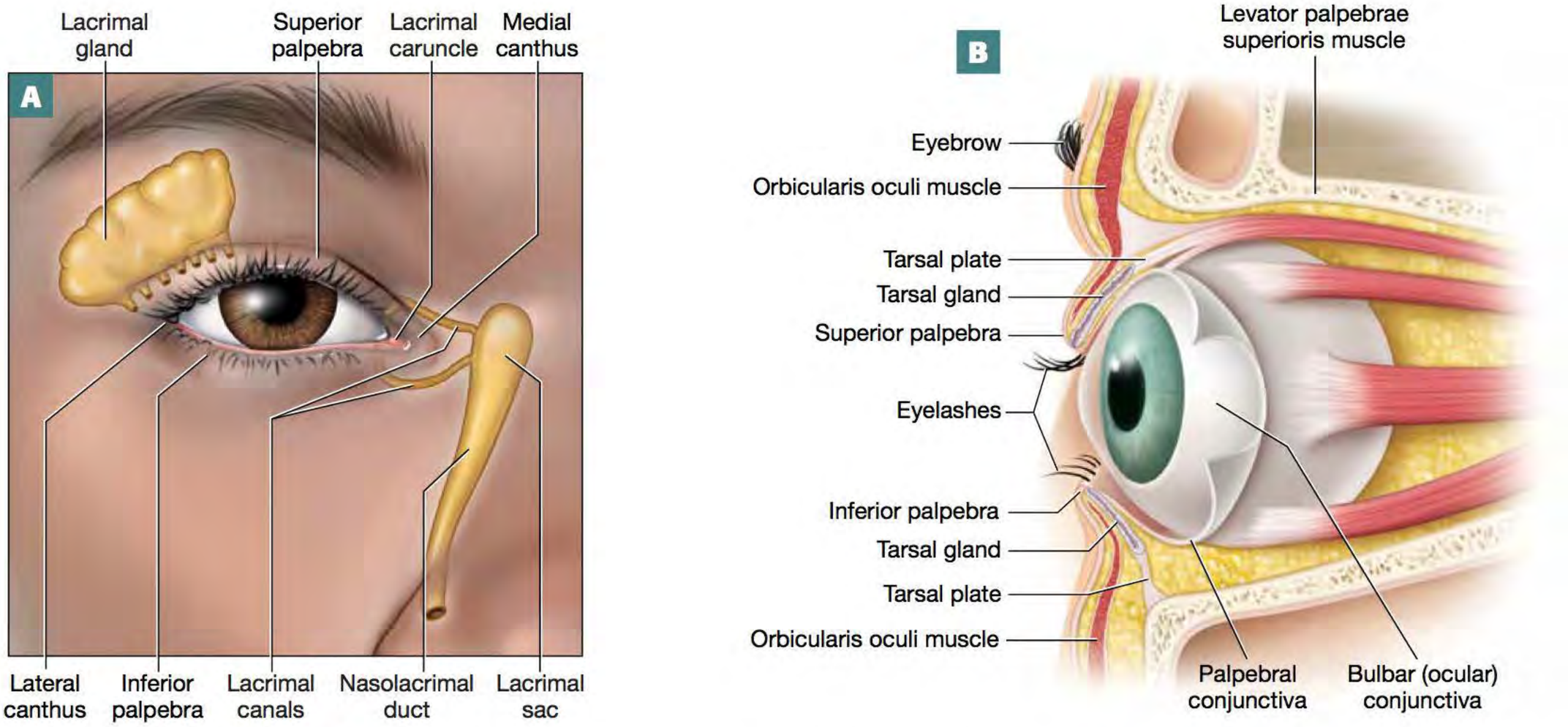


FIGURE **13.5** External and accessory structures of the eye: (**A**) anterior view; (**B**) lateral view.

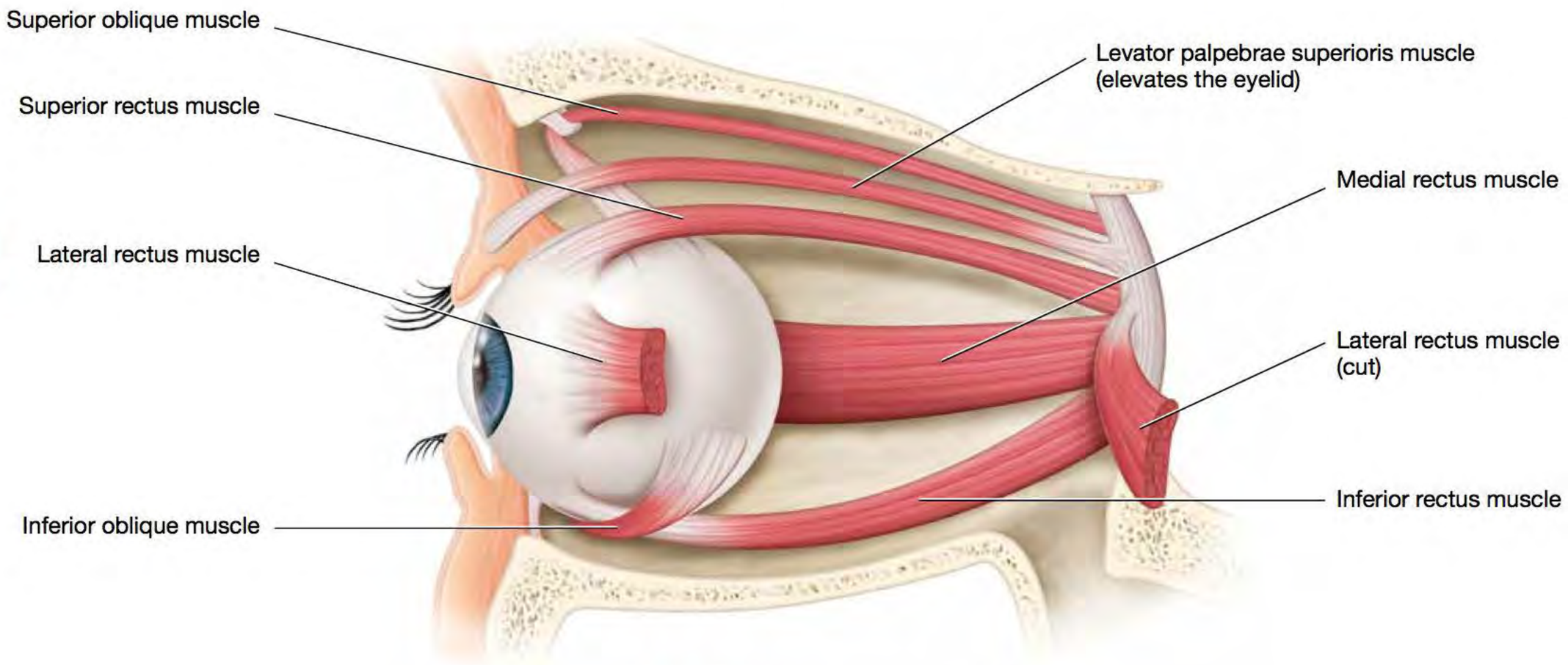


FIGURE **13.6** Extrinsic eye muscles.

The **eyeball** itself is a hollow organ with three distinct tissue layers, or tunics (Figure 13.7):

1. **Fibrous tunic.** This outermost layer of the eyeball is the **fibrous tunic,** which consists mostly of dense irregular collagenous connective tissue. It is avascular (lacks a blood supply) and consists of two parts:
   a. **Sclera.** The **sclera** (SKLEHR-ah) is the white part of the eyeball, and makes up the posterior five-sixths of the fibrous tunic. It is white because of numerous collagen fibers that contribute to its thickness and toughness (in the same way a joint capsule or a ligament is tough and white).
   b. **Cornea.** The clear **cornea** (KOHR-nee-ah) makes up the anterior one-sixth of the fibrous tunic. It is one of the refractory media of the eyeball (it bends light coming into the eye).

2. **Vascular tunic.** Also called the **uvea** (YOO-vee-uh), the **vascular tunic** carries most of the blood supply to the tissues of the eye. It is composed of three main parts:
   a. **Choroid.** The highly vascular **choroid** (KOHR-oyd) makes up the posterior part of the vascular tunic. The choroid is brown in color to prevent light scattering in the eye.
   b. **Ciliary body.** The **ciliary body** (sill-ee-AER-ee) is located at the anterior aspect of the vascular tunic. It is made chiefly of the **ciliary muscle,** smooth muscle fibers that control the shape of the lens. The muscle attaches to the lens via small **suspensory ligaments.**
   c. **Iris.** The pigmented **iris** is the most anterior portion of the vascular tunic. It consists of muscle fibers arranged around an opening called the **pupil.** As the fibers contract, the pupil either constricts or dilates.
3. **Sensory tunic.** The **sensory tunic** consists of the **retina** and the **optic nerve.** The **retina** (RET-in-ah) is a thin, delicate structure that contains **photoreceptors** called **rods** and **cones.** The axons of the neurons of the retina converge to form the **optic nerve,** or cranial nerve II, which brings visual input to the visual cortex of the brain.
   a. **Rods.** The photoreceptors known as **rods** are scattered throughout the retina and are responsible for vision in dim light and for peripheral vision. They can produce vision in black and white only.
   b. **Cones.** The second type of photoreceptors, **cones,** are concentrated at the posterior portion of the retina. They are found in highest numbers in an area called the **macula lutea** (MAK-yoo-lah LOO-tee-ah). At the center of the macula lutea is the **fovea centralis** (FOH-vee-uh sin-TRAL-iss), which contains only cones. Cones are responsible for color and high-acuity (sharp) vision in bright light.

Note that there are no rods or cones at the posteriormost aspect of the eyeball where the optic nerve leaves the eyeball. This location is called the **optic disc.** It is also known as the *blind spot* because its lack of photoreceptors means that this region can produce no images.

Another component of the eyeball is the **lens,** which allows for precise focusing of light on the retina. The lens divides the eyeball into the **anterior** and **posterior cavities.** The anterior cavity is filled with a watery fluid called **aqueous humor,** and the posterior cavity contains a thicker fluid called **vitreous humor** (VIT-ree-us). Both help to refract (bend) light onto the retina. Aqueous humor is produced relatively constantly by the ciliary body and drained by a structure called the

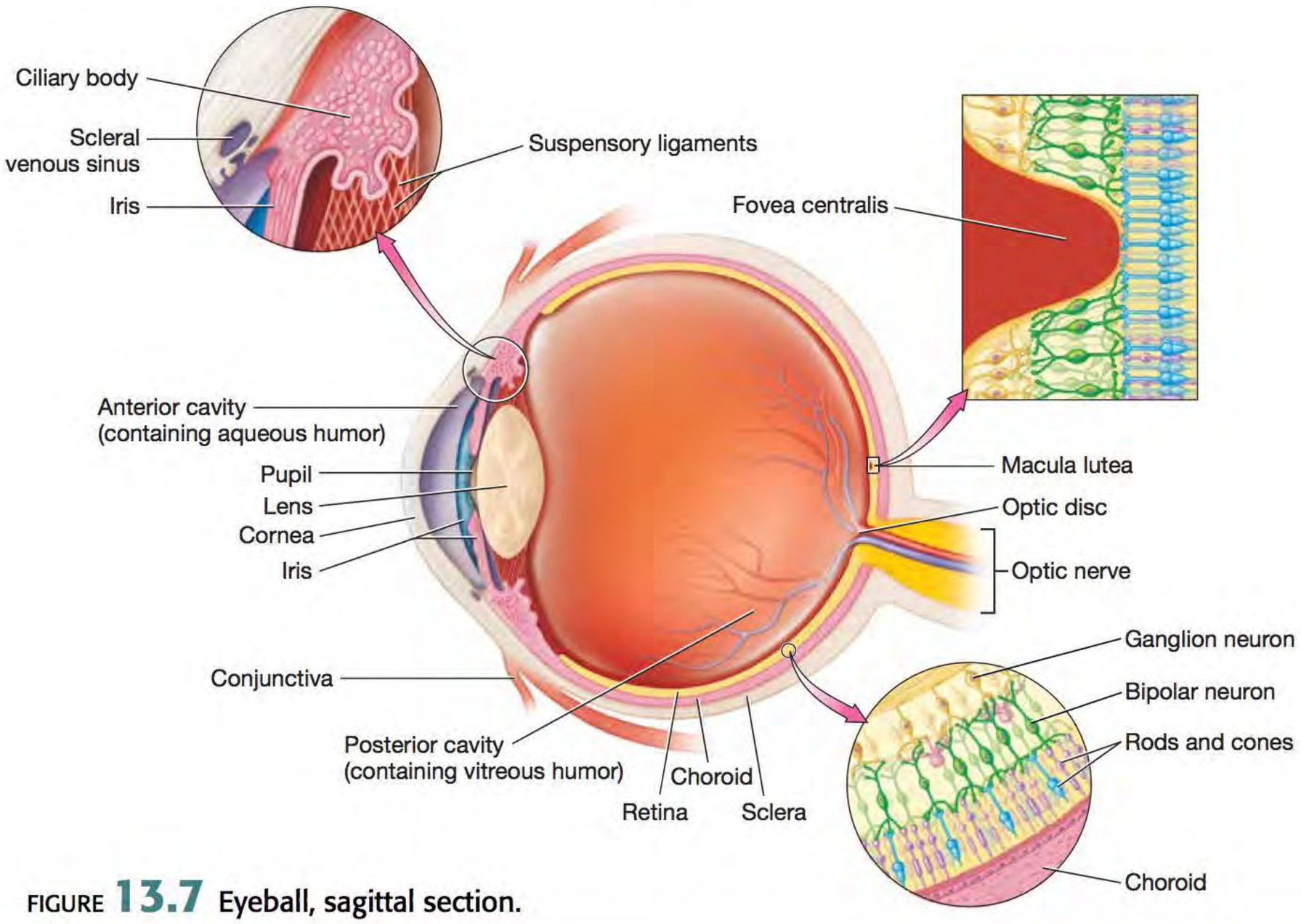


FIGURE **13.7** Eyeball, sagittal section.

scleral venous sinus. However, vitreous humor is present at birth and remains relatively unchanged throughout life. The anterior cavity can be further divided into the **anterior** and **posterior segments** by the iris, with the anterior segment residing anterior to the iris and the posterior segment residing posterior to the iris.

Procedure 1 Model Inventory for the Eye

Identify the following structures of the eye and the eyeball on models and diagrams using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 13.2.

Accessory Structures

1. Palpebrae
2. Medial and lateral commissures
3. Lacrimal caruncle
4. Tarsal glands
5. Conjunctiva
6. Lacrimal apparatus
   a. Lacrimal gland
   b. Lacrimal canals
   c. Lacrimal sac
   d. Nasolacrimal duct
7. Extrinsic eye muscles
   a. Superior oblique
   b. Inferior oblique
   c. Superior rectus
   d. Inferior rectus
   e. Medial rectus
   f. Lateral rectus

Eyeball

1. Fibrous tunic
   a. Sclera
   b. Cornea
2. Vascular tunic (uvea)
   a. Choroid
   b. Ciliary muscle
   c. Suspensory ligaments
   d. Iris
   e. Pupil
3. Sensory tunic
   a. Retina
   b. Optic nerve (cranial nerve II)
   c. Macula lutea
   d. Fovea centralis
   e. Optic disc
4. Lens
5. Anterior cavity
   a. Anterior chamber
   b. Posterior chamber
   c. Aqueous humor
   d. Scleral venous sinus
6. Posterior cavity
   a. Vitreous humor

TABLE 13.2 Model Inventory for the Eye

Model/Diagram	Structures Identified

Procedure 2 Eyeball Dissection

In this exercise you will examine the structures of the eyeball on a fresh or preserved eyeball. Eyeball dissection isn't as gross as it sounds—I promise!

Safety Note

Goggles and gloves are required!

1 Examine the external anatomy of the eyeball (Figure 13.8), and record the structures you can identify.

2 Use scissors to remove the adipose tissue surrounding the eyeball. Identify the optic nerve.

3 Hold the eyeball at its anterior and posterior poles, and use a sharp scalpel or scissors to make an incision in the frontal plane. Watch out, as aqueous humor and vitreous humor are likely to spill everywhere.

4 Complete the incision, and separate the anterior and posterior portions of the eyeball (Figure 13.9). Take care to preserve the fragile retina—the thin, delicate yellow-tinted inner layer.

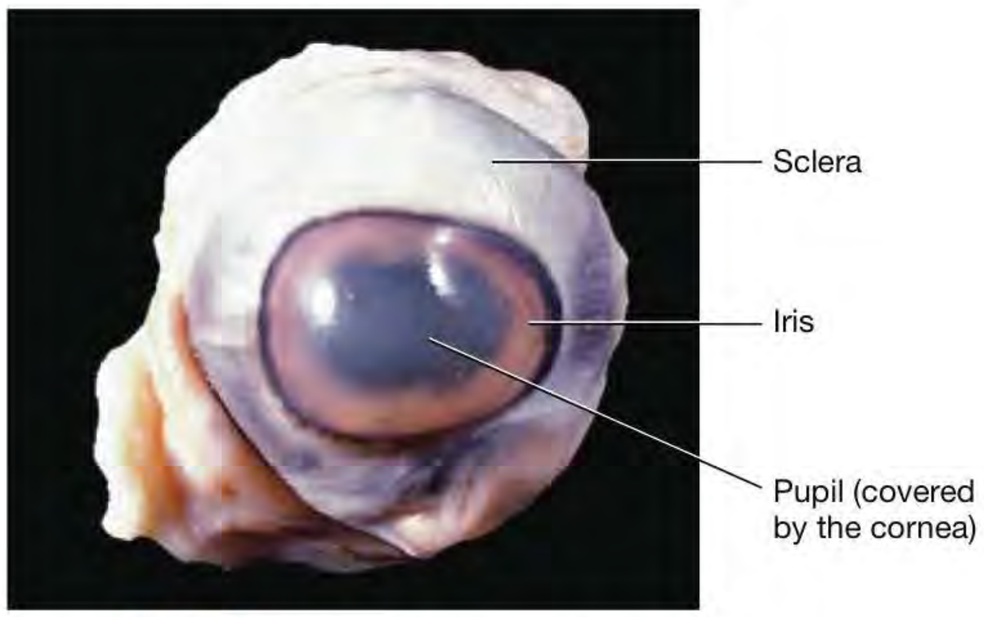


FIGURE **13.8** Anterior view of an eyeball.

5 List the structures you can identify in the anterior half of the eyeball (Figure 13.10):

6 List the structures you can identify in the posterior half of the eyeball:

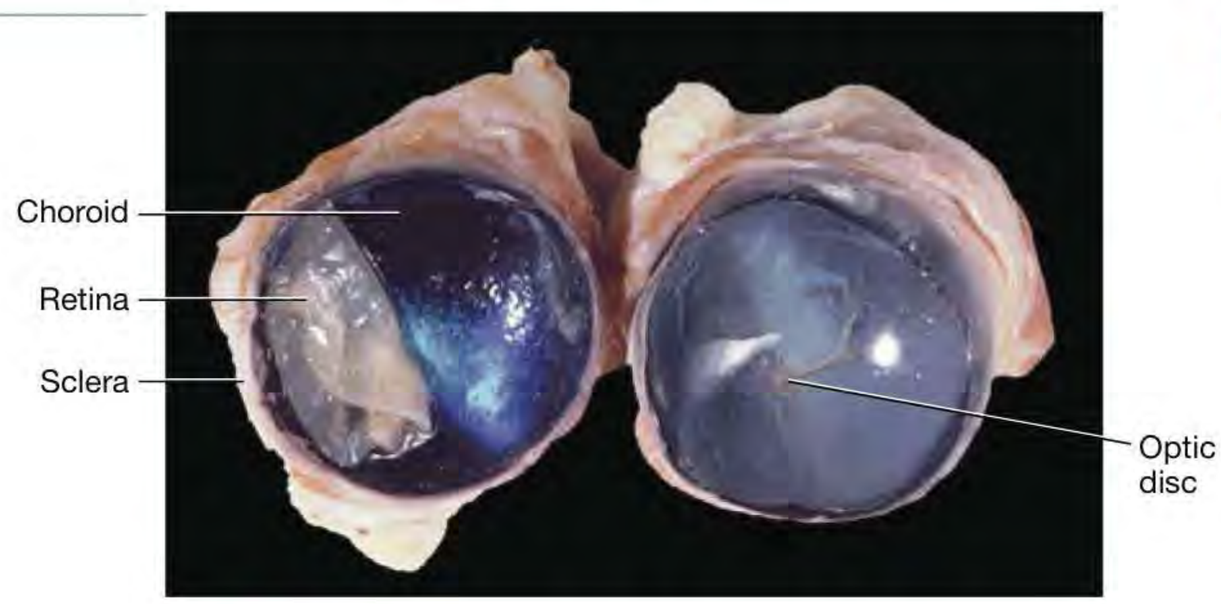


FIGURE **13.9** Frontal section of an eyeball showing the tunics.

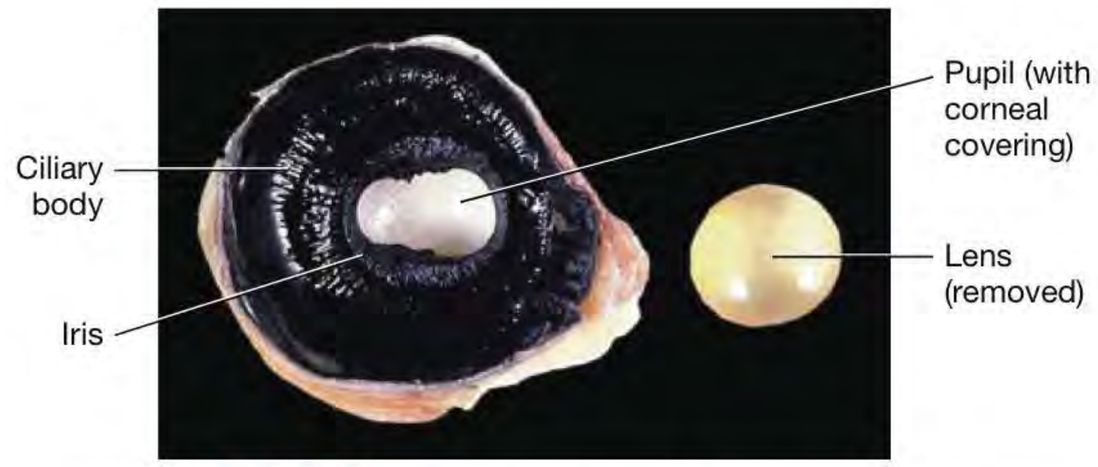


FIGURE **13.10** Posterior view of the anterior portion of the eyeball and lens.

Procedure 3 Comparing the Distribution of Rods and Cones

We discussed earlier the unequal distribution of the photoreceptors in the retina. In this exercise you will see (no pun intended) firsthand the differences in vision produced by the rods and the vision produced by the cones. After you have completed the activity, answer Check Your Understanding questions 1 and 2 (p. 341).

1 On a small sheet of paper, write the phrase "Anatomy is fun" in your regular-size print.

2 Hold this piece of paper about 25 cm (10 inches) directly in front of your lab partner's eyes, and have your lab partner read the phrase.

Can your partner read the phrase clearly? _____

Which photoreceptors are producing the image? _____

3 Now write a second phrase on the paper, and don't tell your partner what the phrase says. Hold the paper about 10 inches from your partner's peripheral vision field. Have them continue to stare forward and attempt to read what you have written.

Can your partner read the phrase clearly? _____

Which photoreceptors are producing the image? _____

4 For the next test, dim the lights in the room. Have your partner stand 20 feet in front of a Snellen eye chart and read the chart. You should stand next to the chart to verify that the letters your partner reads are correct. This indicates your partner's vision relative to someone with perfect vision. For example, a person with 20/40 vision can see at 20 feet what someone with perfect vision could see at 40 feet. Record the number of the smallest line he or she can read without errors (e.g., 20/40).

Visual acuity: _____

5 With the lights still dimmed and your partner standing in the same place, hold a piece of dark green or dark blue paper over the Snellen chart. Ask your partner to identify the color of the paper you are holding.

Paper color: _____

6 Repeat the above processes with the lights illuminated.

Visual acuity: _____

Paper color: _____

7 In which scenario were visual acuity and color vision better? Explain your findings.

_____

_____

_____

_____

_____

_____

Procedure 4 Testing the Extrinsic Eye Muscles

In this procedure, you will determine which extrinsic eye muscles are responsible for moving the eyeballs in each direction.

1 Trace a line in the air about 1 foot in front of your partner's eyes, moving from your partner's left to right. Have your partner follow your finger without moving their head. Which extrinsic eye muscles produce the movements you see for each eye?

Right eye _____ Left eye _____

2 Now trace a diagonal line, starting at the upper right corner and moving to the lower left corner. Have your partner follow your finger again. Which extrinsic eye muscles produce the movements you see for each eye?

Right eye _____ Left eye _____

3 Again have your partner follow your finger, but trace a horizontal line from left to right. Which extrinsic eye muscles produce the movements you see for each eye?

Right eye _____ Left eye _____

4 Finally, trace another diagonal, this time from your partner's lower right to the upper left, and have your partner follow along (you should have traced out an hourglass shape overall). Which extrinsic eye muscles produce the movements you see for each eye?

Right eye _____ Left eye _____

Procedure 5 Finding the Blind Spot

Recall that the location where the optic nerve exits the eyeball lacks photoreceptors and so leaves a "blind spot"—a place that can produce no images. You can find the blind spot with the simple diagram shown in Figure 13.11.

1 Close your left eye, and hold Figure 13.11 about 56 cm (18 inches) in front of your right eye so that the "X" is directly in line with your right eye.

2 Slowly move Figure 13.11 toward your right eye while staring at the "X" until the large dot disappears. When it disappears, it is in your blind spot.

3 Have your lab partner measure with a ruler the distance from the page to your eye.

Distance in centimeters: _____

4 Repeat the process for your left eye.

Distance in centimeters: _____

FIGURE 13.11 Blind spot test.

Procedure 6 Testing for Astigmatism

The condition called **astigmatism** is characterized by irregularities in the surfaces in the cornea and/or the lens. These irregularities cause the vision to become blurred because these structures are unable to focus light precisely on the retina. You can test for astigmatism by using a chart like the one shown in Figure 13.12.

1. Hold Figure 13.12 a comfortable reading distance from your eyes, about 35 cm (14 inches).
2. Cover one eye, and stare at the center of Figure 13.12. All lines should appear equally distinct and black. If any of the lines appear blurry or gray, astigmatism may be present.
3. Cover the other eye and repeat the process.
4. Was astigmatism present in either eye? _____

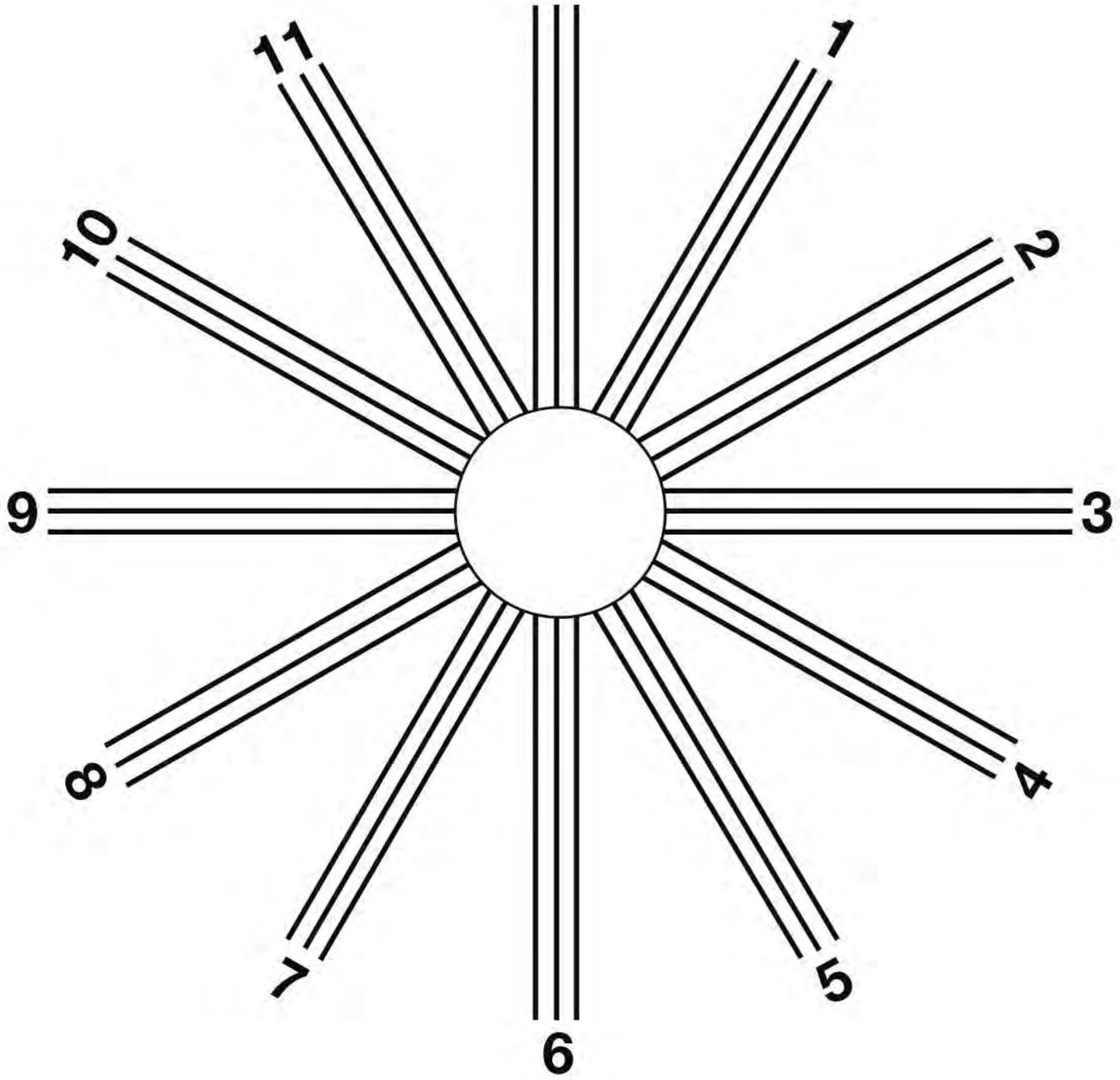


FIGURE 13.12 Astigmatism test chart.

Exercise 13-2

Anatomy of the Ear, Hearing, and Equilibrium

MATERIALS

- ❑ Ear models
- ❑ Tuning fork (500–1,000 Hz)
- ❑ Chalk

The ear contains structures both for hearing and equilibrium. It is divided into three regions: the outer, middle, and inner ear (Figure 13.13).

1. **Outer ear.** The **outer ear** begins with the **auricle** (OHR-ih-kul), or *pinna*, a shell-shaped structure composed primarily of elastic cartilage that surrounds the opening to the **external auditory canal.** The external auditory canal extends about 2.5 cm into the temporal bone, where it ends in the **tympanic membrane,** a thin sheet of epithelium and connective tissue that separates the outer ear from the middle ear.
2. **Middle ear.** The **middle ear** is a small air-filled cavity within the temporal bone that houses tiny bones called the **auditory ossicles** (AW-sih-kullz)—the **malleus** (MAL-ee-us; hammer), **incus** (ING-kus; anvil), and **stapes** (STAY-peez; stirrup). The ossicles transmit vibrations from the tympanic membrane to the inner ear through a structure called the **oval window.** An additional structure in the middle ear is the **pharyngotympanic tube** (fah-ring-oh-tim-PAN-ik; also called the auditory tube), which connects the middle ear to the pharynx (throat) and equalizes pressure in the middle ear.
3. **Inner ear.** The **inner ear** contains the sense organs for hearing and equilibrium. It consists of cavities collectively called the **bony labyrinth** filled with a fluid called **perilymph** (PEHR-ee-limf). Within the perilymph is a series of membranes called the **membranous labyrinth** that contain a thicker fluid called **endolymph** (EN-doh-limf; Figure 13.14). The bony labyrinth has three regions:
   a. **Vestibule.** The **vestibule** is an egg-shaped bony cavity that houses two structures responsible for equilibrium—the **saccule** (SAK-yool) and the **utricle** (YOO-trih-kul). Both structures transmit impulses down the vestibular portion of the vestibulocochlear nerve.
   b. **Semicircular canals.** Situated at right angles to one another, the **semicircular canals** house the **semicircular ducts** and the **ampulla,** which work together with the organs of the vestibule to maintain equilibrium. Their orientation allows them to sense rotational movements of the head and body. Like the saccule and utricle, the semicircular ducts and the ampulla transmit impulses down the vestibular portion of the vestibulocochlear nerve.

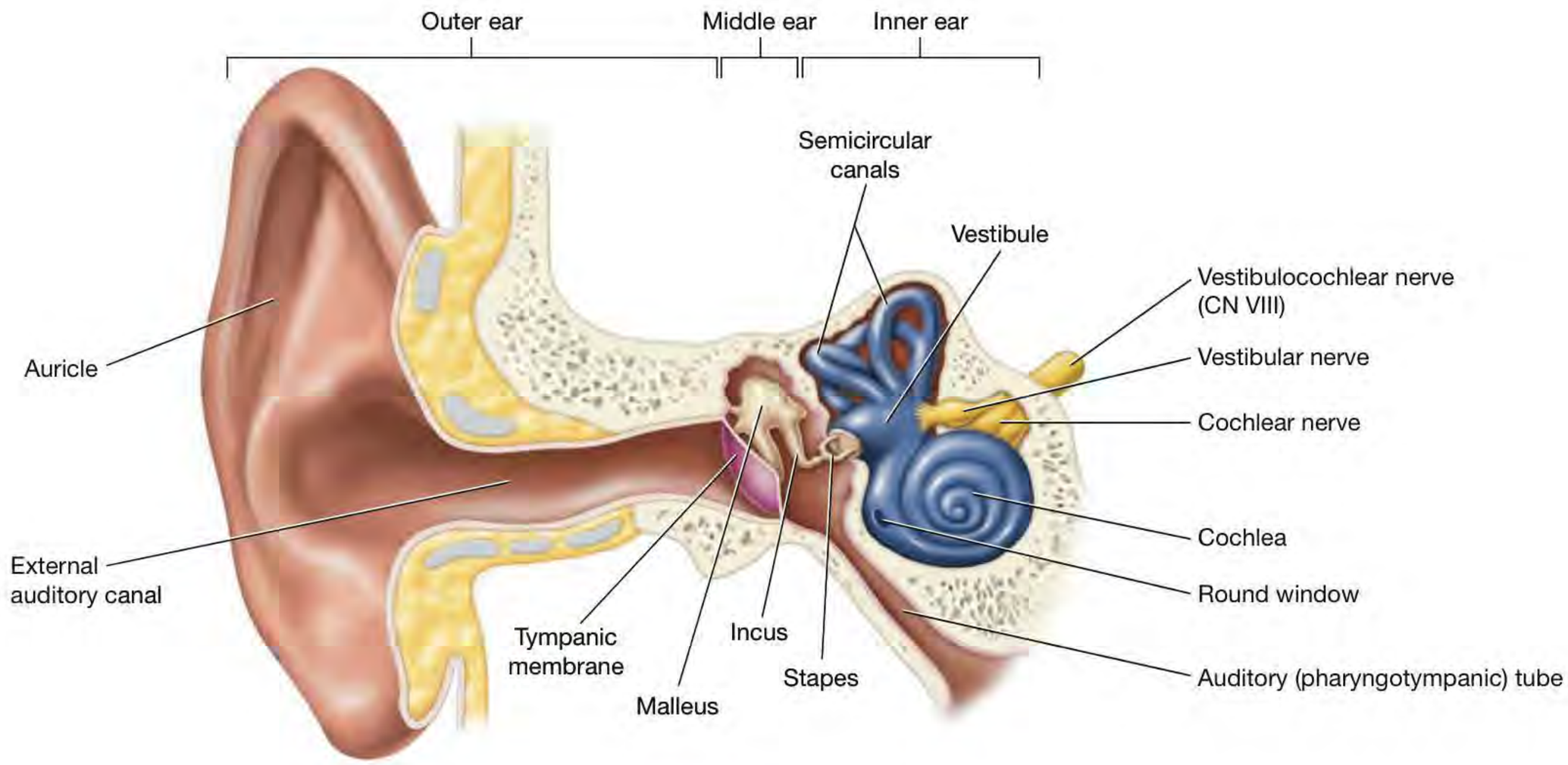


FIGURE **13.13** Anatomy of the ear.

c. **Cochlea.** The **cochlea** (KOHK-lee-ah) is a spiral bony canal that contains the **organ of Corti,** whose specialized **hair cells** transmit sound impulses to the cochlear portion of the vestibulocochlear nerve. The cochlea has a hole in its lateral wall called the **round window** which plays a role in allowing the perilymph in the cochlea to vibrate.

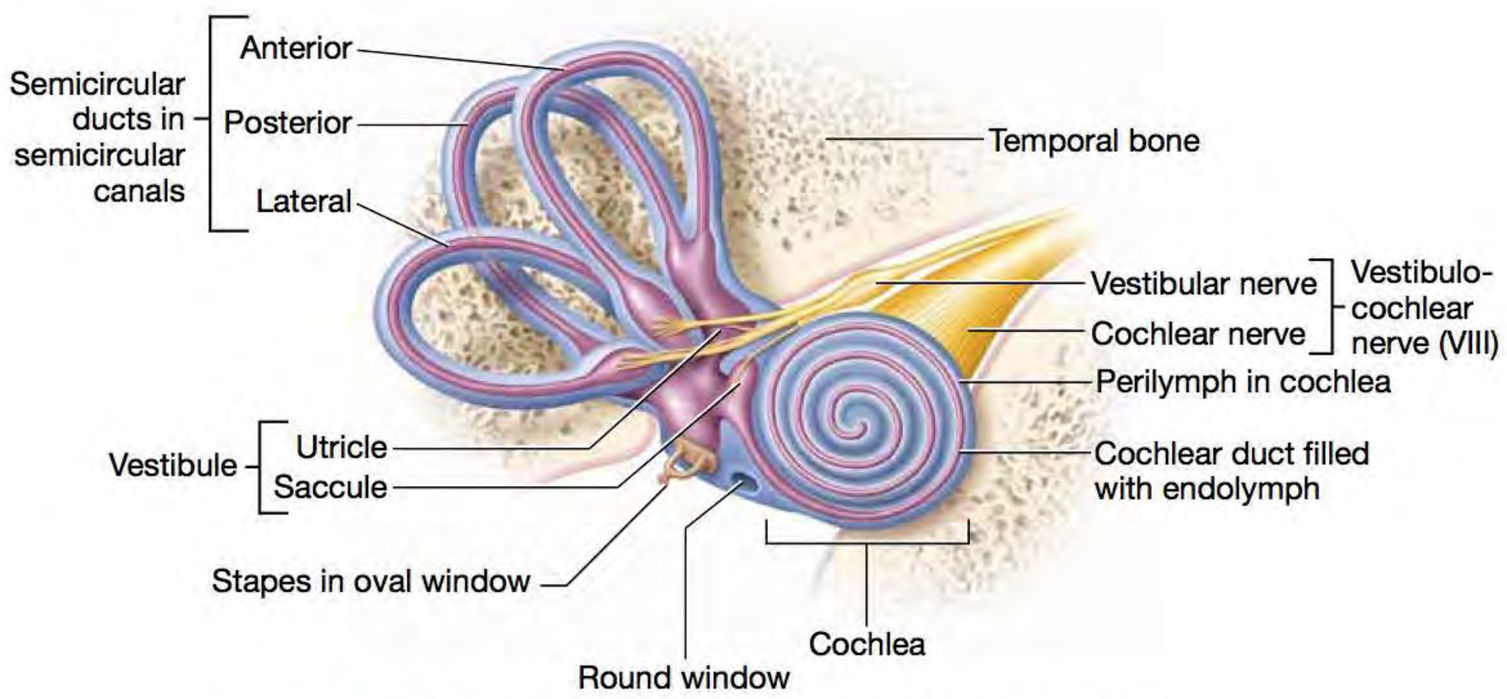


FIGURE **13.14** The membranous labyrinth of the inner ear.

Procedure 1 Model Inventory for the Ear

Identify the following structures of the ear on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 13.3. After you have completed the activity, answer Check Your Understanding questions 3 and 4 (p. 341).

1. Outer ear
   a. Auricle (pinna)
   b. External auditory canal
2. Middle ear
   a. Tympanic membrane
   b. Ossicles
      (1) Malleus
      (2) Incus
      (3) Stapes
   c. Oval window
   d. Pharyngotympanic (auditory) tube
3. Inner ear
   a. Vestibule
      (1) Saccule
      (2) Utricle
   b. Semicircular canals
      (1) Semicircular duct
      (2) Ampulla
   c. Cochlea
      (1) Organ of Corti
      (2) Cochlear duct
      (3) Round window
   d. Vestibulocochlear nerve (cranial nerve VIII)
      (1) Vestibular nerve
      (2) Cochlear nerve

13

TABLE **13.3** Model Inventory for the Ear

Model/Diagram	Structures Identified

Hearing Acuity

There are two possible types of hearing loss:

1. **Conductive hearing loss** results from interference of sound conduction through the outer and/or middle ear.
2. **Sensorineural hearing loss** results from damage to the inner ear or the vestibulocochlear nerve.

Two clinical tests can help a healthcare professional determine if hearing loss is conductive or sensorineural: the Weber test and the Rinne (rinn-ay) test. Both tests use tuning forks that vibrate at specific frequencies when struck. The tuning forks are placed either directly on the bones of the skull to evaluate bone conduction—the ability to hear the vibrations transmitted through the bone—and/or near the ear, not touching bone, to evaluate air conduction—the ability to hear the vibrations transmitted through the air. After you have completed both tests, answer Check Your Understanding question 5 (p. 342).

Procedure 2 Weber Test

1 Obtain a tuning fork with a frequency of 500–1,000 Hz (cycles per second).

2 Hold the tuning fork by the base, and strike it lightly with a mallet, or tap it on the edge of the table. The fork should begin ringing softly. If it is ringing too loudly, grasp the tines to stop it from ringing, and try again.

3 Place the base of the vibrating tuning fork on the midline of your partner's head, as shown in Figure 13.15.

4 Ask your partner if the sound is heard better in one ear or if the sound is heard equally in both ears. If the sound is heard better in one ear, this is called lateralization.

Was the sound lateralized? If yes, to which ear? _____

5 To illustrate what it would sound like if the sound were lateralized, have your partner place their finger in one ear. Repeat the test.

a In which ear was the sound heard better? _____

b If a patient has conduction deafness, in which ear do you think the sound will be heard most clearly (the deaf ear or the good ear)?

_____

Why? (If you are confused, think about your results when one ear was plugged.)

_____

_____

_____

_____

c If a patient has sensorineural deafness, in which ear do you think the sound will be best heard?

_____

FIGURE **13.15** Weber test.

Procedure 3 Rinne Test

1. Strike the tuning fork lightly to start it ringing, as shown in Figure 13.16.
2. Place the base of the tuning fork on your partner's mastoid process.
3. Time the interval during which your partner can hear the sound. Your partner will have to tell you when he or she can no longer hear the ringing.

   Time interval in seconds:

   _____

4. Once your partner cannot hear the ringing, quickly move the still-vibrating tuning fork 1–2 cm lateral to the external auditory canal (the fork should not be touching your partner at this point).
5. Time the interval from the point when you moved the tuning fork in front of the external auditory canal to when your partner can no longer hear the sound.

   Time interval in seconds: _____

   Which situation tested bone conduction? _____

   Which situation tested air conduction? _____
6. Typically, the air-conducted sound is heard twice as long as the bone-conducted sound. For example, if the bone-conducted sound was heard for 15 seconds, the air-conducted sound should be heard for 30 seconds.

   Were your results normal? _____

   What type of deafness is present if the bone-conducted sound is heard longer than the air-conducted sound?

   _____

FIGURE 13.16 Rinne test.

Equilibrium

A common and simple test of equilibrium is the **Romberg test**, in which the person is asked to stand still, first with the eyes open and then with the eyes closed. Under normal conditions, the vestibular apparatus should be able to maintain equilibrium in the absence of visual input. If the vestibular apparatus is impaired, however, the brain relies on visual cues to maintain balance.

Procedure 4 Romberg Test

1. Have your partner stand erect with the feet together and the arms at the sides in front of a chalkboard.
2. Use chalk to draw lines on the board on either side of your partner's torso. These lines are for your reference in the next part.
3. Have your partner stand in front of the chalkboard for 1 minute, staring forward with his or her eyes open. Use the lines on either side of his or her torso to note how much he or she sways as she stands. Below, record the amount of side-to-side swaying (i.e., minimal or significant):

4. Now have your partner stand in the same position for 1 minute with his or her eyes closed. Again note the amount of side-to-side swaying, using the chalk lines for reference.

   Was the amount of swaying more or less with their eyes closed? _____

   Why do you think this is so? _____

   What do you predict would be the result for a person with an impaired vestibular apparatus? Explain.

Exercise 13-3

Olfactory and Taste Senses

MATERIALS

- ❑ Head and neck models
- ❑ Tongue model

Both olfaction and taste are sometimes referred to as the **chemosenses,** because they both rely on chemoreceptors to relay information about the environment to the brain. The chemoreceptors of the olfactory sense are located in a small patch in the roof of the nasal cavity called the **olfactory epithelium** (Figure 13.17). The olfactory epithelium contains bipolar neurons called **olfactory receptor cells**. Their axons, which are collectively called **cranial nerve I** or the **olfactory nerve,** penetrate the holes in the cribriform plate to synapse on the **olfactory bulb,** which then sends the impulses down the axons of the **olfactory tract** to the olfactory cortex.

Taste receptors are located on **taste buds** housed on projections from the tongue called **papillae** (Figure 13.18). Of the four types of papillae—**filiform, fungiform, foliate,** and **circumvallate**—all but filiform papillae house taste buds. **Fungiform papillae** are scattered over the surface of the tongue, whereas the large **circumvallate papillae** are located at the posterior aspect of the tongue, arranged in a V shape. **Foliate papillae** contain taste buds primarily during childhood; they are located on the lateral aspects of the tongue.

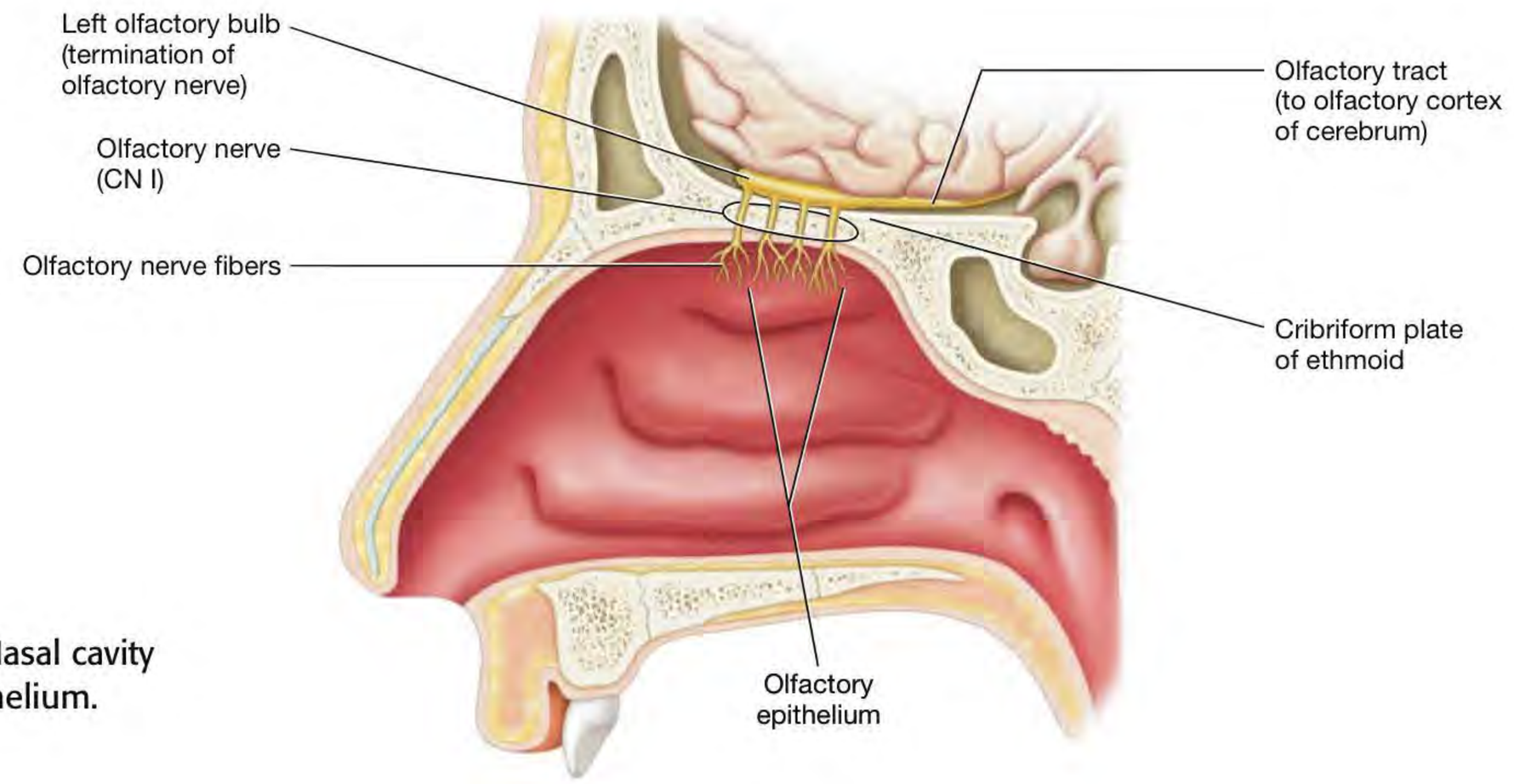


FIGURE **13.17** Nasal cavity and olfactory epithelium.

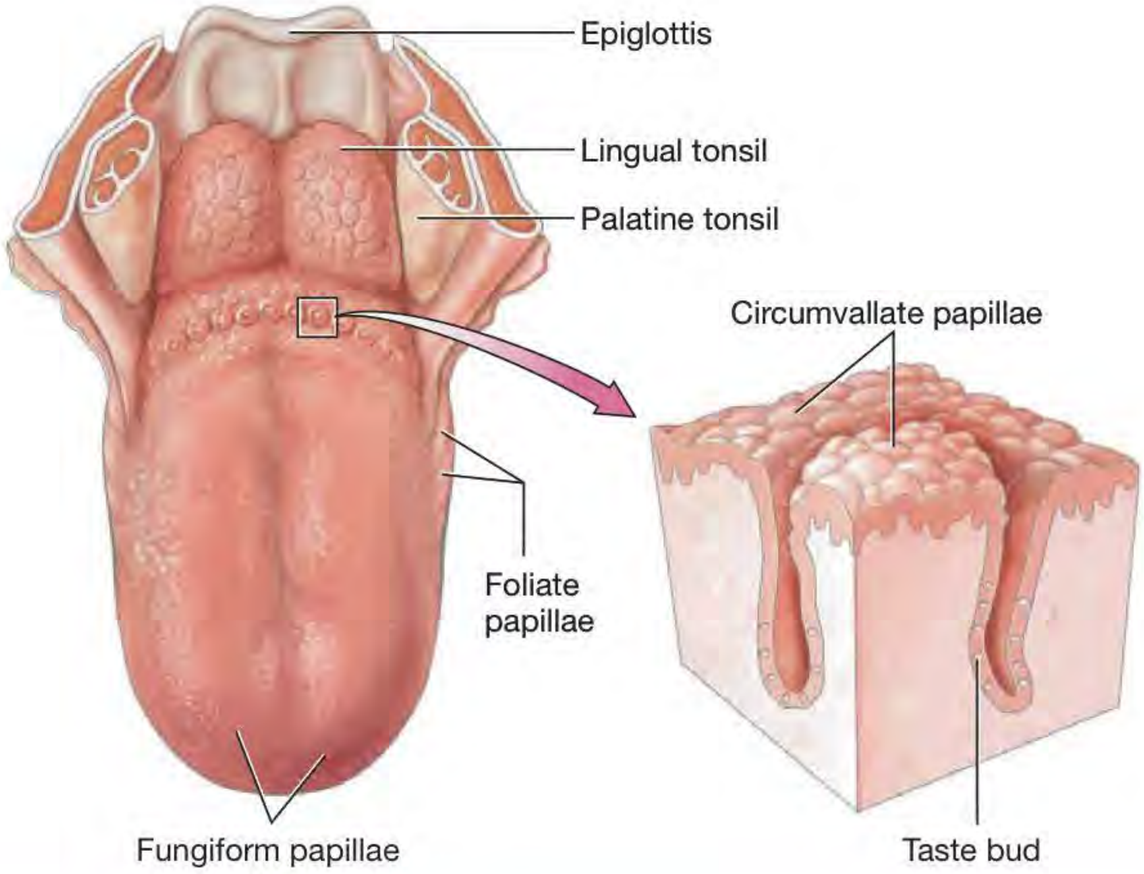


FIGURE **13.18** Surface of the tongue.

Procedure 1 Model Inventory for Olfaction and Taste

Identify the following structures of the olfactory and taste senses on anatomical models and charts. As you examine the anatomical models and diagrams, record on the model inventory in Table 13.4 the name of the model and the structures you were able to identify. After you have completed the activity, answer Check Your Understanding question 6 (p. 342).

Olfaction

1. Nasal cavity
   a. Cribriform plate
2. Olfactory epithelium
   a. Olfactory receptor cells
3. Olfactory nerve (cranial nerve I)
4. Olfactory bulbs
5. Olfactory tract

Taste

1. Taste buds
2. Papillae
   a. Fungiform papillae
   b. Circumvallate papillae
   c. Foliate papillae

TABLE 13.4 Model Inventory for Olfaction and Taste

Model/Diagram	Structures Identified

Exercise 13-4

The General Senses: Cutaneous Sensation

MATERIALS

- ❑ Water-soluble marking pens (two colors)
- ❑ Ruler
- ❑ 2 wooden applicator sticks (or toothpicks)
- ❑ Alcohol swabs

Sensory receptors in the skin respond to different stimuli, including temperature, touch, and pain. These receptors are not distributed throughout the skin equally, but instead are concentrated in certain regions of the body. The following experiments will allow you to determine the relative distribution of the receptors for touch in the skin by performing two tests: the error of localization and two-point discrimination. After you complete the activities, answer Check Your Understanding question 7 (p. 342).

Error of Localization

Every region of the skin corresponds to an area of the primary somatosensory cortex of the cerebrum. Some regions are better represented than others and are therefore capable of localizing stimuli with greater precision than are less well-represented areas. The **error of localization** (also called tactile localization) tests the ability to determine the location of the skin touched and demonstrates how well-represented each region of the skin is in the cerebral cortex.

Procedure 1 Testing Error of Localization

1. Have your partner sit with their eyes closed.
2. Use a water-soluble marking pen to place a mark on your partner's anterior forearm.
3. Using a different color of marker, have your partner, still with eyes closed, place a mark as close as possible to where they believe the original spot is located.
4. Use a ruler to measure the distance between the two points in millimeters. This is your error of localization.
5. Repeat this procedure for each of the following locations:
   - a. Anterior thigh
   - b. Face
   - c. Palm of hand
   - d. Fingertip
6. Record your data in Table 13.5.

TABLE 13.5 Error of Localization

Location	Error of Localization (mm)
Anterior forearm	
Anterior thigh	
Face	
Palm of hand	
Fingertip	

Two-Point Discrimination

The **two-point discrimination test** assesses the ability to perceive the number of stimuli ("points") placed on the skin. Areas that have a higher density of touch receptors are better able to distinguish between multiple stimuli than those with fewer touch receptors.

Procedure 2 Testing Two-Point Discrimination

1. Have your partner close their eyes.
2. Place the ends of two wooden applicator sticks close together (they should be nearly touching) on your partner's skin on the anterior forearm. Ask your partner how many points they can discriminate—one or two.
3. If they can sense only one point, move the sticks farther apart. Repeat this procedure until your partner can distinguish two separate points touching their skin.
4. Use a ruler to measure the distance between the two sticks in millimeters. This is your two-point discrimination.
5. Repeat this procedure for each of the following locations:
   a. Anterior thigh
   b. Face (around the lips and/or eyes)
   c. Vertebral region
   d. Fingertip
6. Record your data in Table 13.6.

TABLE **13.6** Two-Point Discrimination

Location	Two-Point Discrimination (mm)
Anterior forearm	
Anterior thigh	
Face	
Vertebral region	
Fingertip	

7. What results did you expect for each test? Explain.

8 Did your observations agree with your expectations? Interpret your results.

13

Name _____

Section _____ Date _____

UNIT 13 REVIEW

Check Your Recall

1 Label the following parts of the eyeball on Figure 13.19.

- ❑ Choroid
- ❑ Cornea
- ❑ Ciliary body
- ❑ Iris
- ❑ Lens
- ❑ Optic nerve
- ❑ Posterior cavity
- ❑ Retina
- ❑ Sclera
- ❑ Suspensory ligaments

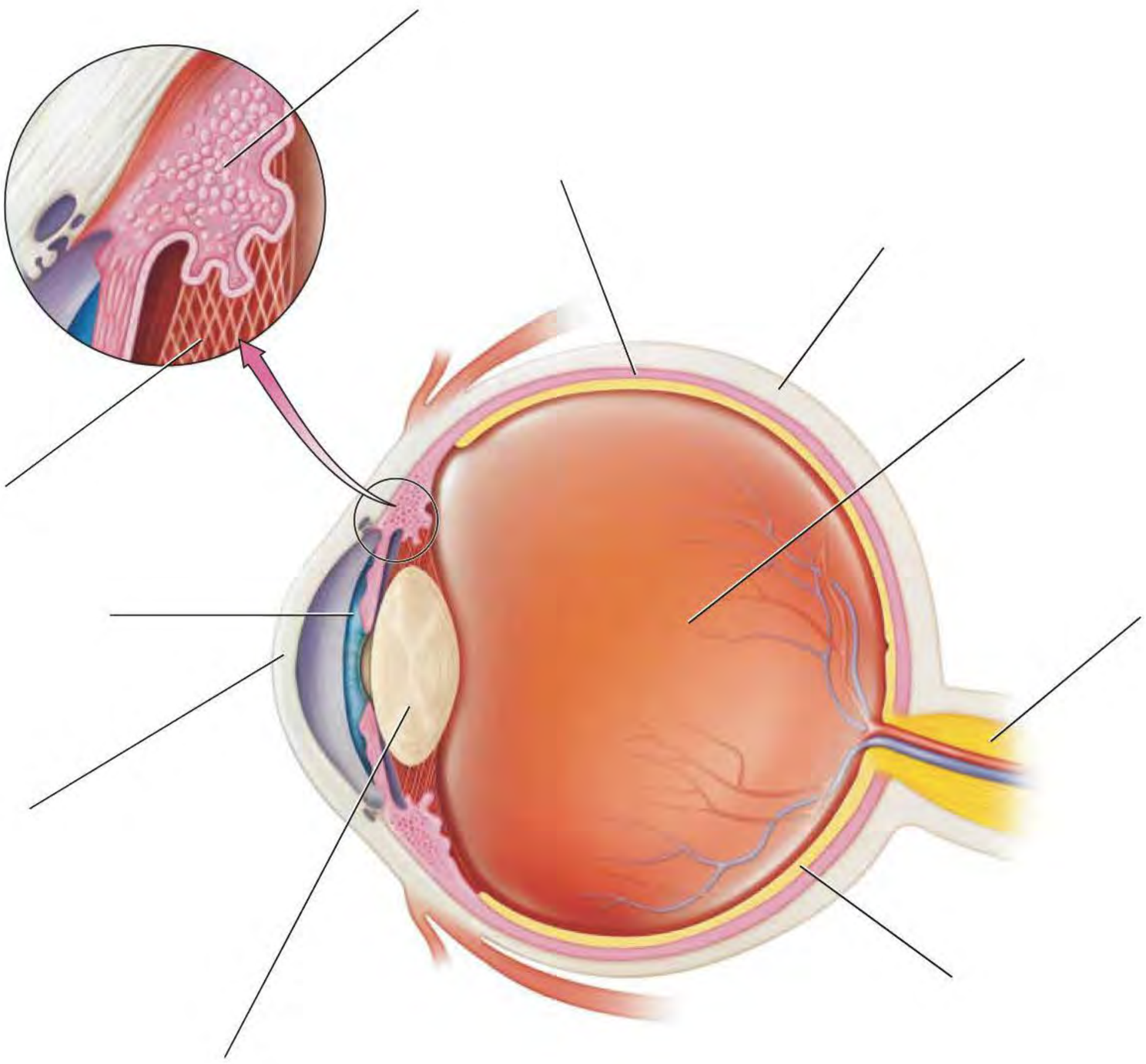


FIGURE **13.19** Eyeball, sagittal section.

2 The lacrimal gland is located in the _____ and produces _____.

a. superolateral orbit; mucus
b. inferomedial orbit; tears
c. superolateral orbit; tears
d. inferomedial orbit; mucus

3 The rods are responsible for _____, whereas the cones are responsible for _____.

a. peripheral and dim light vision; high-acuity color vision
b. high-acuity color vision; peripheral and dim light vision
c. peripheral and color vision; high-acuity and dim light vision
d. high-acuity and dim light vision; peripheral and color vision

4 Label the following parts of the ear on Figure 13.20.

- ❑ Auricle
- ❑ Cochlea
- ❑ External auditory canal
- ❑ Incus
- ❑ Malleus
- ❑ Pharyngotympanic tube
- ❑ Semicircular canals
- ❑ Stapes
- ❑ Tympanic membrane
- ❑ Vestibule
- ❑ Vestibulocochlear nerve

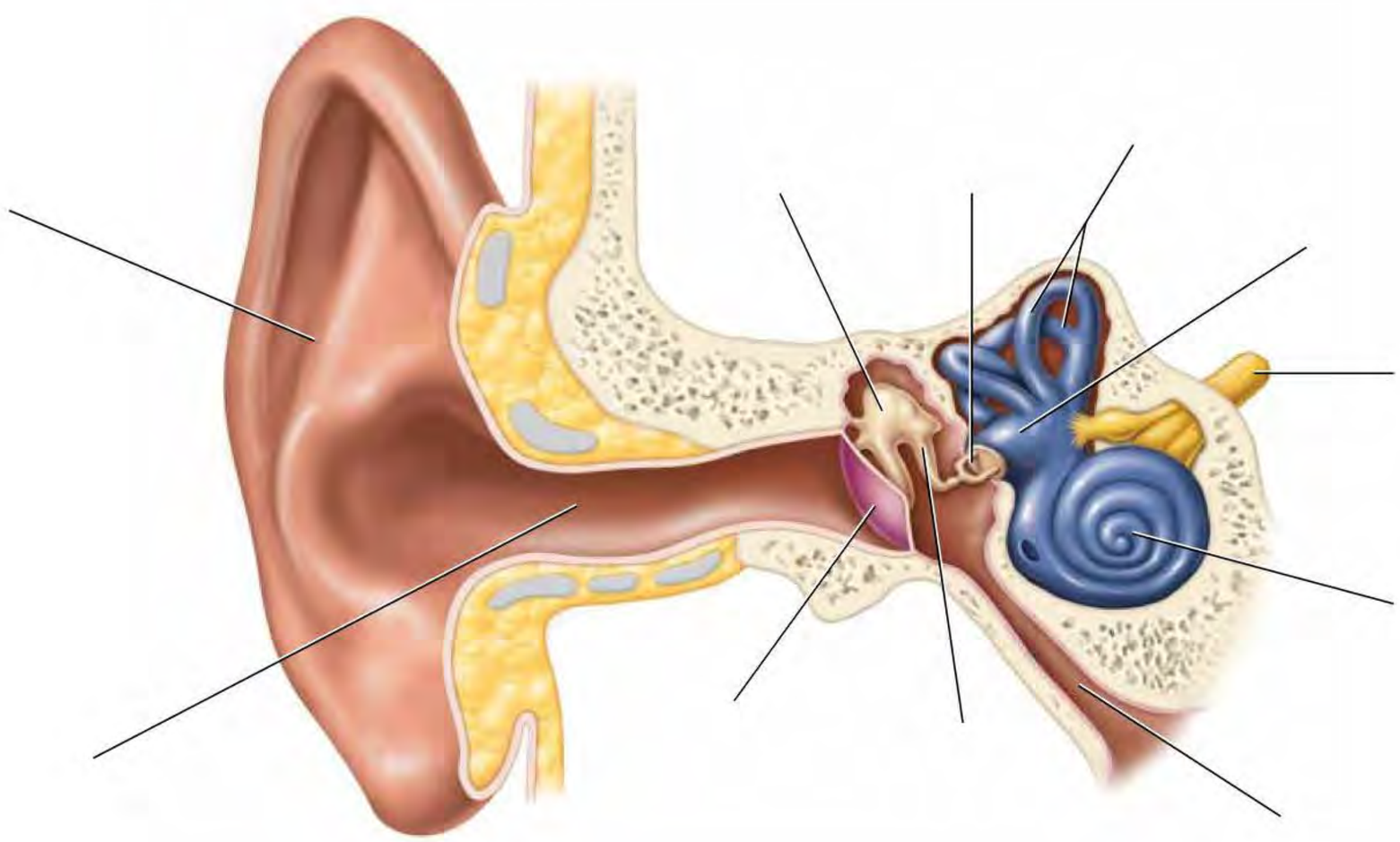


FIGURE **13.20** Anatomy of the ear.

Name _____

Section _____ Date _____

UNIT 13

5 **The auditory ossicles transmit vibrations from the _____ to the _____.**

a. auricle; malleus
b. tympanic membrane; inner ear
c. tympanic membrane; middle ear
d. auricle; inner ear

6 **The structures of the cochlea are responsible for _____, whereas the structures of the vestibule and semicircular canals are responsible for _____.**

a. equilibrium; balance
b. equilibrium; hearing
c. hearing; equilibrium
d. hearing; audition

7 ***Mark the following statements as true (T) or false (F).*** **If the statement is false, correct it so it is a true statement.**

_____ a. Conductive hearing loss results from damage to the inner ear or the vestibulocochlear nerve.

_____ b. The ciliary muscle controls the diameter of the iris.

_____ c. The Weber and Rinne tests assess balance and equilibrium.

_____ d. The six extrinsic eye muscles move the eyeball.

_____ e. Smell and taste are considered chemosenses.

_____ f. The photoreceptors are located in the vascular tunic of the eyeball.

8 **The receptors for smell are located in the**

a. gustatory mucosa.
b. olfactory epithelium.
c. olfactory fossa.
d. squamous epithelium.

9 **Taste buds are located on the**

a. filiform, fungiform, and circumvallate papillae.
b. filiform, fungiform, and foliate papillae.
c. filiform and circumvallate papillae only.
d. fungiform, foliate, and circumvallate papillae.

10 **You would expect the error of localization and the two-point discrimination threshold to be lowest on the**

a. back.
b. forearm.
c. fingertip.
d. thigh.

Name _____

Section _____ Date _____

UNIT 13 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 The disease *macular degeneration* is characterized by a gradual loss of vision as a result of degeneration of the macula lutea. Considering the type of cells located in the macula lutea, which type of vision do you think a sufferer of macular degeneration would lose? Why?

2 How would the signs and symptoms differ from those in question 1 in a condition that caused degeneration of rods?

3 What signs and symptoms would you expect to see from *otitis interna* (inner ear infection)? Why?

4 Explain why infectious *otitis media* (inflammation of the middle ear) may result in a simultaneous *pharyngitis* (inflammation of the throat).

5 *Otosclerosis* is a condition that results in irregular ossification (bone formation) around the stapes bone. Would you expect this to result in conductive or in sensorineural hearing loss? What results would you expect from the Rinne and Weber tests in an individual with otosclerosis?

6 Your patient is in a car accident and several days later complains of a loss of smell. An x-ray reveals a fracture of the cribriform plate. What structures specifically have been damaged? How has this interfered with your patient's sense of smell?

7 The *sensory homunculus* is a small figure of a human whose body parts are represented in proportion to the amount of the somatosensory cortex dedicated to them. Parts of the body that are well represented in the somatosensory cortex are drawn as larger, and those that are poorly represented in the somatosensory cortex are drawn as smaller. Which areas of the body do you think would be larger on the homunculus? Which areas do you think would be smaller? Explain your reasoning.

14 Endocrine System

OBJECTIVES

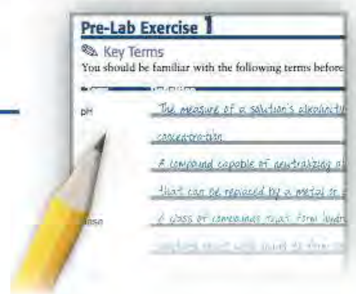
Once you have completed this unit, you should be able to:

1. Identify endocrine organs and structures.
2. Identify microscopic structures of endocrine organs.
3. Trace the functions, stimulus for secretion, and target tissues of various hormones.
4. Apply principles of the endocrine system to clinical cases.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 14-1

Key Terms

You should be familiar with the following terms before coming to lab. Please note that key hormones are covered in Pre-Lab Exercise 14-3 (p. 347).

Term	Definition
General Terms	
Endocrine organ (gland)	
Hormone	
Target tissue	
Negative feedback	
Endocrine Organs	
Hypothalamus	
Anterior pituitary	
Posterior pituitary	
Thyroid gland	
Parathyroid glands	
Pineal gland	
Thymus	

Name _____ Section _____ Date _____

Pancreas _____

_____

Adrenal cortex _____

_____

Adrenal medulla _____

_____

Ovaries _____

_____

Testes _____

_____

14

Pre-Lab Exercise 14-2

Endocrine System Anatomy

Label and color the structures of the endocrine system in Figure 14.1 with the terms from Exercise 14-1 (p. 349). Use your text and Exercise 14-1 in this unit for reference.

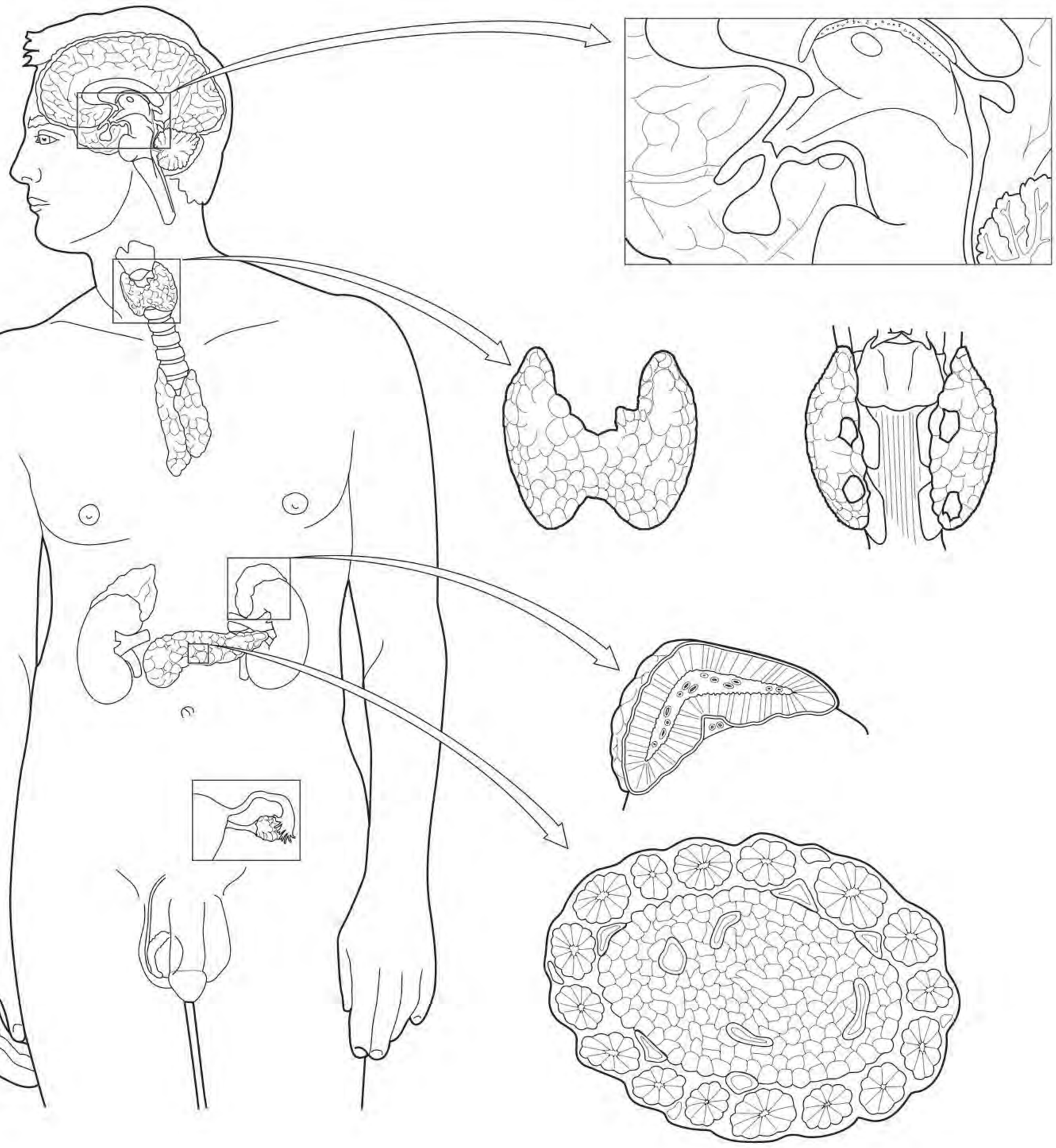


FIGURE **14.1** Endocrine system.

Name _____ Section _____ Date _____

Pre-Lab Exercise 14-3

Hormones: Target Tissues and Effects

Fill in Table 14.1 with the organ that secretes each hormone, the hormone's target tissue, and its main effects.

TABLE **14.1** Properties of Hormones

Hormone	Organ That Secretes the Hormone	Target Tissue(s)	Main Effects
Antidiuretic hormone			
Oxytocin			
Thyroid-stimulating hormone			
Adrenocorticotropic hormone			
Growth hormone			
Prolactin			
Melatonin			
Thyroxine and triiodothyronine (T4 and T3)			
Calcitonin			

(continues)

TABLE **14.1** Properties of Hormones *(continued)*

Hormone	Organ That Secretes the Hormone	Target Tissue(s)	Main Effects
Thymosin and thymopoietin			
Parathyroid hormone			
Cortisol			
Aldosterone			
Epinephrine and norepinephrine			
Insulin			
Glucagon			

EXERCISES

The **endocrine system** is a diverse group of ductless glands that plays a major role in maintaining the body's homeostasis. It works closely with the other system that maintains homeostasis—the nervous system. Although these two systems both work toward the same goal, you will notice that the methods by which they do so differ. The nervous system works via action potentials (nerve impulses) and releases **neurotransmitters** that directly affect target cells. The effects are nearly immediate, but they are very short in duration. In contrast, the endocrine system works via secretion of **hormones**—chemicals secreted into the bloodstream that typically act on distant targets. The effects of hormones are not immediate, but they are longer-lasting than those of the nervous system.

In general, hormones function to regulate the processes of other cells, including inducing the production of enzymes or other hormones, changing the metabolic rate of a cell, and altering permeability of the plasma membranes. You might think of hormones as the "middle managers" of the body, because they communicate the messages from their "bosses" (the endocrine glands) and tell other cells what to do. Some endocrine glands (e.g., the thyroid and anterior pituitary glands) secrete hormones as their primary function. Others, however, secrete hormones as a secondary function, examples of which are the heart (atrial natriuretic peptide), adipose tissue (leptin), the kidneys (erythropoietin), and the stomach (gastrin).

This unit introduces you to the anatomy, histology, and physiology of the endocrine organs and hormones. To close out this unit, you will play "endocrine detective" and try to solve three "endocrine mysteries."

Exercise 14-1

Endocrine System Anatomy

MATERIALS

- ❑ Endocrine system models
- ❑ Human torso models
- ❑ Head and neck models
- ❑ Fetal models

The 10 organs in the body that have hormone secretion as a primary function are the hypothalamus, the pituitary gland, the pineal gland, the thyroid gland, the parathyroid glands, the thymus, the adrenal gland, the pancreas, and the ovaries or testes (Figure 14.2). The testes and ovaries are discussed further in Unit 22.

1. **Hypothalamus and Pituitary Gland.** The **hypothalamus**, the inferior part of the diencephalon, is known as a **neuroendocrine organ.** It can be likened to the endocrine system's chief executive officer (CEO). It has a close working relationship with the **pituitary gland** (pih-TOO-ih-tehr-ee), to which it is attached by a stalk called the **infundibulum.** Notice in Figure 14.3 that the pituitary gland is actually two separate structures. The **anterior pituitary gland,** or **adenohypophysis** (ad-en-oh-hy-POF-ih-sis), is composed of glandular epithelium and secretes a variety of hormones that affect other tissues in the body. The **posterior pituitary** or **neurohypophysis** (noor-oh-hy-POF-ih-sis), is actually composed of nervous tissue rather than glandular tissue.

The hypothalamus produces two types of hormones. The first are those that that inhibit and stimulate secretion—called **inhibiting** and **releasing hormones,** respectively—from the anterior pituitary gland. The anterior pituitary in turn releases hormones that stimulate other endocrine and exocrine glands in the body. In Figure 14.3A, you can see how the hypothalamus accomplishes this via a specialized set of blood vessels collectively called the **hypothalamic-hypophyseal portal system** (hy-PAW-fih-see-ul). The releasing and inhibiting hormones are synthesized by hypothalamic neurons and enter into capillaries in the hypothalamus, after which they travel through small veins in the infundibulum. They then enter a second capillary bed in the anterior pituitary, where they exit the blood and interact with anterior pituitary cells to influence their functions.

In addition to inhibiting and releasing hormones, the hypothalamus makes the hormone **oxytocin** (awks-ee-TOH-sin), which triggers uterine contraction and milk ejection from the mammary gland, and **antidiuretic hormone** (an-ty-dy-yoo-RET-ik; **ADH**), which causes water retention from the collecting ducts of the kidneys. These hormones are produced by hypothalamic neurons that extend the length of the infundibulum down into the posterior pituitary, which you can see in Figure 14.3B. Here they are stored in the posterior pituitary gland.

a. The **anterior pituitary gland** mostly produces hormones known as *tropic hormones*, or those that influence the functions of other glands. Examples include **thyroid-stimulating hormone** (**TSH**), which stimulates growth of and

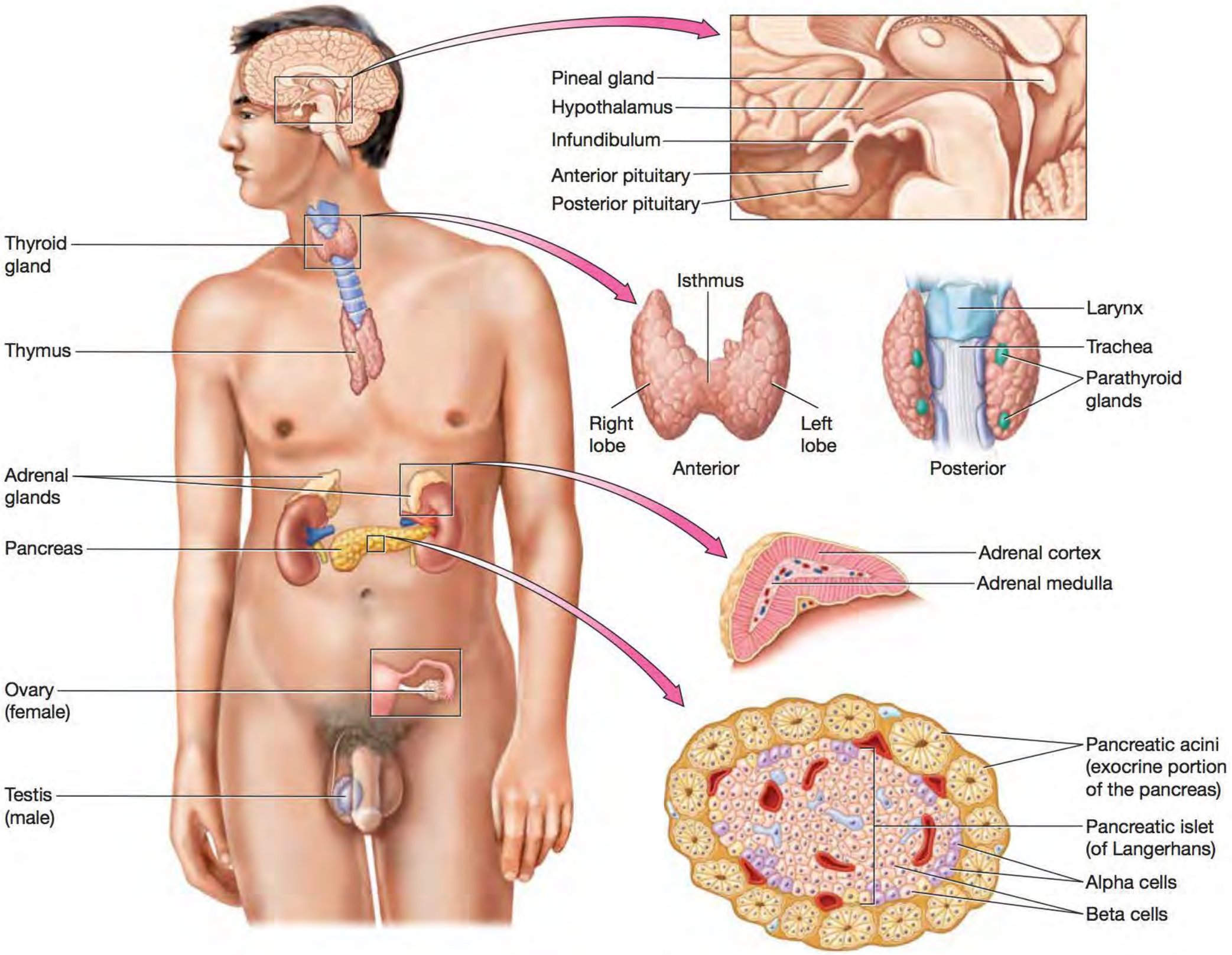


FIGURE **14.2** Endocrine system.

secretion from the thyroid; **prolactin**, which stimulates milk production from mammary glands; **adrenocorticotropic hormone** (ah-dree-noh-kohr-tih-koh-TROH-pik; ACTH), which stimulates secretion from the adrenal cortex; and two reproductive hormones, **luteinizing hormone** (LOO-tee-in-aye-zing) and **follicle-stimulating hormone**, which affect primarily the testes and ovaries. An exception is **growth hormone** (GH), which increases the rate of cell division and protein synthesis in all tissues, and has both tropic and non-tropic effects.

b. The posterior pituitary doesn't produce any hormones at all and functions merely as a place to store the oxytocin and ADH produced by the hypothalamus.

2. **Pineal gland.** Recall from Unit 11 (p. 272) that the tiny **pineal gland** (pin-EEL) is located in the posterior and superior diencephalon. This neuroendocrine organ secretes the hormone **melatonin** in response to decreased light levels and acts on the reticular formation of the brainstem to trigger sleep.

3. **Thyroid gland.** The **thyroid gland**, located in the anterior and inferior neck superficial to the larynx, consists of right and left lobes connected by a thin band of tissue called the **isthmus**. Microscopically, it is composed of hollow spheres called **thyroid follicles** (Figure 14.4). The cells that line the thyroid follicles are simple cuboidal cells called **follicle cells**, and they surround a gelatinous, iodine-rich substance called **colloid** (KAWL-oyd). The follicle cells respond to TSH from the anterior pituitary by secreting a chemical into the colloid that reacts with iodine to produce two different hormones: **thyroxine** or **T4**, which has four iodine molecules, and **triiodothyronine** (try-eye-oh-doh-THY-roh-neen) or **T3**, which has three iodine molecules. T3 is the most active of the two hormones and acts on essentially all cells in

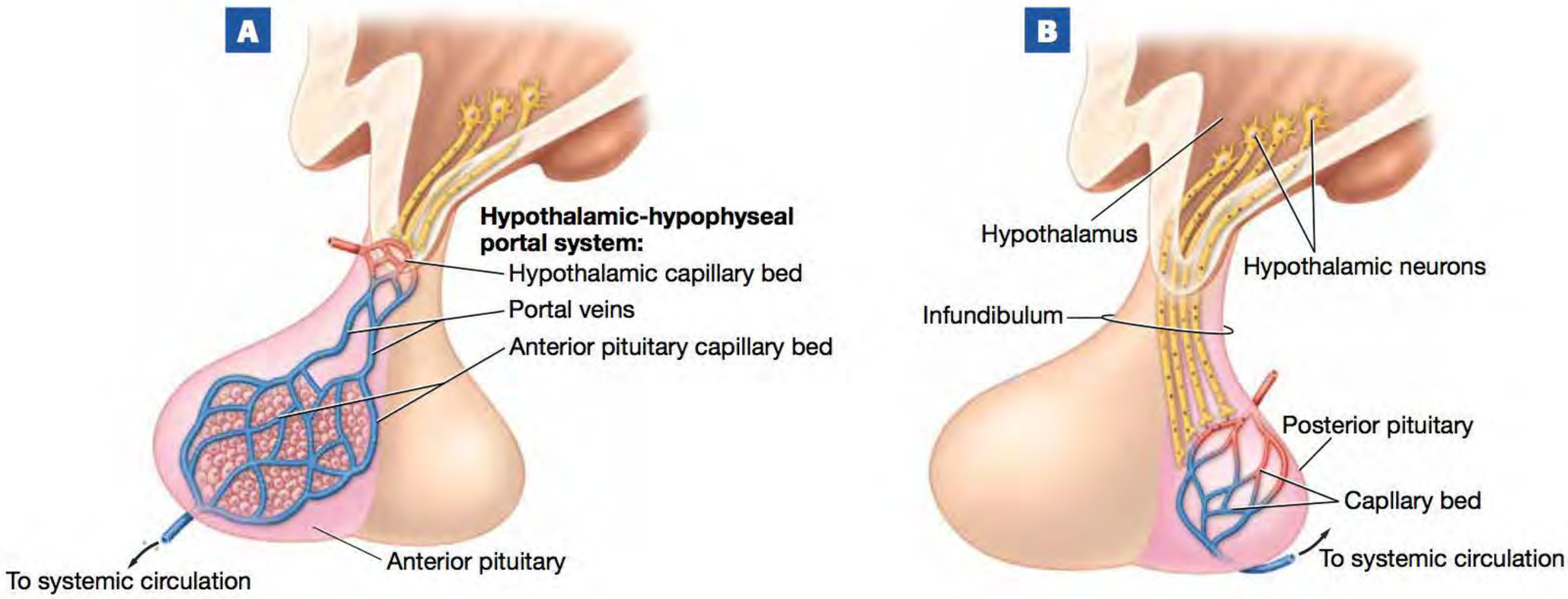


FIGURE **14.3** Hypothalamus and pituitary gland: (**A**) the hypothalamus and anterior pituitary; (**B**) the hypothalamus and posterior pituitary.

the body to increase the metabolic rate, increase protein synthesis, and regulate the heart rate and blood pressure, among other things. About 10 times as much T4 is produced as T3, and the body converts T4 to T3 when T3 levels in the blood drop.

Between the follicles we find another cell type called the **parafollicular cells**. These cells produce the hormone **calcitonin** (kal-sih-TOH-nin), a hormone that plays a role in calcium ion homeostasis. Calcitonin is secreted when calcium ion levels in the blood rise, and it triggers osteoblast activity and bone deposition.

4. **Parathyroid glands.** Refer back to Figure 14.2 where you can see the small **parathyroid glands** on the posterior thyroid gland. They secrete the hormone **parathyroid hormone** (**PTH**), which is the main hormone in the body that maintains calcium ion homeostasis. PTH is secreted in response to a decreased level of calcium ions in the blood. It triggers osteoclast activity and resorption of bone tissue, increased calcium ion absorption from the intestines, and increased calcium ion reabsorption from the kidneys. Hormones such as PTH and calcitonin that have opposite actions are called **antagonists.**
5. **Thymus.** The **thymus** sits in the superior mediastinum. It is largest and most active in infancy and early childhood, during which time it secretes the hormones **thymosin** and **thympoietin** (thy-moh-poh-EE-tin). Both of these hormones

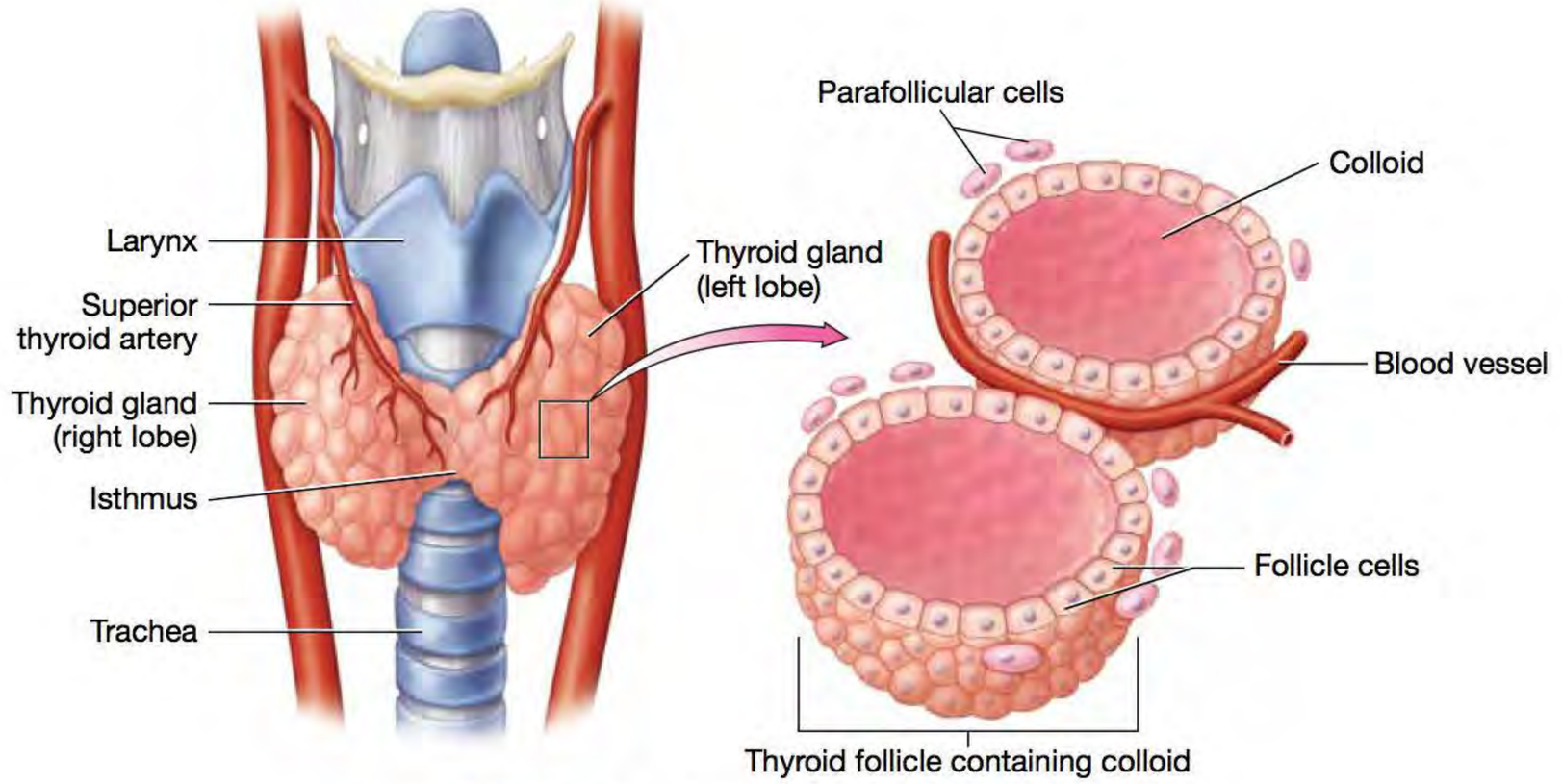


FIGURE **14.4** Thyroid gland and thyroid follicles.

stimulate the development of T lymphocytes within the thymus. In adults most of the thymic tissue is gradually replaced by fat and other connective tissue.

6. **Adrenal gland.** As the name implies, the **adrenal glands** sit atop the superior pole of each kidney (*ad-* = next to; *renal* = kidney). Like the pituitary gland, the adrenal gland is actually two separate glands (Figure 14.5).
   a. The superficial region consists of glandular tissue called the **adrenal cortex,** which secretes **steroid hormones** in response to stimulation by ACTH and other factors. The outermost zone of the adrenal cortex, the **zona glomerulosa** (glom-ehr-yoo-LOH-sah), secretes steroids called **mineralocorticoids** (min-er-al-oh-KORT-ih-koydz), such as **aldosterone** (al-DAHS-tur-ohn), that regulate fluid and electrolyte homeostasis. The middle zone of the adrenal cortex, the **zona fasciculata** (fah-SIK-yoo-lah-tah), secretes steroids called **glucocorticoids** (GLOO-koh-kort-ih-koydz), such as **cortisol,** that regulate the stress response, blood glucose, fluid homeostasis, and inflammation. The innermost zone, the **zona reticularis,** secretes glucocorticoids and steroids called **gonadocorticoids** that affect the gonads and other tissues.
   b. The deep region of the adrenal gland, called the **adrenal medulla** (meh-DOOL-uh), consists of modified postsynaptic sympathetic neurons that secrete **epinephrine** and **norepinephrine** in response to sympathetic stimulation.

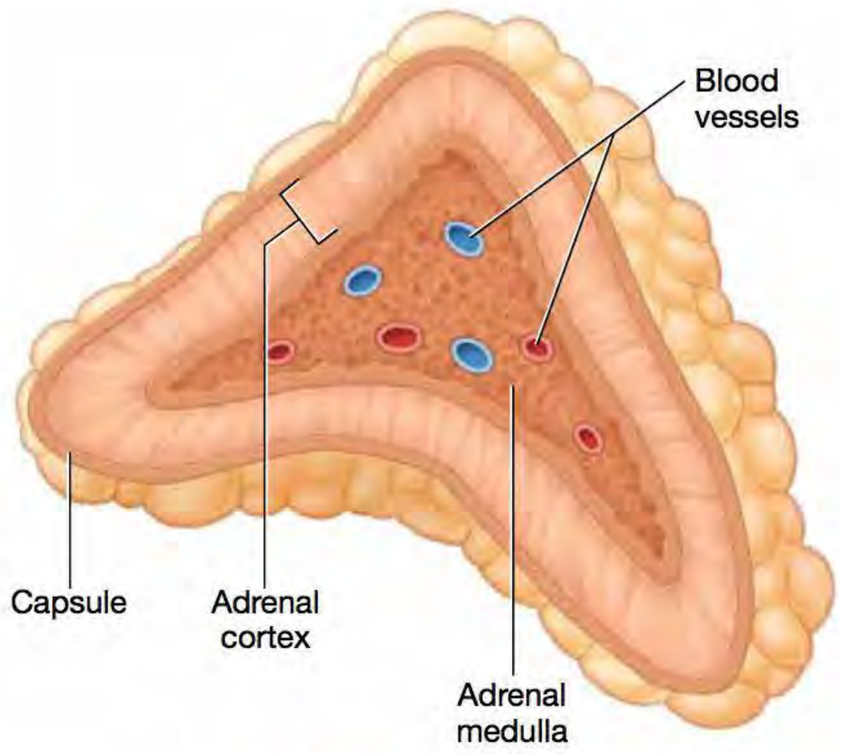


FIGURE **14.5** Adrenal gland.

7. **Pancreas.** The **pancreas** (PAYN-kree-iss) has both endocrine and exocrine functions. Its endocrine functions are carried out by cells in small, round "islands" called **pancreatic islets** (Figure 14.6). The cells within the pancreatic islets secrete the hormones **insulin** and **glucagon** (GLOO-kah-gawn), which play a major role in regulating blood glucose levels. Insulin triggers the uptake of glucose by cells, which decreases blood glucose, and glucagon triggers the release of stored glucose from the liver, which increases blood glucose. Note that glucagon and insulin are antagonists.

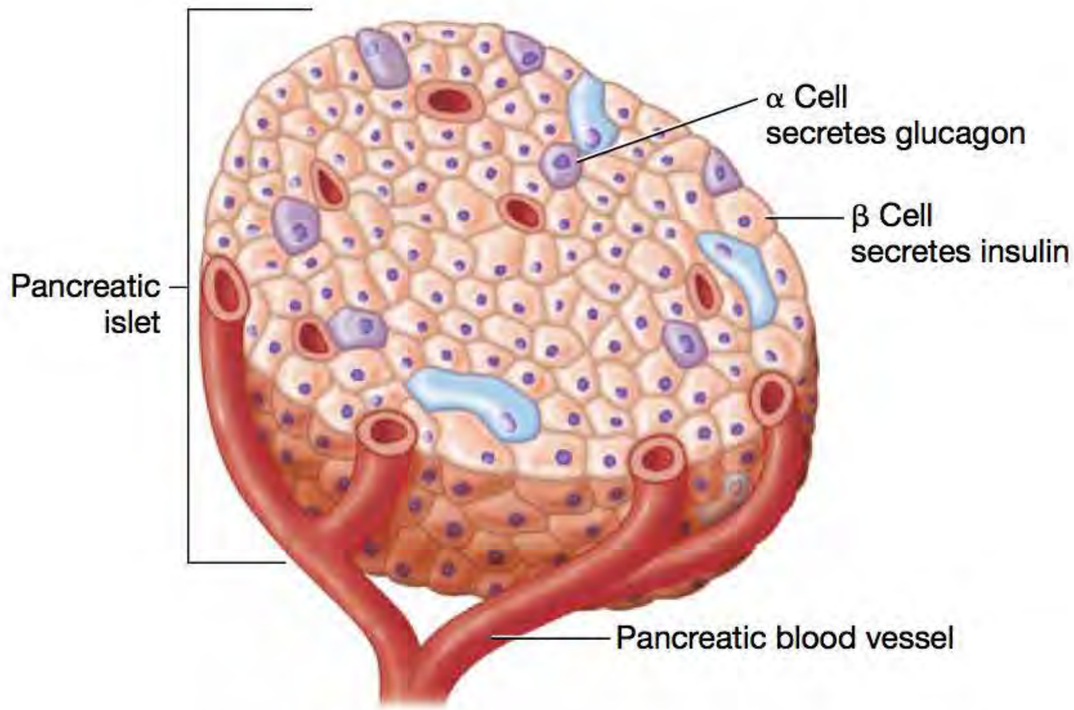
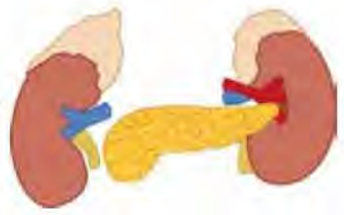


FIGURE **14.6** Pancreas and pancreatic islet.

8. **Testes.** The **testes** are the male reproductive organs that produce sperm cells, the male gametes. Cells within the testes called **interstitial cells** produce a steroid hormone called **testosterone.** This hormone promotes the production of sperm cells and the development of male secondary sex characteristics such as a deeper voice, greater bone and muscle mass, and facial hair.
9. **Ovaries.** The **ovaries** are the female reproductive organs that produce ooctyes, the female gametes. The ovaries produce steroid hormones called **estrogens** and **progesterone.** Estrogens play a role in the development of oocytes, female secondary sex characteristics such as breasts and subcutaneous fat stores, and a variety of other processes. Progesterone has a number of effects that prepare the body for pregnancy.

Let's now examine these structures on models and charts. Note that human torso models are typically a good place to start when studying the endocrine system, because most of the organs are easy to find. The one exception is the thymus; many torsos and models choose not to show this structure because it is fairly inactive in adults. Fetal models, however, typically show well-developed thymus glands.

Procedure 1 Model Inventory of the Endocrine System



Identify the following structures of the endocrine system on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 14.2. After you have completed this activity, answer Check Your Understanding questions 1 through 4 (pp. 365–366).

Endocrine Glands

1. Hypothalamus
   a. Infundibulum
2. Pituitary gland
   a. Anterior pituitary
   b. Posterior pituitary
3. Pineal gland
4. Thyroid gland
   a. Right and left lobes
   b. Isthmus
5. Parathyroid glands
6. Thymus gland
7. Adrenal glands
   a. Adrenal cortex
   b. Adrenal medulla
8. Pancreas
9. Ovaries
10. Testes

TABLE 14.2 Model Inventory for the Endocrine System

Model/Diagram	Structures Identified

Exercise 14-2

Endocrine Organ Histology

MATERIALS

- ❑ Thyroid gland slide
- ❑ Adrenal gland slide
- ❑ Pancreas slide
- ❑ Light microscope
- ❑ Colored pencils

In this exercise you will examine the histology of three endocrine organs: the thyroid gland, the adrenal gland, and the pancreas. (We will examine the ovary and testis in the last unit.) Following are keys to identification of each tissue:

1. **Thyroid gland.** Thyroid follicles are perhaps one of the easiest structures to identify (Figure 14.7). Look for a ring of simple cuboidal epithelium surrounding the reddish-brown, acellular colloid. Note that in between the follicles, you can see large parafollicular cells.
2. **Adrenal gland.** The zones of the adrenal cortex each appear differently and so are fairly easy to tell apart on a slide. Notice in Figure 14.8 that the cells in the thin outer *zona glomerulosa* are arranged in clusters, whereas the cells in the thick middle *zona fasciculata* are stacked on top of one another and resemble columns. Finally, the cells of the thin inner *zona reticularis* stain more darkly and are tightly packed. The innermost adrenal medulla is distinguished from the zones of the cortex by its numerous, loosely arranged blood vessels. The regions of the adrenal gland are best viewed on low or medium power. Switch to high power to get more detail of the individual cells.
3. **Pancreas.** There are two main groups of cells in the pancreas: (1) the pancreatic islets, and (2) the exocrine, enzyme-secreting *acinar cells*. Most of the pancreas is composed of acinar cells; however, note the small "islands" of tissue in Figure 14.9. These islands are, of course, the insulin- and glucagon-secreting pancreatic islets. Typically, the islets are lighter in color than the surrounding acinar cells. On high power, the differences between the two tissues are easily seen: The acinar cells are slightly cuboidal and are arranged around a duct, whereas the islet cells have no distinctive arrangement (there also may be larger, stain-free spaces between the islet cells).

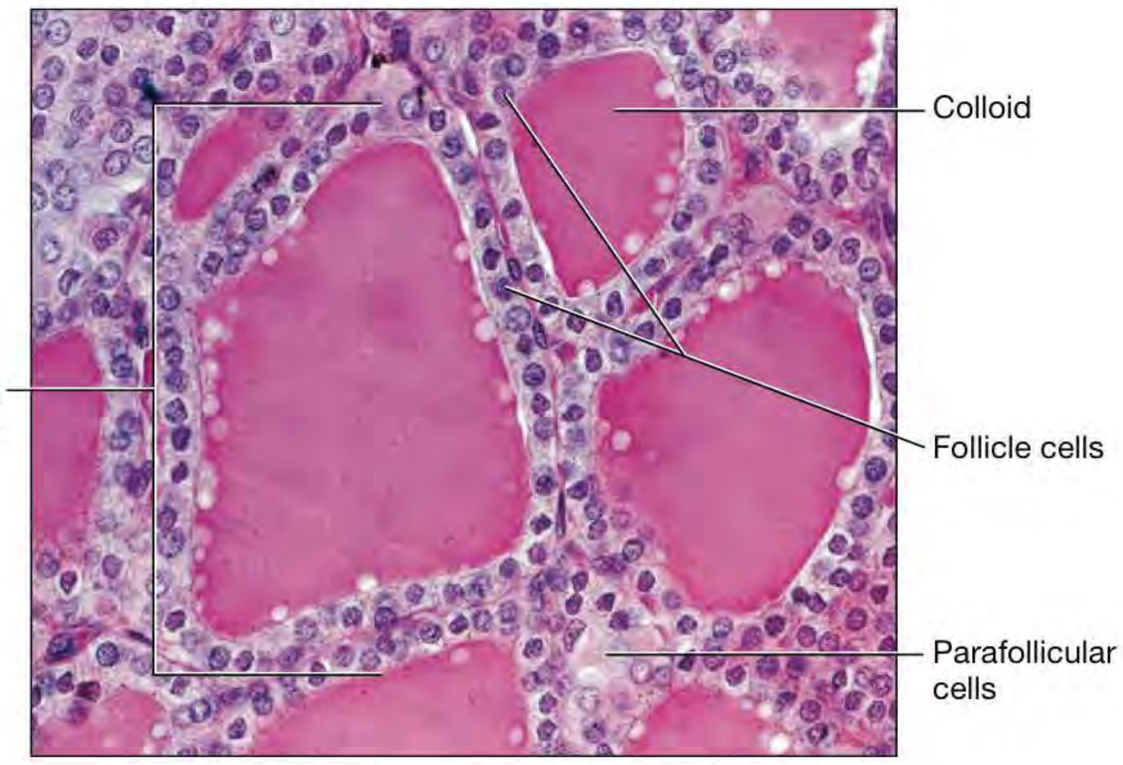


FIGURE **14.7** Thyroid gland, photomicrograph.

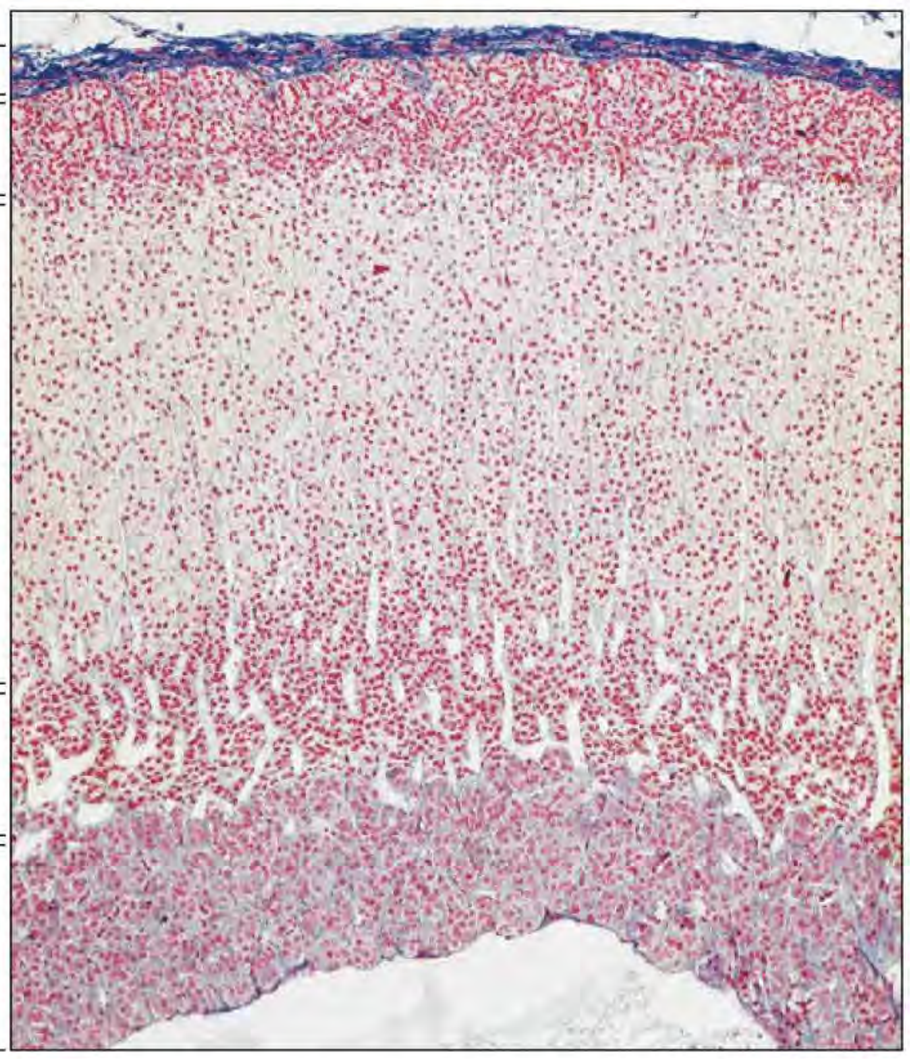


FIGURE **14.8** Zones of the adrenal gland, photomicrograph.

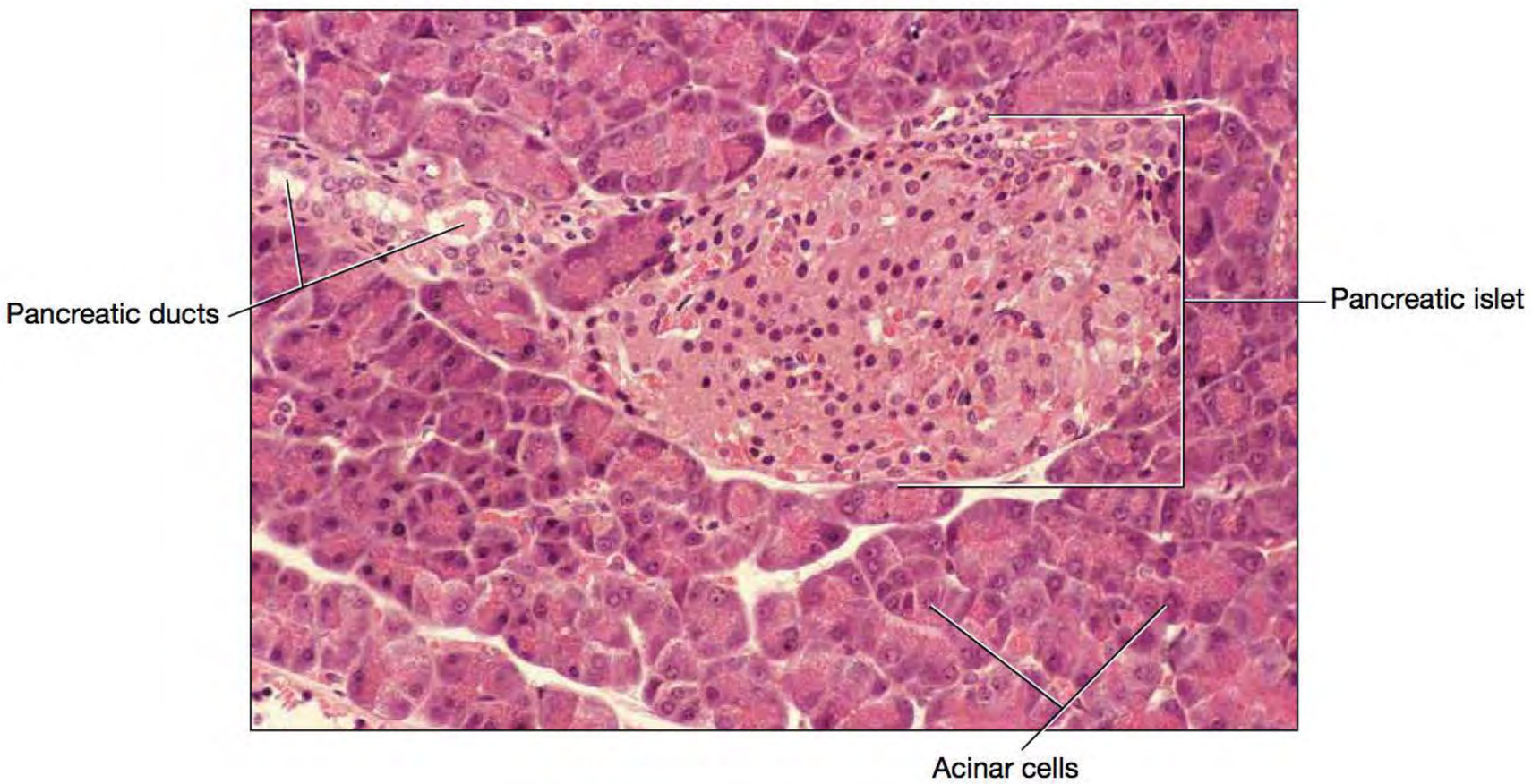


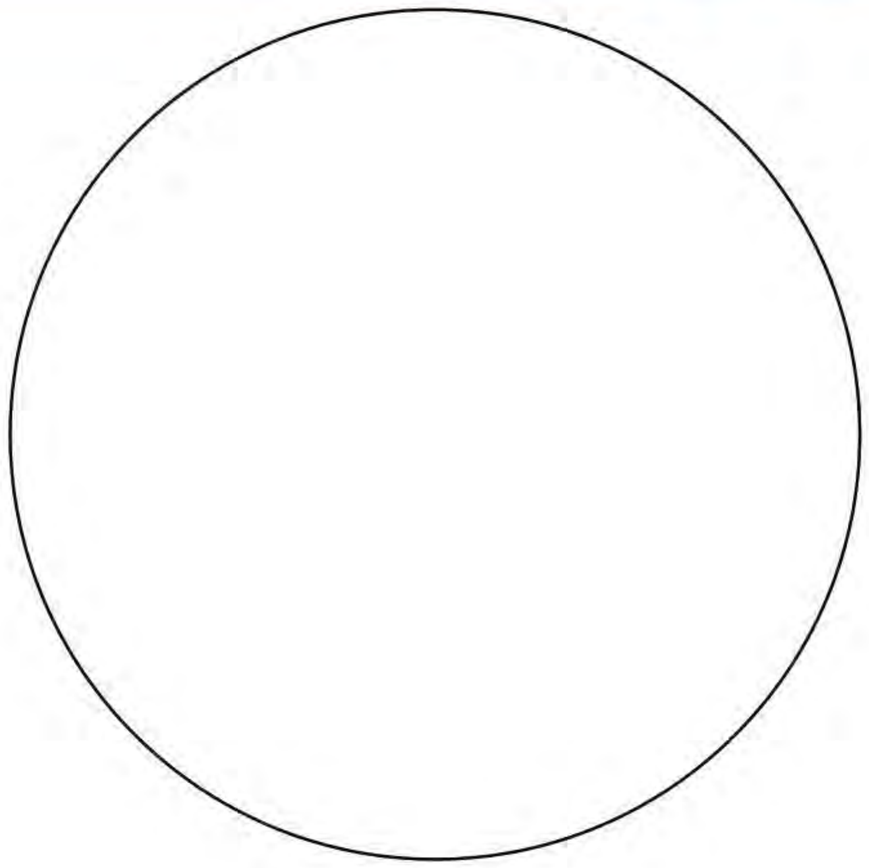
FIGURE **14.9** Pancreas, photomicrograph.

Procedure 1 Microscopy

Obtain prepared slides of the thyroid gland, the adrenal gland, and the pancreas. Place each slide on the stage of the microscope, and scan it on low power. Advance to higher power to see the cells and associated structures in greater detail. Use your colored pencils to draw what you see in the field of view, and label your drawing with the terms indicated.

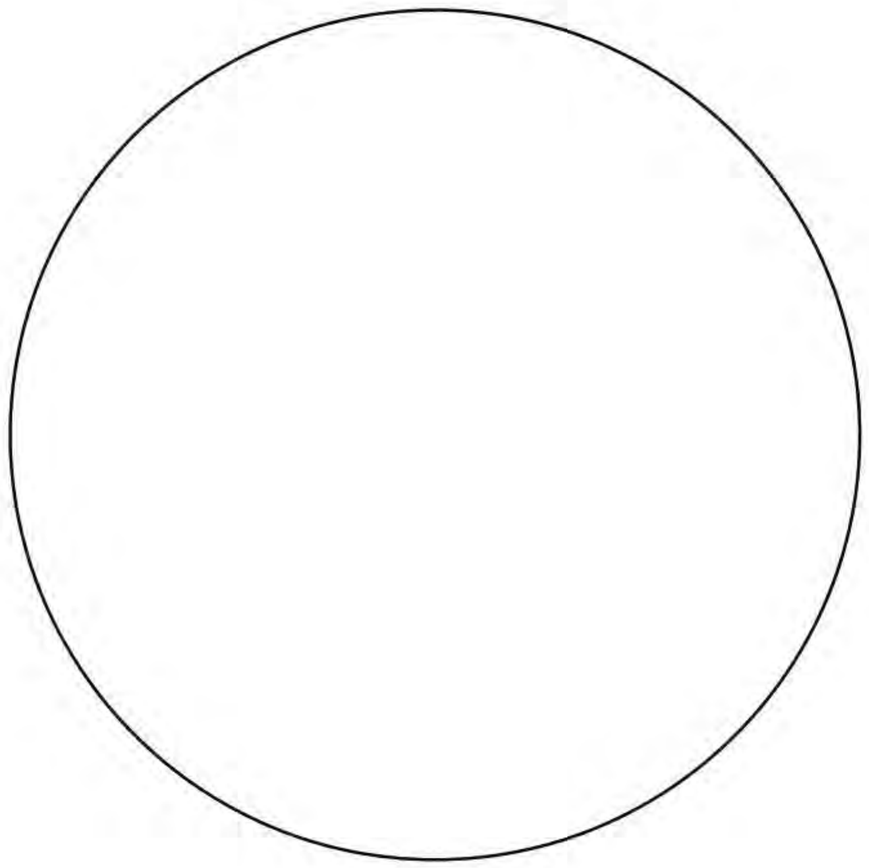
Thyroid

1. Follicle cells
2. Colloid
3. Parafollicular cells



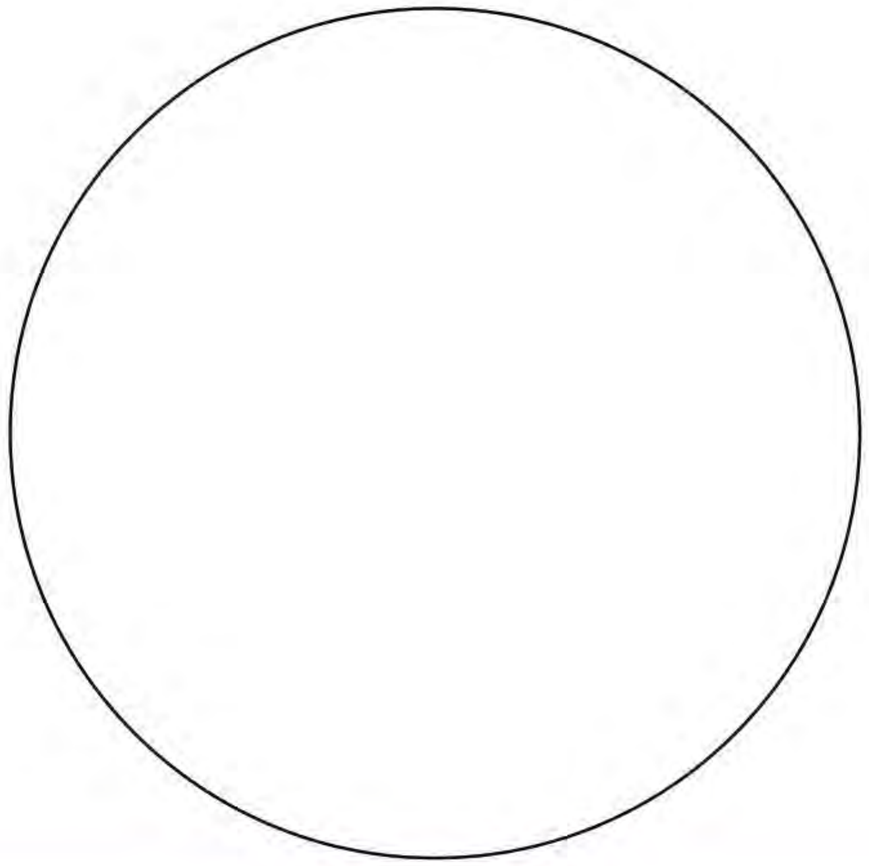
Adrenal Gland

1. Zones of the adrenal cortex:
   a. Zona glomerulosa
   b. Zona fasciculata
   c. Zona reticularis
2. Adrenal medulla



Pancreas

1. Acinar cells (exocrine portion)
2. Pancreatic islets (endocrine portion)



Exercise 14-3

Time to Trace: Negative Feedback Loops

Earlier in this unit we pointed out that each hormone has its own stimulus for secretion. The stimulus for secretion is generally a disturbance of homeostasis such as a change in body temperature, a change in the concentration of blood glucose or electrolytes, or a stressor. The hormone's response is to act on distant target cells to cause changes that restore homeostasis. When homeostasis is restored, the activity of the glands and concentration of the hormone declines. This type of response is called a **negative feedback loop**.

In this exercise you will be tracing a hormone's negative feedback loop from the initial homeostatic disturbance through the hormone's effects on its target cells to restore homeostasis, and finally the decline of the concentration of the hormone in the blood. Following is an example:

Start: The level of glucose in the blood falls → the pancreas releases glucagon → the level of glucagon in the blood rises → glucagon causes glycogenolysis by the liver → the level of glucose in the blood rises → the level of glucagon in the blood declines → **End**

Now it's your turn! Note that sometimes the effects of the hormones cross over, so I've given you a hint at the start of each negative feedback loop as well as the general number of steps in each loop. After you have completed the activity, answer Check Your Understanding question 5 (p. 366).

1 **Start:** the concentration of the blood increases (i.e., there is *inadequate water* in the blood) → the hypothalamus releases _____ and stores it in the _____ → the level of _____ in the blood rises → _____ increases _____ → the concentration of the blood _____ → the level _____ of in the blood decreases → **End**

2 **Start:** blood glucose increases → the pancreas releases _____ → the level of _____ in the blood rises → _____ causes _____ → blood glucose levels _____ → the level of _____ in the blood decreases → **End**

3 **Start:** blood calcium ion concentration decreases → the parathyroid glands release _____ → the level of _____ in the blood rises → _____ causes _____ → the concentration of calcium ions in the blood _____ → the level of _____ in the blood decreases → **End**

Exercise 14-4

Endocrine "Mystery Cases"

In this exercise you will be playing the role of "endocrine detective" to solve endocrine disease mysteries. In each case you will have a victim who has suddenly fallen ill with a mysterious malady. You will be presented a set of "witnesses," each of whom will give you a clue as to the nature of the illness. Other clues will come from samples you send off to the lab for analysis. You will solve the mystery by providing the victim a diagnosis. You may wish to use your textbook for assistance with these cases. When you have completed the cases, answer Check Your Understanding question 6 (p. 366).

Case 1: The Cold Colonel

You are called upon to visit the ailing Col. Lemon. Before you see him, you speak with three witnesses who were with him when he fell ill.

Witness statements:

- *Ms. Magenta*: "Col. Lemon has been hot-blooded for as long as I've known him. But I noticed that he couldn't seem to keep warm. He kept complaining about being cold. . . ."
- *Mr. Olive*: "Just between you and me, I've noticed that the old chap has put on quite a bit of weight lately."
- *Professor Purple:* "The colonel and I used to go on major expeditions together. Now he just doesn't seem to have the energy to do much of anything."

What are your initial thoughts about the witnesses' statements? Does one hormone come to mind that may be the cause? Explain.

You see the colonel and collect some blood to send off to the lab. The analysis comes back as follows:

T3 (triiodothyronine): 0.03 ng/dl (normal: 0.2–0.5 ng/dl)

T4 (thyroxine): 1.1 µg/dl (normal: 4–7 µg/dl)

TSH (thyroid-stimulating hormone): 86 mU/l (normal: 0.3–4.0 mU/l)

Analyze the results. Why do you think the T3 and T4 are low and the TSH is elevated?

Based upon the witness statements and the laboratory analysis, what is your final diagnosis? Explain Col. Lemon's symptoms.

Case 2: The Parched Professor

Your last call is to the aid of Professor Purple. Three witnesses are present from whom to take statements.

Witness statements:

- *Mr. Olive*: "I swear that I saw him drink a full glass of water every half an hour today. He kept saying how thirsty he was!"
- *Mrs. Blanc*: "He must be going to the . . . well, you know, the little boys' room, two or three times every hour!"
- *Ms. Feather*: "He's been saying lately that his mouth is dry and that he feels weak. Personally, I think he's just not following a healthy diet! He should be drinking some of my herbal teas!"

Based upon the witnesses' statements, what are your initial thoughts? Does one hormone come to mind that could produce these effects? Explain.

You interview Professor Purple and collect blood and urine specimens to be sent off to the lab for analysis. The lab reports that the urine osmolality is 150 mOsm/kg, which means the urine is overly dilute (too *much* water in the urine). The blood osmolality is 300 mOsm/kg, meaning the blood is overly concentrated (too *little* water in the blood). The lab also reports that his blood glucose is completely *normal*. What is the significance of these clues?

Based upon the witness statements and the laboratory analysis, what is your final diagnosis? (*Hint:* Think of the hormone that is supposed to trigger water retention from the kidneys. Is there a disease where this hormone is deficient?) Explain Prof. Purple's symptoms.

Name _____

Section _____ Date _____

UNIT 14 REVIEW

Check Your Recall

1 Label Figure 14.10 with the terms below.

- ❑ Adrenal cortex
- ❑ Anterior medulla
- ❑ Anterior pituitary
- ❑ Hypothalamus
- ❑ Ovary
- ❑ Pancreas
- ❑ Pancreatic islet
- ❑ Parathyroid glands
- ❑ Posterior pituitary
- ❑ Testis
- ❑ Thyroid gland

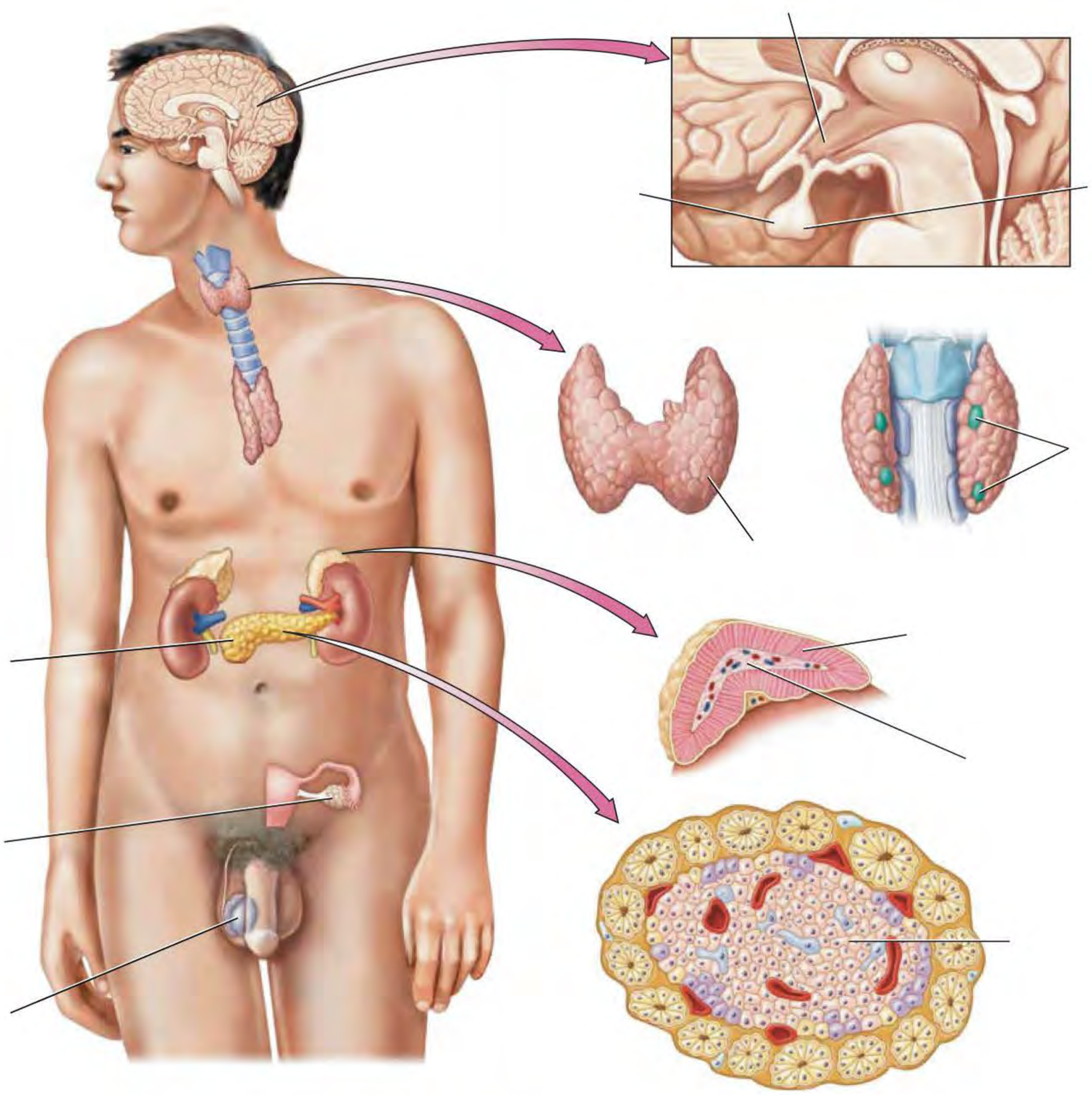


FIGURE **14.10** Endocrine system.

2 ***Fill in the blanks:*** **The nervous system works through secretion of _____, whereas the endocrine system works via secretion of _____.**

3 **Which of the following is not a function of the hypothalamus?**

a. Produces antidiuretic hormone and oxytocin
b. Stimulates production and release of hormones from the anterior pituitary
c. Stimulates production and release of hormones from the posterior pituitary
d. Inhibits the production and release of hormones from the anterior pituitary

4 **Which of the following endocrine organs are part of the diencephalon?**

a. Hypothalamus
b. Pineal gland
c. Thymus
d. Both a and b are correct.
e. Both b and c are correct.

5 Label Figure 14.11 with the terms below.

- ❑ Isthmus
- ❑ Thyroid follicle
- ❑ Follicle cells
- ❑ Parafollicular cells
- ❑ Colloid
- ❑ Right lobe of thyroid gland
- ❑ Left lobe of thyroid gland

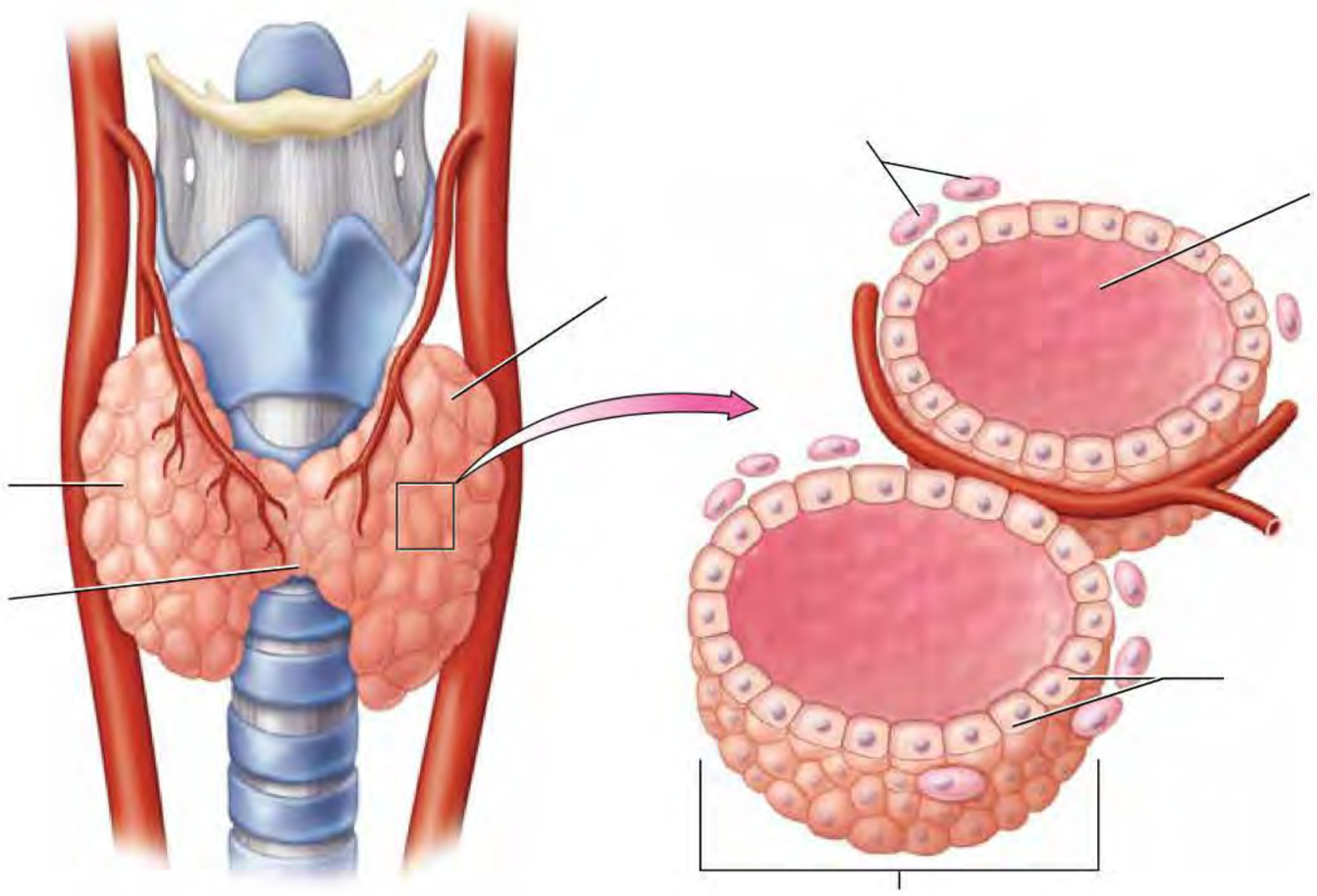


FIGURE **14.11** Thyroid gland.

Name _____

Section _____ Date _____

6 Label Figure 14.12 with the terms below.

- ❑ Adrenal medulla
- ❑ Adrenal cortex
- ❑ Adrenal capsule

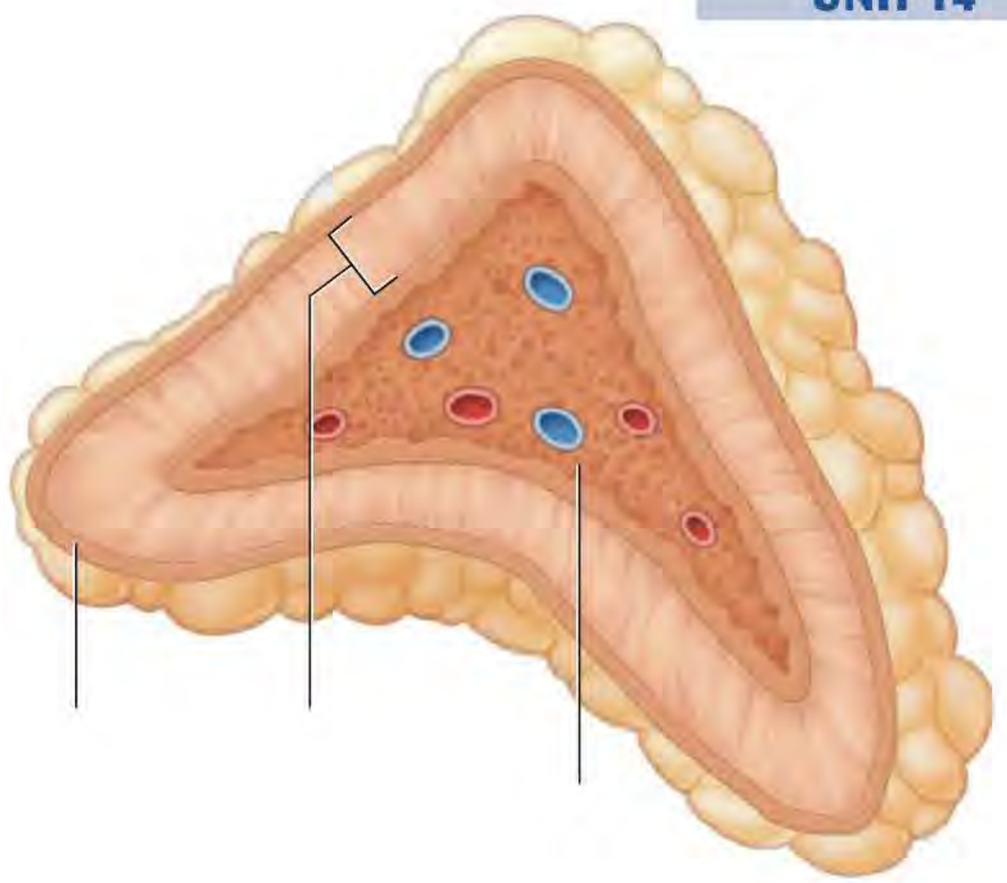


FIGURE **14.12** Adrenal gland.

7 **Which of the following sets of hormones are antagonists?**

a. T3 and T4
b. Calcitonin and parathyroid hormone
c. Epinephrine and cortisol
d. Growth hormone and thyroxine

8 ***Matching:*** **Match the following endocrine organs with the hormone(s) each secretes.**

_____ Pineal gland
_____ Thyroid gland
_____ Pancreas
_____ Thymus
_____ Parathyroid glands
_____ Adrenal cortex
_____ Anterior pituitary
_____ Adrenal medulla

A. Parathyroid hormone
B. Insulin and glucagon
C. Steroid hormones
D. Epinephrine and norepinephrine
E. Thyroxine, triiodothyronine, and calcitonin
F. Thyroid-stimulating hormone, growth hormone
G. Melatonin
H. Thymosin and thymopoietin

9 **Which of the following is not true regarding endocrine organ histology?**

a. The thyroid gland consists of rings of simple cuboidal follicle cells surrounding colloid.
b. The pancreas has an exocrine portion consisting of pancreatic islets and an endocrine portion consisting of acinar cells.
c. The adrenal cortex has three zones of cells that secrete three different types of hormones.
d. The adrenal medulla is modified nervous tissue of the sympathetic nervous system.

10 What is a negative feedback loop? Describe an example of a negative feedback loop in the endocrine system.

Name _____

Section _____ Date _____

UNIT 14 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 How does the way in which the hypothalamus communicates with the anterior and posterior pituitary glands differ? How does this reflect the functional differences of the anterior and posterior pituitary glands?

2 Tumors of the parathyroid gland often result in secretion of excess parathyroid hormone. Considering the function of this hormone, predict the effects of such a tumor.

3 The hormone calcitonin is prescribed to treat the disease *osteoporosis*. Explain why this hormone would help to reduce bone loss in patients affected with this disease.

4 The disease *diabetes mellitus*, type I, is characterized by destruction of the cells that produce insulin in the pancreatic islets. How would this affect the level of glucose in the blood? Why?

5 In the condition hyperthyroidism, patients have elevated levels of both T3 and T4 due to a malfunction of the immune system that causes the thyroid gland to overproduce thyroid hormones. Do you think the negative feedback loops would lead to high levels of TSH or low levels of TSH? Explain.

6 In case 2, we saw that Professor Purple had insufficient antidiuretic hormone (ADH). However, the opposite condition can also occur in which excess ADH is present, called *syndrome of inappropriate ADH secretion*. Predict the symptoms of this condition.

Cardiovascular System
Part I: The Heart

15

OBJECTIVES

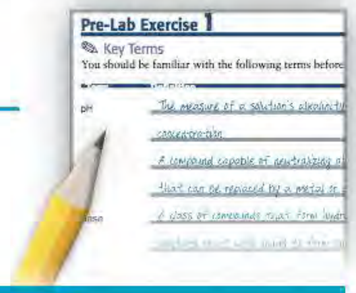
Once you have completed this unit, you should be able to:

1. Identify structures of the heart.
2. Trace the pathway of blood flow through the heart.
3. Describe the histology of cardiac tissue.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 15-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Layers of the Heart Wall

Fibrous pericardium _____

Pericardial cavity _____

Myocardium _____

Endocardium _____

Structures of the Heart

Atria (right and left) _____

Ventricles (right and left) _____

Tricuspid valve _____

Mitral (bicuspid) valve _____

Pulmonary valve _____

Aortic valve _____

Chordae tendineae _____

Papillary muscles _____

Name _____ Section _____ Date _____

Great Vessels

Superior vena cava _____

_____

Inferior vena cava _____

_____

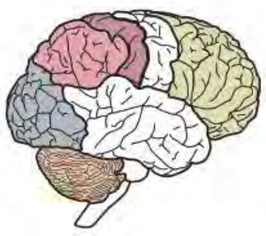
Pulmonary trunk _____

_____

Pulmonary veins _____

_____

Aorta _____



Pre-Lab Exercise 15-2

Anatomy of the Thoracic Cavity

Label and color the structures in the thoracic cavity in Figure 15.1 with the terms from Exercise 15-1 (p. 373). Use your text and Exercise 15-1 in this unit for reference.

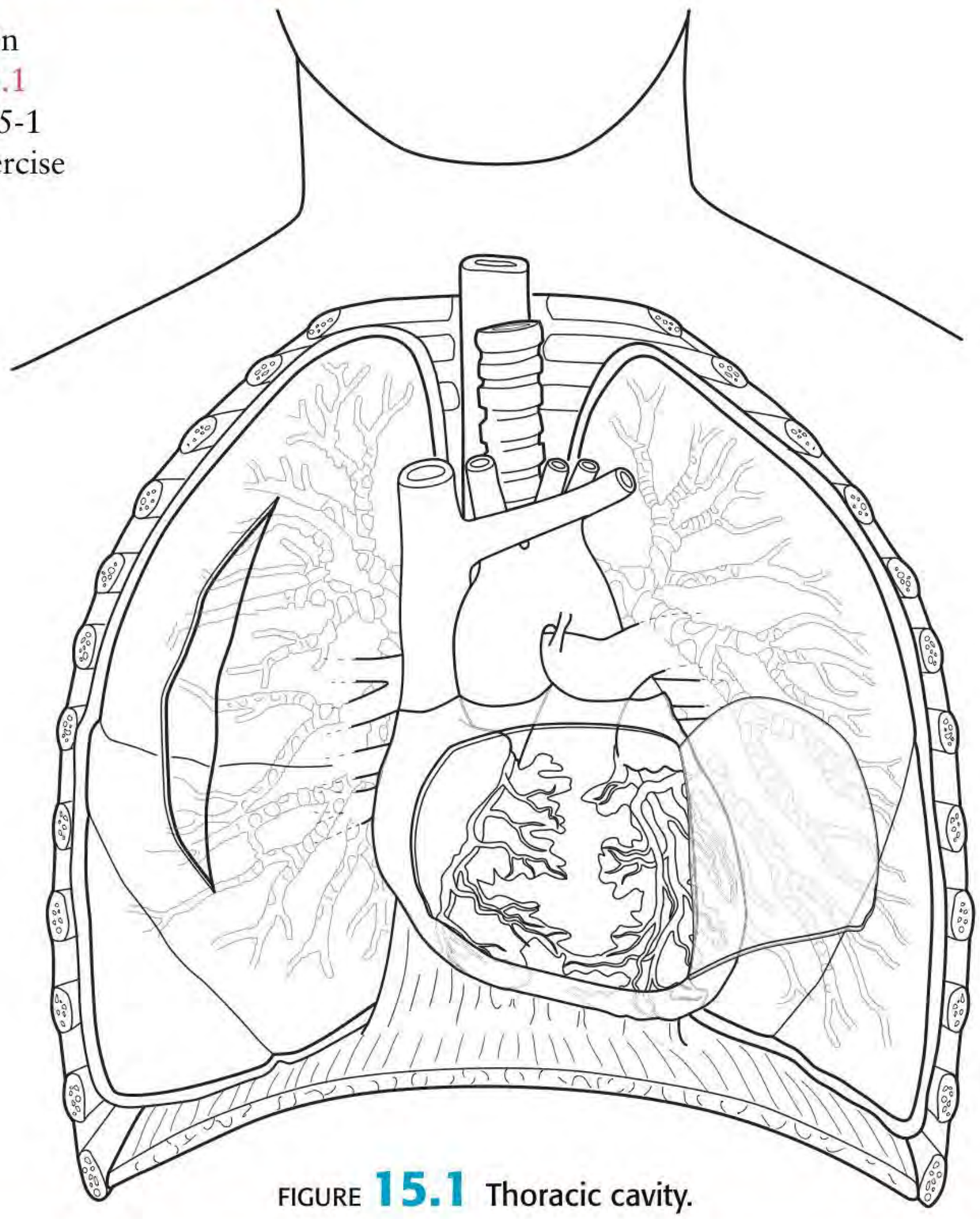
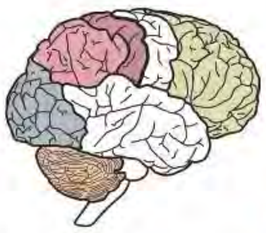


FIGURE **15.1** Thoracic cavity.

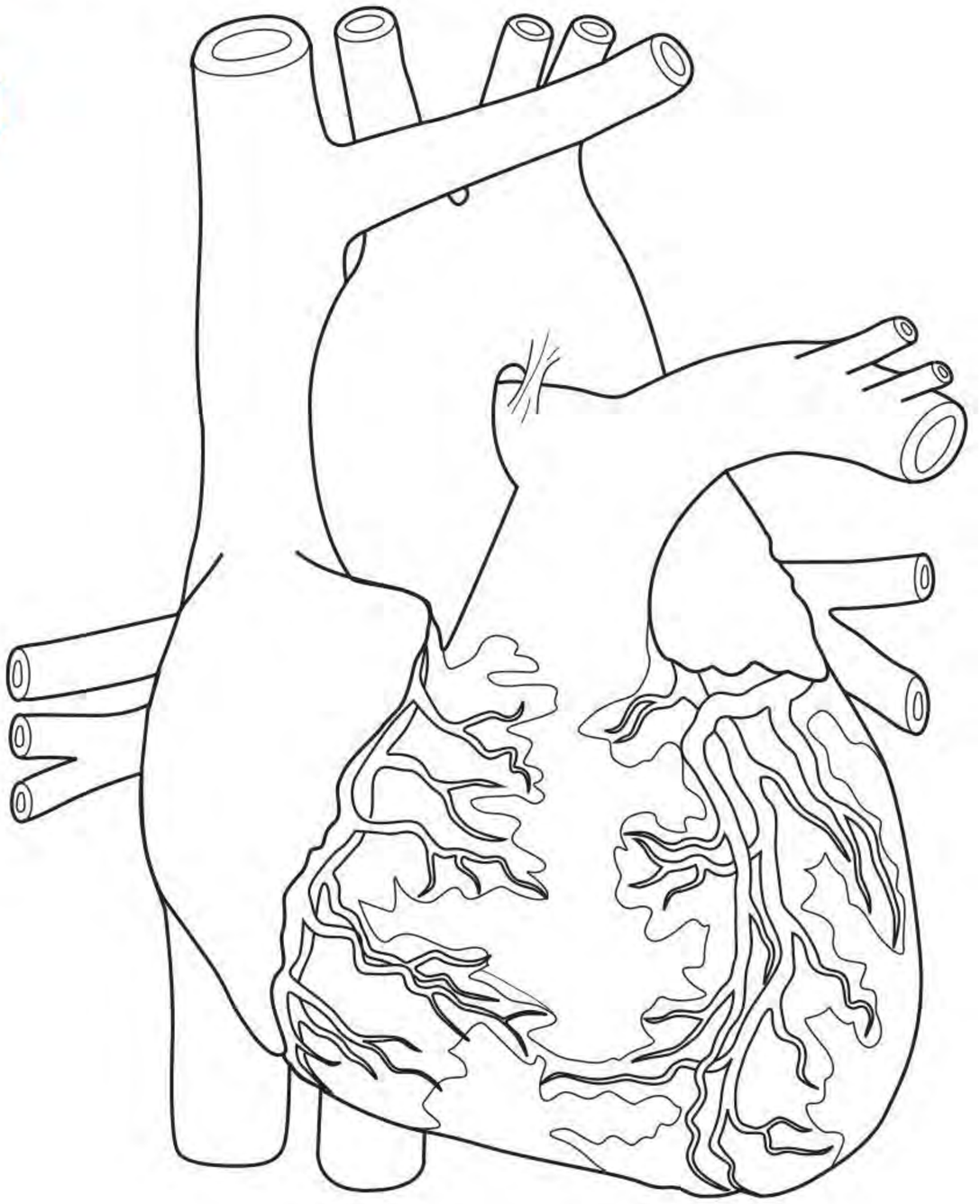


Pre-Lab Exercise 15-3

Anatomy of the Heart

Label and color the three views of the heart in Figure 15.2 with the terms from Exercise 15-1 (p. 373). Use your text and Exercise 15-1 in this unit for reference.

A



B

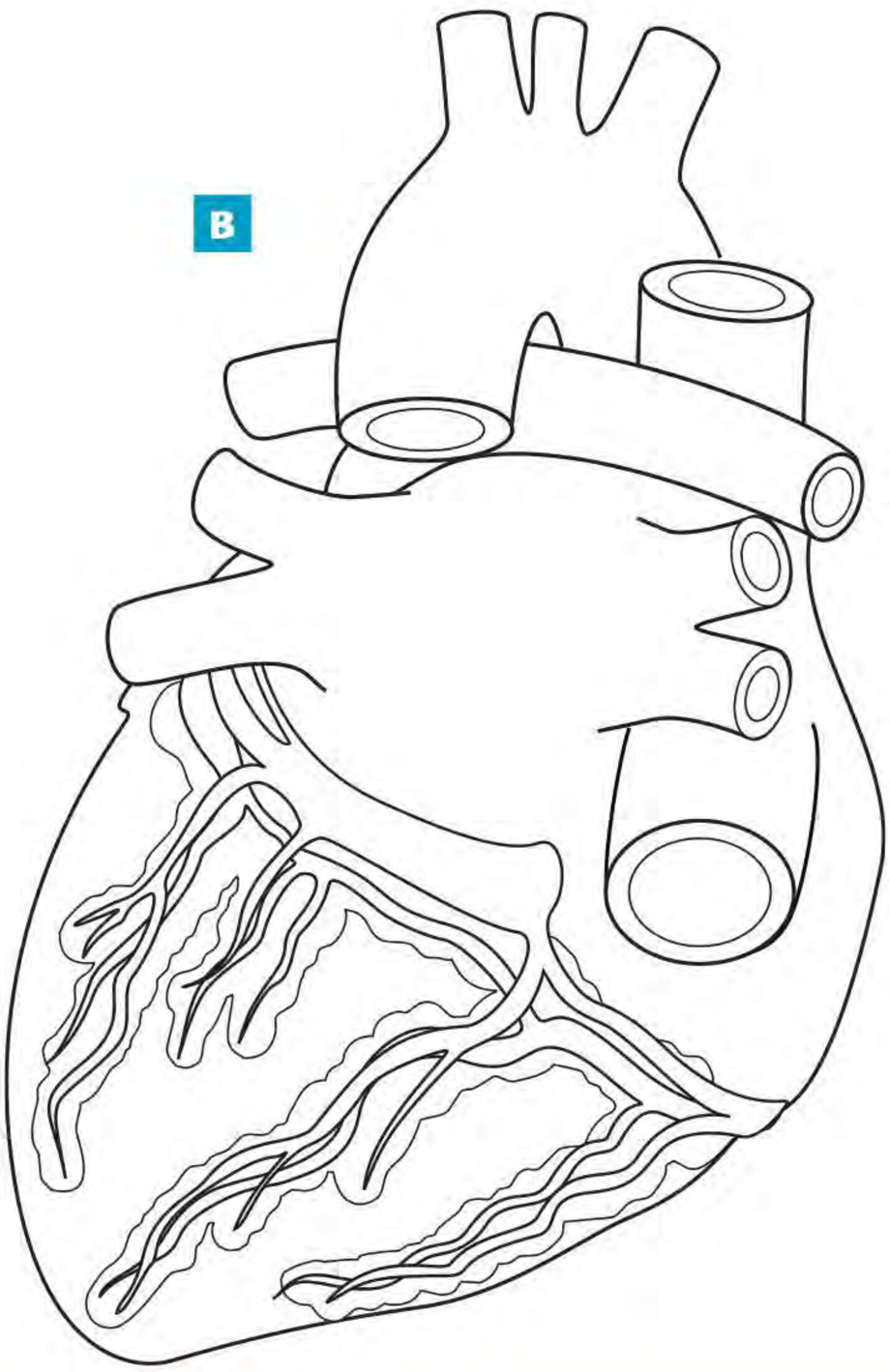


FIGURE **15.2** Heart:
(**A**) anterior view;
(**B**) posterior view
(continues)

Name _____ Section _____ Date _____

C

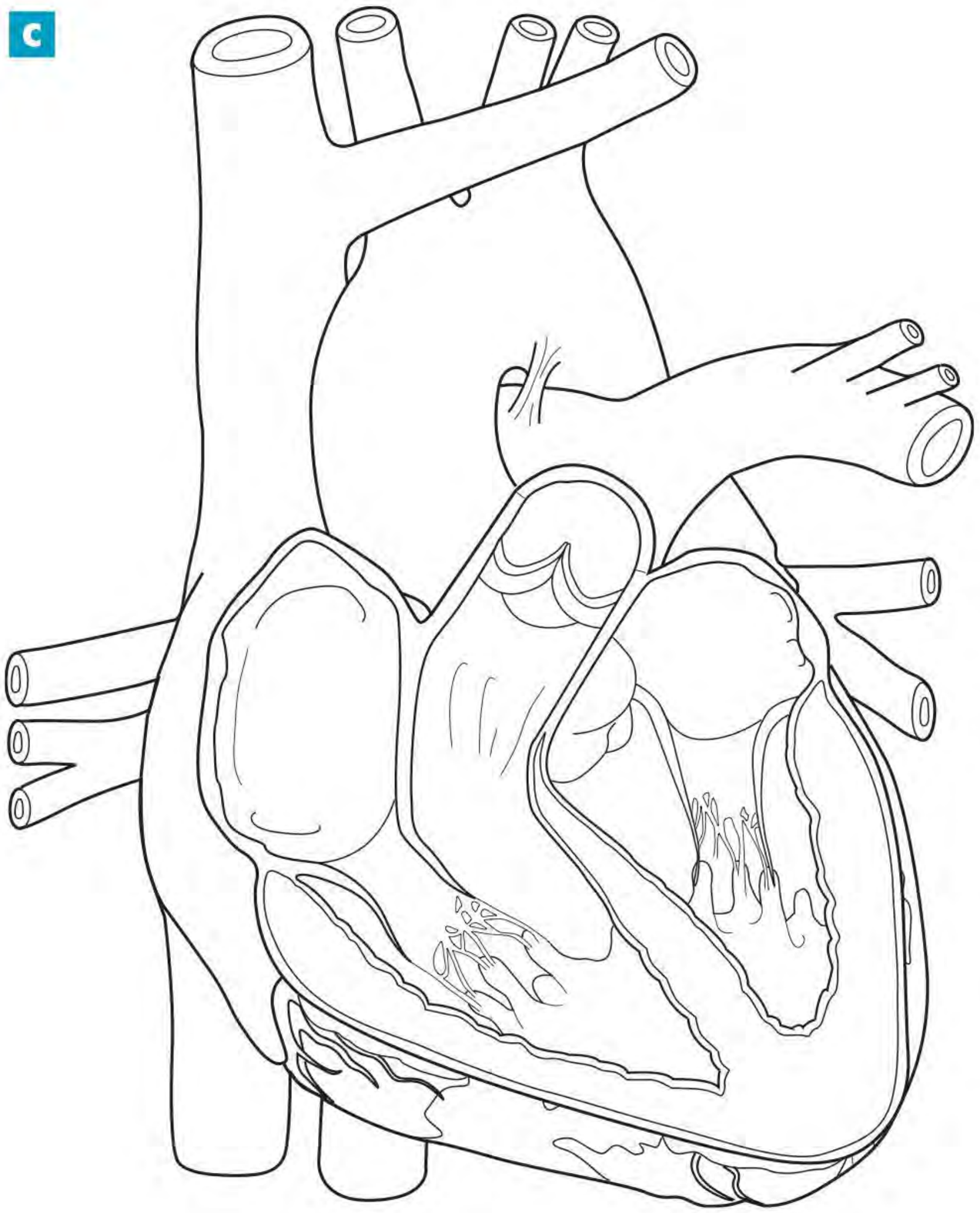


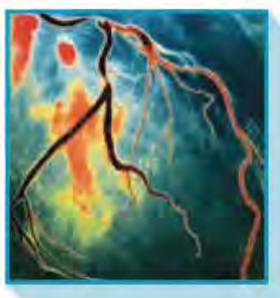
FIGURE **15.2** Heart *(cont.)*: (C) frontal section.

Pre-Lab Exercise 15-4

Pathway of Blood Flow through the Heart

Answer the following questions about the pathway of blood flow through the heart. Use your textbook and Exercise 15-1 (p. 373) in this unit for reference.

1. Regarding veins:
   a. Where do veins carry blood? _____
   b. Is this blood generally oxygenated or deoxygenated? _____
   c. Does this rule have any exceptions? If yes, where? _____
2. Regarding arteries:
   a. Where do arteries carry blood? _____
   b. Is this blood generally oxygenated or deoxygenated? _____
   c. Does this rule have any exceptions? If yes, where? _____
3. Where does each atrium pump blood when it contracts?
   a. Right atrium: _____
   b. Left atrium: _____
4. Where does each ventricle pump blood when it contracts?
   a. Right ventricle: _____
   b. Left ventricle: _____



EXERCISES

The **cardiovascular system** transports oxygen, nutrients, wastes, other solutes, and cells throughout the body. In this unit we begin our exploration of the cardiovascular system with the pump that drives it—the heart. The heart is a remarkable organ, tirelessly beating more than 100,000 times per day to pump more than 8,000 liters of blood around the body. In this unit we examine the anatomy of this remarkable organ, including the blood flow through the heart and the histology of cardiac muscle.

Exercise 15-1

Anatomy of the Heart

MATERIALS

- ❑ Heart models
- ❑ Preserved heart
- ❑ Dissection equipment
- ❑ Dissection tray
- ❑ Blue and red water-soluble marking pens
- ❑ Laminated outline of the heart and lungs
- ❑ Colored pencils

The heart is located in the mediastinum and is on average about the size of a fist (Figure 15.3). Its **apex** is its pointy inferior tip, and its **base** is its flattened posterior side. As you can see in Figure 15.4, the heart is surrounded by a double-layered membrane called the **pericardium** (pehr-ee-KAR-dee-um). The outermost layer of the pericardium, called the **fibrous pericardium**, anchors the heart to surrounding structures. It is made of dense irregular collagenous connective tissue that is not very distensible, which helps to prevent the heart from overfilling. The inner layer, called the **serous pericardium**, is itself composed of two layers. The outer portion, called the **parietal pericardium**, is functionally fused to the fibrous pericardium. The parietal pericardium folds over on itself to attach to the heart muscle and form the inner portion called the **visceral pericardium**, also known as the **epicardium**. Between the parietal and visceral layers we find a thin layer of serous fluid that occupies a narrow potential space called the **pericardial cavity**. The fluid within the pericardial cavity helps the heart to beat without friction.

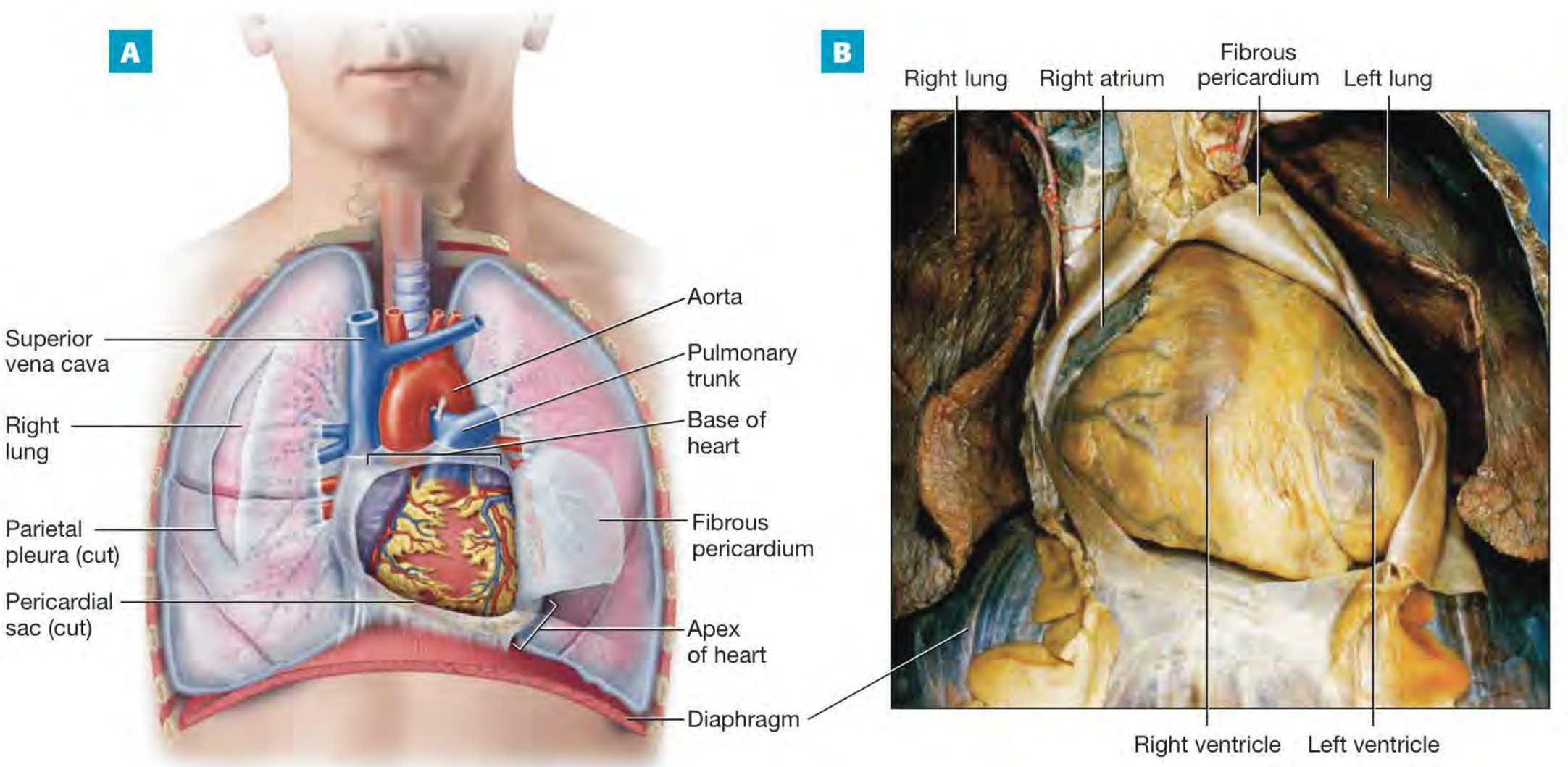


FIGURE **15.3** Thoracic cavity: (**A**) illustration; (**B**) photograph.

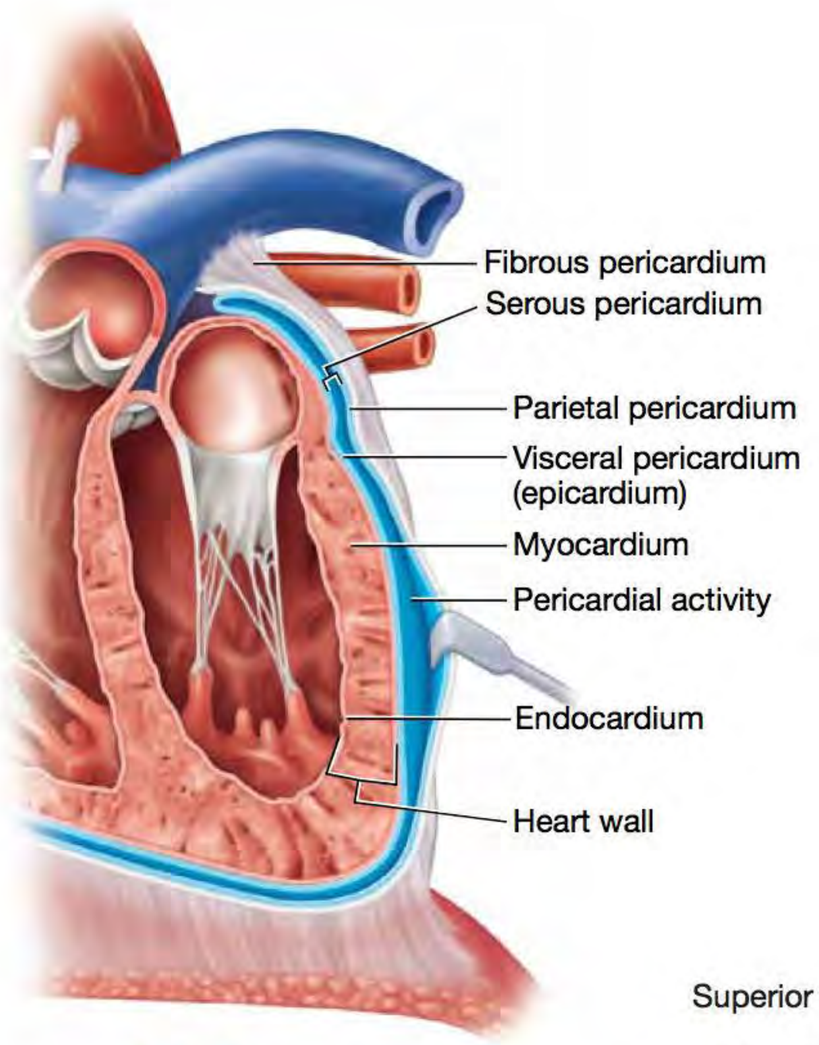
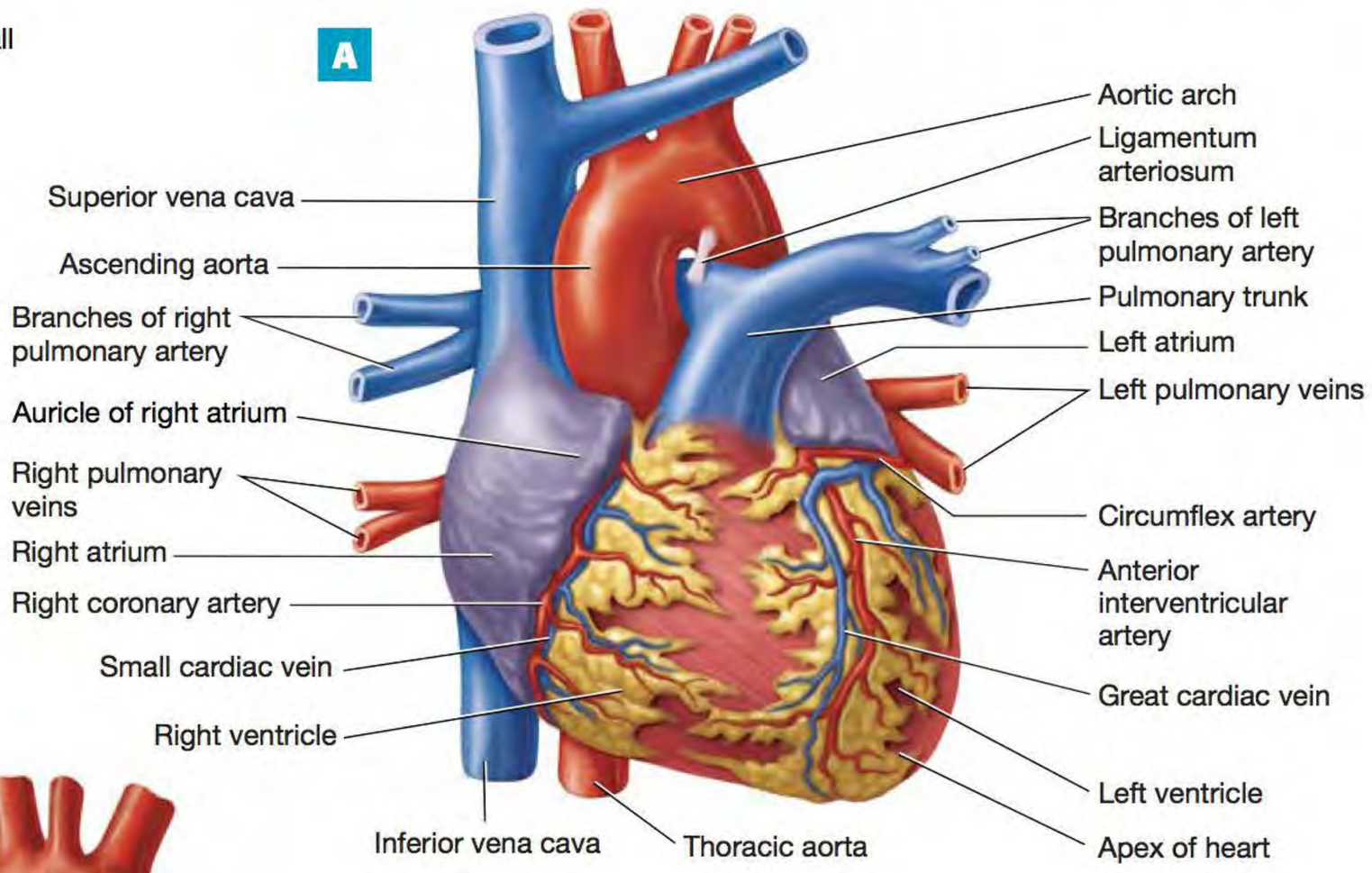


FIGURE **15.4** Layers of the heart wall.

The heart itself is an organ that consists of three tissue layers:

1. **Epicardium.** The **epicardium** (ep-ee-CAR-dee-um) or visceral pericardium is considered the outermost layer of the heart wall. It consists of a layer of epithelial tissue and loose connective tissue.
2. **Myocardium.** The middle **myocardium** (MY-oh-kar-dee-um) is the actual muscle of the heart. It consists of cardiac muscle tissue and its fibrous skeleton.
3. **Endocardium.** The innermost **endocardium** is a type of simple squamous epithelium called **endothelium.** It is continuous with the endothelium lining all blood vessels in the body.

Let's look now at the external anatomy of the heart, shown in Figure 15.5. The heart is composed of four chambers—the small, superior *right* and *left atria* and the larger, inferior *right* and *left ventricles*.



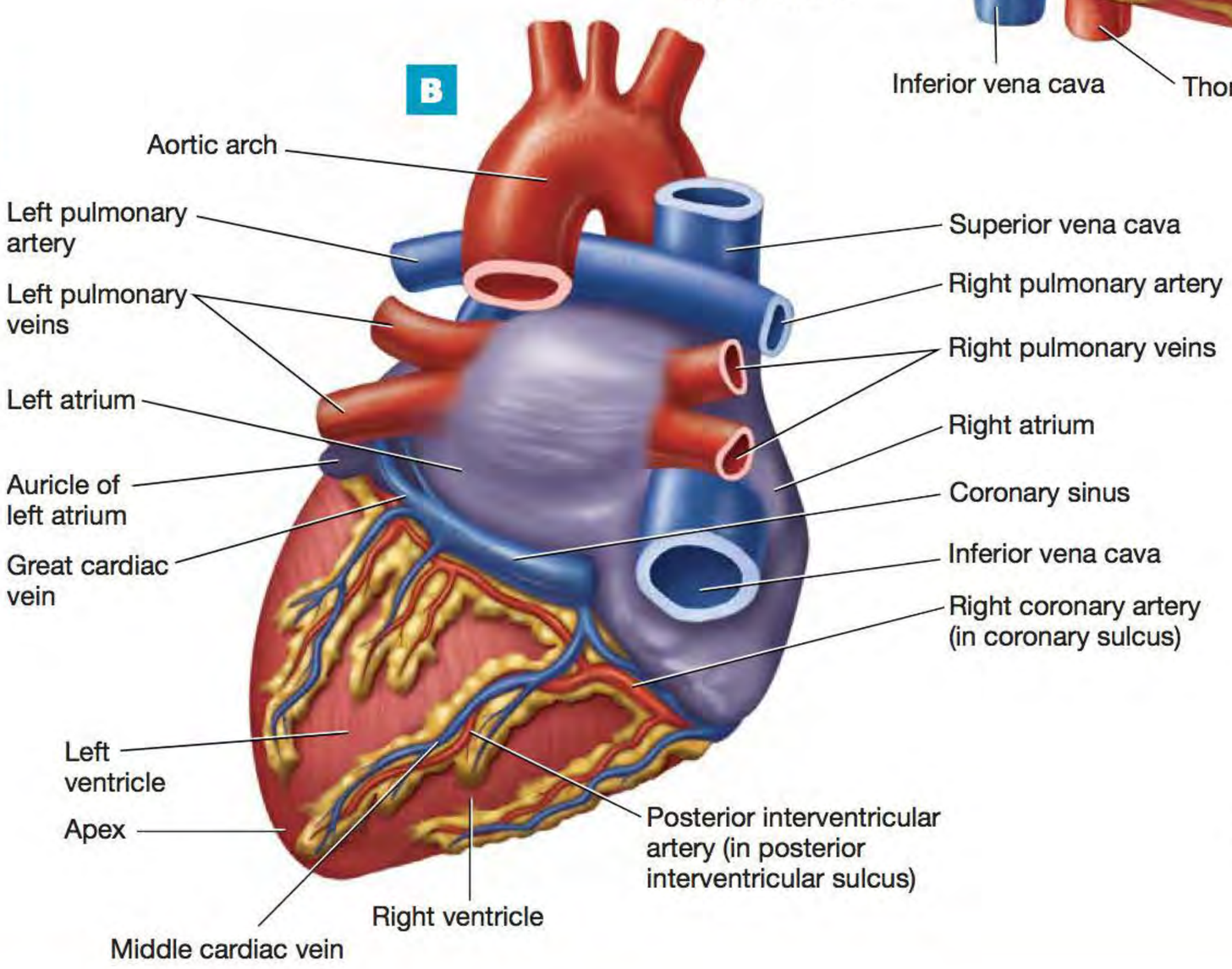


FIGURE **15.5** Heart: (**A**) anterior view; (**B**) posterior view.

The atria receive blood from the body's largest veins, and the ventricles eject blood into the body's largest arteries. These large blood vessels are known as the **great vessels**, and they include the following:

1. **Superior and inferior venae cavae.** The **superior vena cava** (VEE-nuh KAY-vuh) is a large vein that in general drains deoxygenated blood from structures above the diaphragm, while the **inferior vena cava** drains structures below the diaphragm. Both empty into the right atrium. These veins drain a group of blood vessels collectively called the **systemic circuit**, in which gases and nutrients are exchanged between the blood and the tissues outside of the lungs.
2. **Pulmonary trunk.** The **pulmonary trunk** is a large artery that branches from the right ventricle. Shortly after it forms, it splits into **right** and **left pulmonary arteries**, which deliver deoxygenated blood to the lungs through a series of vessels collectively called the **pulmonary circuit.** Within the pulmonary circuit, gases are exchanged, and the blood becomes oxygenated.
3. **Pulmonary veins.** The **pulmonary veins** bring oxygenated blood back from the pulmonary circuit and deliver it to the left atrium. There are generally four pulmonary veins.
4. **Aorta.** The large **aorta** (ay-OHR-tah) is an artery that stems from the left ventricle, after which it branches repeatedly to deliver oxygenated blood to the systemic circuit.

HINTS & TIPS

Red or Blue?

On anatomical models, vessels that carry oxygenated blood are red, whereas those that carry deoxygenated blood are blue. Systemic arteries carry oxygenated blood to the body's cells and so are red on anatomical models. Systemic veins, on the other hand, carry deoxygenated blood back to the right atrium and so are blue. But be sure to remember that the reverse is true in the pulmonary circuit: The pulmonary arteries carry deoxygenated blood to the lungs and the pulmonary veins carry oxygenated blood to the heart. So, in the pulmonary circuit, the arteries are blue and the veins are red.

The other set of blood vessels visible on the external surface of the heart are the vessels collectively called the **coronary circulation** (KOHR-oh-nehr-ee). The **coronary arteries** branch off the base of the aorta and bring oxygenated blood to the cells of the myocardium, and they are drained by a set of **cardiac veins**. The first coronary artery, the **right coronary artery**, travels in a groove between the atria and ventricles called the right **atrioventricular sulcus** (ay-tree-oh-ven-TRIK-yoo-lur). It branches into the **marginal artery**, which serves the lateral part of the right atrium and right ventricle, and the **posterior interventricular artery**, which serves the posterior heart. The other coronary artery is the **left coronary artery**, which branches shortly after it forms into the **anterior interventricular artery** (also known as the **left anterior descending artery**), which travels along a groove between the right and left ventricles called **interventricular sulcus** to supply the anterior heart. Its second branch is the **circumflex artery** (SIR-kum-flex), which travels in the left atrioventricular sulcus to supply the left atrium and posterior left ventricle. When a coronary artery is blocked, the reduced blood flow to the myocardium can result in hypoxic injury and death to the tissue, a condition termed **myocardial infarction** (commonly called a heart attack).

The anatomy of the cardiac veins often varies from person to person, but the following three main veins generally are present:

1. **small cardiac vein**, which drains the inferolateral heart,
2. **middle cardiac vein**, which drains the posterior heart, and
3. **great cardiac vein**, which drains most of the left side of the heart.

All three veins drain into the large **coronary sinus** located on the posterior right atrium. The coronary sinus drains into the right atrium.

On a dissection of the heart, as shown in Figure 15.6, we can see that the atria and ventricles are divided by muscular walls called *septa*. In between the atria is a thin wall called the **interatrial septum** (in-ter-AY-tree-ul). This wall has a small dent in it called the **fossa ovalis**, which is a remnant of a hole that was present during fetal life called the *foramen ovale*. The much thicker **interventricular septum** separates the two ventricles. The heart's four chambers include the:

1. **Right atrium.** The **right atrium** (AY-tree-um) is the superior right chamber. It receives deoxygenated blood from the body's main veins—the **superior vena cava**, the **inferior vena cava**, and the **coronary sinus**—the openings for which we find on the right atrium's posterior side. Externally, it has a large pouch called the **right auricle** (OHR-ih-kul) that allows the right atrium to expand and fill with more blood. Internally, the anterior surface of the right atrium is rough due to muscular ridges called **pectinate muscles** (PEK-tin-et).

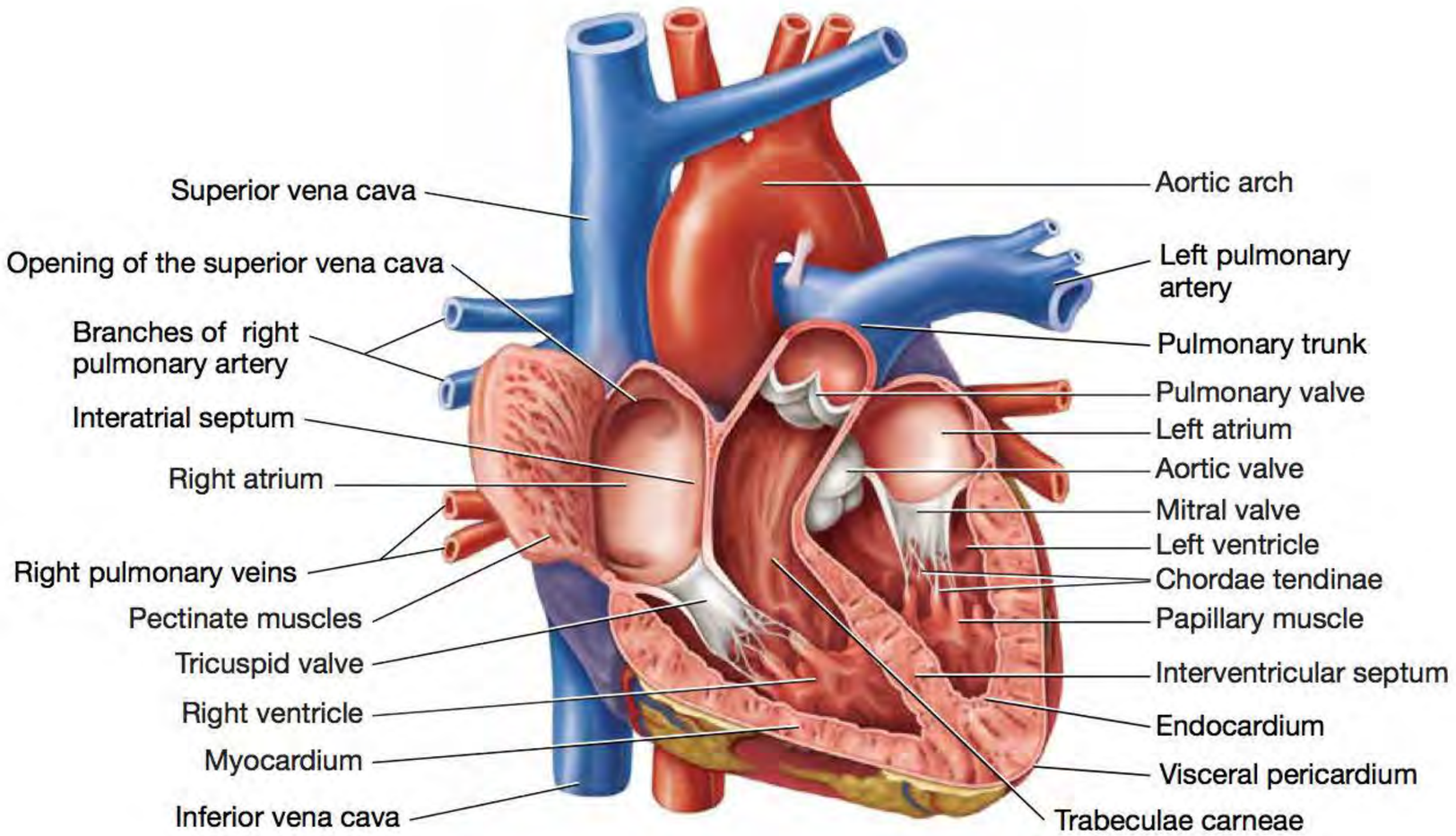


FIGURE **15.6** Frontal dissection of the heart.

2. **Right ventricle.** The **right ventricle** is a wide, crescent-shaped, thin-walled chamber inferior to the right atrium, from which it receives deoxygenated blood. It ejects blood into a vessel called the **pulmonary trunk.** Internally, its surface contains ridge-like protrusions of cardiac muscle called **trabeculae carneae** (trah-BIK-yoo-lee kar-NEE-ee).
3. **Left atrium.** The superior left chamber is the **left atrium.** It receives oxygenated blood returning from the pulmonary circuit via four **pulmonary veins.** Externally, it has a **left auricle,** although it is much smaller than the right auricle. Internally, its surface is mostly smooth and it lacks pectinate muscles.
4. **Left ventricle.** The **left ventricle** is a thick, long, circular chamber that receives oxygenated blood from the left atrium and pumps it into the **aorta.** Note that the left ventricle is considerably thicker than the right ventricle. This reflects the fact that the pressure is much higher in the systemic circuit than it is in the pulmonary circuit. The higher pressure requires the left ventricle to pump harder, and thus it is thicker. Like the right ventricle, we find trabeculae carneae lining the internal surface of the left ventricle.

We find structures called **valves** that prevent the blood from flowing backward in the heart in two places (Figures 15.6 and 15.7). First are the valves between the atria and ventricles, which are called **atrioventricular valves.** The three-cusped **tricuspid valve** is between the right atrium and right ventricle, and the two-cusped **mitral** (MY-trul) or **bicuspid valve** is between the left atrium and left ventricle. Each cusp of the atrioventricular valves is attached to collagenous "strings" called **chordae tendineae** (KOHRD-ee tin-din-EE-ee), which are attached to muscles within the ventricular wall called **papillary muscles.** When the ventricles contract, the papillary muscles pull the chordae tendineae taut, which puts tension on the cusps and prevents them from everting into the atria, a condition called **prolapse.**

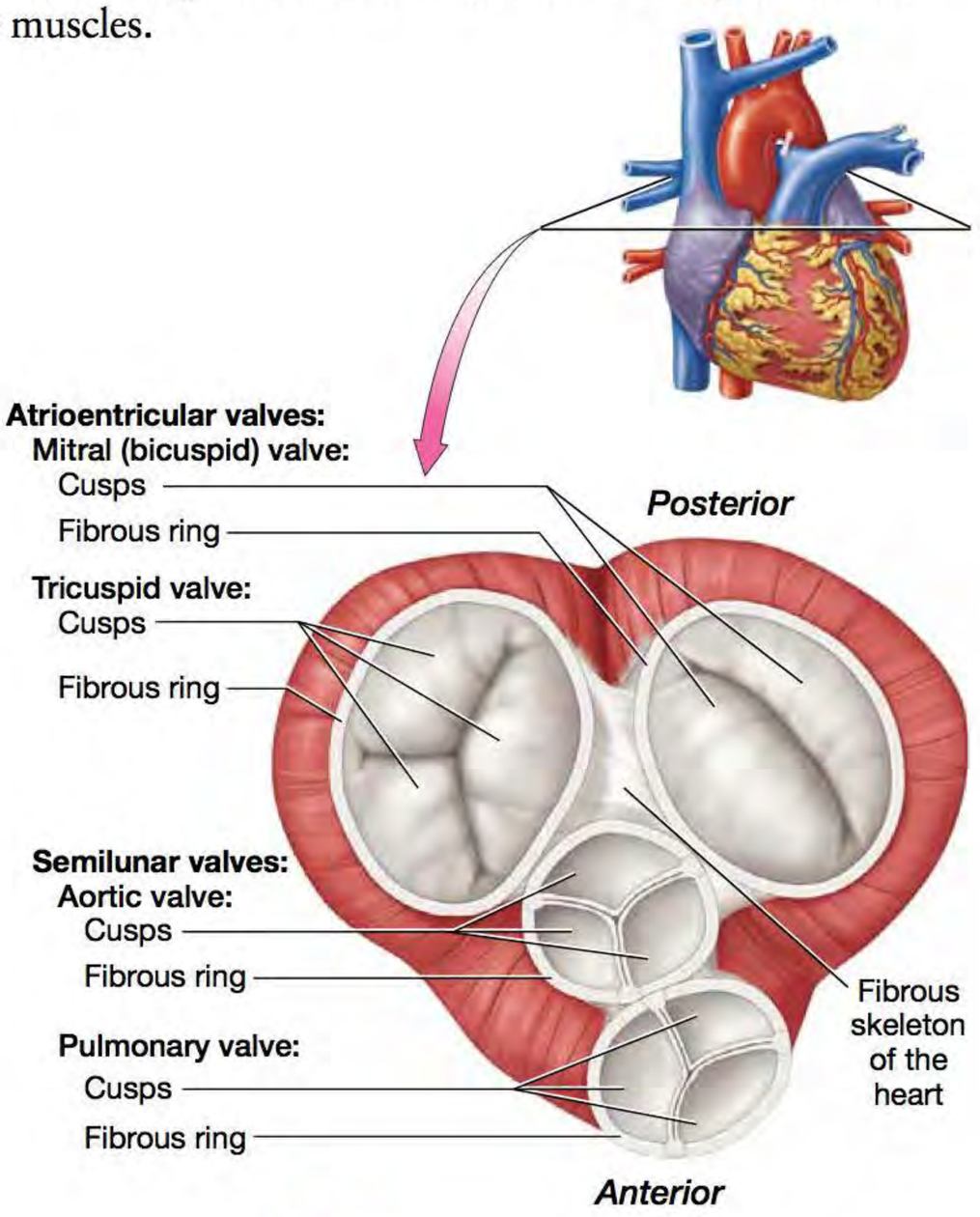


FIGURE **15.7** Transverse section of the heart showing all four valves.

Second are the valves between the ventricles and their arteries, which are called **semilunar valves.** The **pulmonary valve** lies between the right ventricle and the pulmonary trunk, and the **aortic valve** lies between the left ventricle and the aorta. Note that there are no chordae tendineae or papillary muscles attached to the semilunar valves.

Procedure 1 Model Inventory for the Heart

Identify the following structures of the heart on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 15.1. When you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 389).

1. General structures
   a. Mediastinum
   b. Apex of the heart
   c. Base of the heart
   d. Pericardium
      (1) Fibrous pericardium
      (2) Serous pericardium
         (a) Parietal pericardium
         (b) Visceral pericardium (epicardium)
         (c) Pericardial cavity
   e. Myocardium
   f. Endocardium
2. Great vessels
   a. Superior vena cava
   b. Inferior vena cava
   c. Pulmonary trunk
   d. Right and left pulmonary arteries
   e. Pulmonary veins
   f. Aorta
3. Coronary arteries
   a. Right coronary artery
   b. Atrioventricular sulcus
   c. Marginal artery
   d. Posterior interventricular artery
   e. Left coronary artery
   f. Anterior interventricular artery
   g. Interventricular sulcus
   h. Circumflex artery
4. Cardiac veins
   a. Small cardiac vein
   b. Middle cardiac vein
   c. Great cardiac vein
   d. Coronary sinus
5. Interatrial septum
   a. Fossa ovalis
6. Interventricular septum
7. Right atrium
   a. Opening of the superior vena cava
   b. Opening of the inferior vena cava
   c. Opening of the coronary sinus
   d. Right auricle
   e. Pectinate muscles
8. Right ventricle
   a. Trabeculae carneae
9. Left atrium
   a. Left auricle
10. Left ventricle
    a. Trabeculae carneae
11. Atrioventricular valves
    a. Tricuspid valve
    b. Mitral valve
    c. Chordae tendineae
    d. Papillary muscles
12. Semilunar valves
    a. Pulmonary valve
    b. Aortic valve

TABLE **15.1** Model Inventory for the Heart

Model/Diagram	Structures Identified

Procedure 2 Time to Draw

In the space below, draw, color, and label one of the heart models that you examined. Draw both the anterior view and the frontal dissection. In addition, write the function of each structure that you label.

Procedure 3 Heart Dissection

You will now examine a preserved heart or a fresh heart, likely from a sheep or a cow. Follow the procedure below to find the structures you just studied on models. When you have completed the dissection, answer Check Your Understanding question 4 (p. 390).

Safety Note

Safety glasses and gloves are required!

1 Orient yourself by first determining the superior aspect and the inferior aspect of the heart. The superior aspect of the heart is the broad end, and the inferior aspect (apex) is the pointy tip. Now orient yourself to the anterior and posterior sides. The easiest way to do this is to locate the pulmonary trunk—the vessel directly in the middle of the anterior side. Find the side from which the pulmonary trunk originates, and you will be on the anterior side, which you can see in Figure 15.8. Structures to locate at this time are the

a. parietal pericardium (may not be attached),
b. visceral pericardium (shiny layer over the surface of the heart),
c. aorta,
d. pulmonary trunk,
e. superior vena cava,
f. inferior vena cava,
g. pulmonary veins,
h. ventricles, and
i. atria.

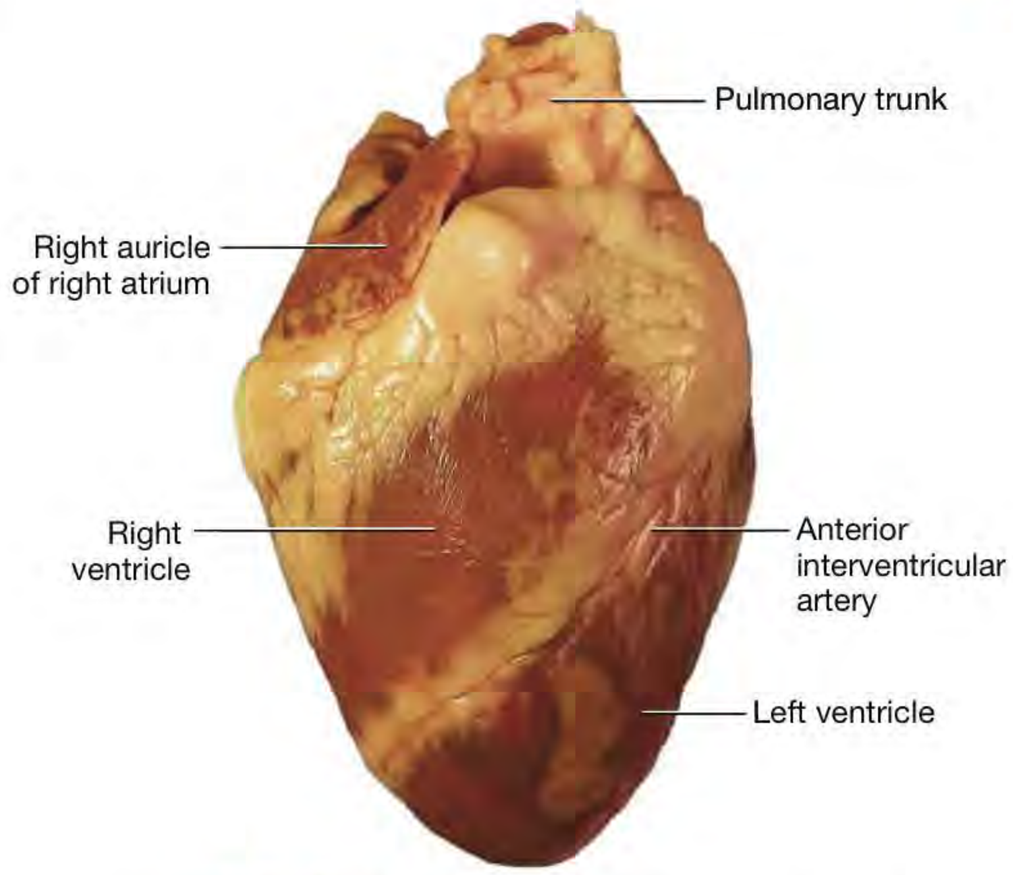


FIGURE 15.8 Anterior view of a sheep heart.

Finding the coronary vessels tends to be difficult because the superficial surface of the heart is covered with adipose tissue. To see the coronary vessels, carefully dissect the adipose tissue.

2 Locate the superior vena cava. Insert scissors or a scalpel into the superior vena cava and cut down into the right atrium. Before moving on to step 3, note the structure of the tricuspid valve, and draw it in the space provided. How many flaps do you see? What is the function of this valve?

3 Once the right atrium is exposed, continue the cut down into the right ventricle, which is shown in Figure 15.9. Structures to locate at this time include the

a. tricuspid valve,
b. chordae tendineae,
c. papillary muscles,
d. myocardium, and
e. endocardium (shiny layer on the inside of the heart).

4 Insert the scissors into the pulmonary trunk. Note the structure of the pulmonary valve, and draw it in the space provided. How does it differ structurally from the tricuspid valve? What is the function of this valve?

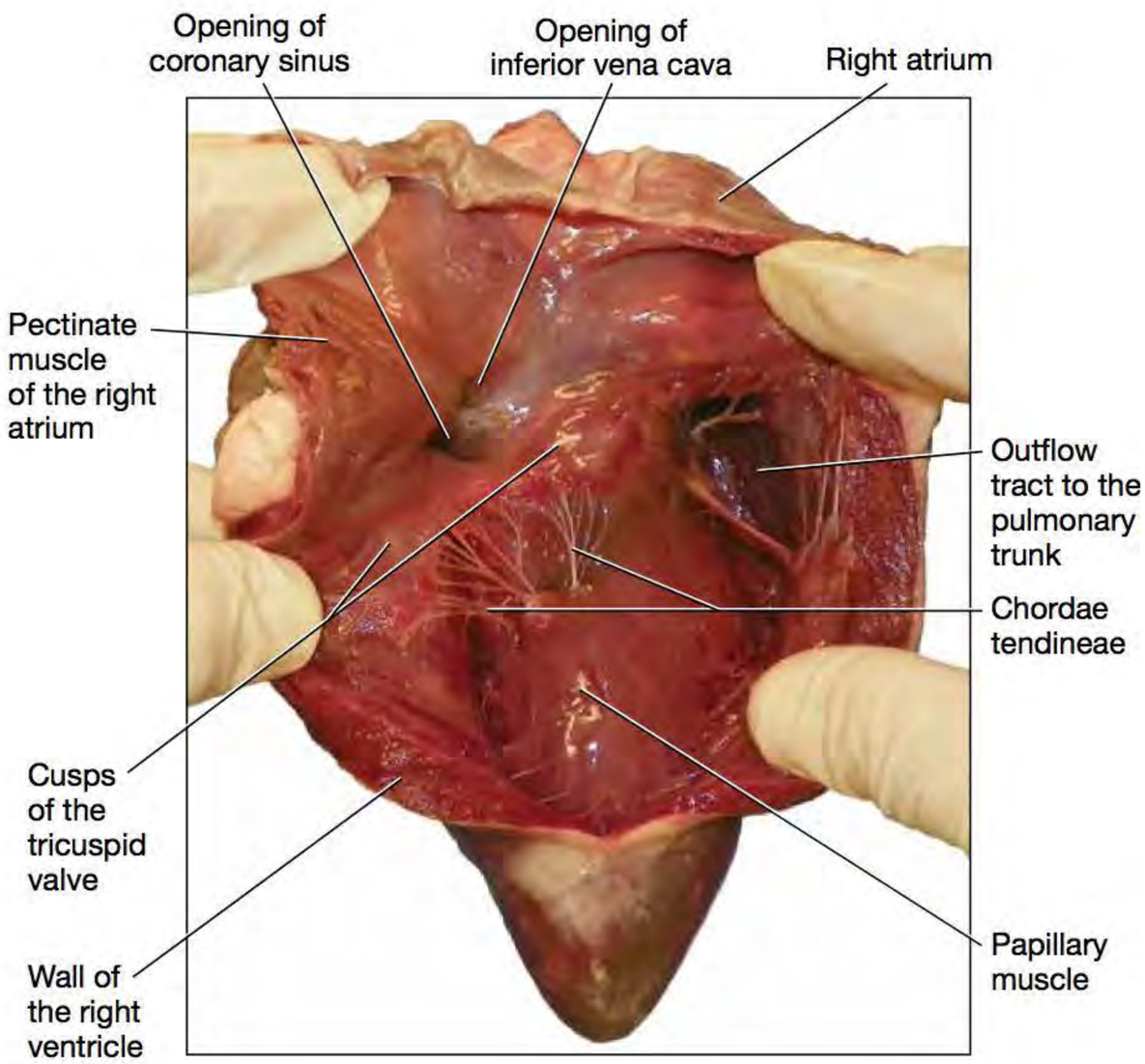


FIGURE **15.9** Right ventricle of a sheep heart.

5 Insert the scissors into a pulmonary vein. Cut down into the left atrium. Note the structure of the mitral valve, and draw it below. What is the function of this valve? How does its structure differ from that of the pulmonary and tricuspid valves?

6 Continue the cut into the left ventricle. Note the thickness of the left ventricle, as shown in Figure 15.10. How does it compare with the thickness of the right ventricle? Why is there a difference?

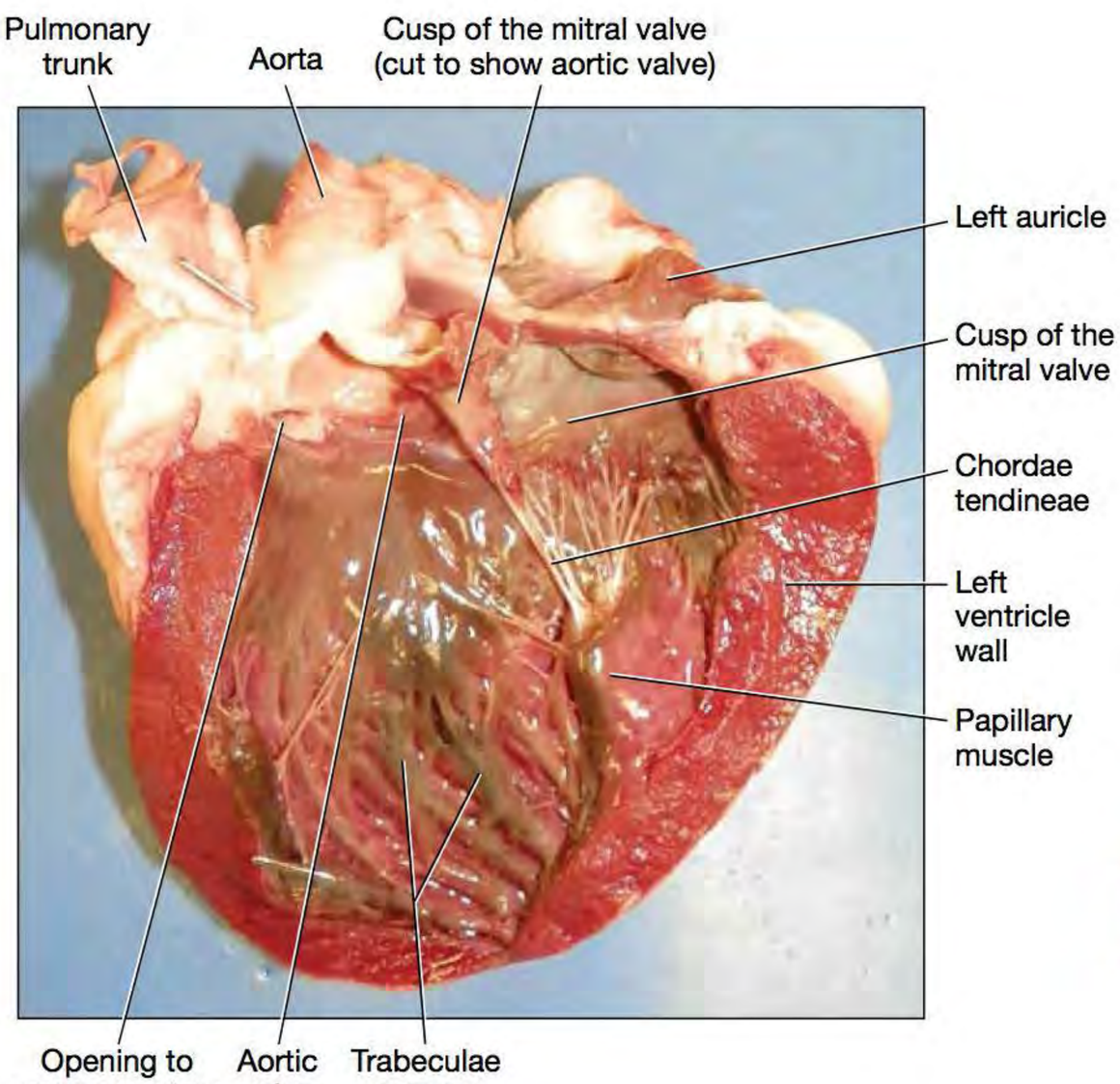


FIGURE **15.10** Left ventricle of a sheep heart.

7 Insert the scissors into the aorta. Extend the cut until you can see the aortic valve. Draw the aortic valve in the space provided. Is it structurally more similar to the pulmonary valve or the mitral valve? What is the function of this valve?

8 Your instructor may wish you to identify other structures on the heart. List any additional structures in the space provided.

Procedure 4 Tracing Blood through the Heart

Use water-soluble markers and a laminated outline of the heart to trace the pathway of blood as it flows through the heart and pulmonary circulation. Use a blue marker to indicate areas that contain deoxygenated blood and a red marker to indicate areas that contain oxygenated blood. If no laminated outline is available, use Figure 15.11. When you have completed the activity, answer Check Your Understanding question 5 (p. 390).

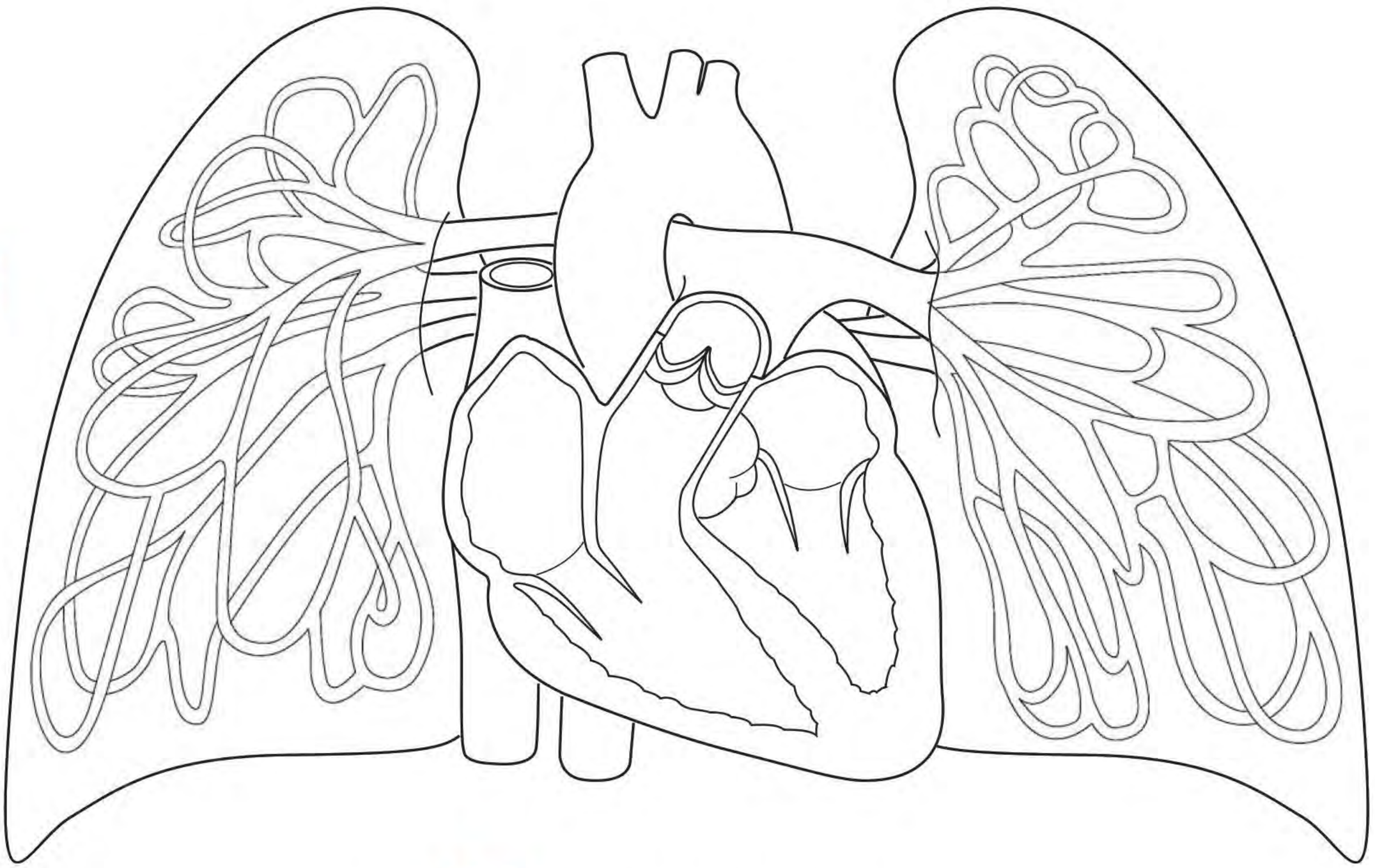


FIGURE **15.11** Heart, lungs, and pulmonary circulation.

Exercise 15-2

Cardiac Muscle Histology

MATERIALS

- ❑ Cardiac muscle tissue slide
- ❑ Light microscope
- ❑ Colored pencils

Recall from Unit 4 (p. 82) that cardiac muscle tissue is striated like skeletal muscle tissue but otherwise is quite different (Figure 15.12). Following are some important differences:

- Cells of cardiac muscle, known as cardiac myocytes, are shorter, wider, and branched, whereas skeletal muscle fibers are long, thin, and unbranched.
- Cardiac muscle cells typically are uninucleate, although some have multiple nuclei. The nucleus is generally located in the center of the cell.
- These cells contain specialized adaptations called intercalated discs (in-TER-kah-layt-ed) that appear as dark lines parallel to the striations. These discs contain desmosomes and gap junctions that hold adjacent cardiac cells tightly together to allow the cells to communicate chemically and electrically. This adaptation is important to the heart's function, as all of the cells of the atria, followed by all of the cells of the ventricles, must be able to contract simultaneously as a unit. Contrast this with skeletal muscles, in which the number of muscle fibers that contract is proportional to the strength of the contraction.

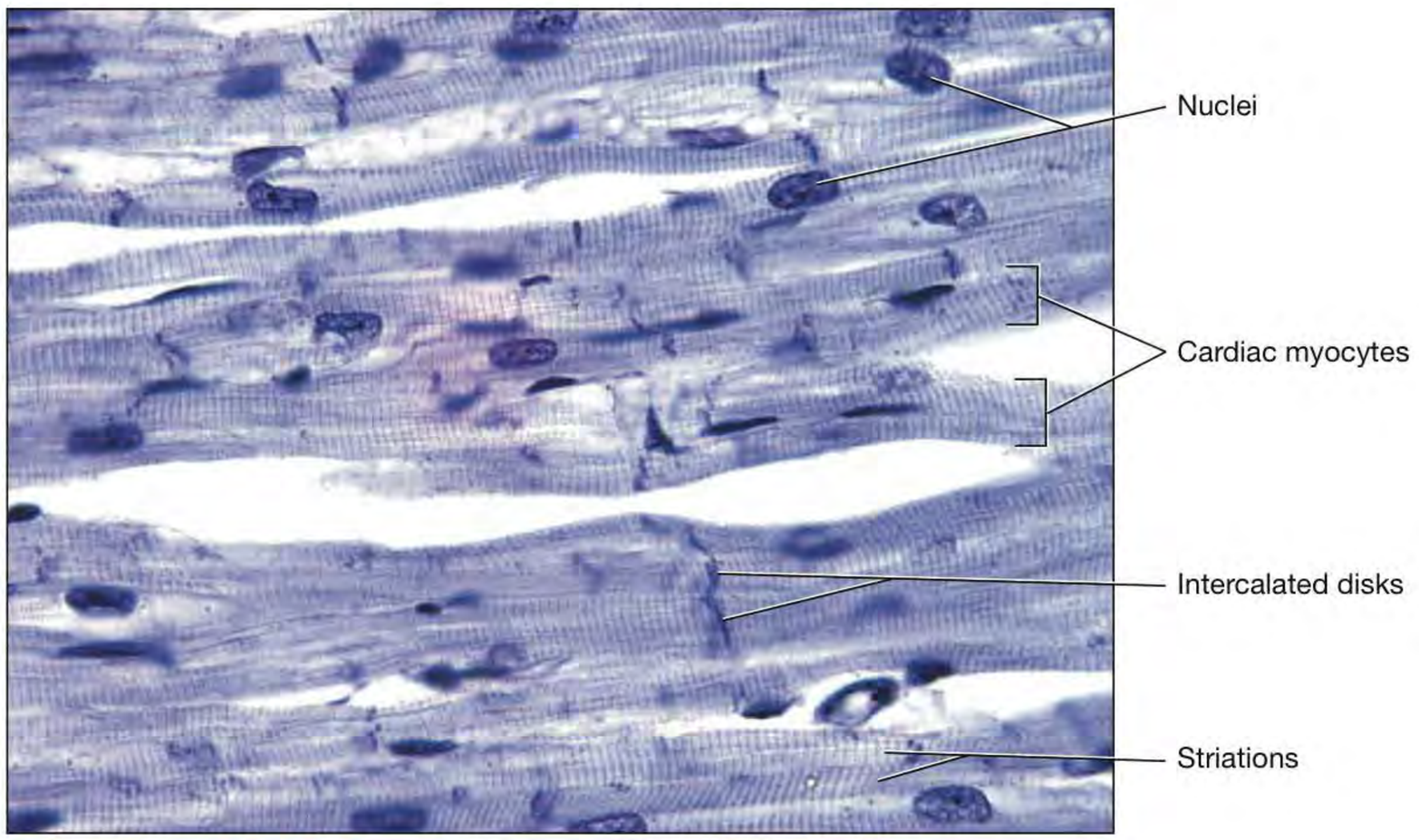
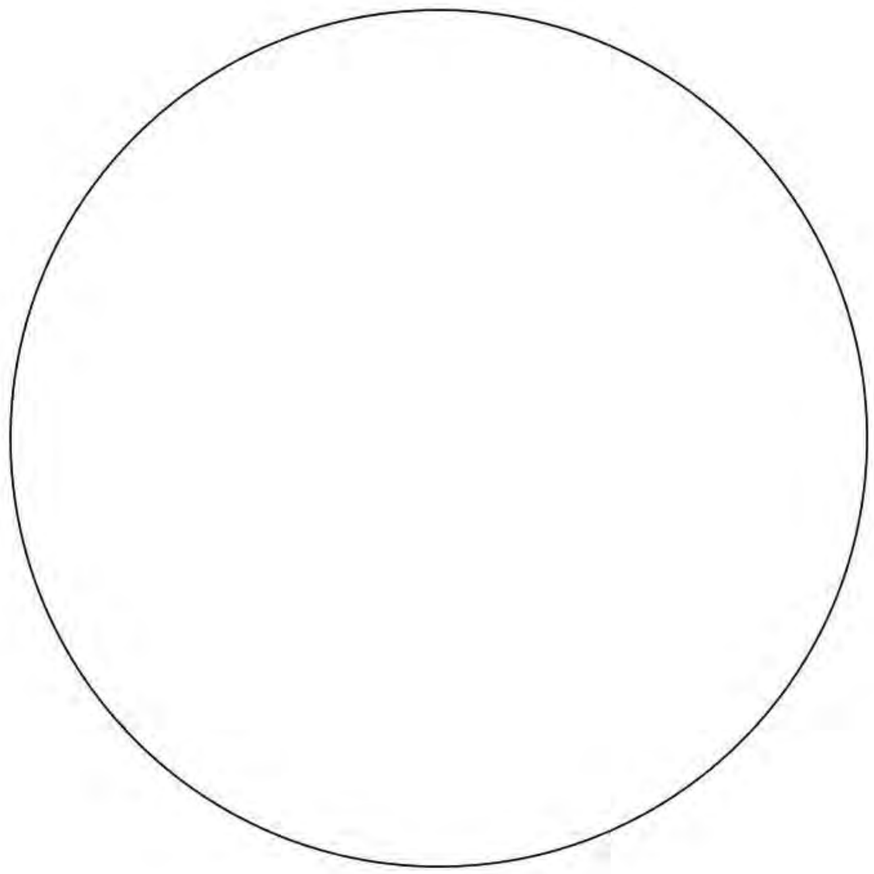


FIGURE **15.12** Cardiac muscle tissue, photomicrograph.

Procedure 1 Microscopy of Cardiac Muscle Tissue

Examine a prepared slide of cardiac muscle tissue on high power. Use colored pencils to draw what you see, and label the listed structures. When you have completed the activity, answer Check Your Understanding question 6 (p. 390). Label the following structures:

1. Cardiac myocyte
2. Intercalated discs
3. Striations
4. Nucleus



Name _____

Section _____ Date _____

UNIT 15 REVIEW

Check Your Recall

1 Label the following parts of the heart on Figure 15.13.

- ❑ Anterior interventricular artery
- ❑ Aorta
- ❑ Circumflex artery
- ❑ Inferior vena cava
- ❑ Pulmonary trunk
- ❑ Pulmonary veins
- ❑ Right coronary artery
- ❑ Superior vena cava

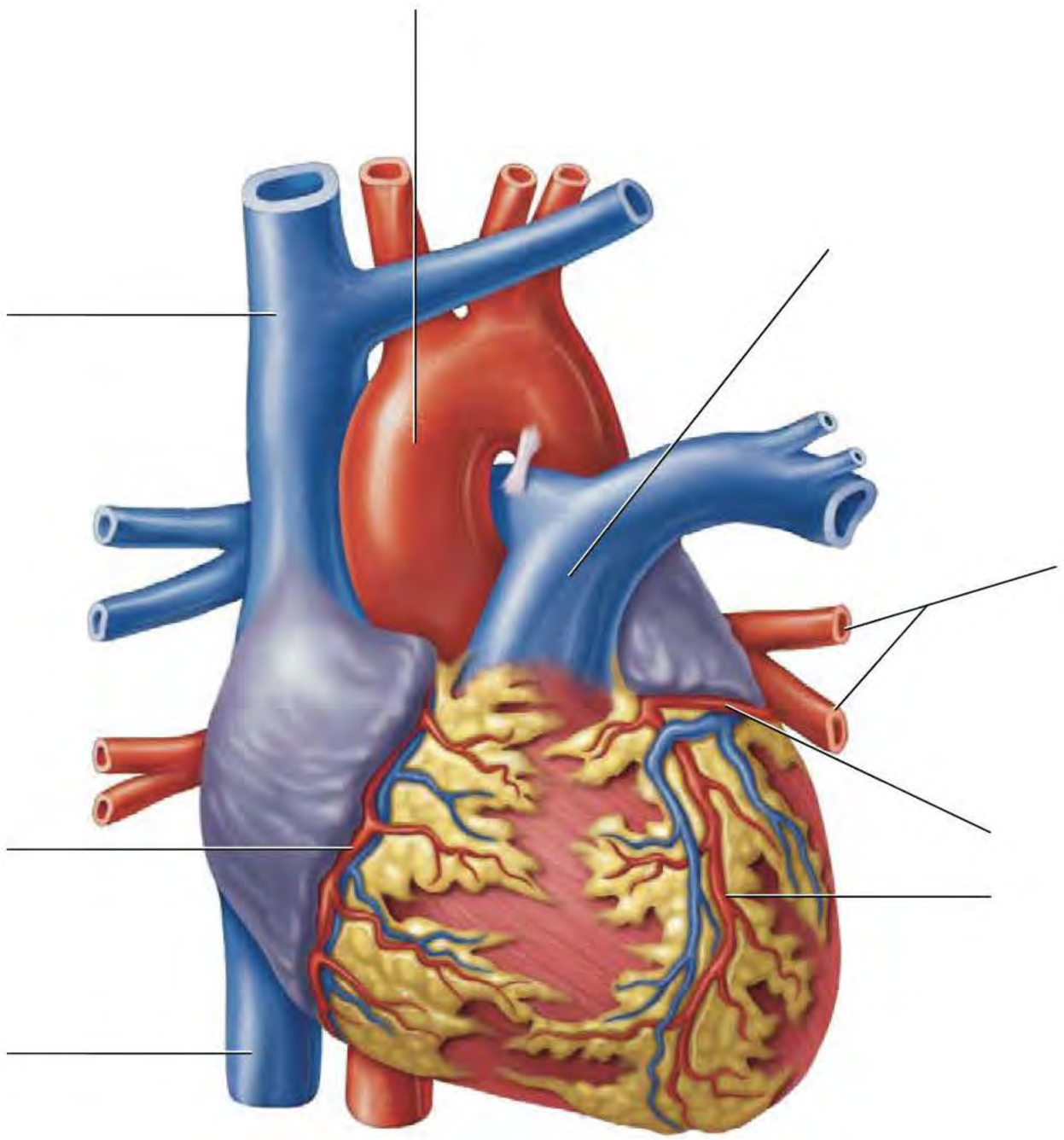


FIGURE **15.13** Heart, anterior view.

2 Label the following parts of the heart on Figure 15.14.

- ❑ Chordae tendineae
- ❑ Interventricular septum
- ❑ Left atrium
- ❑ Left ventricle
- ❑ Papillary muscles
- ❑ Right atrium
- ❑ Right ventricle

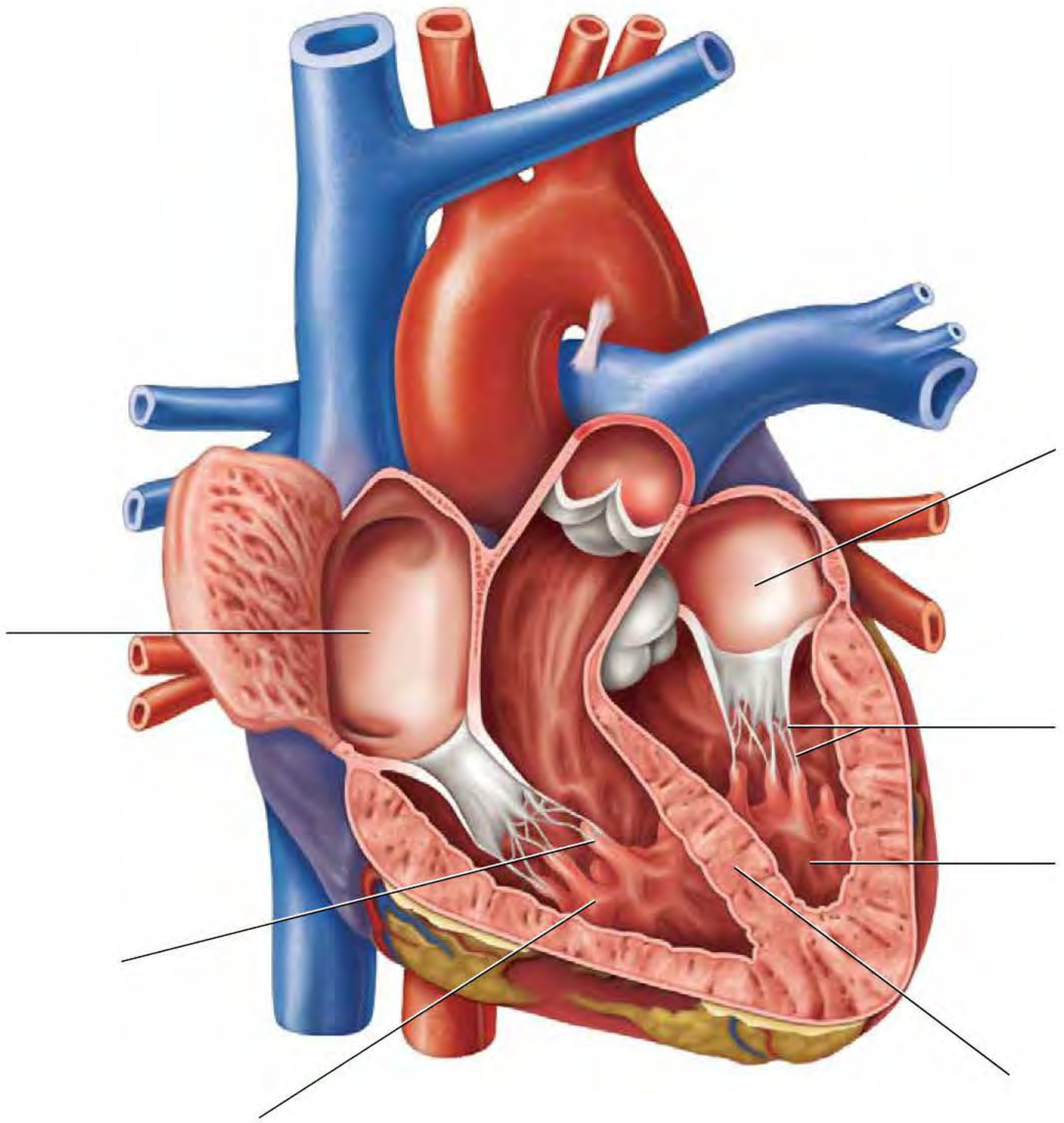


FIGURE **15.14** Frontal section of the heart.

Name _____

Section _____ Date _____

UNIT 15

3 Label the following parts of the heart on Figure 15.15.

- ❑ Aortic valve
- ❑ Mitral valve
- ❑ Pulmonary valve
- ❑ Tricuspid valve

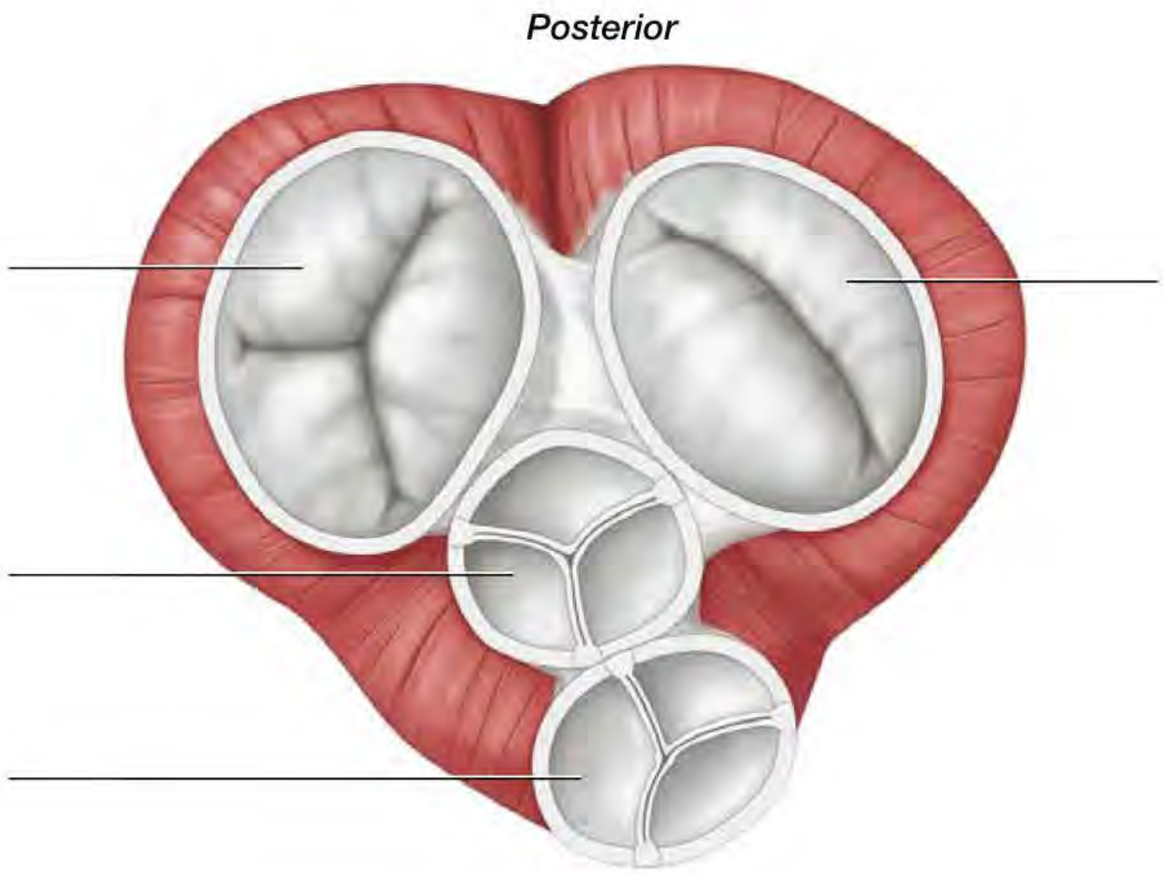


FIGURE **15.15** Transverse section of the heart showing all four valves.

4 *Matching:* Match the following terms with the correct definition.

_____ Myocardium
_____ Parietal pericardium
_____ Tricuspid valve
_____ Aortic valve
_____ Papillary muscles
_____ Pulmonary veins
_____ Mitral valve
_____ Visceral pericardium
_____ Pulmonary trunk
_____ Chordae tendineae

A. Located between the left ventricle and the aorta
B. Located between the left atrium and left ventricle
C. Inner layer of the serous pericardium
D. Bring(s) oxygenated blood to the left atrium from the lungs
E. Layer of the heart composed of cardiac muscle tissue
F. Bring(s) deoxygenated blood to the lungs
G. Located between the right atrium and the right ventricle
H. Fingerlike muscular projections from the ventricles
I. Outer layer of the serous pericardium
J. Fibrous cord(s) that attach(es) to valves

5 **The veins of the systemic circuit carry _____ blood, and the veins of the pulmonary circuit carry _____ blood.**

a. oxygenated; deoxygenated
b. oxygenated; oxygenated
c. deoxygenated; deoxygenated
d. deoxygenated; oxygenated

6 **The pulmonary and aortic valves are known as the**

a. atrioventricular (AV) valves.
b. semilunar valves.
c. coronary valves.
d. chordae tendineae.

7 **The right and left coronary arteries are the first branches off the**

a. aorta.
b. superior vena cava.
c. pulmonary trunk.
d. pulmonary veins.

8 **The main vein that drains the coronary circulation is the**

a. superior vena cava
b. pulmonary vein
c. small cardiac vein
d. coronary sinus

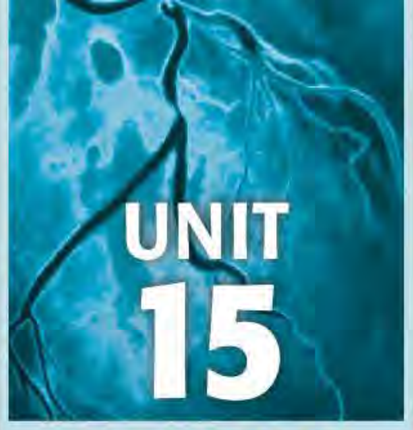
9 **The coronary artery that resides in the left atrioventricular sulcus is the**

a. anterior interventricular artery
b. circumflex artery
c. right coronary artery
d. marginal artery

10 ***Fill in the blanks:*** **Cardiac muscle cells are also known as _____. Adjacent cells are joined together by _____, which allow the heart to _____.**

Name _____

Section _____ Date _____



Check Your Understanding

Critical Thinking and Application Questions

1 When the pericardium fills with blood, it produces a condition called *cardiac tamponade*, which can be rapidly lethal. Why is this condition so dangerous? (*Hint:* Consider the structure of the fibrous pericardium.)

2 High pressure in the systemic and pulmonary circuits often results in *ventricular hypertrophy*, in which the ventricle enlarges to pump against greater force. Which side(s) of the heart would be affected by high pressure in the pulmonary circuit? Which side(s) of the heart would be affected by high pressure in the systemic circuit? Explain.

3 One potential cause of valve dysfunction is rupture of the chordae tendineae. Why would this lead to valve dysfunction? Would this affect the atrioventricular valves, the semilunar valves, or both? Explain.

4 In the heart dissection you performed, you saw the smooth texture of the valves and how the leaflets fit together. How do you think the function of the valves would be affected if the valves were tough and filled with calcium deposits? Explain.

5 The condition known as *atrial septal defect* is characterized by the presence of a hole in the interatrial septum. How would this condition affect the normal pattern of blood flow? What effect would this have on the oxygenation of the blood?

6 Skeletal muscle cells exhibit a phenomenon known as *recruitment*, in which the number of muscle cells recruited to contract is proportional to the strength of muscle contraction needed. In this way, we activate a few fibers to produce a small contraction to pick up a piece of paper, and we activate many fibers to produce a larger contraction to pick up a textbook. Would you expect to see recruitment in cardiac muscle tissue? Why or why not?

Cardiovascular System
Part II: Blood Vessel Anatomy

16

OBJECTIVES

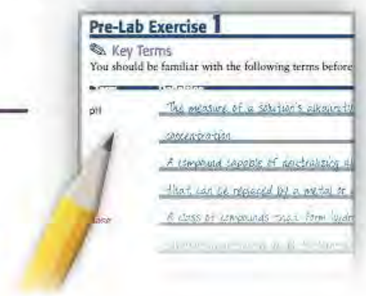
Once you have completed this unit, you should be able to:

1. Identify selected arteries and veins.
2. Describe the organs and regions supplied and drained by each artery and vein.
3. Describe the unique blood flow patterns through the brain and the hepatic portal system.
4. Trace the pathway of blood flow through various arterial and venous circuits.
5. Describe the histological differences between arteries and veins.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 16-1

Key Terms: Arteries

Describe the location and the organ or region of the body supplied by each of the arteries in Table 16.1.

TABLE **16.1** Major Arteries of the Body

Artery	Location	Organ/Region Supplied
Arteries of the Trunk		
Brachiocephalic artery		
Celiac trunk		
Inferior mesenteric artery		
Renal artery		
Splenic artery		
Superior mesenteric artery		
Arteries of the Head and Neck		
Basilar artery		
Circle of Willis		
External carotid artery		

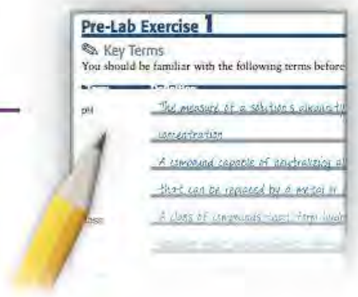
(continues)

TABLE **16.1** Major Arteries of the Body *(cont.)*

Artery	Location	Organ/Region Supplied
Arteries of the Head and Neck		
Internal carotid artery		
Temporal artery		
Vertebral artery		
Arteries of the Upper Limb		
Axillary artery		
Brachial artery		
Radial artery		
Subclavian artery		
Ulnar artery		
Arteries of the Lower Limb		
Dorsalis pedis artery		
Femoral artery		
Posterior tibial artery		

Name _____ Section _____ Date _____

Pre-Lab Exercise 16-2



✎ Key Terms: Veins

Describe the location and the organ or region of the body drained by each of the veins in Table 16.2.

TABLE **16.2** Major Veins of the Body

Vein	Location	Organ/Region Drained
Veins of the Trunk		
Brachiocephalic vein		
Hepatic portal vein		
Inferior mesenteric vein		
Renal vein		
Splenic vein		
Superior mesenteric vein		
Veins of the Head and Neck		
Dural sinuses		
Internal jugular vein		

(continues)

TABLE **16.2** Major Veins of the Body *(cont.)*

Vein	Location	Organ/Region Drained
Veins of the Upper Limb		
Basilic vein		
Brachial vein		
Cephalic vein		
Subclavian vein		
Veins of the Lower Limb		
Femoral vein		
Greater saphenous vein		

Name _____ Section _____ Date _____

Pre-Lab Exercise 16-3

Arterial Anatomy

Label the arterial diagrams in Figure 16.1A–D with the terms from Exercise 16-1 (p. 399). Use your text and Exercise 16-1 in this unit for reference. Note that these diagrams are presented in color to facilitate identification of the vessels.

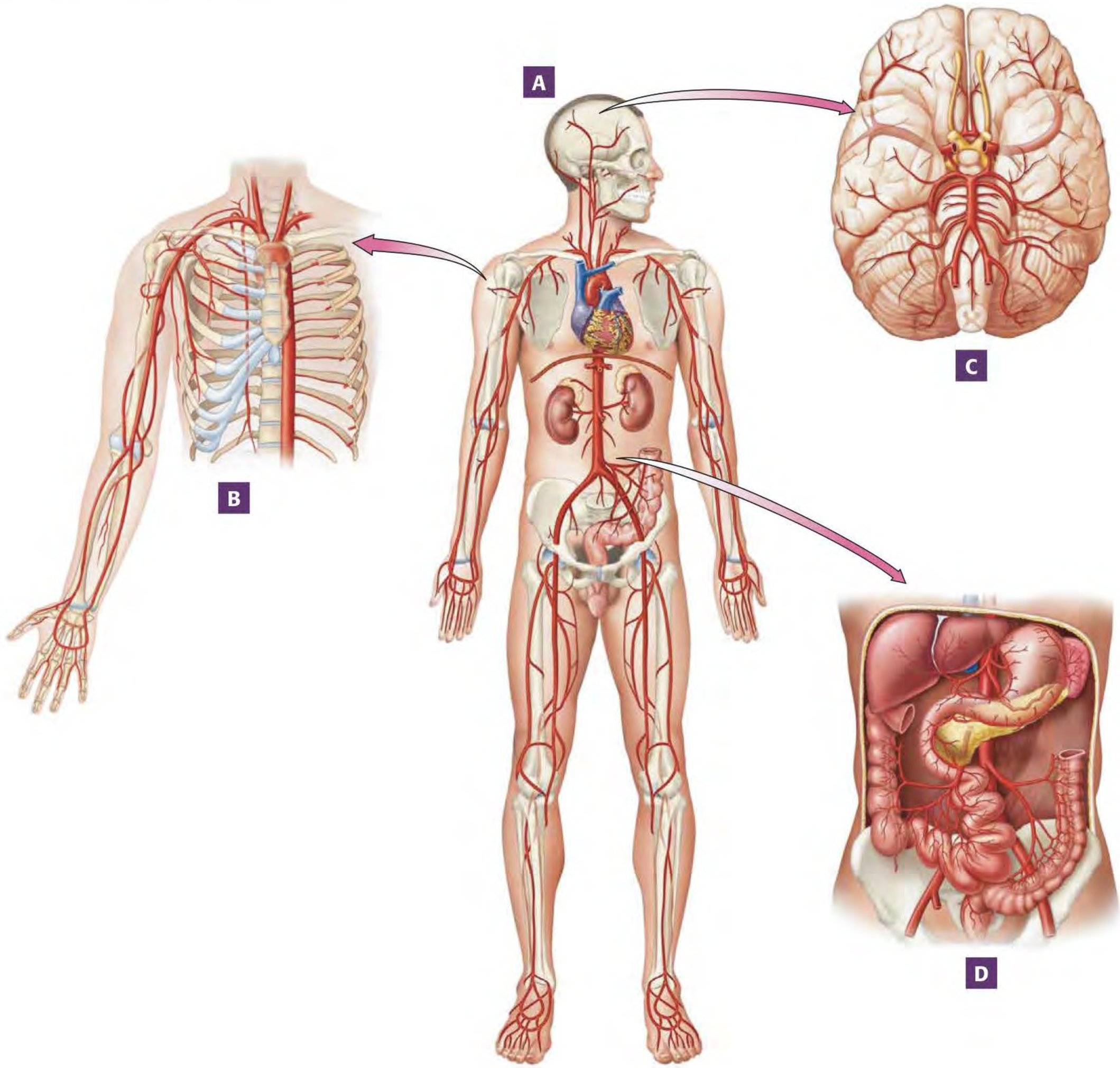


FIGURE **16.1** (**A**) Major arteries of the body: (**B**) right arm and thorax; (**C**) brain; (**D**) abdomen.

Pre-Lab Exercise 16-4

Venous Anatomy

Label the venous diagrams in Figure 16.2A–D with the terms from Exercise 16-2 (p. 404). Use your text and Exercise 16-2 in this unit for reference. Note that these diagrams are presented in color to facilitate identification of the vessels.

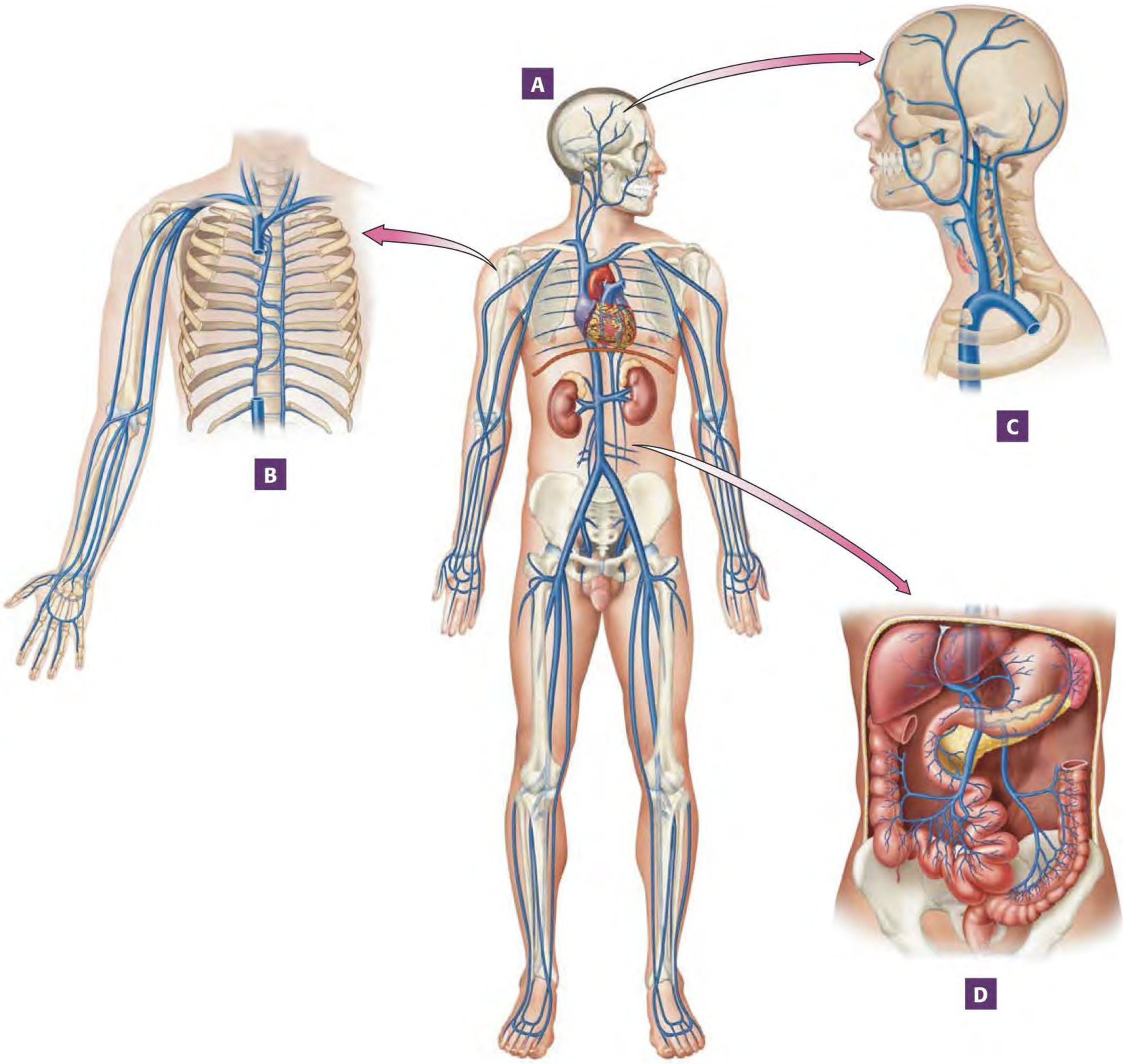


FIGURE **16.2** (**A**) Major veins of the body: (**B**) right arm and thorax; (**C**) head and neck; (**D**) abdomen.

EXERCISES

Blood vessels are a closed system of tubes that transport blood around the body. The heart pumps blood away from the heart through a series of **arteries**. Arteries branch as they pass through organs and tissues to form progressively smaller vessels until they branch into tiny **capillary beds**, where gas, nutrient, and waste exchange take place. The blood is drained from the capillaries via a series of **veins** that return the blood to the heart.

The three major circuits of blood flow in the body are

1. the **systemic circuit**, which delivers oxygenated blood to most organs and tissues in the body,
2. the **coronary circuit**, which delivers oxygenated blood to the heart, and
3. the **pulmonary circuit**, which delivers deoxygenated blood to the lungs.

In this unit we will address primarily the systemic circuit, as the coronary and pulmonary circuits were discussed in Unit 15. In the upcoming exercises, you will identify the systemic circuit's major blood vessels, trace various pathways of blood flow through the body, and examine the histology of the blood vessel wall. In the final exercise, you will perform some clinical examinations of blood vessels.

Exercise 16-1

Major Arteries of the Body

MATERIALS

- ❑ Blood vessel models:
  - human torsos
  - brain
  - head and neck
  - abdomen
  - upper limb
  - lower limb

The systemic arterial circuit begins with the largest artery in the body, the **aorta** (Figure 16.3). The aorta originates from the left ventricle as the **ascending aorta,** which ascends until it curves around to form the **aortic arch**. The aortic arch has three major branches: the *brachiocephalic artery*, the *left common carotid artery*, and the *left subclavian artery*. The **brachiocephalic artery** (bray-kee-oh-seh-FAL-ik) is a small trunk that veers to the right. Shortly after passing deep to the clavicle, it splits into the right common carotid and right subclavian arteries.

The arterial supply of the head and neck comes primarily from the **right** and **left common carotid arteries** (kah-RAWT-id; Figure 16.4). In the neck, these arteries branch into the internal and external carotid arteries. The **external carotid artery** gives off many branches that supply the structures of the head, neck, and face. One of its terminal branches is the large **superficial temporal artery**, which crosses the temporal bone to supply the scalp.

The **internal carotid arteries** supply the brain, along with the **vertebral arteries**, which pass through the vertebral foramina of the cervical vertebrae. Notice in Figure 16.5 that the two vertebral arteries fuse at the brainstem to become the single **basilar artery** (BAY-zih-lar), which then splits again into the **posterior cerebral arteries**. These vessels then give off the small **posterior communicating arteries**, which connect the circulation of the basilar artery with that of the internal carotid arteries. From here, the internal carotid artery gives off a pair of **anterior cerebral arteries**, which themselves are connected by a small **anterior communicating artery**. As you can see in Figure 16.5, these vessels form a continuous structure known as the **cerebral arterial circle**. These vessels are connected to provide alternate routes of circulation to the brain if one of the arteries supplying the brain becomes blocked.

The arterial supply to the upper limb begins with the right and left **subclavian arteries** (sub-KLAY-vee-in; Figure 16.6). The right subclavian artery becomes the **axillary artery** near the axilla. In the arm, the axillary artery becomes the **brachial artery** (BRAY-kee-uhl), which branches into the **radial artery** and the **ulnar artery**. As you would expect, these arteries travel alongside the bones for which they are named—the radial artery is lateral and the ulnar artery is medial.

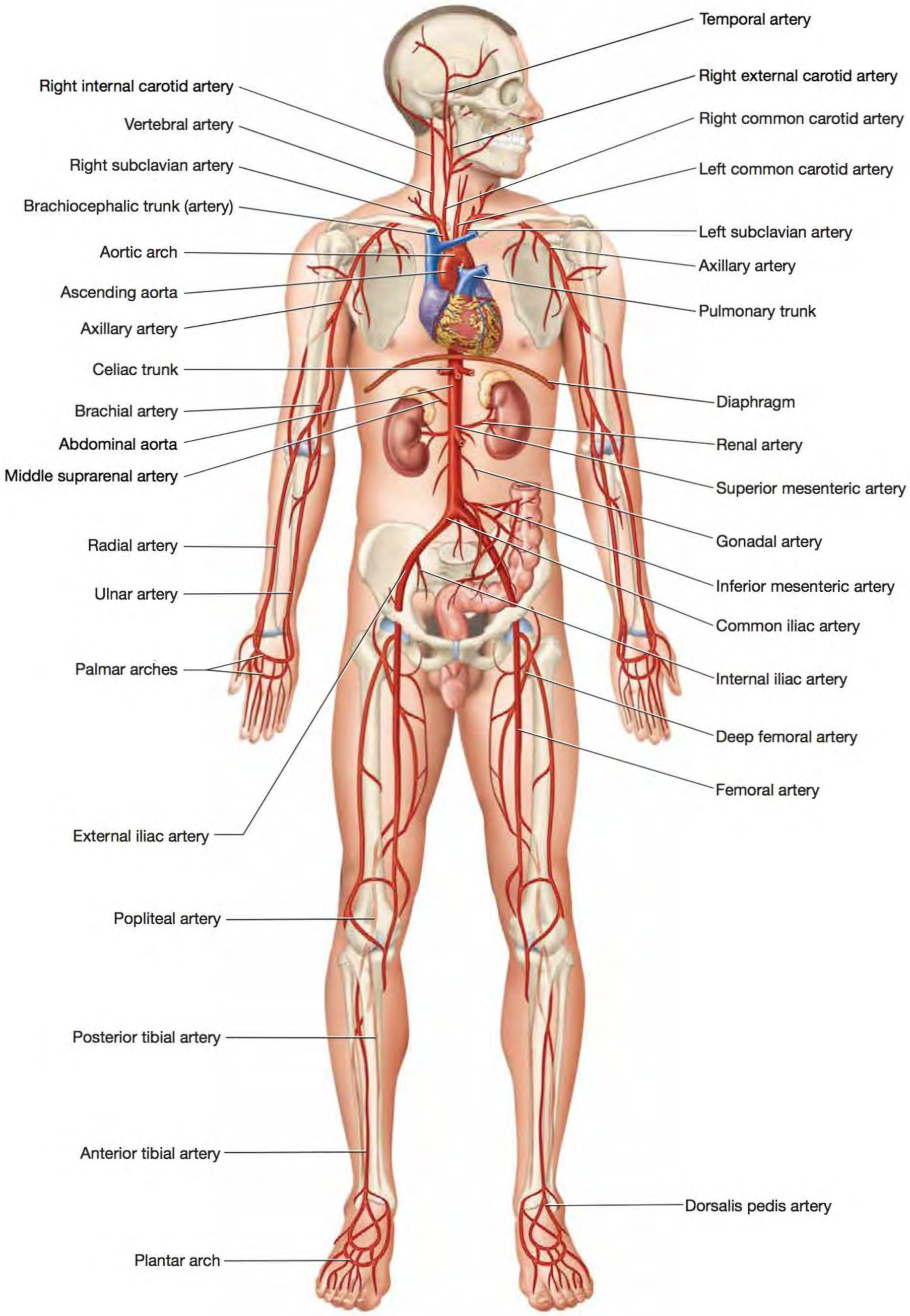


FIGURE **16.3** Major arteries of the body.

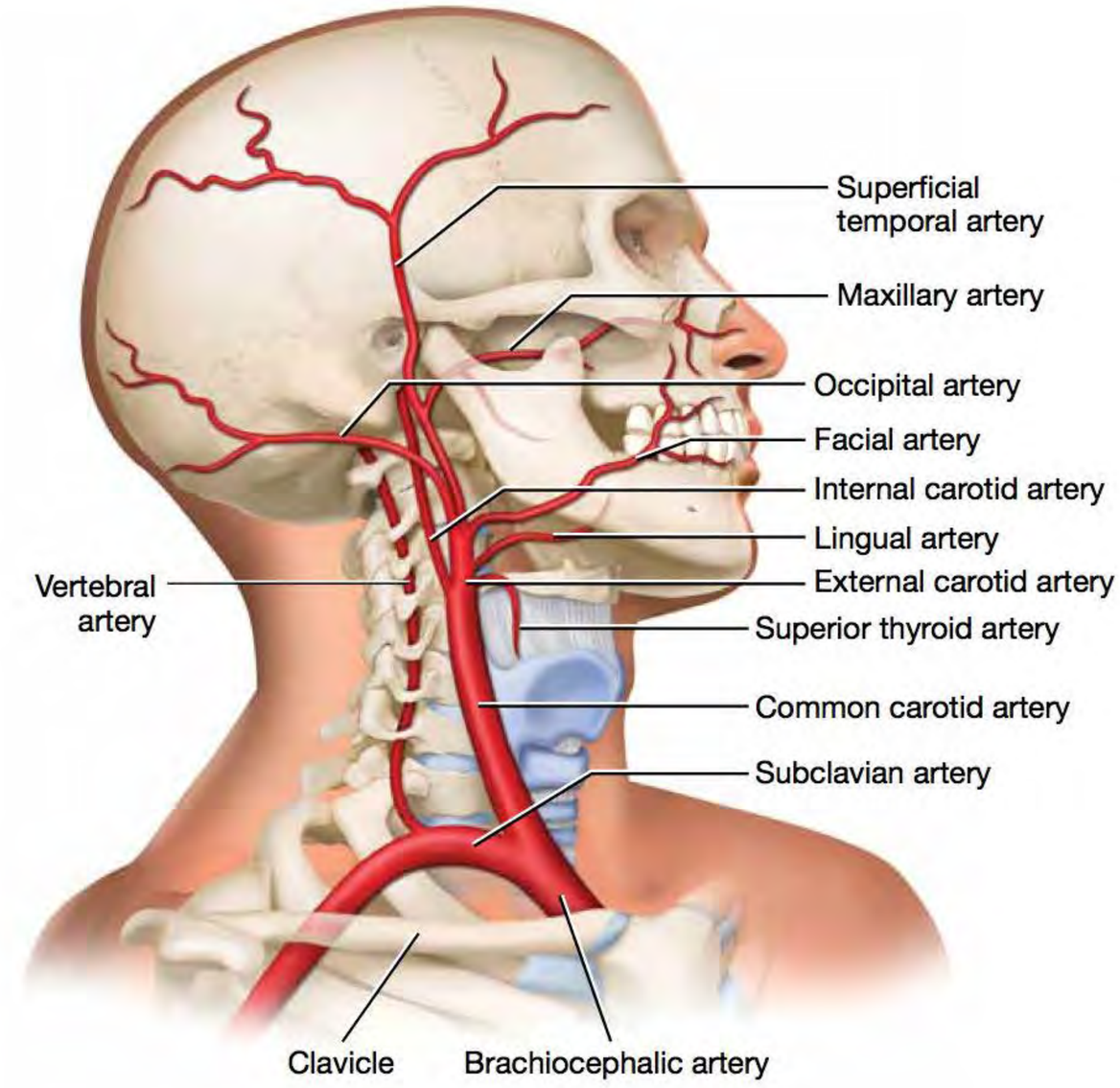


FIGURE **16.4** Arteries of the head and neck.

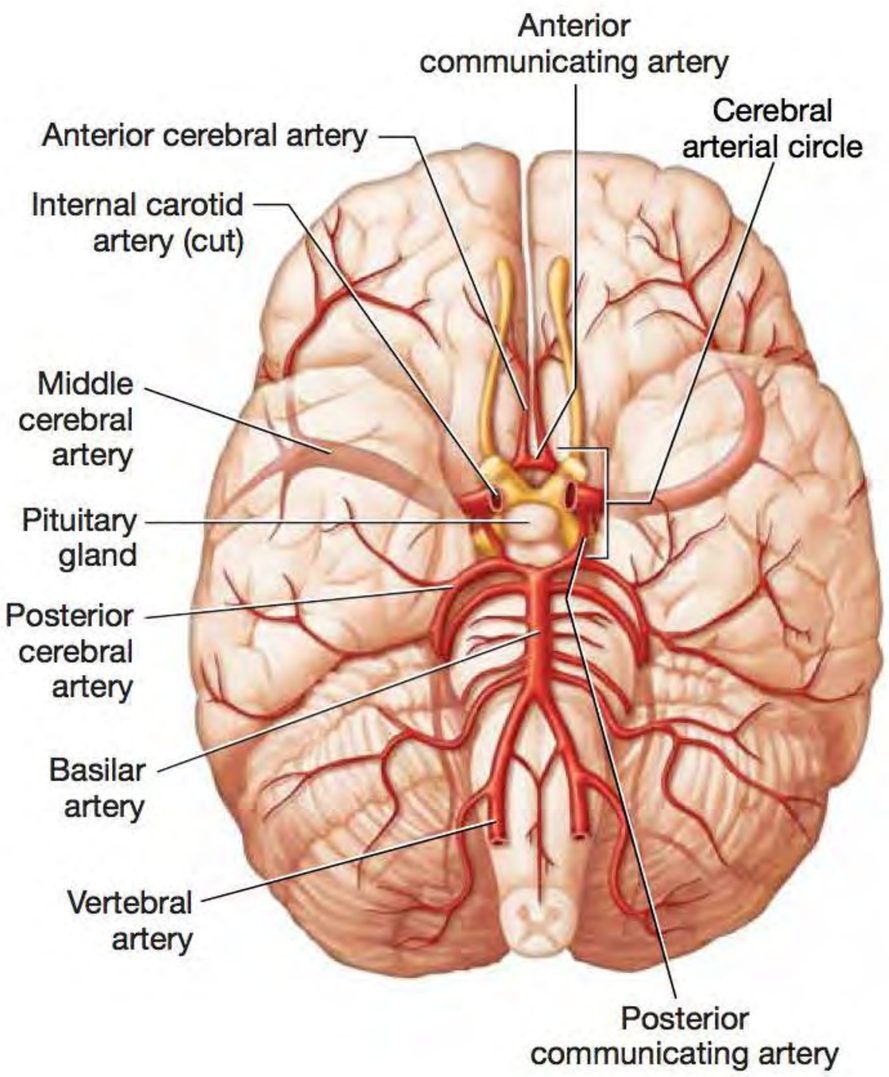


FIGURE **16.5** Arteries of the brain, inferior view.

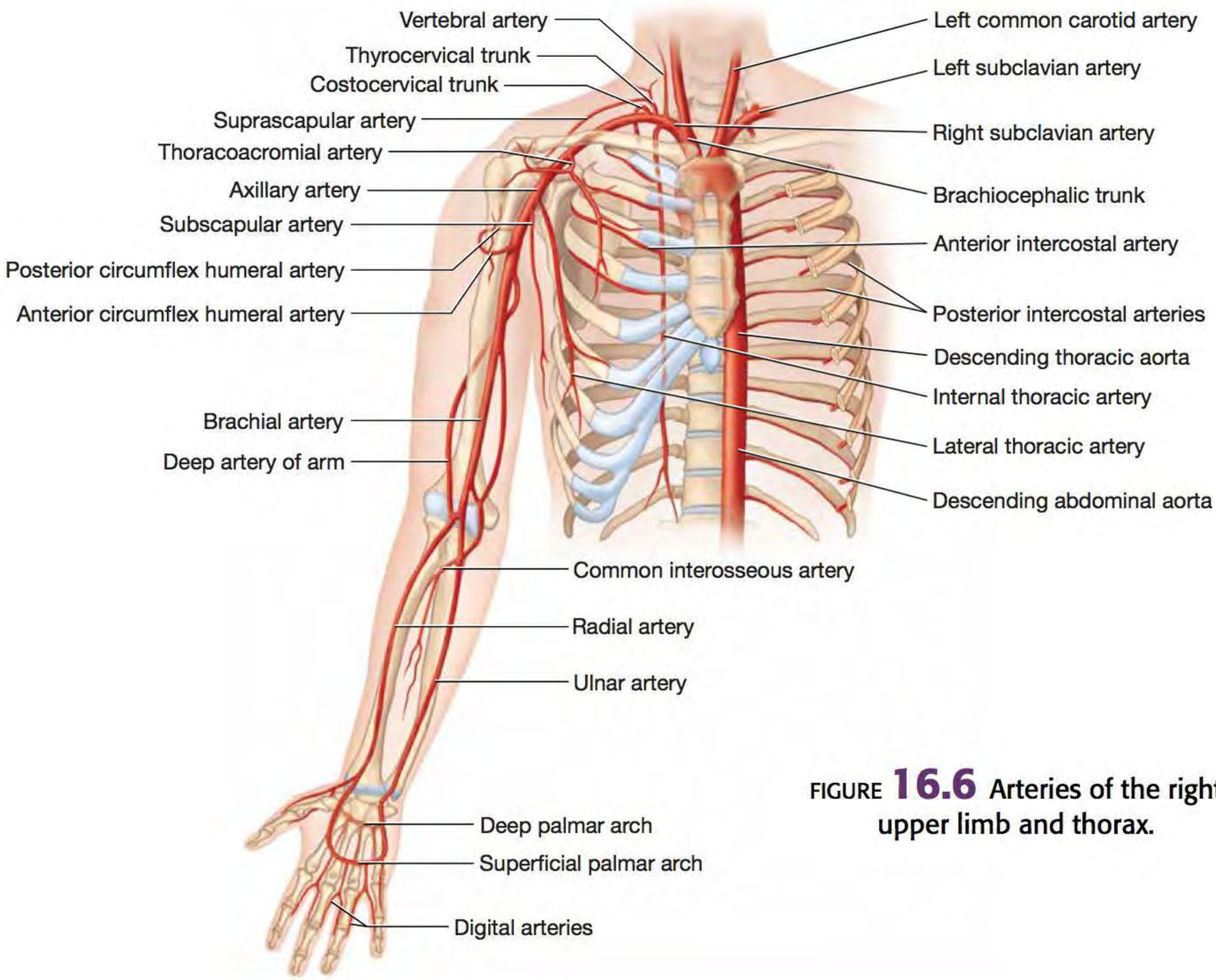


FIGURE **16.6** Arteries of the right upper limb and thorax.

After the branches of the aortic arch, the aorta turns inferiorly to become the **thoracic aorta.** The thoracic aorta descends through the thoracic cavity posterior to the heart, after which it passes through the diaphragm to become the **abdominal aorta.** The six major branches of the abdominal aorta, shown in Figure 16.7, include the following:

1. **Celiac trunk.** The short, stubby **celiac trunk** (SEE-lee-ak) is the first branch off of the abdominal aorta. It splits almost immediately into the **common hepatic artery,** which supplies the liver, stomach, pancreas, and duodenum (part of the small intestine); the **splenic artery** (SPLEN-ik), which supplies the spleen, stomach, and pancreas; and the **left gastric artery, which supplies the stomach.**
2. **Middle suprarenal arteries.** Just inferior to the celiac trunk are the small **middle suprarenal arteries,** which supply the adrenal glands that are found on top of the kidneys.
3. **Renal arteries.** Inferior to the celiac trunk we find the two **renal arteries** (REE-nul), which serve the kidneys. Note that the renal arteries are not illustrated in Figure 16.5, but they are visible in Figure 16.3, p. 400.
4. **Superior mesenteric artery.** Right around the renal arteries is another branch called the **superior mesenteric artery** (mez-en-TEHR-ik). As its name implies, it travels through the membranes of the intestines (called the *mesentery*) and supplies the small and much of the large intestine.
5. **Gonadal arteries.** Inferior to the superior mesenteric arteries we find a small pair of arteries that serve the reproductive organs, or *gonads*, and so are called the **gonadal arteries.**
6. **Inferior mesenteric artery.** The last large branch off of the abdominal aorta is the **inferior mesenteric artery,** which supplies the remainder of the large intestine.

The abdominal aorta terminates by bifurcating into two **common iliac arteries** (ILL-ee-ak), which themselves bifurcate into an **internal iliac artery** and an **external iliac artery** (Figure 16.8). The **internal iliac artery** supplies structures of the pelvis, and the **external iliac artery** passes deep to the inguinal ligament to enter the thigh, where it becomes the **femoral artery.** The femoral artery continues to the area around the popliteal fossa (the posterior knee), where it becomes the **popliteal artery** (pop-lih-TEEL). Shortly thereafter, the popliteal artery divides into its two main branches: the **anterior tibial artery,** which continues in the anterior foot as the **dorsalis pedis artery** (dohr-SAL-is PEE-dis), and the **posterior tibial artery,** which curls underneath the medial malleolus and continues to the plantar surface of the foot.

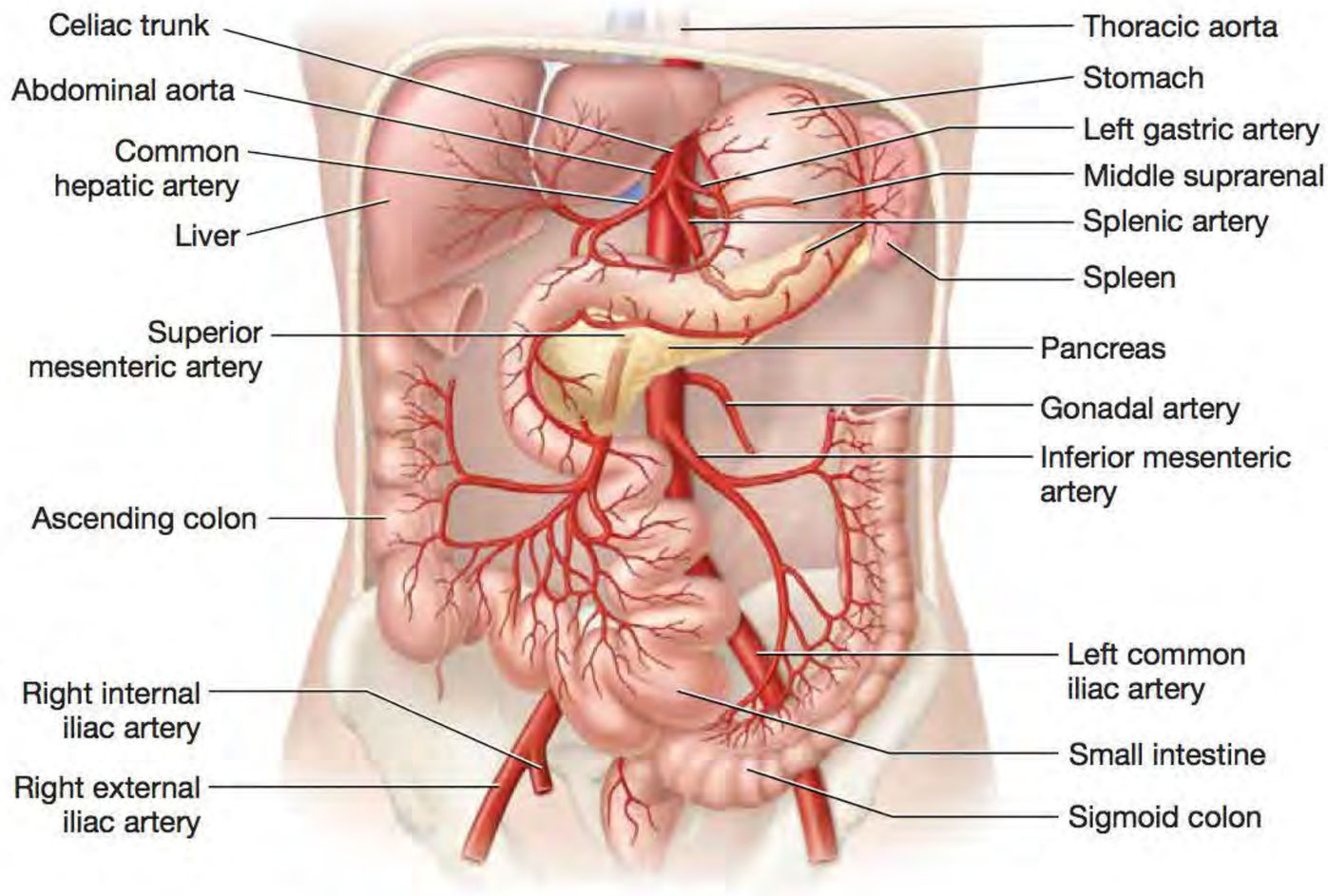


FIGURE **16.7** Arteries of the abdomen.

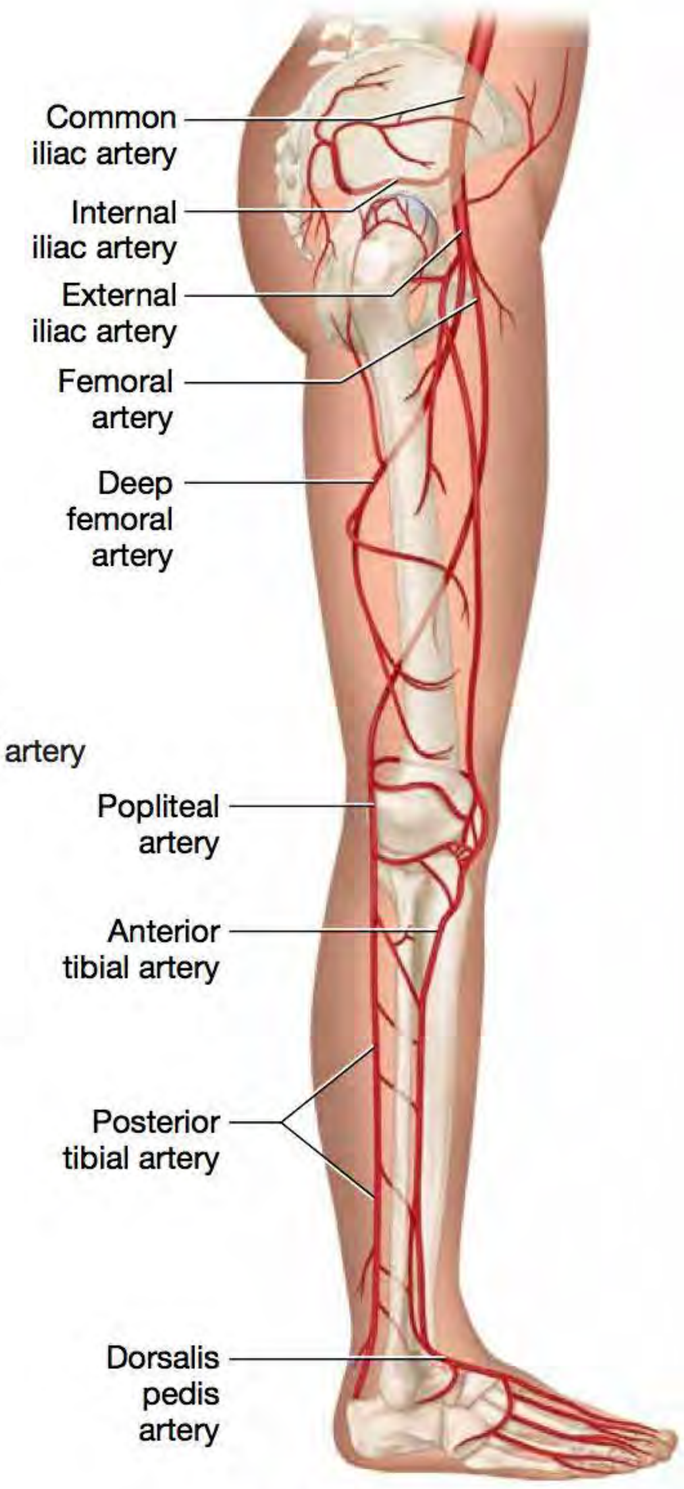


FIGURE **16.8** Arteries of the right lower limb, lateral view.

Procedure 1 Model Inventory for Arteries

Identify the following arteries on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 16.3. When you have completed the activity, answer Check Your Understanding questions 1 and 2 (p. 423).

Arteries of the Trunk

1. Aorta
   a. Ascending aorta
   b. Aortic arch
   c. Thoracic (descending) aorta
   d. Abdominal aorta
2. Brachiocephalic artery
3. Celiac trunk
   a. Splenic artery
   b. Left gastric artery
   c. Common hepatic artery
4. Superior mesenteric artery
5. Middle suprarenal artery
6. Renal artery
7. Inferior mesenteric artery
8. Gonadal artery
9. Common iliac artery
   a. Internal iliac artery

Arteries of the Head and Neck

1. Common carotid artery
   a. External carotid artery
      (1) Temporal artery
   b. Internal carotid artery
2. Vertebral artery
3. Basilar artery
4. Cerebral arterial circle
   a. Anterior communicating arteries
   b. Posterior communicating arteries
5. Anterior cerebral artery
6. Middle cerebral artery
7. Posterior cerebral artery

Arteries of the Upper Limbs

1. Subclavian artery
2. Axillary artery
3. Brachial artery
4. Radial artery
5. Ulnar artery

Arteries of the Lower Limbs

1. External iliac artery
2. Femoral artery
3. Popliteal artery
   a. Anterior tibial artery
      (1) Dorsalis pedis artery
   b. Posterior tibial artery

TABLE **16.3** Model Inventory for Arteries

Model/Diagram	Structures Identified

Exercise 16-2

Major Veins of the Body

MATERIALS

- ❑ Blood vessel models:
  - human torsos
  - brain
  - head and neck
  - abdomen
  - upper limb
  - lower limb
  - dural sinuses

Arteries of the systemic circuit deliver oxygenated, nutrient-rich blood to capillary beds, and here gases, nutrients, and wastes are exchanged. The deoxygenated, carbon dioxide–rich blood is then drained from the capillary beds by a series of veins. The two largest veins in the body are the **superior vena cava**, which drains most structures superior to the diaphragm, and the **inferior vena cava**, which drains most structures inferior to the diaphragm (Figure 16.9).

The head and the neck are drained primarily by the internal and external jugular veins, with a small contribution from the **vertebral** vein in the posterior neck (Figure 16.10). The much smaller and more lateral **external jugular vein** (JUG-yoo-lur) drains the face and the scalp, and the larger **internal jugular vein**, which travels in a sheath with the common carotid artery, drains the brain. Note, however, that venous blood from the brain does not simply drain into one vein and exit the head. Instead, blood from brain capillaries drains into cerebral veins, and then into spaces between the two layers of the dura mater called the **dural sinuses** (Figure 16.11). As you can see in the figure, two of the sinuses, the **superior** and **inferior sagittal sinuses**, are located within the falx cerebri. Blood from the inferior sagittal sinus drains posteriorly into the **straight sinus**, and then joins with the blood from the superior sagittal sinus by draining into the **transverse sinuses**. From here, blood drains into the **sigmoid sinuses**, which also receive blood from the anterior **cavernous sinus**. At this point blood drains into the internal jugular vein.

Blood from the deep structures of the upper limb is drained by the **radial** and **ulnar veins**, both of which parallel the bones for which they are named (Figure 16.12). These two veins merge in the arm to form the **brachial vein**, which becomes the **axillary vein** in the axilla. Near the clavicle, the axillary vein becomes the **subclavian vein**, which drains into the **brachiocephalic vein** and finally into the superior vena cava. The superficial structures of the upper limb are drained by the **cephalic vein** on the lateral side and the **basilic vein** on the medial side. Notice in the figure that the cephalic vein and the basilic vein are united in the antecubital fossa by the **median cubital vein** (KYOO-bit-uhl). This is a frequent site for drawing blood with a syringe. The basilic vein joins the brachial vein to form the axillary vein, and the cephalic vein joins the axillary vein to form the subclavian vein.

The venous blood of the posterior thoracic and abdominal walls drains into a set of veins called the **azygos system** (ay-ZY-gus), which consists of three veins: the **azygos vein**, the **hemiazygos vein**, and the **accessory hemiazygos vein**. The vessels on the left side of the thorax, such as the *posterior intercostal veins*, drain into either the hemiazygos or accessory hemiazygos veins, which then drain into the azygos vein. Vessels on the right side of the thorax drain into the azygos vein. Blood in the azygos vein then drains directly into the superior vena cava.

Veins draining blood from the organs of the abdomen are named largely in parallel with the arteries that serve the organs: The **renal veins** drain the kidneys, the **gonadal veins** drain the gonads, the **suprarenal veins** drain the adrenal glands (Figure 16.13), the **splenic vein** drains the spleen, the **gastric veins** drain the stomach, the **superior mesenteric vein** drains the small intestine and much of the large intestine, and the **inferior mesenteric vein** drains the remainder of the large intestine. Although the renal veins and gonadal veins empty into the inferior vena cava, the blood from the latter four veins does not drain into the inferior vena cava directly. Instead, note in Figure 16.14 that each vein drains into a common vein called the **hepatic portal vein**. Here, the nutrient-rich blood passes through the sinusoids of the liver, where it is processed and detoxified. In this way, everything we ingest (except lipids, which we discuss in Unit 20) must travel through the liver before entering the systemic circulation. Once the blood has filtered through the hepatic portal system, it exits via **hepatic veins** and drains into the inferior vena cava.

The deep structures of the lower limb are drained by the **anterior** and **posterior tibial veins**, which unite in the popliteal fossa to form the **popliteal vein** (Figures 16.9 and 16.15). In the distal thigh, the popliteal vein becomes the **femoral vein**, which becomes the **external iliac vein** after it passes under the inguinal ligament. In the pelvis, the external iliac vein merges with the **internal iliac vein**, which drains pelvic structures, forming the **common iliac vein**. The two common iliac veins unite to form the inferior vena cava near the superior part of the pelvis. The largest superficial vein of the lower limb is the **greater saphenous vein** (SAF-en-us), which drains the medial leg and thigh and empties into the femoral vein. Another superficial vein is the **small saphenous vein**, which is located in the lateral leg and empties into the popliteal vein.

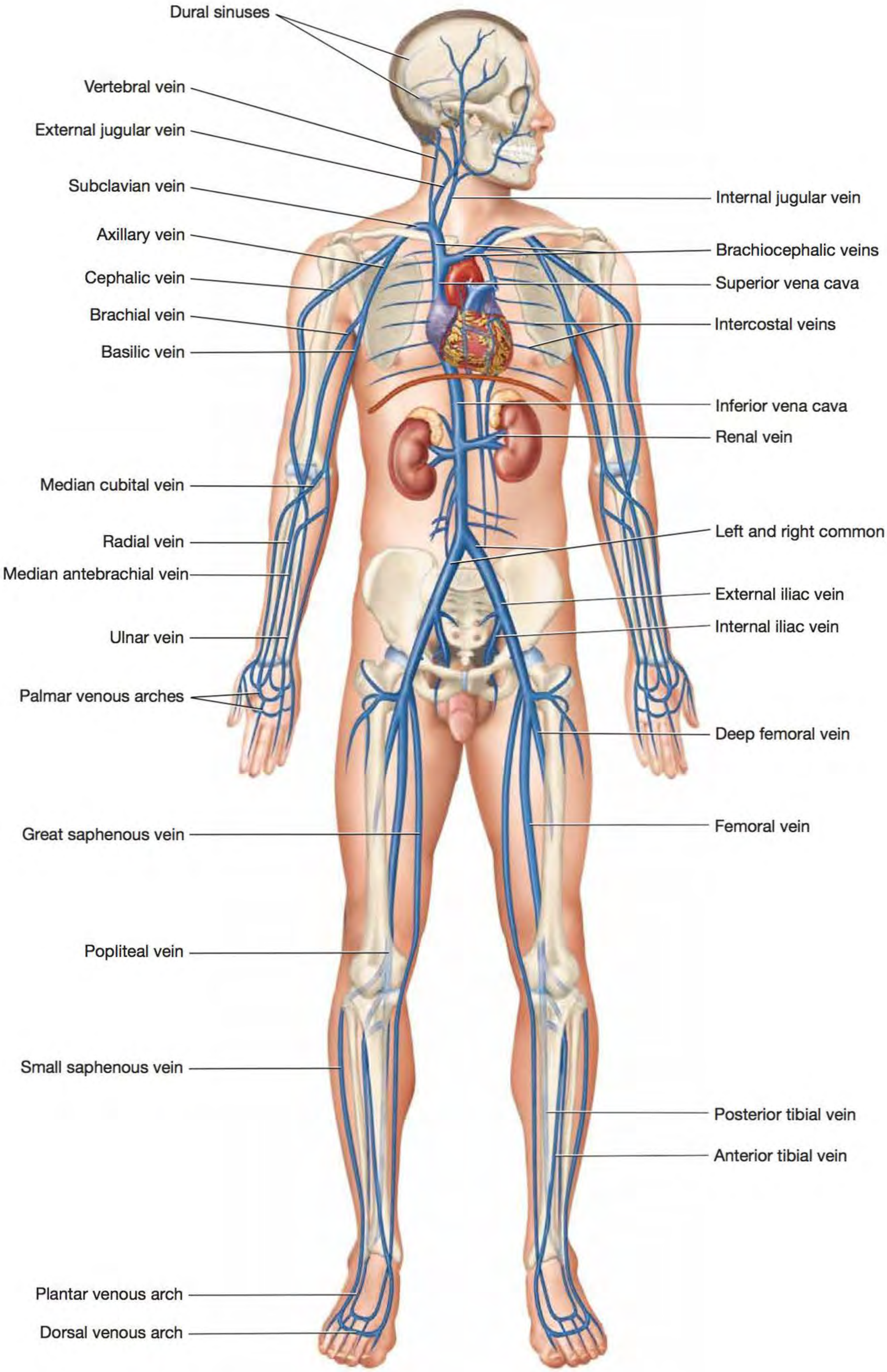


FIGURE **16.9** Major veins of the body.

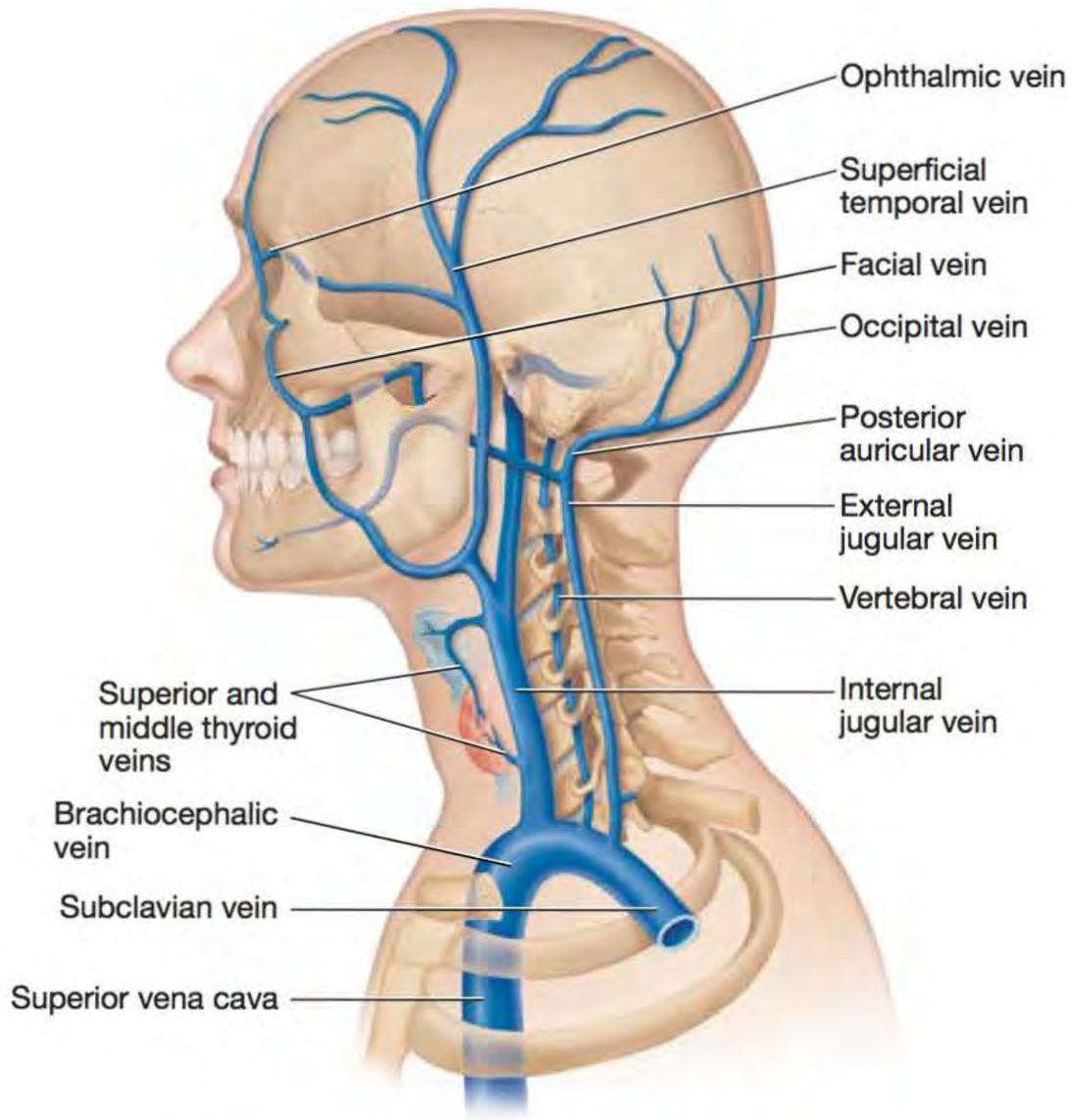


FIGURE **16.10** Superficial veins of the head and neck.

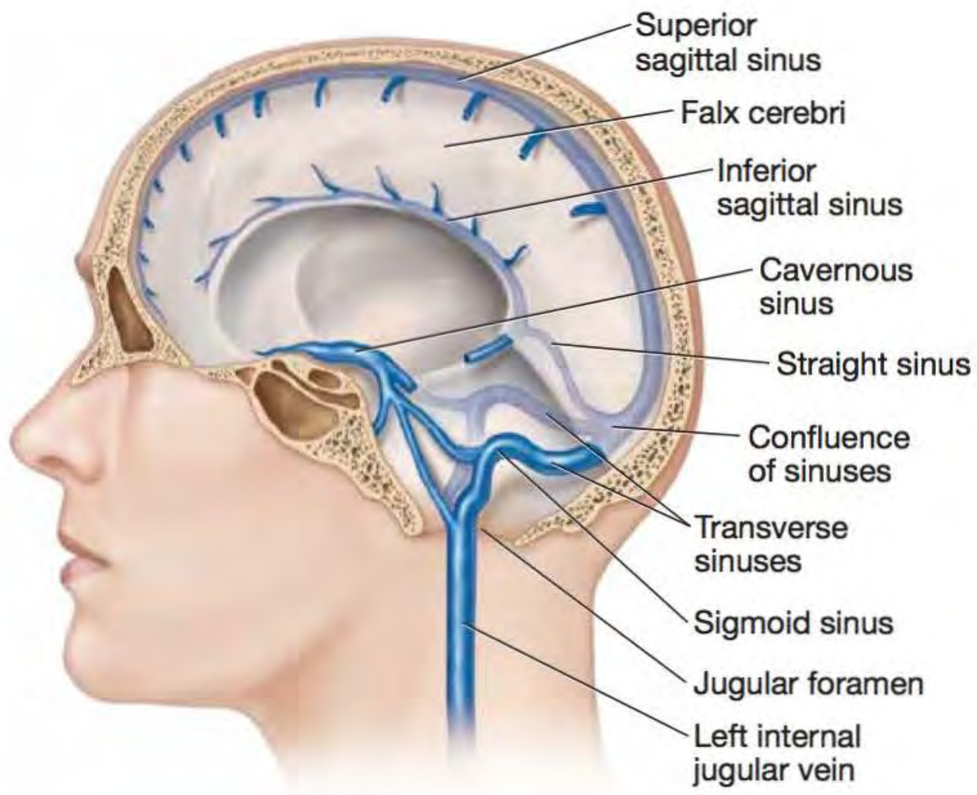


FIGURE **16.11** Veins draining dural sinuses of the brain.

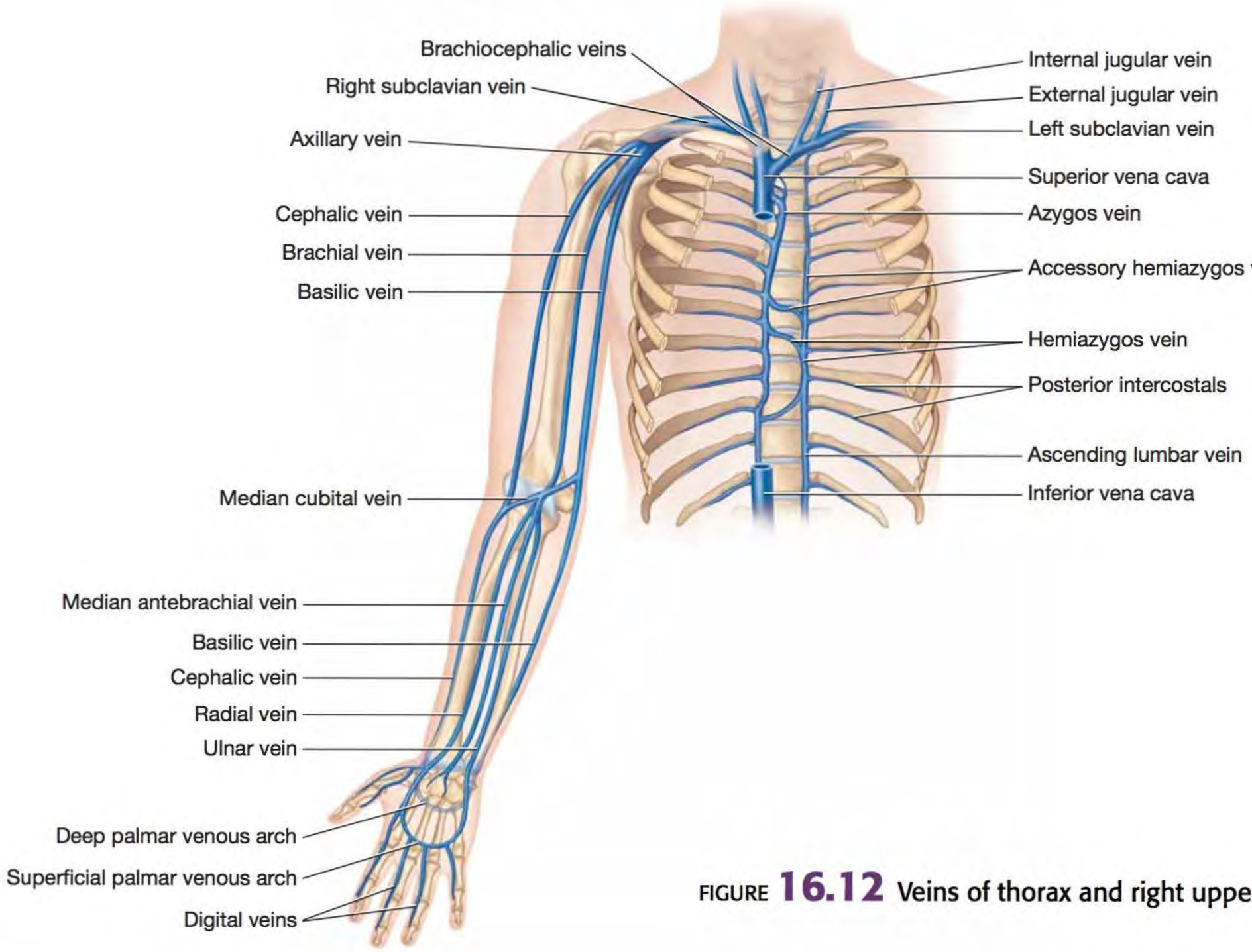


FIGURE **16.12** Veins of thorax and right upper limb.

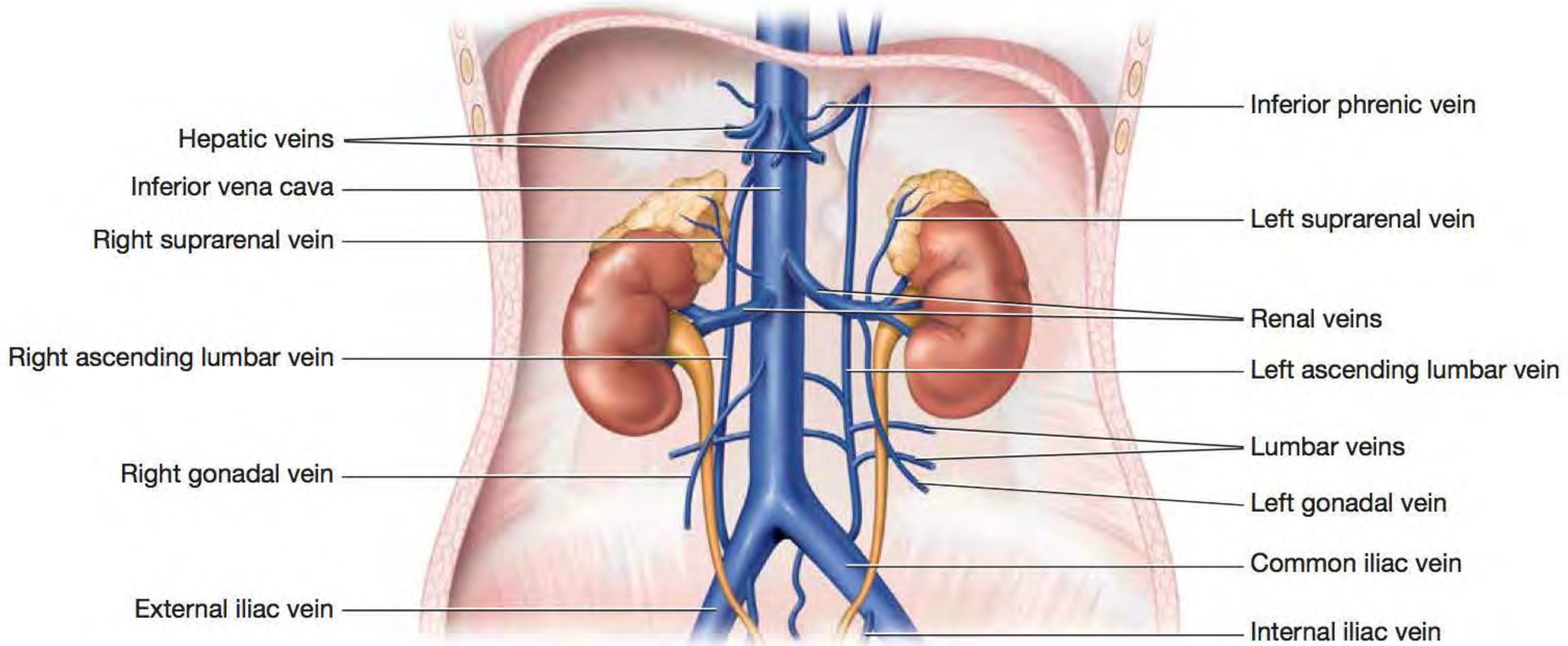


FIGURE **16.13** Veins draining the abdominal area (excluding the hepatic portal system).

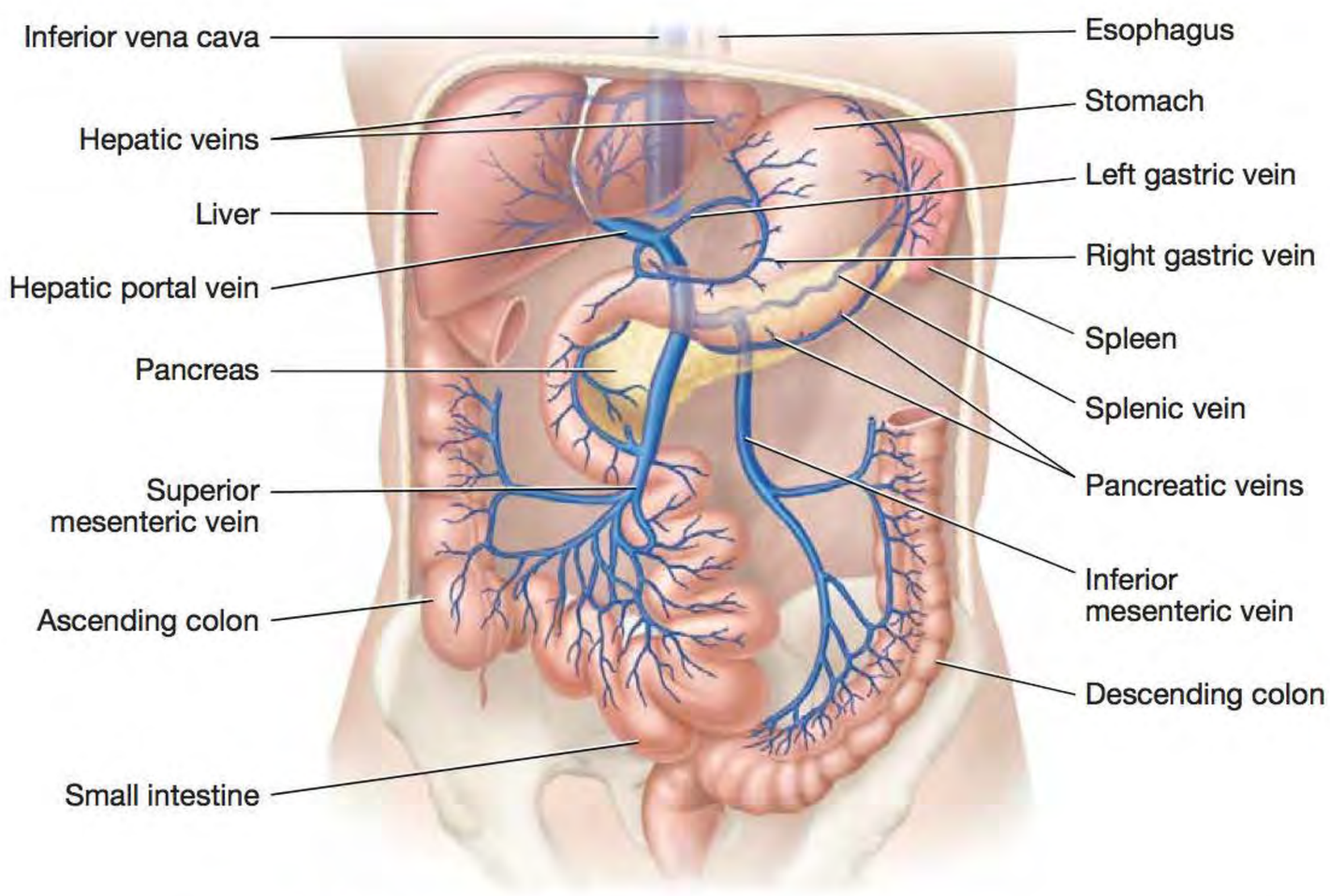


FIGURE **16.14** Veins of the abdomen and the hepatic portal system.

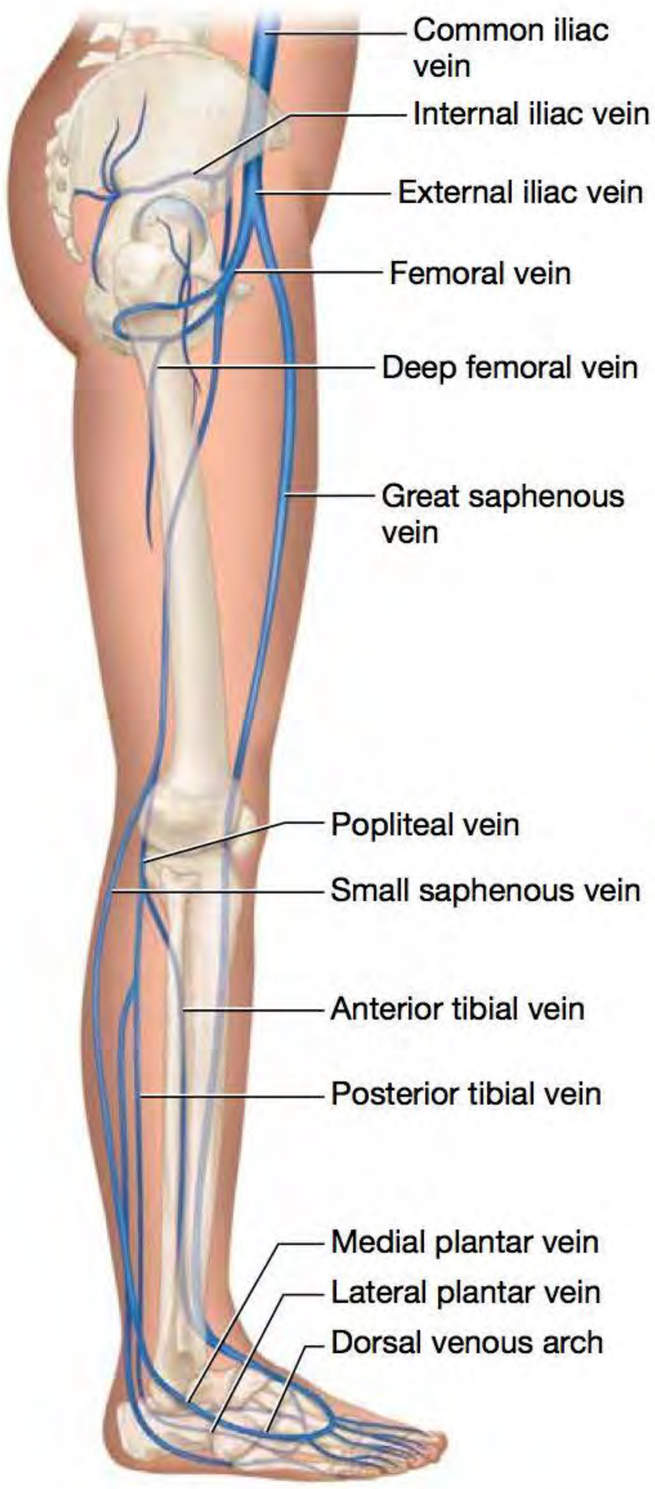


FIGURE **16.15** Veins of the lower limb, lateral view.

Procedure 1 Model Inventory for Veins

Identify the following veins on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 16.4. When you have completed the activity, answer Check Your Understanding questions 3 and 4 (pp. 423–424).

Veins of the Trunk

1. Superior vena cava
2. Inferior vena cava
3. Azygos system
   a. Azygos vein
   b. Hemiazygos vein
   c. Accessory hemiazygos vein
4. Renal vein
5. Gonadal veins
6. Suprarenal vein
7. Splenic vein
8. Gastric vein
9. Superior mesenteric vein
10. Inferior mesenteric vein
11. Hepatic portal vein
12. Hepatic veins

Veins of the Head and Neck

1. Vertebral vein
2. External jugular vein
3. Internal jugular vein
4. Dural sinuses
   a. Superior sagittal sinus
   b. Inferior sagittal sinus
   c. Straight sinus
   d. Transverse sinus
   e. Sigmoid sinus
   f. Cavernous sinus

Veins of the Upper Limbs

1. Radial vein
2. Ulnar vein
3. Brachial vein
4. Axillary vein
5. Subclavian vein
6. Brachiocephalic vein
7. Cephalic vein
8. Basilic vein
9. Median cubital vein

Veins of the Lower Limbs

1. Anterior tibial vein
2. Posterior tibial vein
3. Popliteal vein
4. Femoral vein
5. External iliac vein
6. Internal iliac vein
7. Common iliac vein
8. Great saphenous vein
9. Small saphenous vein

TABLE **16.4** Model Inventory for Veins

Model/Diagram	Structures Identified

Exercise 16-3

Time to Trace!

MATERIALS

- ❑ Laminated outline of the human body
- ❑ Water-soluble marking pen

In this exercise you will trace the blood flow through various places in the body. As you trace, keep the following hints in mind:

- Don't forget about the hepatic portal system! Remember that most venous blood coming from the abdominal organs has to go through the hepatic portal vein and the hepatic portal system before it can enter the general circulation.
- Don't forget that the venous blood in the brain drains first into the dural sinuses, then into a vein.
- If you start in a vein, you have to go through the venous system and through the heart before you can get back to the arterial system.
- If you start in an artery, you have to go through the arterial system and then through a *capillary bed* before you can go through the venous system. You can't go backward through the arterial system—that's cheating!
- If you start in an artery and end in an artery, you likely will have to go through the arterial circuit, through a capillary bed, through the venous circuit, back to the heart and lungs, and *then* reenter the arterial circuit. Whew!
- Sometimes there is more than one right answer, because you may take multiple paths.
- Following is an example in which we have started in the right popliteal vein and ended in the left internal carotid artery:

Start: right popliteal vein → right femoral vein → right external iliac vein → right common iliac vein → inferior vena cava → right atrium → tricuspid valve → right ventricle → pulmonary valve → pulmonary artery → lungs → pulmonary veins → left atrium → mitral valve → left ventricle → aortic valve → ascending aorta → aortic arch → left common carotid artery → left internal carotid artery → **End**

Wasn't that easy?

Procedure 1 Tracing Blood Flow Patterns

Trace the path of blood flow through the following circuits, using the example on page 409 for reference. It is helpful to draw the pathway out on a laminated outline of the human body, and label each vessel as you trace. If a laminated outline is not available, use Figures 16.16–16.19 instead.

1 *Start:* Right radial vein
End: Right renal artery

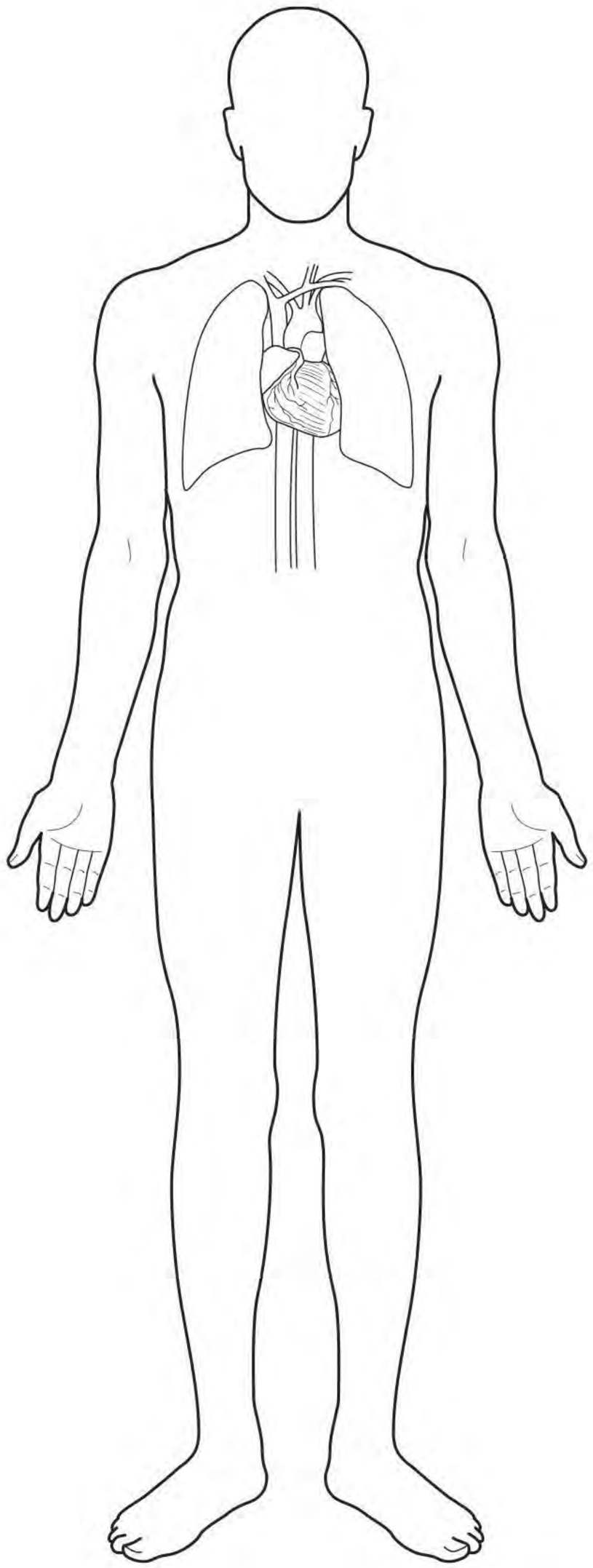


FIGURE **16.16** Outline of the human body.

2 *Start:* Left coronary artery

End: Dorsalis pedis artery

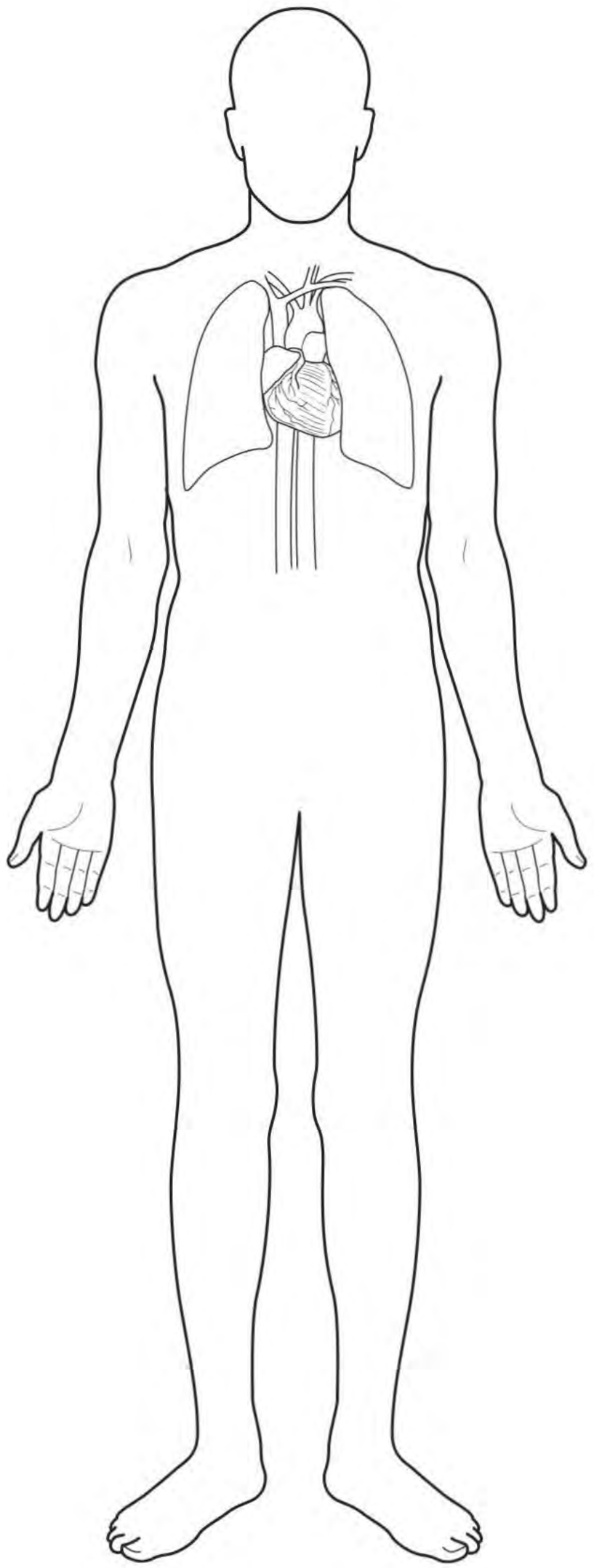


FIGURE **16.17** Outline of the human body.

3 *Start:* Superior mesenteric vein

End: Superior mesenteric artery

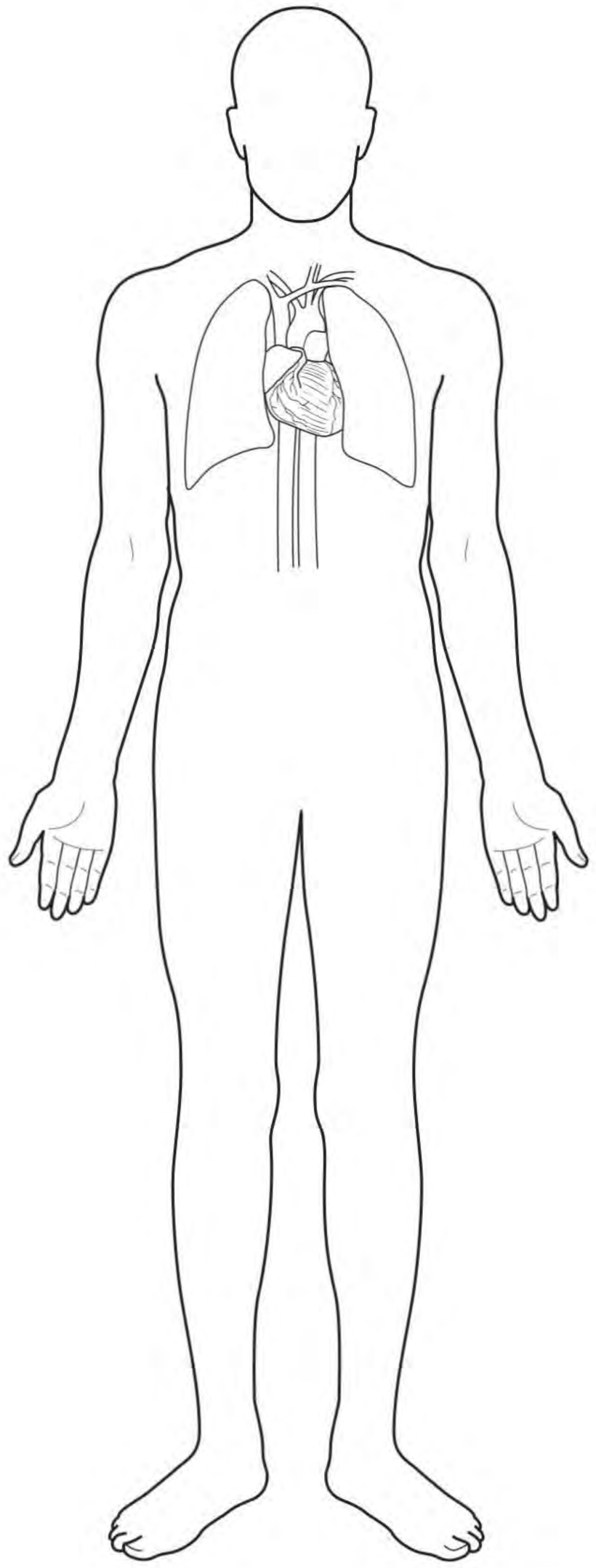


FIGURE **16.18** Outline of the human body.

4 *Start:* Renal artery

End: Internal jugular vein

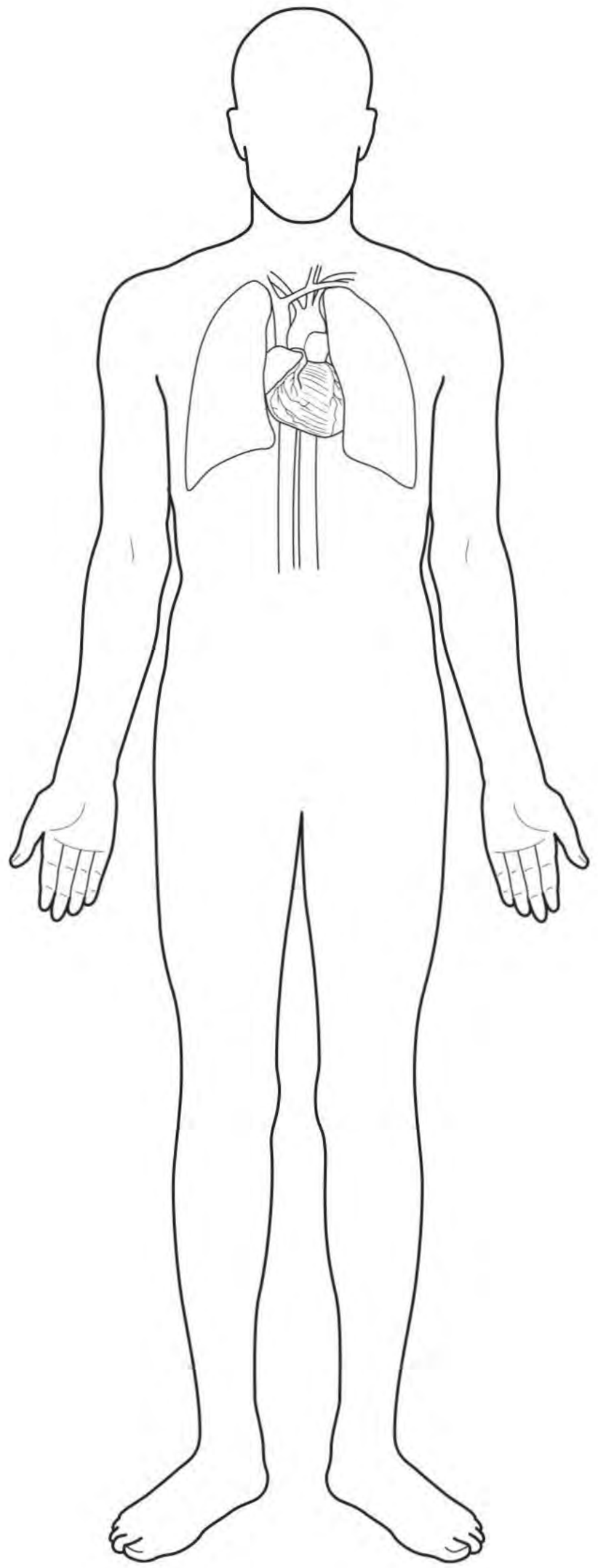


FIGURE **16.19** Outline of the human body.

Exercise 16-4

Histology of the Blood Vessel Wall

MATERIALS

- ❑ Blood vessel slide
- ❑ Light microscope
- ❑ Colored pencils

Three distinct tissue layers make up the walls of arteries and veins. The three layers, shown in Figure 16.20, are as follows:

1. **Tunica interna.** The innermost lining of the blood vessel is called the **tunica interna.** It consists of a specialized type of simple squamous epithelium called **endothelium.** It rests on top of a thin layer of connective tissue.
2. **Tunica media.** The middle layer of the blood vessel wall is called the **tunica media** and consists of smooth muscle and elastic fibers. The smooth muscle, innervated by the sympathetic nervous system, controls the diameter of the vessel and plays an important role in tissue perfusion and blood pressure. The elastic fibers allow the vessel to expand with changing pressure and return to its original shape and diameter.
3. **Tunica externa.** The outermost layer of the blood vessel wall is the **tunica externa** (or **tunica adventitia**), which consists of dense irregular collagenous connective tissue with abundant collagen fibers. The collagen fibers reinforce the blood vessel and prevent it from rupturing when the pressure in the vessel increases.

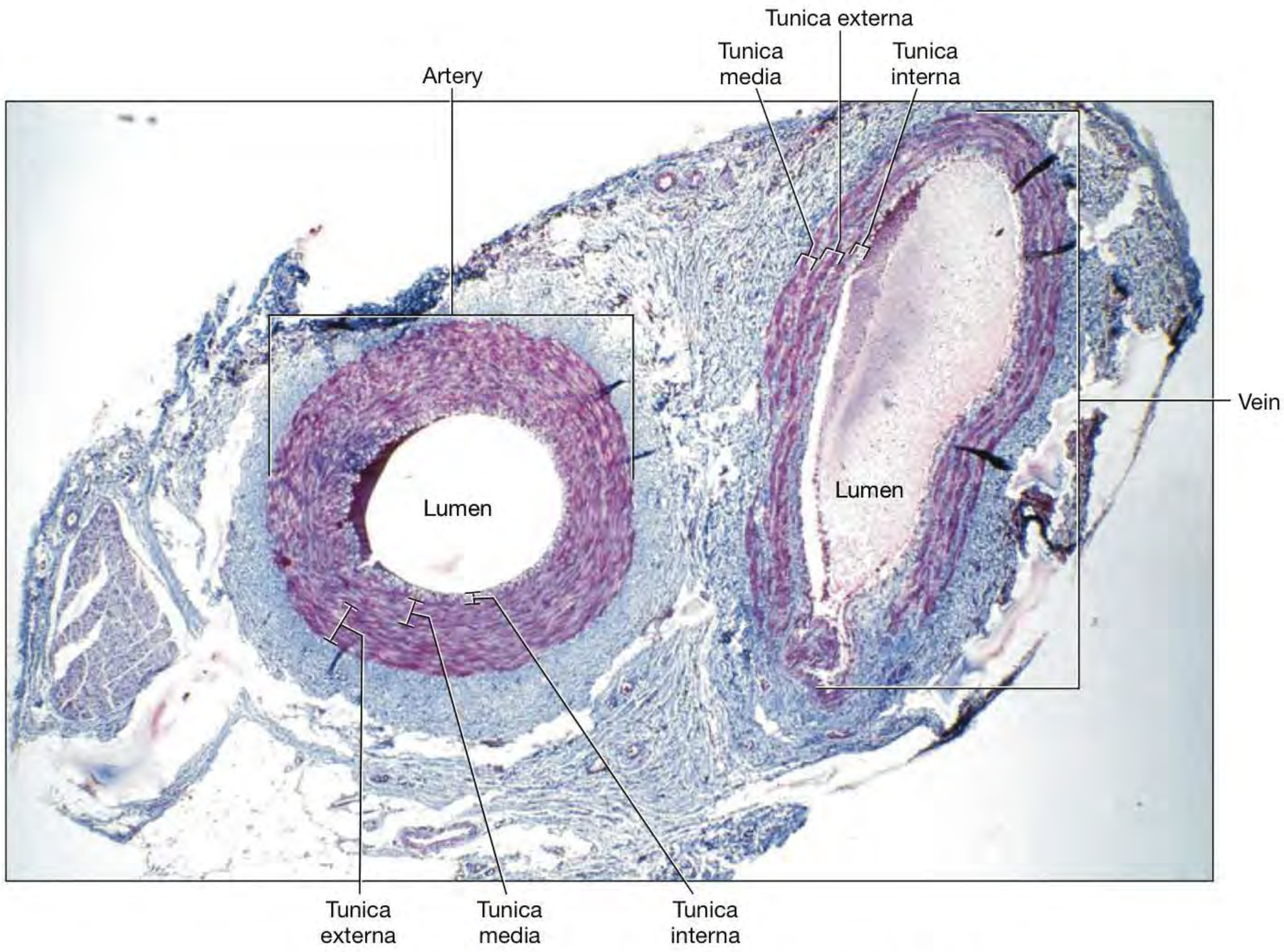


FIGURE **16.20** Photomicrograph of artery and vein.

HINTS & TIPS

Like any other organ, the structure of each type of blood vessel follows its function. For this reason, the characteristics of the three layers of the blood vessel wall are considerably different in arteries, capillaries, and veins. They are easy to identify if you bear the following in mind:

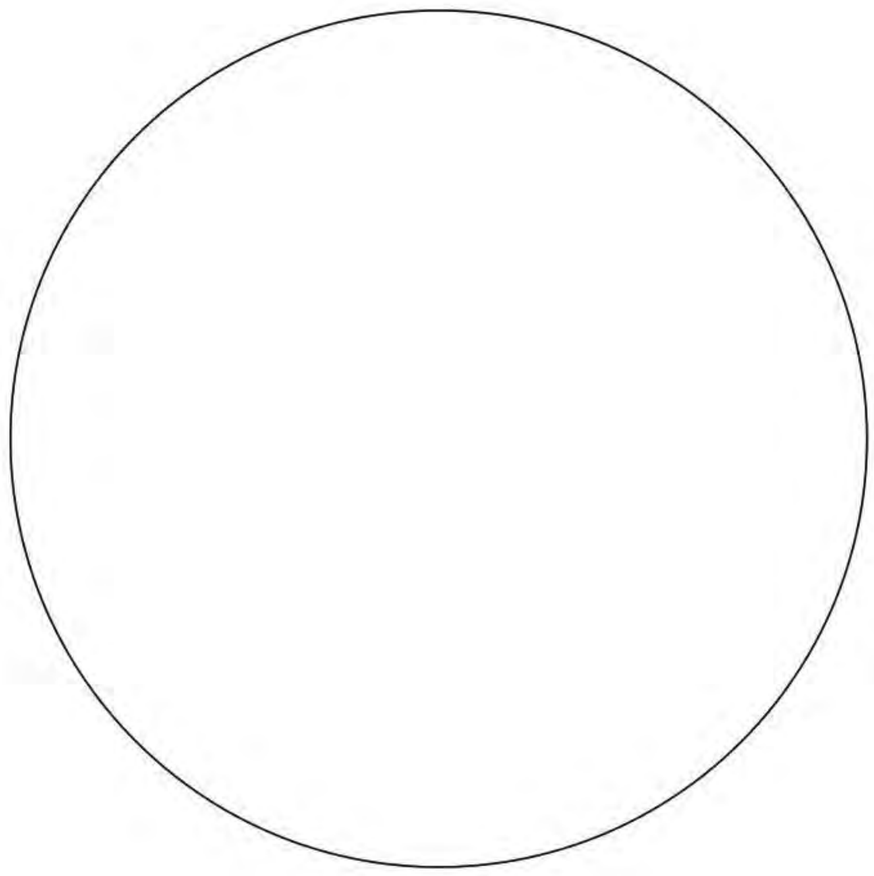
- An artery has a much thicker tunica media, with prominent elastic fibers that typically appear as a wavy purple line. It appears circular in cross sections because of its thick wall. An artery closer to the heart is under very high pressure and so has more elastic fibers in the tunica media and more collagen fibers in the tunica externa.
- A vein has a thin tunica media with few elastic fibers. Because the wall is so much thinner, the lumen is wider, and the vein is typically collapsed on the slide.
- A capillary is extremely thin-walled and consists only of a thin tunica interna. The smallest capillaries are large enough for only one red blood cell to fit through at a time.

Procedure 1 Microscopy

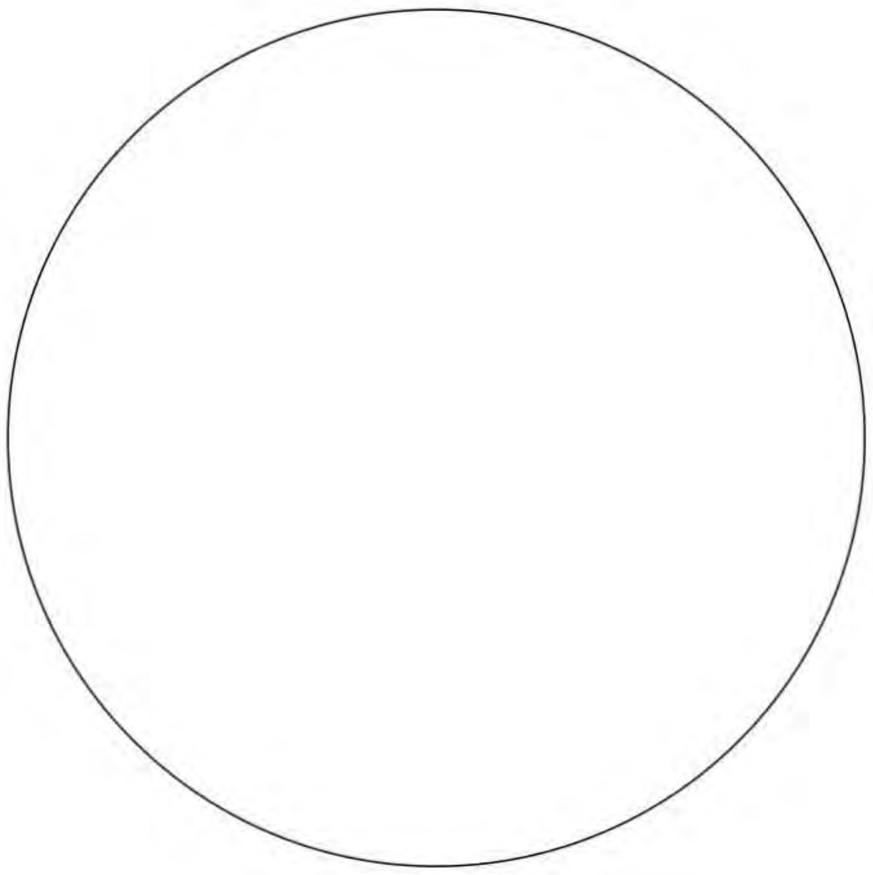
Examine prepared microscope slides of an artery, a capillary, and a vein. The capillary may be on a separate slide. Use colored pencils to draw what you see, and label your diagrams with the listed terms. When you have completed the activity, answer Check Your Understanding questions 5 through 7 (p. 424).

1 Artery

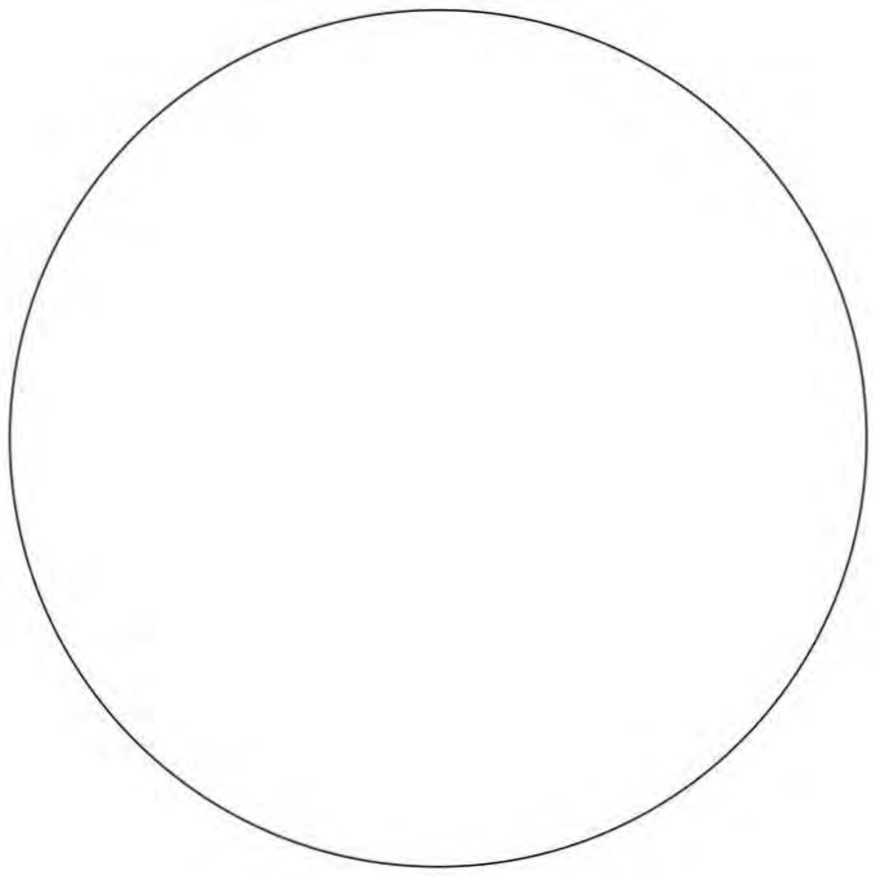
a. Tunica interna (endothelium)
b. Tunica media
   (1) Smooth muscle
   (2) Elastic fibers
c. Tunica externa
d. Lumen



2 Capillary
   a. Tunica interna
   b. Blood cell(s)



3 Vein
   a. Tunica interna
   b. Tunica media
      (1) Smooth muscle
   c. Tunica externa
   d. Lumen



Exercise 16-5

Clinical Applications

MATERIALS

- ❑ Blood vessel model or diagram
- ❑ Tourniquets
- ❑ Water-soluble marking pen
- ❑ Alcohol swabs

Knowledge of blood vessel anatomy is important for many different clinical applications. Here we will examine two: (1) pulse palpation, and (2) locating veins for blood draws and intravenous access. Note that you're not actually going to be sticking each other with needles—you're just going to be finding the veins, not actually putting needles in them.

Procedure 1 Pulse Palpation

Pulse palpation is the process of feeling the pulse with the fingertips. It is performed to assess the rate, rhythm, and regularity of the heartbeat and to assess the arterial circulation to different parts of the body. The pulses commonly measured are those found at the radial, ulnar, brachial, carotid, temporal, femoral, popliteal, posterior tibial, and dorsalis pedis arteries, shown in Figure 16.21.

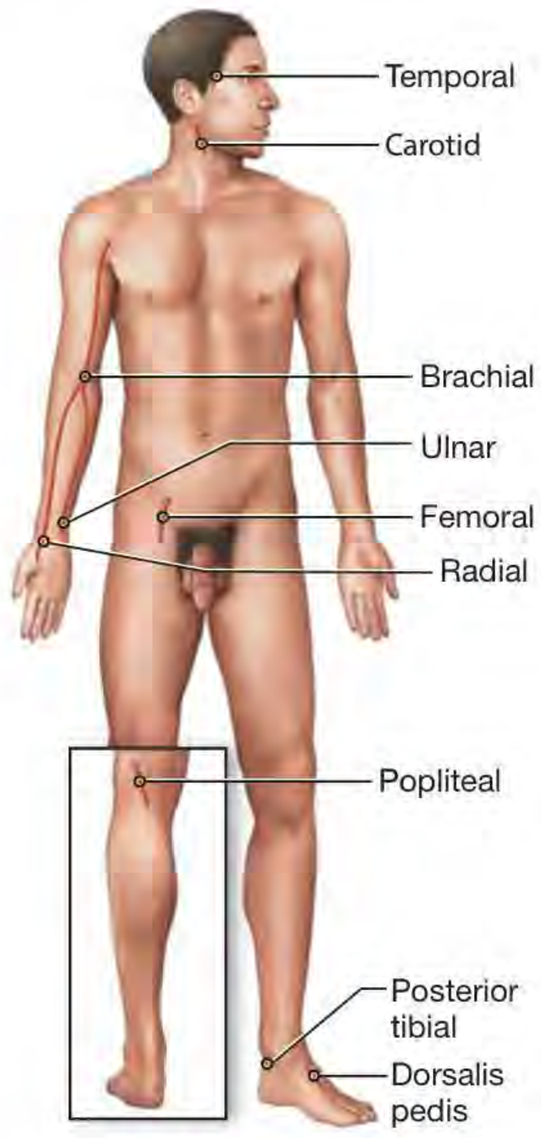


FIGURE **16.21** Common pulse points.

When pulses are palpated, they are **graded** according to a standard scale. This allows healthcare professionals to communicate about a patient unambiguously and to assess the progress or deterioration of a patient's condition. The scale utilizes the following four grades:

Grade **0/4**: The pulse is absent.
Grade **1/4**: The pulse is barely or only lightly palpable.
Grade **2/4**: The pulse is normal.
Grade **3/4**: The pulse is abnormally strong.
Grade **4/4**: The pulse is bounding and visible through the skin.

Notice that this scale has no negative numbers or decimal numbers (e.g., you would not use –1/4 or 2.5/4). In a healthy person most pulses are grade 2/4 (read as, "two out of four"), although occasionally a pulse is weak or absent. This is simply normal anatomical variation and does not signify pathology. Students often mistakenly grade any strong pulse as 4/4. If a pulse were truly 4/4, however, this would be a sign of extremely high blood pressure in that artery and would possibly be a medical emergency. Most strong, healthy pulses are graded as 2/4.

Please note before you begin that you should never assess both of your lab partner's carotid arteries at the same time. This might initiate the **baroreceptor reflex** (BEHR-oh-ree-sep-tohr), in which the parasympathetic nervous system triggers a reflexive and often dramatic drop in blood pressure and heart rate. This could cause your lab partner to momentarily lose consciousness.

1. Wash your hands prior to palpating your lab partner's pulses.
2. On a model or diagram, locate the artery you are palpating.
3. Lightly place your index finger and middle finger over the artery. You may increase the pressure slightly, but be careful not to press too hard, because you could cut off blood flow through the artery and also could mistake the pulse in your fingertips for your partner's pulse. If you are unsure if the pulse is yours or your partner's, feel the lab table. If the lab table "has a pulse," you are feeling the pulse in your own fingertips.
4. Palpate *only* one side (right or left) at a time, especially in the carotid artery.
5. Grade your partner's pulses according to the 0/4 to 4/4 scale, and record the results in Table 16.5.

TABLE **16.5** Pulse Point Grades

Artery	Right-Side Grade	Left-Side Grade
Carotid		
Temporal		
Brachial		
Radial		
Ulnar		
Dorsalis pedis		
Posterior tibial		

Procedure 2 Locating Common Blood Draw and Intravenous Access Points

The superficial veins of the arm, forearm, and hand provide multiple places that are relatively easy to access when we need to obtain venous blood. When performing a *blood draw*, or the withdrawal of blood for analysis, the most commonly used veins are the median cubital vein, the cephalic vein, or the basilic vein. When placing an *intravenous catheter* into a vein, generally one of the posterior veins of the hand are used.

If you take a look at your arms and hands right now, you'll see that these superficial veins aren't really all that visible. You might see a few small very superficial veins, but usually none that are large enough in which to place a needle. To get these veins to "pop," medical professionals wrap a tourniquet around the proximal arm, which increases the pressure in the distal veins and decreases venous return. This increases the amount of blood in the veins, and makes them more visible from the surface of the skin (Figure 16.22). Your goal in this activity is to use a tourniquet to make your lab partner's veins "pop" and identify as many superficial veins as possible.

1 Obtain a tourniquet of the appropriate size and place it around your partner's arm about 7.5–10 cm (3–4 inches) proximal to the antecubital fossa. It should be tight, but avoid pinching your partner's skin or causing too much discomfort.

2 First look for the veins on the anterior arm. Wait about 15–20 seconds for the veins to begin to fill with blood. It may help for your partner to open and close his or her fist once or twice. If you can't see the superficial veins, tapping them lightly may also help make them more visible. Do not leave the tourniquet on your partner's arm for longer than one minute.

3 When you can see your partner's veins, trace them lightly with a water-soluble marking pen. Which veins were you able to find and identify?

---

4 Remove the tourniquet from your partner's arm and repeat the procedure on his or her opposite arm, this time looking for veins on the posterior hand. Again, do not leave the tourniquet on your partner's arm for longer than one minute. Which veins were you able to find and identify?

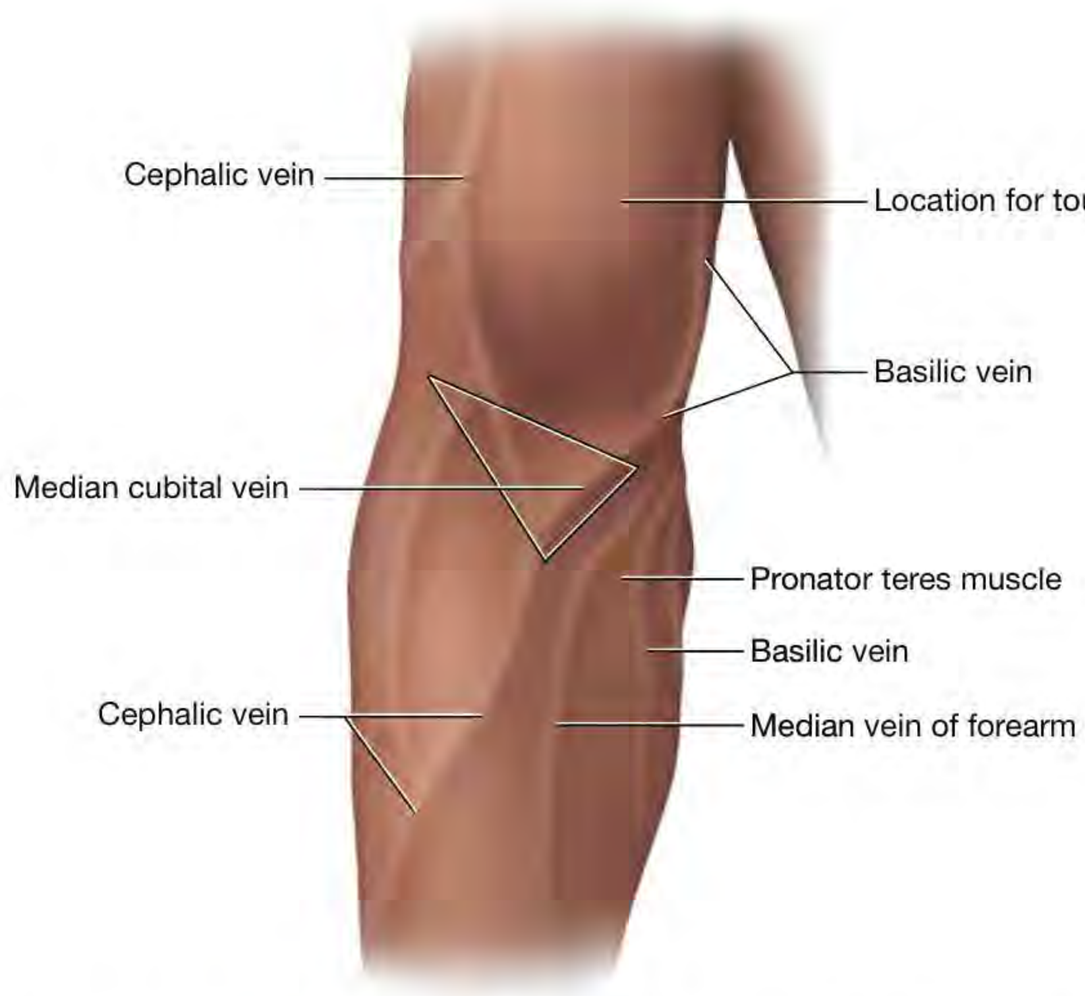


FIGURE **16.22** Surface anatomy of the superficial veins of the arm and forearm.

Name _____

Section _____ Date _____

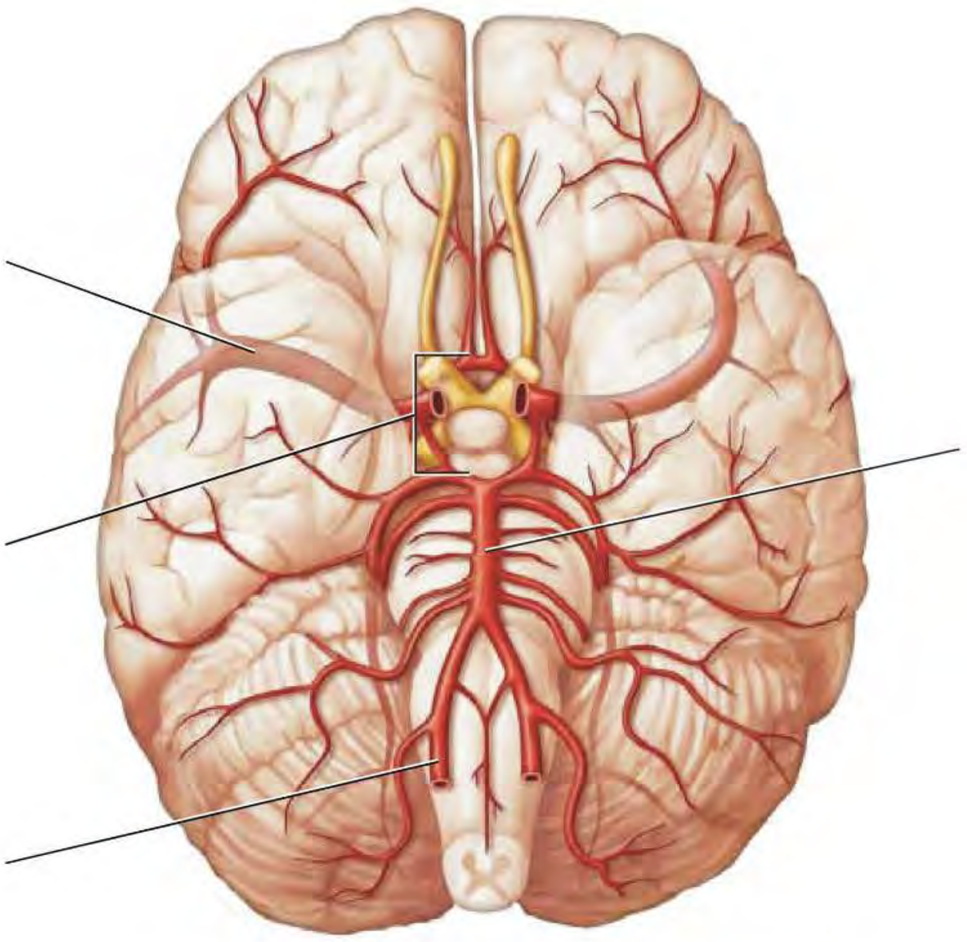
UNIT 16 REVIEW

Check Your Recall

1 Label the arteries in Figure 16.23 below and Figure 16.24 on the following page.

Figure 16.23

- ❑ Basilar artery
- ❑ Brachial artery
- ❑ Cerebral arterial circle
- ❑ Common iliac artery
- ❑ Dorsalis pedis artery
- ❑ Femoral artery
- ❑ Left common carotid artery
- ❑ Middle cerebral artery
- ❑ Posterior tibial artery
- ❑ Radial artery
- ❑ Renal artery
- ❑ Right common carotid artery
- ❑ Right subclavian artery
- ❑ Ulnar artery
- ❑ Vertebral artery



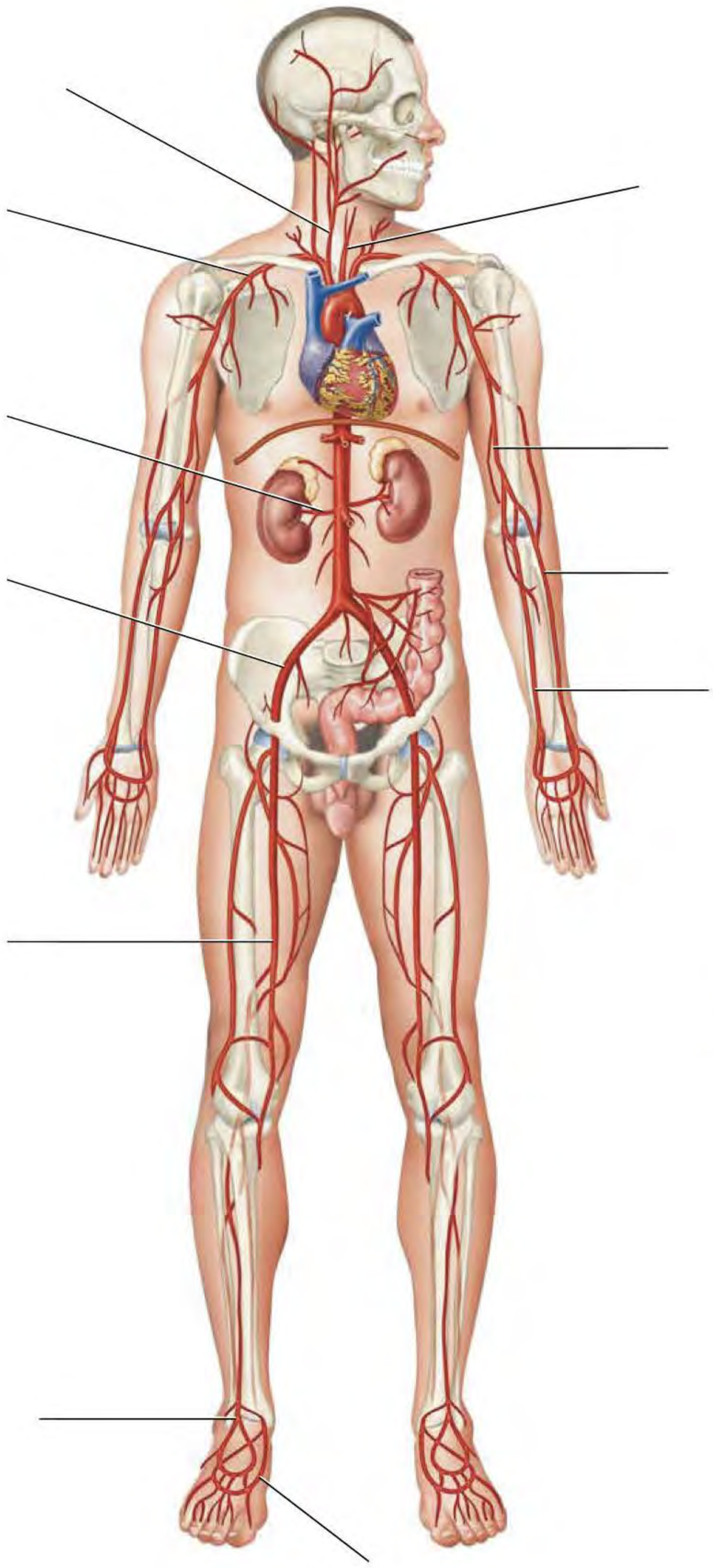


FIGURE **16.23** Major arteries of the body.

Figure 16.24

- ❑ Celiac trunk
- ❑ Common hepatic artery
- ❑ Inferior mesenteric artery
- ❑ Splenic artery
- ❑ Superior mesenteric artery

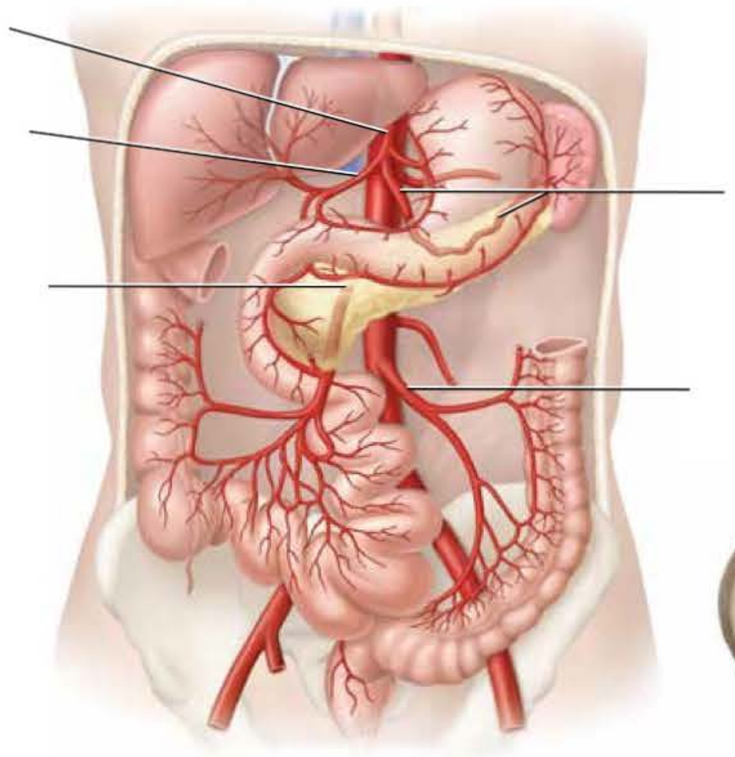
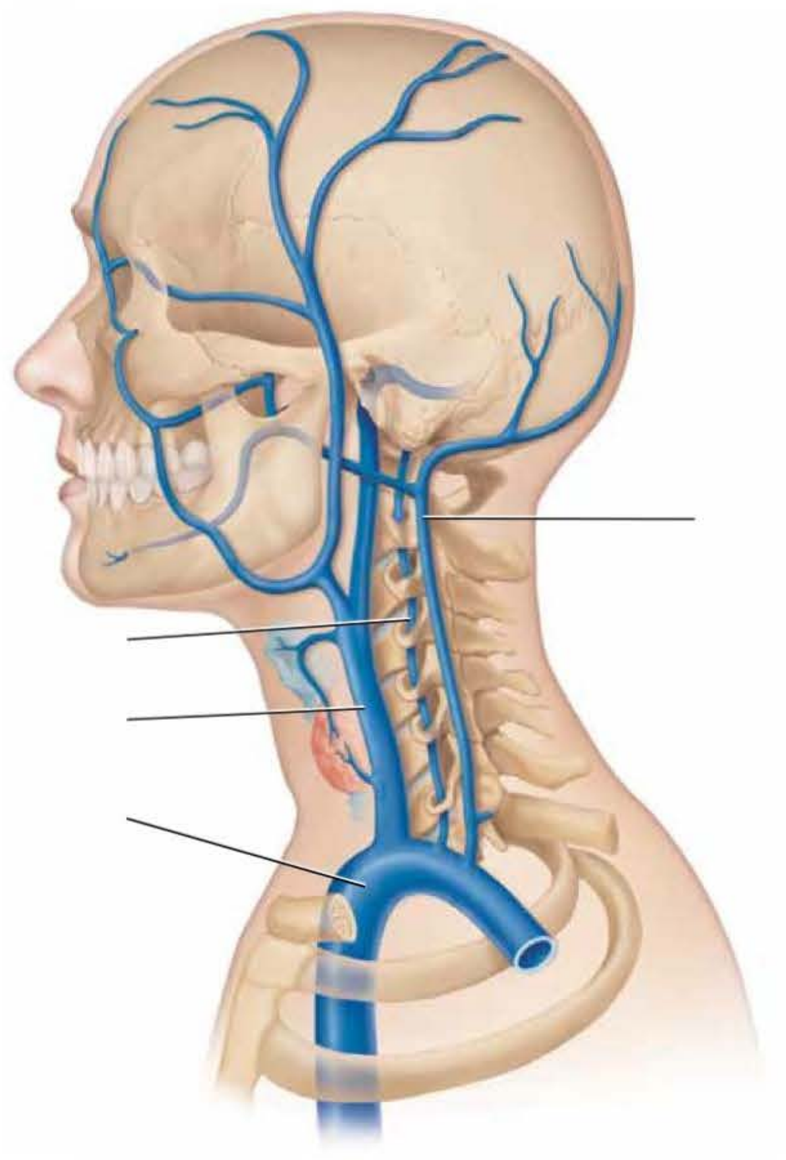


FIGURE **16.24** Arteries of the abdomen.

2 Label the veins on Figure 16.25 below and Figure 16.26 on the following page.

Figure 16.25

- ❑ Brachial vein
- ❑ Brachiocephalic vein
- ❑ Cephalic vein
- ❑ Common iliac vein
- ❑ External jugular vein
- ❑ Femoral vein
- ❑ Great saphenous vein
- ❑ Internal jugular vein
- ❑ Renal vein
- ❑ Subclavian vein
- ❑ Vertebral vein



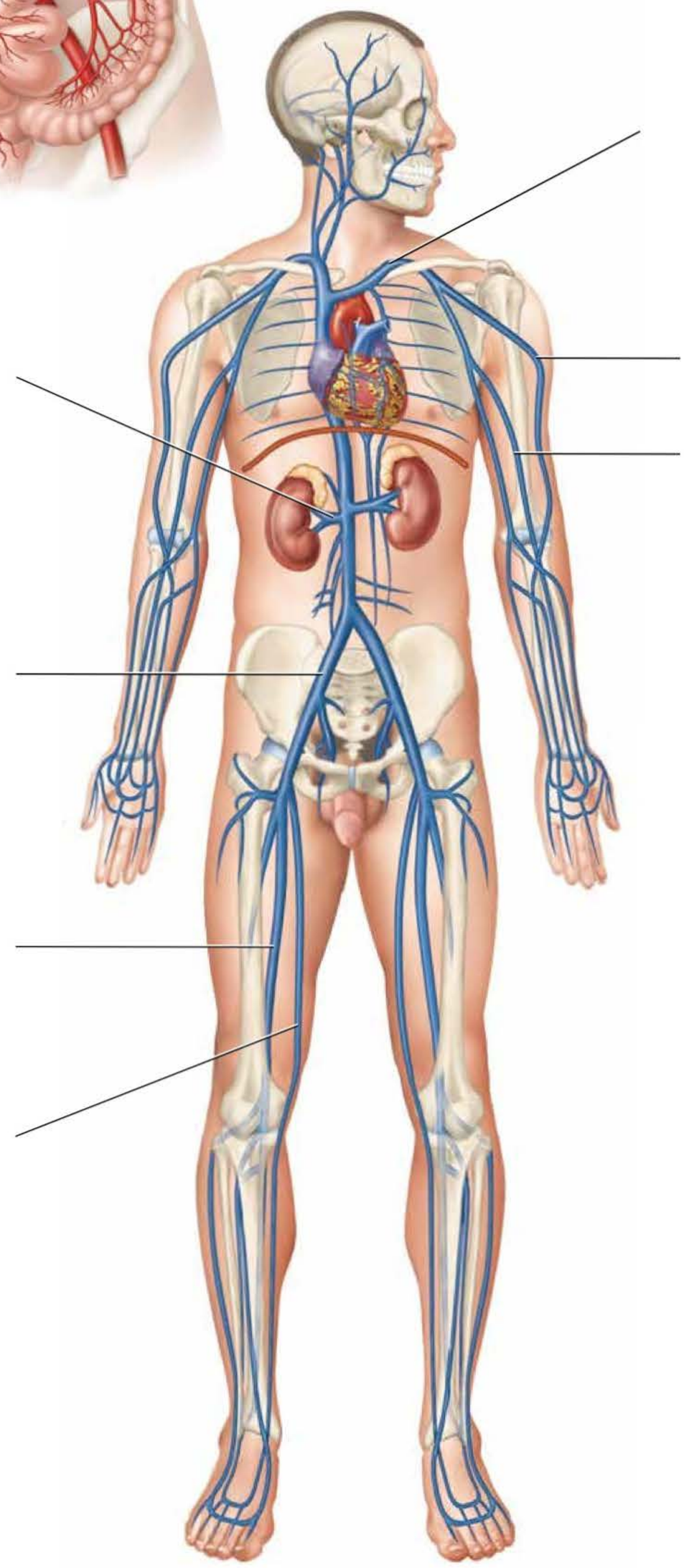


FIGURE **16.25** Major veins of the body.

Name _____

Section _____ Date _____

UNIT 16

Figure 16.26

- ❑ Hepatic portal vein
- ❑ Hepatic veins
- ❑ Inferior mesenteric vein
- ❑ Left gastric vein
- ❑ Splenic vein
- ❑ Superior mesenteric vein

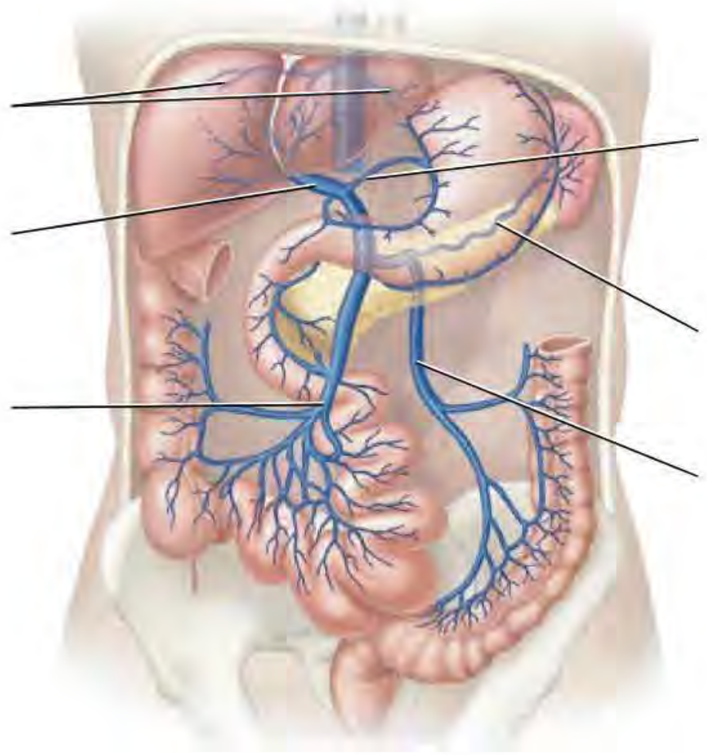


FIGURE **16.26** Veins of the abdomen and the hepatic portal system.

3 Which of the following is *not* a major circuit of blood flow in the body?

a. Coronary circuit
b. Cerebral circuit
c. Pulmonary circuit
d. Systemic circuit

4 How do the right and left common carotid arteries differ in terms of the arteries from which they originate?

_____

_____

_____

16

5 The cerebral arterial circle

a. provides alternate routes of blood flow in the brain.
b. supplies the face and the scalp.
c. provides alternate routes of blood flow in the liver.
d. supplies the myocardium.

6 The venous blood of the brain drains into a set of _____ before draining into a vein.

a. coronary arteries
b. cerebral veins
c. dural sinuses
d. paranasal sinuses

7 **Which of the following veins drain into the hepatic portal vein?** ***(Circle all that apply.)***

a. Renal vein
b. Splenic vein
c. Superior mesenteric vein
d. Inferior mesenteric vein
e. Hepatic veins
f. Gastric veins

8 **Which of the following describes the purpose of the hepatic portal system?**

a. It provides the liver with oxygenated blood.
b. It allows the liver to process and detoxify nutrient-rich blood from most of the abdominal organs.
c. It drains blood from the liver to the inferior vena cava.
d. All of the above.

9 **From superficial to deep, the layers of the blood vessel wall include the:**

10 **Which of the following correctly describes the role of the smooth muscle cells in the blood vessel wall?**

a. They play an important role in determining the amount of blood flowing to a tissue (tissue perfusion).
b. They play an important role in determining blood pressure.
c. They control the diameter of the blood vessel.
d. All of the above.
e. None of the above.

Name _____

Section _____ Date _____

UNIT 16 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Would a blood clot lodged in one of the anterior or posterior communicating arteries of the cerebral arterial circle be likely to cause significant deficits in blood flow to the brain? Why or why not?

2 Your patient presents with severe abdominal pain. Your team orders a CT scan and discovers a large blood clot lodged in the celiac trunk. What organs could this blood clot potentially affect? Why do you think the clot is causing abdominal pain?

3 Certain drugs cannot be taken by mouth because the entire dose of the drug is destroyed in the liver before it ever reaches the general circulation. Explain why these same drugs can be given by injection, either intravenously or intramuscularly. (*Hint*: Consider the hepatic portal system.)

4 In the surgical procedure called a bypass graft, a vessel is removed from a patient and used to make a vascular bridge that bypasses one of that patient's blocked arteries. A common vessel used for this procedure is the greater saphenous vein. Why do you think a surgeon might use the greater saphenous vein instead of the femoral vein or a large artery?

5 Predict what might happen if the elastic fibers in a blood vessel's wall were defective. Would such a condition be more problematic for arteries or for veins? Explain.

6 The conditions known as *collagen vascular diseases* are characterized by defects in the collagen fibers in the tunica externa. What effects would you expect such diseases to have on the structure and function of blood vessels?

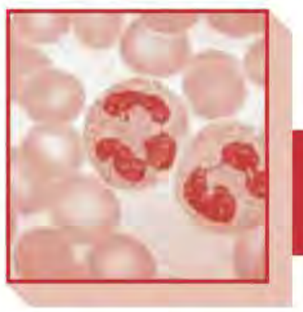
7 Collagen vascular diseases may lead to the formation of an aneurysm, or the ballooning of a blood vessel, generally in the aorta. Why do you think aneurysms are more likely to form in the aorta than in other vessels?

17 Blood

OBJECTIVES

Once you have completed this unit, you should be able to:

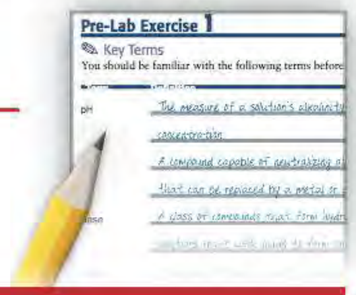
1. Identify the formed elements of blood.
2. Determine the differential white blood cell count of a blood smear.
3. Perform blood typing of the ABO and Rh blood groups using simulated blood.
4. Explain the basis for blood typing and matching for blood donation.
5. Determine appropriate blood donors for a given recipient.
6. Determine your own blood type and the hemoglobin content of your blood.



Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 17-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Formed Elements

Erythrocyte _____

Leukocyte _____

Granulocyte _____

Neutrophil _____

Eosinophil _____

Basophil _____

Agranulocyte _____

Lymphocyte _____

Monocyte _____

Platelets _____

Blood Typing

Antigen _____

Antiserum _____

Name _____ Section _____ Date _____

Antibody _____

_____

Blood Donation

Universal donor _____

_____

Universal recipient _____

_____

17

Pre-Lab Exercise 17-2

Formed Elements

In this unit we will identify the formed elements of blood on a peripheral blood smear. Each formed element has unique morphological characteristics and functions. Use your text and Exercise 17-1 (p. 429) in this unit to fill in Table 17.1 with these functions and characteristics.

TABLE **17.1** Properties of Formed Elements

Formed Element	Nucleus Shape	Cytoplasm and/or Granule Color	Function(s)	Prevalence
Erythrocyte				
Neutrophil				
Eosinophil				
Basophil				
Lymphocyte				
Monocyte				
Platelet				

EXERCISES

Safety concerns often preclude the use of real blood in the laboratory, but we can still demonstrate important principles of blood by viewing prepared microscope slides of blood cells and by using simulated blood to learn about blood typing. There is no real concern over blood-borne diseases with simulated blood, but do keep in mind that the simulated blood contains chemicals that are hazardous. Therefore, use appropriate safety protocols when handling all materials in this lab.

In this unit you will identify the formed elements of blood on microscope slides. You will also play a murder mystery game in which you use simulated blood to apply blood-typing techniques, after which you use the same cast of characters to examine blood donation. If your lab has the appropriate protocols for the use of real blood, you will also type your own blood and determine its hemoglobin content.

Exercise 17-1

Formed Elements (Cells) of Blood

MATERIALS

- ❑ Blood slides
- ❑ Light microscope
- ❑ Colored pencils

Whole blood consists of two main components: **plasma**, the fluid portion of blood, and **formed elements**, or the cellular portion of blood. Plasma accounts for about 55% of the volume of whole blood and consists primarily of water, proteins, and other solutes such as nutrients and ions. Formed elements account for about 45% of the volume of whole blood. Formed elements can be divided into three classes, each of which is shown in Figure 17.1.

1. **Erythrocytes. Erythrocytes** (eh-RITH-roh-syt′z), also known as **red blood cells**, are the most numerous blood cells. These cells carry oxygen around the body on an iron-containing molecule called **hemoglobin** (HEEM-oh-glohb-in). Erythrocytes are easily distinguished from the other formed elements by their red color and the fact that mature erythrocytes lack nuclei and most organelles.
2. **Leukocytes. Leukocytes** (LOO-koh-syt′z), also known as **white blood cells**, play a role in the immune system. The two subclasses of leukocytes are based upon the presence or absence of visible granules in their cytoplasm.

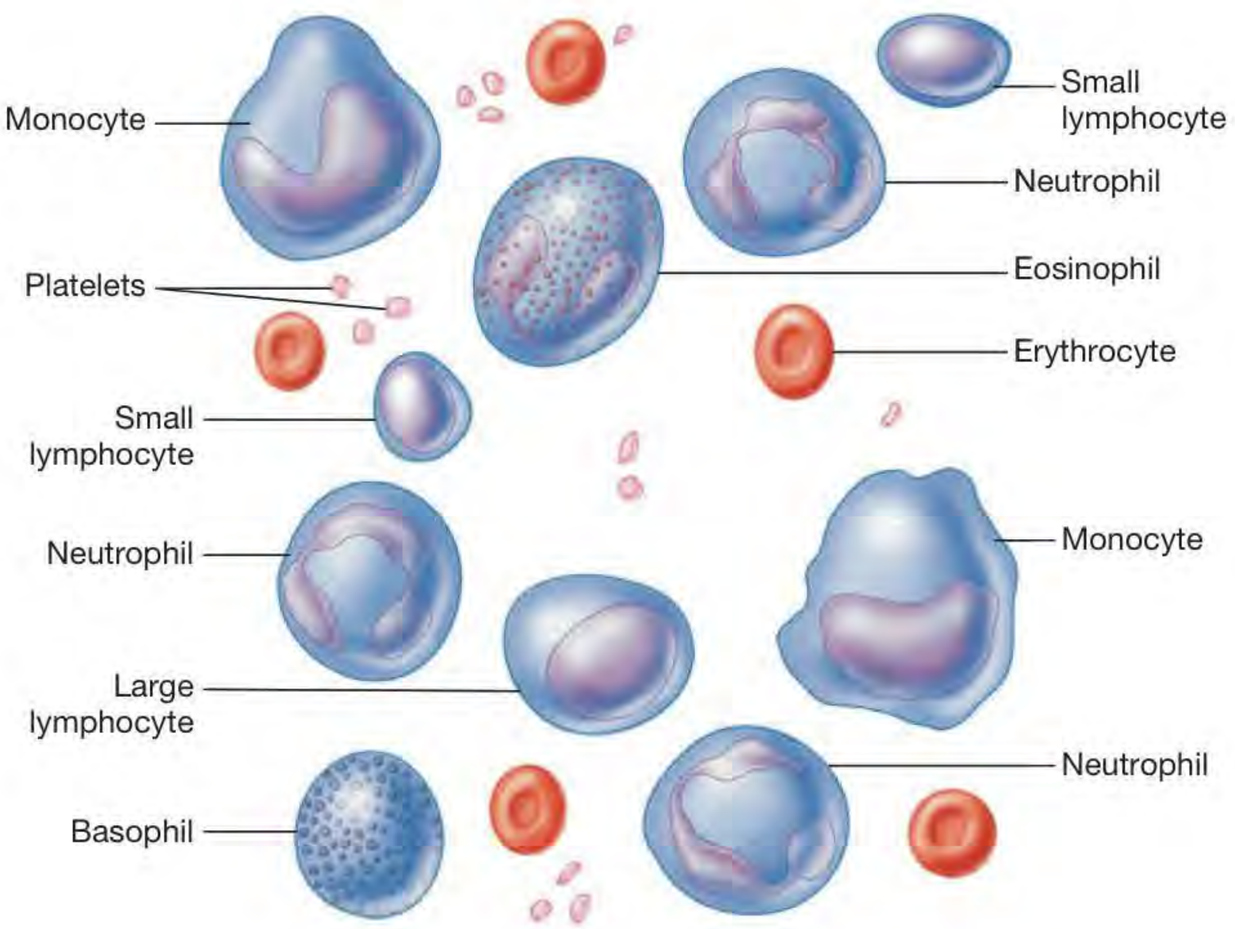
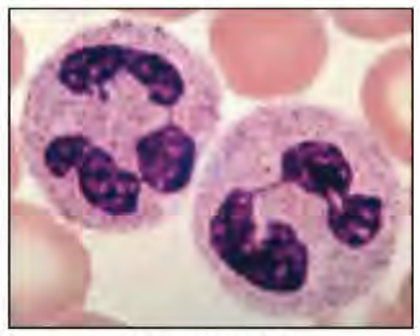
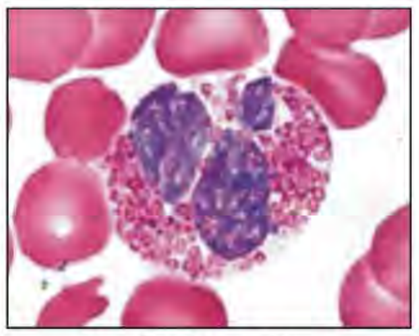
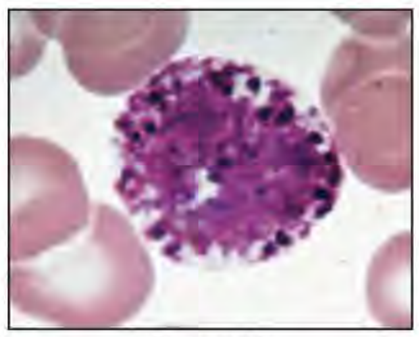
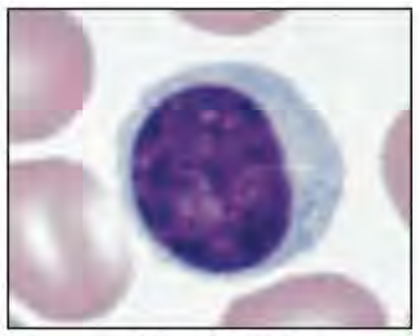


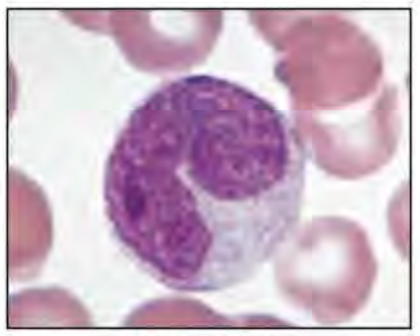
FIGURE **17.1** Formed elements of the blood.


Neutrophils


Eosinophil


Basophil


Lymphocyte


Monocyte

a. **Granulocytes.** As implied by their name, **granulocytes** are cells containing cytoplasmic granules that are visible when stained. The three types of granulocytes stain differently when treated with the dyes hematoxylin and eosin and are named for the type of stain with which they interact.
   i. **Neutrophils** (NOO-troh-filz) do not interact strongly with either type of dye, and their granules stain a light violet-pink color. They are the most numerous type of leukocyte and have multilobed nuclei. Their nuclei often vary in appearance, and for this reason they are sometimes called *polymorphonucleocytes*. Neutrophils are attracted to the site of any cellular injury, and are particularly active in ingesting and destroying bacteria.
   ii. **Eosinophils** (ee-oh-SIN-oh-filz) interact strongly with the red dye eosin, and their granules stain bright red. They are far less numerous than neutrophils and tend to have bilobed nuclei. Eosinophils play a role in the immune response to infection with parasitic worms and the allergic response.
   iii. **Basophils** (BAY-zoh-filz) take up the dark purple stain hematoxylin (it is a basic dye, hence their name *baso*-phil), and their granules appear dark blue-purple. They tend to have bilobed nuclei, but their nuclei are often obscured by their dark granules. They are the least numerous of the leukocytes and will likely be the most difficult to find on your slide. Basophils are primarily involved in the allergic response.

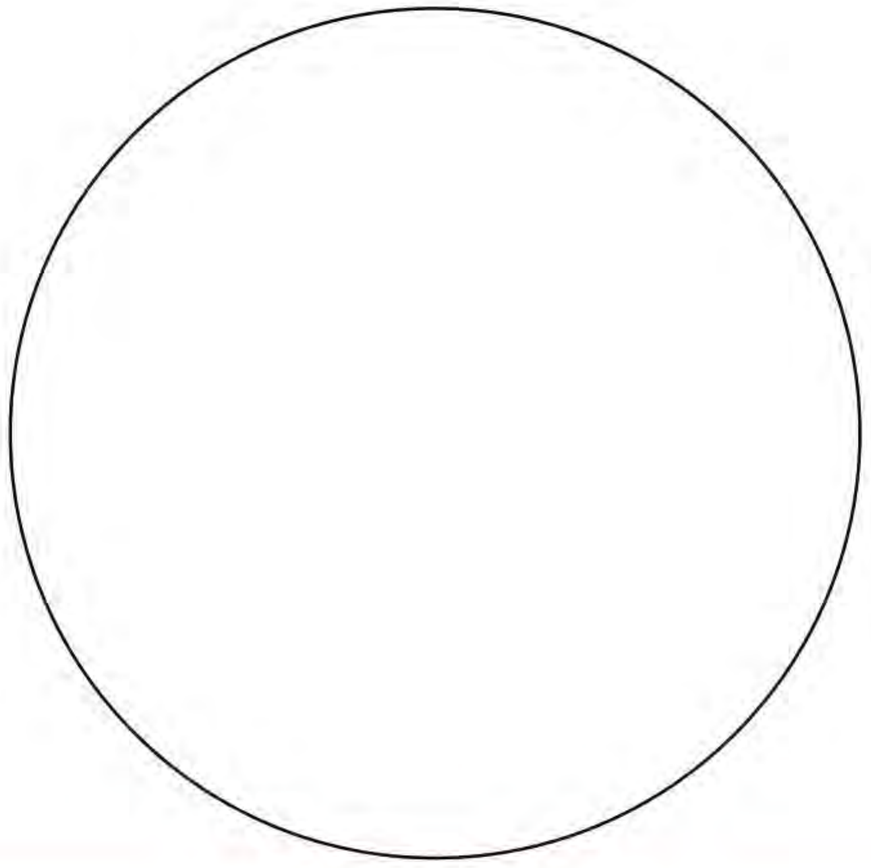
b. **Agranulocytes.** The cells known as **agranulocytes** (AY-gran-yoo-loh-syt′z) lack cytoplasmic granules. The two types of agranulocytes are the following:
   i. **Lymphocytes** (LIMF-oh-syt′z) tend to be smaller than granulocytes and have large, spherical nuclei. They are the second most numerous type of leukocyte. There are two populations of lymphocytes. *B lymphocytes* produce proteins called *antibodies* that bind foreign glycoproteins called *antigens*. *T lymphocytes* play numerous roles, including enhancing other aspects of the immune response, destroying cancer cells, and destroying cells infected with viruses.
   ii. **Monocytes** (MAHN-oh-syt′z) are the largest of the leukocytes and have "U"-shaped or horseshoe-shaped nuclei. They are the third most numerous type of leukocyte, and are very active phagocytes.

3. **Platelets.** Note in Figure 17.1 that **platelets** (PLAYT-letz) aren't actually cells at all but are instead just small cellular fragments. As such, they lack nuclei and most organelles and are much smaller than the other formed elements. Platelets are involved in blood clotting.

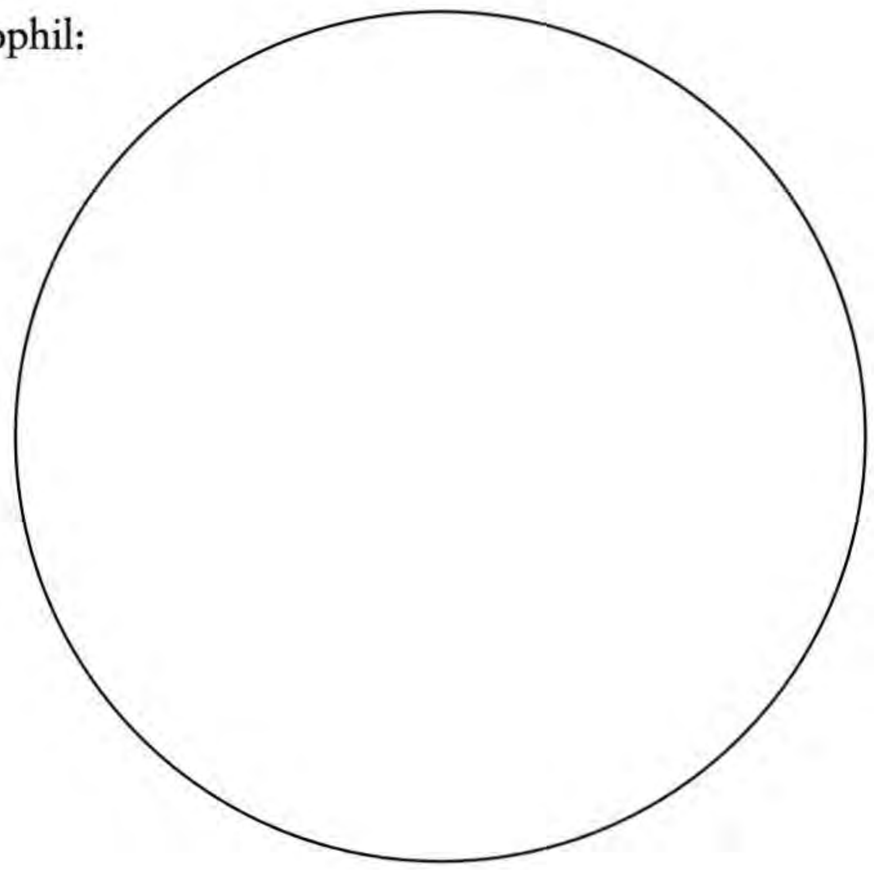
Procedure 1 Microscopy of a Peripheral Blood Smear

In this exercise, you will examine a blood slide called a **peripheral blood smear**. Examine the peripheral blood smear on high power, and scroll through to find each of the formed elements. Note that you may have to find a second slide to locate certain cells, because some types are more difficult to find (in particular the eosinophils and basophils). In the spaces provided, use colored pencils to draw and describe each formed element you locate. When you have finished, answer Check Your Understanding questions 1 through 3 (pp. 447–448).

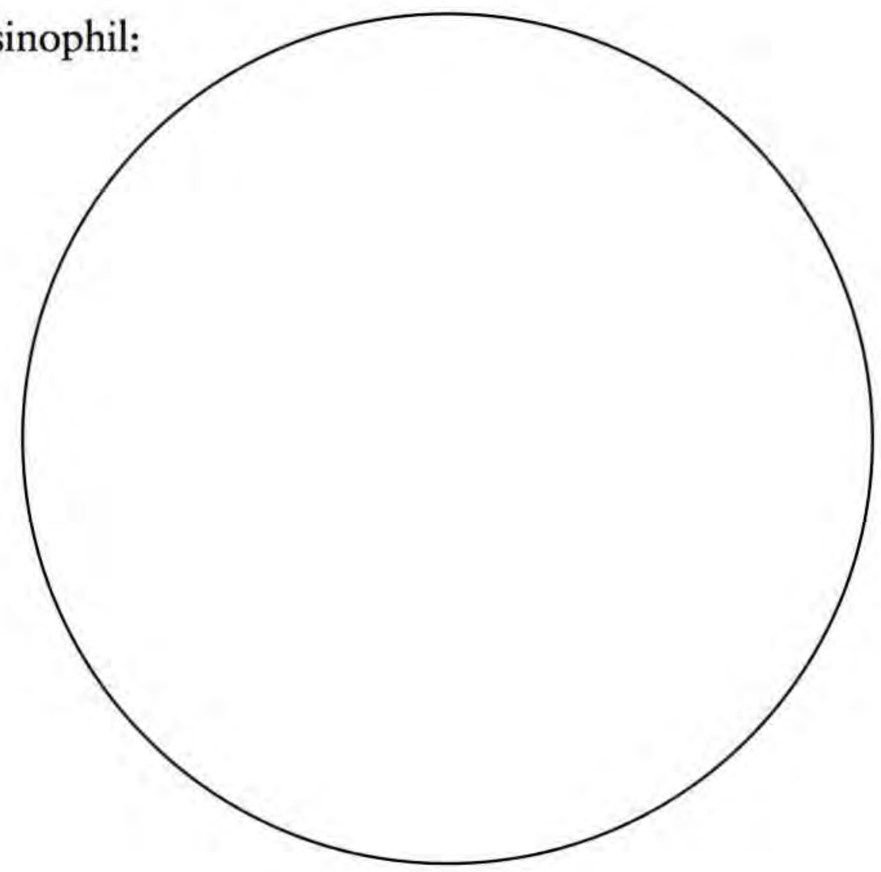
1 Erythrocyte:



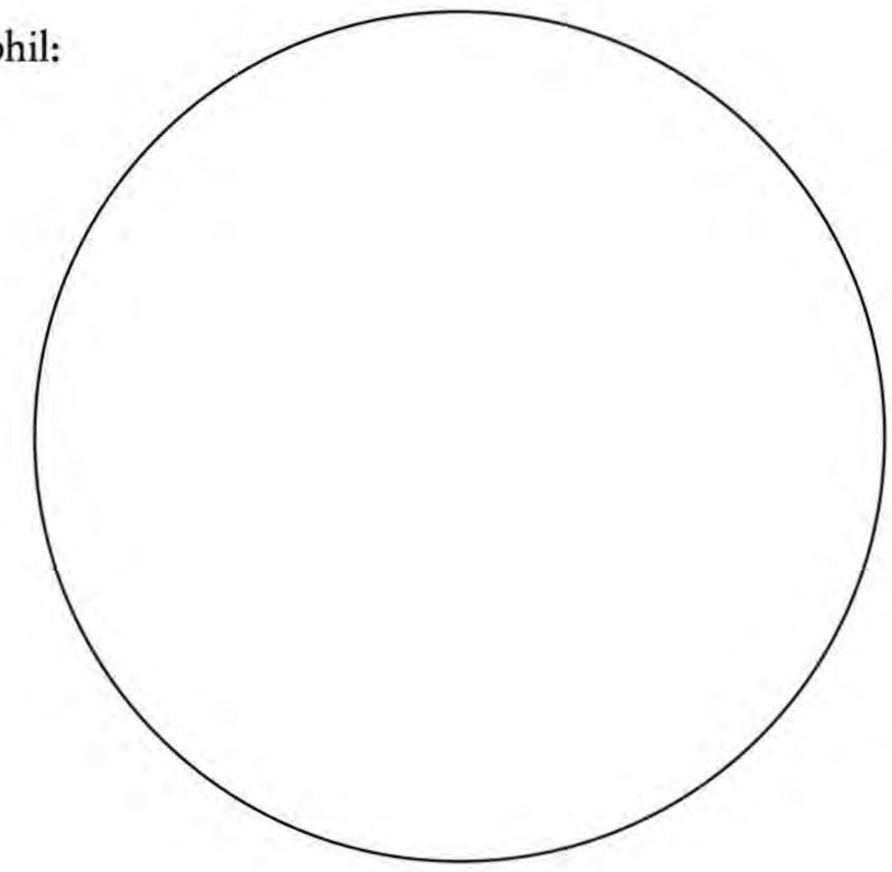
2 Neutrophil:



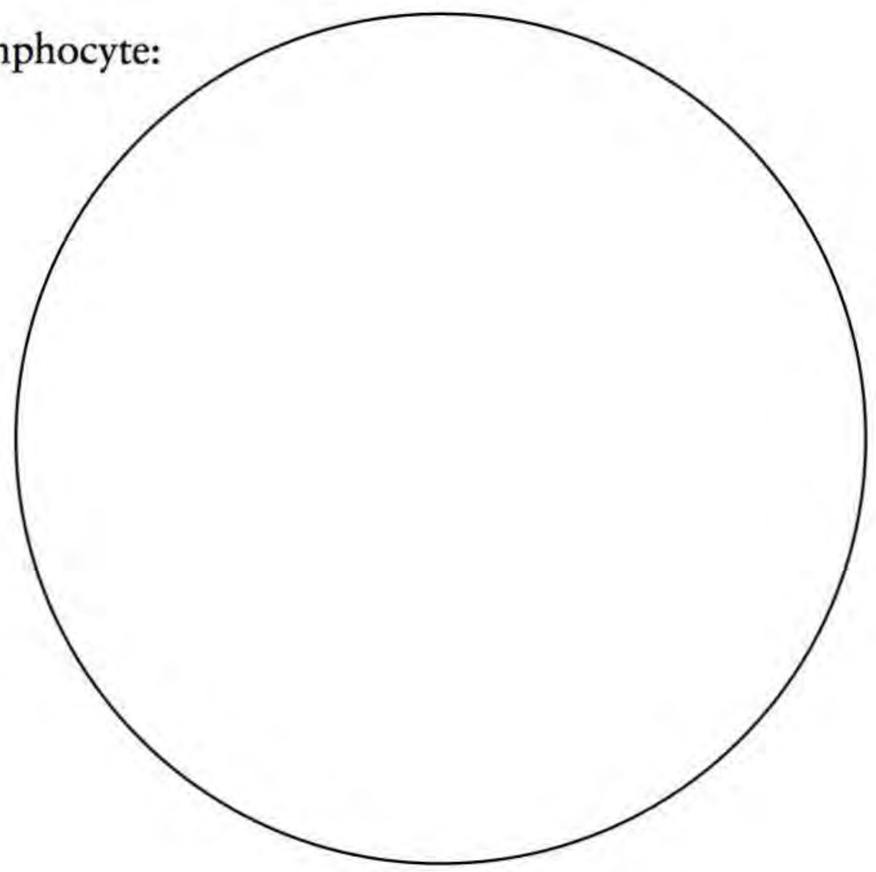
3 Eosinophil:



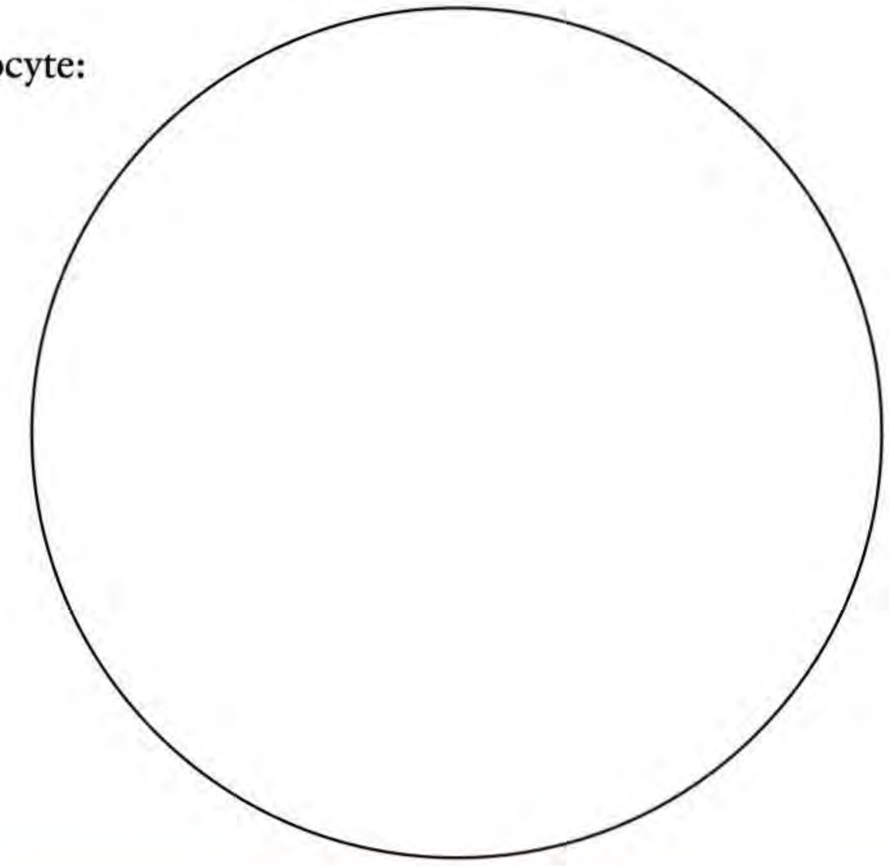
4 Basophil:



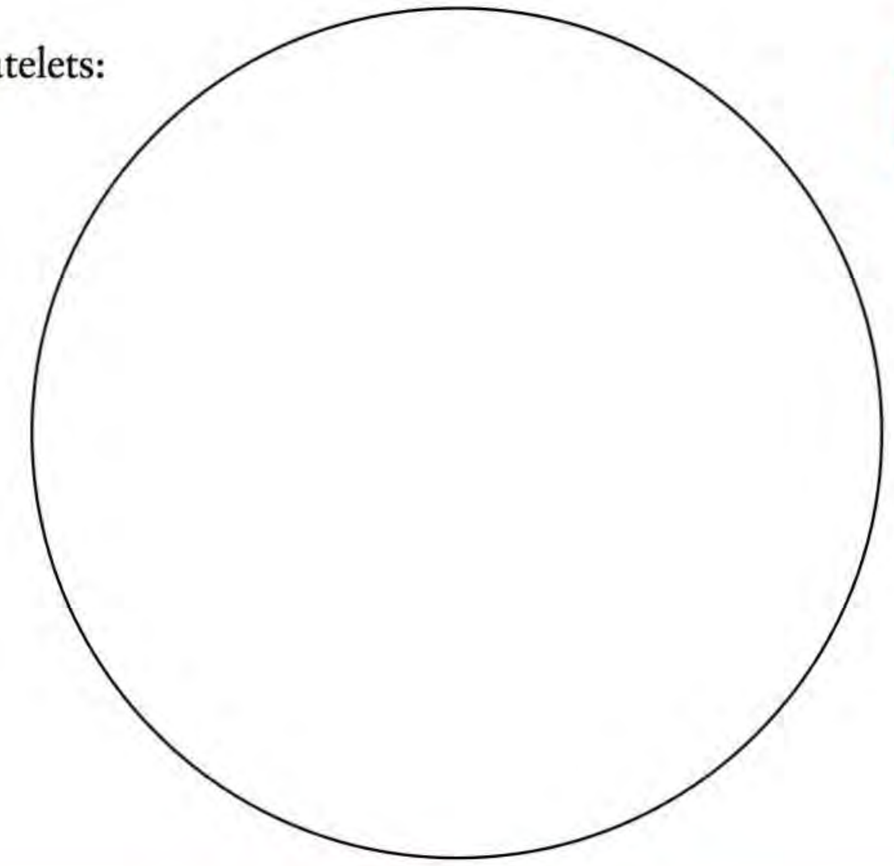
5 Lymphocyte:



6 Monocyte:



7 Platelets:



Procedure 2 Performing a Differential White Blood Cell Count

One of the most common blood analyses performed by a laboratory is a *differential white blood cell count*. In this procedure, the number and types of leukocytes in a blood sample are counted to determine the relative frequency of each type. This can give important information about the cause of a patient's illness, because different conditions will cause an elevation of different types of leukocytes. Differential counts were previously performed manually by a laboratory technician, as you will do here. Now, however, they are generally done by a machine, but the technician will still manually examine the cells if any abnormalities are noted.

1 Obtain a blood smear slide, and scan it on low power to find an area where the cells appear to be evenly distributed.

2 Advance the microscope objective to a power high enough for you to distinguish between the different types of leukocytes. For some microscopes, medium power will suffice, and for others, high power or even oil immersion might be necessary.

3 Scan the slide for leukocytes, and create a running tally of the number of each type you find below. Do this until you have counted 100 total leukocytes.

Neutrophils *Eosinophils* *Basophils* *Lymphocytes* *Monocytes*

4 Total the number of each leukocyte you counted, and record these data in Table 17.2. Refer to Table 17.1 in the Pre-Lab Exercises (p. 428) for the predicted percentage of each type of leukocyte in the blood. How do the totals you found compare with the predicted percentages?

TABLE **17.2** Differential White Blood Cell Totals

Leukocyte	Number Counted	Percentage (of 100)	Predicted Percentage
Neutrophils			
Eosinophils			
Basophils			
Lymphocytes			
Monocytes			

Exercise 17-2

ABO and Rh Blood Groups

MATERIALS

- ❑ Well plates
- ❑ Simulated blood types A–, B+, AB–, and O+
- ❑ Simulated antisera: anti-A, anti-B, anti-Rh

Blood typing is done by checking the blood for the presence or absence of specific glycoproteins called **antigens** found on the cell surface. Two clinically relevant antigens are the **A antigen** and the **B antigen**. The blood type is named based upon which of the antigens is present (Figure 17.2).

- Type A blood has A antigens on the cell surface.
- Type B blood has B antigens on the cell surface.
- Type AB blood has both A and B antigens on the cell surface.
- Type O blood has neither A nor B antigens on the cell surface.

An additional clinically relevant antigen is the Rh antigen.

- Blood that has the Rh antigen is denoted as Rh positive (e.g., A+).
- Blood that lacks the Rh antigen is denoted as Rh negative (e.g., A–).

The prevalence of different blood types in the United States varies with different ethnic groups. In general, we can say that the most common type is O+, followed by A+, and then B+.

The antigens present on the surface of an erythrocyte can be determined by combining it with a solution called an **antiserum**. An antiserum is a solution that contains proteins produced by B lymphocytes called **antibodies** that bind to specific antigens. When antibodies bind to antigens on erythrocytes, they cause **agglutination** (ah-gloo-tin-AY-shun), or clumping of the erythrocytes, in the sample. In this exercise we are using simulated blood, so you won't see agglutination unless your instructor sets up a demonstration or permits you to type your blood (which is in a later, optional procedure). The antisera used to determine the blood type of a sample are named according to the antigen they bind:

- Anti-A antiserum contains anti-A antibodies that bind to erythrocytes with A antigens.
- Anti-B antiserum contains anti-B antibodies that bind to erythrocytes with B antigens.
- Anti-Rh antiserum contains anti-Rh antibodies that bind to erythrocytes with Rh antigens.

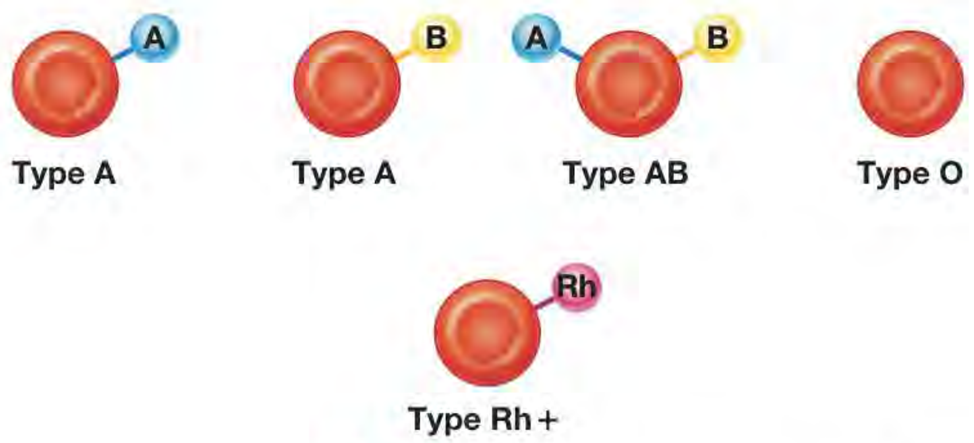


FIGURE 17.2 The basic ABO and Rh blood types.

Antigen-Antibody Reactions

This exercise allows you to examine the antigen-antibody reactions of known blood types. Each table should take one well plate and one set of dropper bottles. The bottles are labeled A–, B+, AB–, and O+ to represent each of those blood types, and anti-A, anti-B, and anti-Rh to represent the different antisera. You can see what a positive reaction looks like in Figure 17.3. Notice that a positive reaction is indicated by the formation of a white, cloudy precipitate. So, for type A+, a positive reaction is seen in the wells to which anti-A and anti-Rh antisera were added, but there is no reaction in the well containing anti-B antiserum.

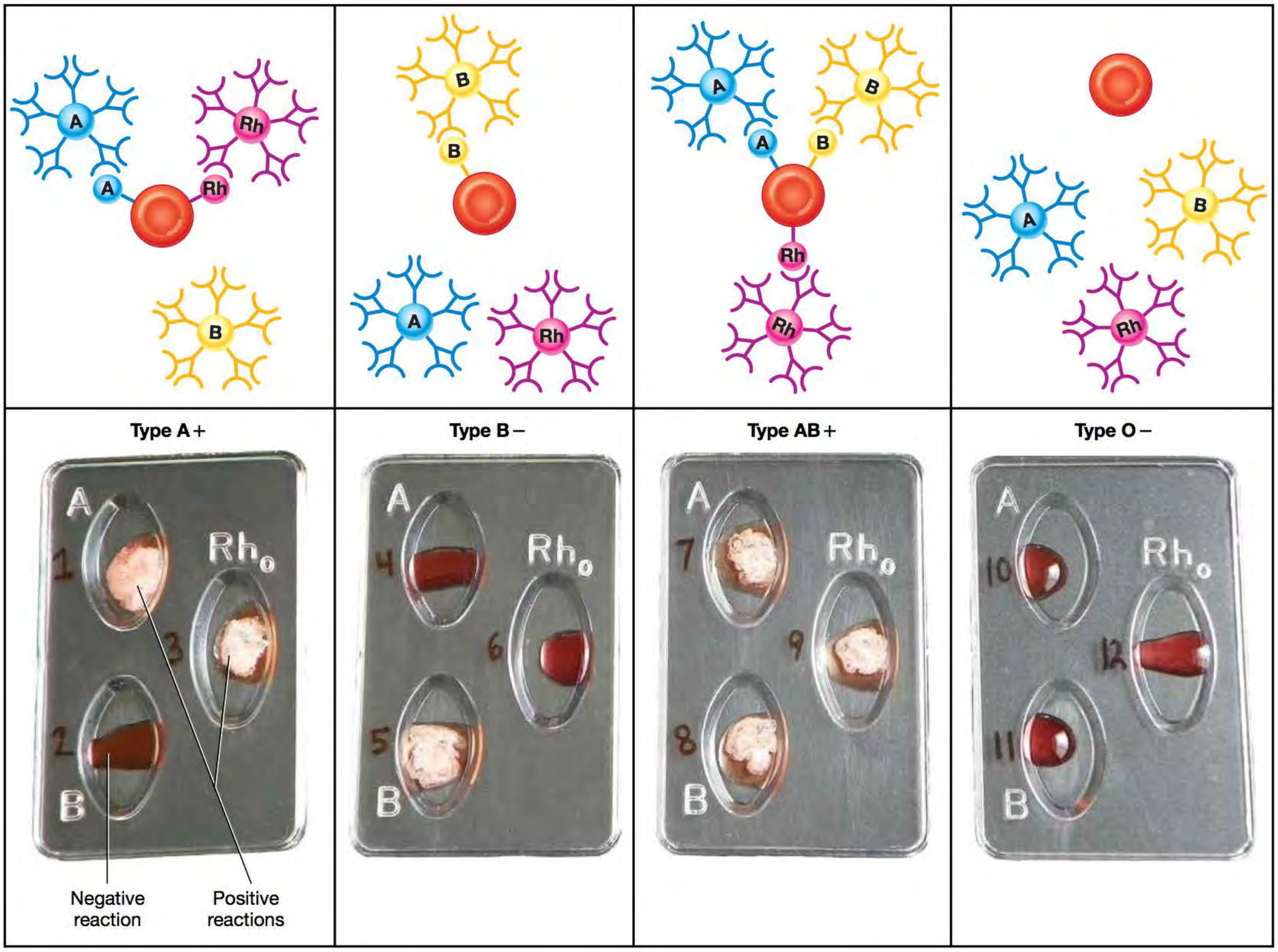


FIGURE **17.3** Reactions of simulated blood with simulated antisera.

Procedure 1 Testing Simulated Blood

Use Figure 17.4 as a guide to placement of samples in the wells.

1. Label wells on the well plate as wells 1–12.
2. Drop two drops of type A− blood in well 1, well 2, and well 3.
3. Drop two drops of type B+ blood in well 4, well 5, and well 6.
4. Drop two drops of type AB− blood in well 7, well 8, and well 9.
5. Drop two drops of type O+ blood in well 10, well 11, and well 12.
6. Add two drops of the anti-A antiserum to wells 1, 4, 7, and 10.
7. Add two drops of the anti-B antiserum to wells 2, 5, 8, and 11.
8. Add two drops of the anti-Rh antiserum to wells 3, 6, 9, and 12.
9. Observe the samples for changes in color symbolizing the agglutination or clumping that would normally occur between antisera and specific blood types. Record your results in Table 17.3.

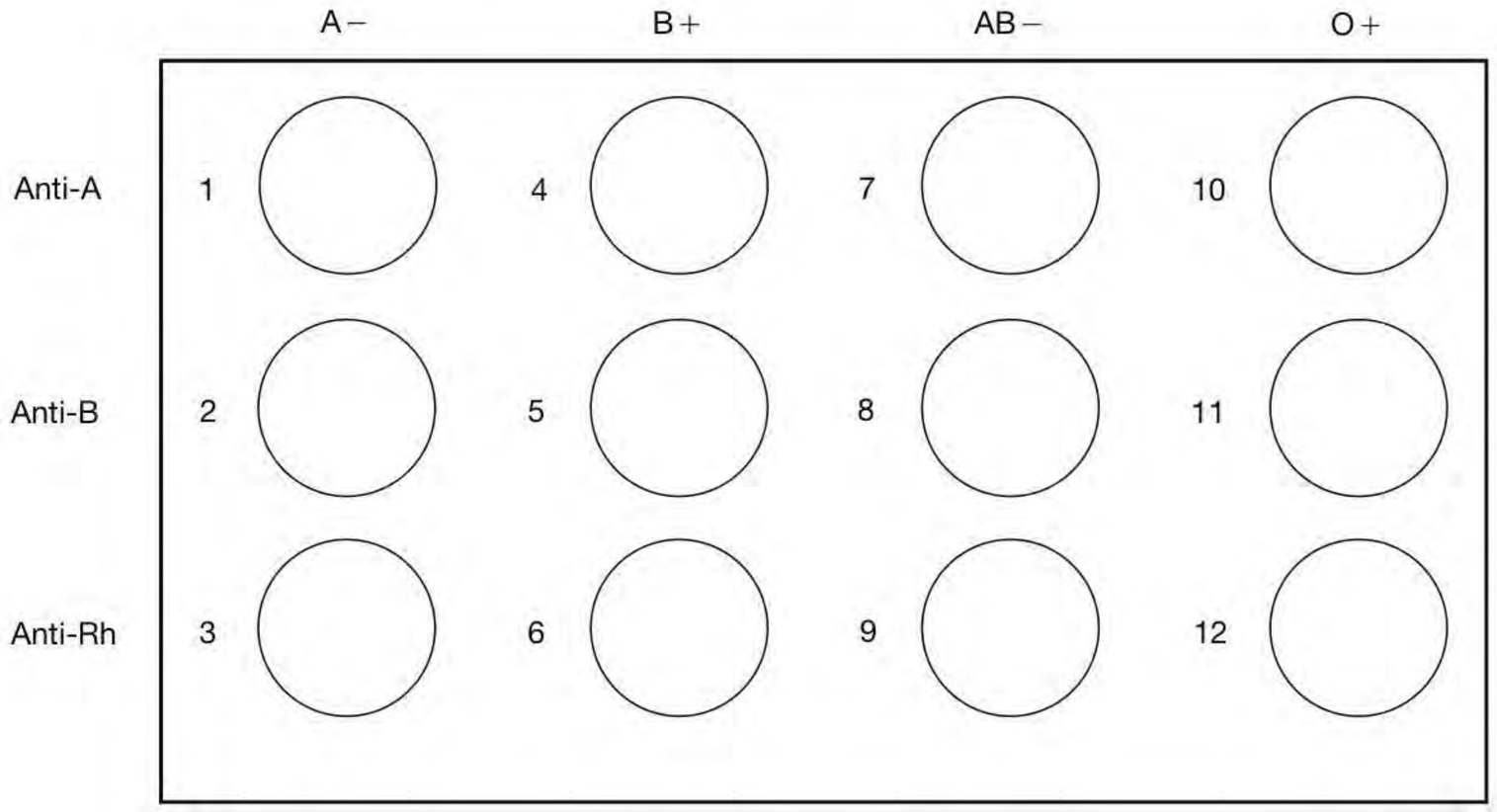


FIGURE 17.4 Well plate diagram.

TABLE 17.3 Blood Typing Results

Blood Type	Reacted with anti-A? (yes/no)	Reacted with anti-B? (yes/no)	Reacted with anti-Rh? (yes/no)	Antigens Present on Cell Surface
A−				
B+				
AB−				
O+				

Exercise 17-3

Murder Mystery Game

MATERIALS

- ❑ Well plate
- ❑ Simulated antisera: anti-A, anti-B, anti-Rh
- ❑ Murder mystery game

In this game you will be applying the blood-typing techniques you learned in Exercise 17-2 (p. 433) to solve a series of murder mysteries. Each of the following cases presents a victim, a murderer, three suspects, three possible murder rooms, and three possible murder weapons. Your job is to play the role of detective, and determine the identity of the murderer, which weapon he or she used, and in which room the crime was committed.

Procedure 1 Solving the Murder Mysteries

For each case a unique set of bottles is marked with a number that corresponds to the specific cases (i.e., the bottles are marked 1 for Case 1, 2 for Case 2, and 3 for Case 3). The murderer, rooms, and murder weapons are different for each case, but the cast of characters remains the same across the cases.

1. To begin the game, assemble into groups of two or three students. Obtain a well plate, and choose one set of samples to test (e.g., the rooms from Case 1, the suspects from Case 2, or the weapons from Case 3).
2. Test the samples by placing drops of the sample in three separate wells. Add two drops of anti-A antiserum to the first well, add two drops of anti-B antiserum to the second well, and add two drops of anti-Rh antiserum to the third well. After you have tested each of the samples, return them to their proper places in the front of the lab.
3. Read and record the blood type by watching for a reaction with the antisera. Remember that this is simulated blood, just as in Exercise 17-2. A positive reaction is denoted by the formation of a precipitate.
4. To determine the
   - *Murderer*: Match the blood type of one of the *suspects* to that of the murderer.
   - *Weapon and room*: Match the blood type of the *victim* to the blood types found in the rooms and on the weapon.

Case 1: Ms. Magenta

We enter the scene to find the dearly departed Ms. Magenta. Forensic analysis determines that there are two types of blood on the body. One blood type is Ms. Magenta's, and the other blood type is a trace amount left behind from the murderer.

Ms. Magenta's blood type: _____ **Murderer's blood type:** _____

We have three suspects:

1. *Mrs. Blanc* was being blackmailed by Ms. Magenta and Col. Lemon. They had discovered that Mrs. Blanc had murdered her late husband. Mrs. Blanc knew this would ruin her reputation at the country club.
2. *Col. Lemon* wanted to keep the blackmail money for himself and wanted Ms. Magenta out of the way.
3. *Mr. Olive* had been secretly in love with Ms. Magenta for years, and when he told her of his feelings, she rejected him harshly.

Mrs. Blanc's blood type: _____ **Col. Lemon's blood type:** _____

Mr. Olive's blood type: _____

We have three possible murder rooms:

Ballroom blood type: _____ **Library blood type:** _____

Den blood type: _____

We have three possible murder weapons:

Candlestick blood type: _____ **Noose blood type:** _____

Knife blood type: _____

Case 1: Conclusion

Ms. Magenta was killed by _____, in the _____,

with the _____.

Case 2: Col. Lemon

Our next victim is poor Col. Lemon. On his body we find his blood and also trace amounts of the blood of another person, presumably the murderer.

Col. Lemon's blood type: _____ **Murderer's blood type:** _____

We have three potential suspects:

1. *Mrs. Blanc*. Now, with Ms. Magenta out of the way, Mrs. Blanc could easily rid herself of her problem by disposing of the only other person who knows her secret—Col. Lemon.
2. *Professor Purple* believed the colonel had stolen his groundbreaking research into collagen lip injections.
3. *Mr. Olive* couldn't stand the colonel because of his close relationship with Ms. Magenta.

Mrs. Blanc's blood type: _____ **Professor Purple's blood type:** _____

Mr. Olive's blood type: _____

We have blood in three different rooms:

Hall blood type: _____ **Kitchen blood type:** _____

Billiards room blood type: _____

Forensics found blood on three different weapons:

Copper pipe blood type: _____ **Hammer blood type:** _____

Revolver blood type: _____

Case 2: Conclusion

Col. Lemon was killed by _____, in the _____,

with the _____.

Case 3: Mr. Olive

Our next (and hopefully last) victim is Mr. Olive. Analysis demonstrates two blood types: one belonging to Mr. Olive, and trace amounts of another belonging to the murderer.

Mr. Olive's blood type: _____ **Murderer's blood type:** _____

We have three potential suspects:

1. *Ms. Feather* had always secretly loved Mr. Olive, but he spurned her advances in favor of Ms. Magenta.
2. *Mrs. Blanc* was worried that Mr. Olive knew her secret and wanted him out of the way.
3. *Professor Purple* discovered that Mr. Olive—not Col. Lemon—had actually stolen the collagen lip implant research. Whoops!

Ms. Feather's blood type: _____ **Mrs. Blanc's blood type:** _____

Professor Purple's blood type: _____

Blood was found in three rooms:

Lounge blood type: _____ **Dining room blood type:** _____

Greenhouse blood type: _____

We have three potential murder weapons:

Noose blood type: _____ **Hammer blood type:** _____

Revolver blood type: _____

Case 3: Conclusion

Mr. Olive was killed by _____, in the _____,

with the _____.

Exercise 17-4

Blood Donation

Blood transfusion, the infusion of a recipient with a donor's blood cells, is a commonly performed medical procedure. Before a recipient is given a blood transfusion, the medical team must first learn the patient's blood type and then find a suitable, or "matching," donor. This is necessary because of the A, B, and Rh antigens on the surface of the donor erythrocytes and the presence of preformed antibodies in the recipient's blood. If a donor's blood has antigens the recipient's immune system recognizes as foreign, the recipient's antibodies will agglutinate the foreign erythrocytes, and the immune system will destroy them, a process known as **hemolysis** (heem-AH-lih-sis). This is called a **transfusion reaction,** and it is a medical emergency that can lead to kidney failure and death.

To ensure that a transfusion reaction does not occur, we must make sure the donor blood does not have antigens the recipient's immune system will recognize as foreign. Our immune systems produce antibodies to any antigen *not* present on the surface of our own cells.

- People with type A blood have A antigens and so produce anti-B antibodies.
- People with type B blood have B antigens and so produce anti-A antibodies.
- People with type O blood have neither A nor B antigens and so produce anti-A and anti-B antibodies.
- People with type AB blood have both A and B antigens and so produce neither anti-A nor anti-B antibodies.

If you're wondering about the Rh factor, wait just a moment—we're getting there. Let's do an example with the ABO blood groups first:

Patient 1 has type B blood, which means that he has anti-A antibodies. What will happen if we give him blood from a donor with:

- Type A blood? There are A antigens on these erythrocytes, and his anti-A antibodies would agglutinate them. ✗
- Type B blood? Patient 1's anti-A antibodies would have no effect on the B antigens on these erythrocytes, so this blood is safe. ✓
- Type O blood? There are no antigens on these donor erythrocytes, so Patient 1's anti-A antibodies would have no effect on them, and this blood is safe. ✓
- Type AB blood? There are both A and B antigens on these erythrocytes, and Patient 1's anti-A antibodies would agglutinate the erythrocytes. ✗

Now that's easy, isn't it?

Next let's address the Rh factor. The blood of an Rh-negative person does *not* contain preformed antibodies to the Rh antigen. If an Rh-negative person is exposed to the Rh antigen, however, he or she *does* produce anti-Rh antibodies. In an emergency setting, it is generally not possible to determine if an Rh-negative person has been exposed to the Rh antigen, so healthcare professionals err on the side of caution and assume that the person has anti-Rh antibodies. For the sake of simplicity, we will assume the same thing in this exercise. So, for our purposes:

- People with Rh-positive blood do not produce anti-Rh antibodies.
- People with Rh-negative blood do produce anti-Rh antibodies.

Let's do one more example, taking into account the Rh factor this time:

Patient 2 has A− blood, which means that she has anti-B and anti-Rh antibodies. What will happen if we give her blood from a donor with:

- Type A+ blood? There are A and Rh antigens on these erythrocytes, and her anti-Rh antibodies would agglutinate them. ✗
- Type B− blood? There are B antigens on these erythrocytes, and her anti-B antibodies would agglutinate them. ✗
- Type O− blood? There are no antigens on these erythrocytes, so Patient 2's anti-B and anti-Rh antibodies would have no effect on them, and this blood is safe. ✓
- Type AB+ blood? There are A, B, and Rh antigens on these erythrocytes, and Patient 2's anti-B and anti-Rh antibodies would agglutinate them. ✗

Procedure 1 Blood-Type Matching Practice

Use the information above and your text to fill in Table 17.4. After you have filled in the table, answer Check Your Understanding questions 4 and 5 (p. 488).

TABLE **17.4** Blood Donation

Blood Type	Antigens Present	Antibodies Present	Can Donate Safely to Which Blood Types?	Can Receive Safely from Which Blood Types?
A+				
A–				
B+				
B–				
AB+				
AB–				
O+				
O–				

You should notice something from Table 17.4: AB+ blood can receive from any blood type, and O– blood can donate to any blood type. This is because AB+ blood has all three antigens but no antibodies to these antigens, which is why it is often called the **universal recipient**. But Type O– has none of the three antigens for a recipient's antibodies to bind, so it can be donated to any blood type. For this reason, type O– is often called the **universal donor**.

Procedure 2 Type Matching for Transfusions

Gasp! It turns out that Ms. Magenta, Col. Lemon, and Mr. Olive all survived their injuries! But they have lost blood and are in need of blood transfusions. All of the suspects have had a sudden change of heart and have offered to help the three victims by donating blood. Your job is to determine who among the suspects could safely donate blood to whom. You do not need to retest each person's blood type, as you may use your results from Exercise 17-3. After you have finished this activity, answer Check Your Understanding questions 6 and 7 (p. 488).

Recipient 1: Ms. Magenta

Ms. Magenta's blood type: _____

Donors:

Ms. Feather's blood type: _____

Mrs. Blanc's blood type: _____

Professor Purple's blood type: _____

Who could safely donate blood to Ms. Magenta? _____

Who could not safely donate blood to Ms. Magenta? _____

Recipient 2: Col. Lemon

Col. Lemon's blood type: _____

Donors:

Ms. Feather's blood type: _____

Mrs. Blanc's blood type: _____

Professor Purple's blood type: _____

Who could safely donate blood to Col. Lemon? _____

Who could not safely donate blood to Col. Lemon? _____

Recipient 3: Mr. Olive

Mr. Olive's blood type: _____

Donors:

Ms. Feather's blood type: _____

Mrs. Blanc's blood type: _____

Professor Purple's blood type: _____

Who could safely donate blood to Mr. Olive? _____

Who could not safely donate blood to Mr. Olive? _____

HINTS & TIPS

Remember—when trying to work out who can donate blood to whom, you are concerned with the recipient's antibodies and the donor's antigens. So first work out which antibodies the recipient has, then make sure the recipient's antibodies won't bind any antigens on the donor's erythrocytes.

Exercise 17-5

Typing and Examining Your Own Blood

MATERIALS

- ❑ Lancet
- ❑ Alcohol wipes
- ❑ Anti-A, anti-B, and anti-Rh antisera
- ❑ Blank microscope slide
- ❑ Sharpie® pen
- ❑ Toothpicks
- ❑ Tallquist paper and scale
- ❑ Dissection microscope or magnifying glass

If your lab has the appropriate equipment and biohazard disposal means, your instructor may permit you to type and examine your own blood in this optional exercise. Working with blood is actually very safe provided you follow some basic procedures outlined here:

1. Wash your hands with soap and water before starting and after completing the procedures.
2. Prepare your work area by placing a disposable absorbent liner on the lab table.
3. Wear gloves and safety glasses when handling all materials for this lab.
4. Handle only your own lab materials to avoid coming into contact with blood other than your own.
5. Dispose of all lancets and microscope slides in the designated sharps container only.
6. Dispose of all nonsharp materials (disposable pads, gloves, alcohol wipes, and any other materials you have used) in the designated red biohazard bag.
7. When you are finished with the procedures, clean your work area with the disinfectant solution provided by your lab instructor.

In the following procedures, you will determine your blood type and measure the approximate hemoglobin content of your blood. Note that these exercises involve lancing your own finger to stimulate bleeding. If you have any medical conditions that render this activity unsafe, discuss this with your lab instructor.

Procedure 1 Determining Your Blood Type

The process of determining the blood type of real blood is similar to the process you performed earlier with simulated blood: You use three blood samples, and apply three different antisera to look for a reaction; in this case, you are looking for agglutination of erythrocytes (Figure 17.5). The reaction between real blood antigens and antibodies is more subtle than in the simulated blood; in particular, the reaction with Rh antigens and the anti-Rh antibodies can be difficult to see. You may wish to examine your samples under a magnifying glass to more clearly see the reaction.

Safety Note

Safety glasses and gloves are required!

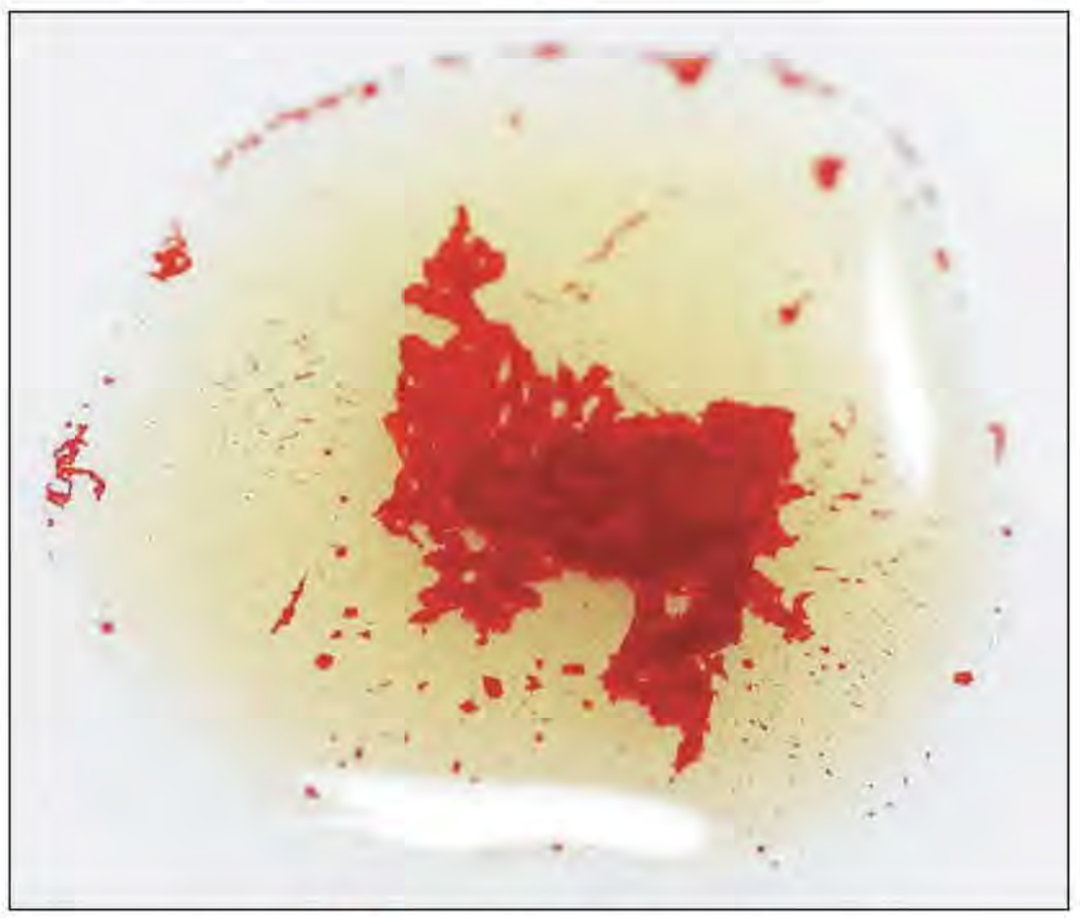


FIGURE **17.5** Erythrocyte agglutination.

1. Obtain a blank microscope slide, and draw three circles on it with a Sharpie® pen. Label the circles A, B, and Rh.
2. Wash your hands, and prepare your work area with a disposable absorbent liner.
3. Place a glove on one hand, and prepare one finger of your ungloved hand by cleaning it with an alcohol wipe.
4. Use a fresh lancet to lance the finger you just cleaned. Dispose of the used lancet in the sharps bin.
5. Squeeze your finger to stimulate bleeding, and squeeze a small drop of blood onto each of the three circles on the slide.
6. Place a drop of anti-A antiserum in the circle marked A, anti-B in the circle marked B, and anti-Rh in the circle marked Rh.
7. Use three toothpicks, one for each circle, to gently mix the blood with the antisera. You must use a different toothpick for each circle to avoid cross-contamination. Watch carefully for a reaction, using a dissection microscope or magnifying glass if needed (be sure to hold a magnifying glass in your gloved hand to avoid coming into contact with blood from your classmates).
8. Determine your blood type based upon the reactions with the antisera. Remember, if the blood reacts with an antiserum, that antigen is present. For example, if your blood reacts with anti-B antiserum and anti-Rh antiserum, the B and Rh antigens are present, and the blood type is B+. Record your blood type here: _____
9. Dispose of your microscope slide in the sharps bin when you have completed the blood-typing procedure.

Procedure 2 Determining the Hemoglobin Content of Your Blood

As you learned in Exercise 17-1, erythrocytes are filled with the protein hemoglobin, which binds and transports oxygen through the blood. The average amount of hemoglobin in erythrocytes averages about 12–16 g/dl in females and about 14–18 g/dl in males. Medically, this is an important value, because a decreased amount of hemoglobin can indicate conditions such as *iron-deficiency anemia*. In a hospital lab, the amount of hemoglobin in the blood is measured with an instrument known as a *hemoglobinometer*. However, in this lab we will employ an older (and less expensive) method using *Tallquist paper*, which provides an estimate of the blood's hemoglobin content.

1. Squeeze your finger to continue to stimulate bleeding. If you need to lance your finger again, obtain a new lancet, and follow the same steps from the first procedure.
2. Obtain a piece of Tallquist paper. Roll your bleeding finger on the paper.
3. Compare the color the paper turns with the scale on the container while the paper is still slightly wet—do not let the paper dry, or you will need to repeat the procedure.

Estimated hemoglobin value: _____

4. Dispose of any remaining sharps in the sharps container and all other blood-containing materials, including the Tallquist paper, in the red biohazard bag. Clean your work area with the disinfectant provided by your lab instructor.

Procedure 3 Calculating the Average Hemoglobin and Most Common Blood Type for Your Class

Once you have completed the first two procedures and cleaned up your work area, you may pool the results for your class to find the most common blood types and the average values for hemoglobin content.

1. Record your blood type on the whiteboard.
2. When everyone in the class has recorded his or her blood type, pool the results, and complete Table 17.5. Calculate the percentage of your class that has each blood type.
3. Your instructor will have two columns for hemoglobin values on the whiteboard, one for female and one for male members of the class. Write your estimated hemoglobin value on the whiteboard under the appropriate column.
4. When all of your classmates have recorded their number on the board, calculate the average value for the females and males of your class. Record these data in Table 17.6. How do the values for your class compare with the averages?

TABLE **17.5** Blood Types for Your Class

Blood Type	Number in Class	Percentage of Total
A+		
A–		
B+		
B–		
AB+		
AB–		
O+		
O–		

TABLE **17.6** Average Hemoglobin Values for Your Class

Group	Average Hemoglobin Value
Females	
Males	

Name _____

Section _____ Date _____

UNIT 17 REVIEW

Check Your Recall

1 ***Mark the following statements as true (T) or false (F).*** **If the statement is false, correct it to make it a true statement.**

_____ a. Red blood cells are also known as leukocytes.

_____ b. White blood cells with granules in their cytoplasm are known as agranulocytes.

_____ c. The granulocytes include the neutrophils, eosinophils, and basophils.

_____ d. Erythrocytes carry oxygen through the body on the protein hemoglobin.

_____ e. Both lymphocytes and monocytes are granulocytes.

_____ f. Platelets are fully formed cells involved in blood clotting.

2 **Label the formed elements on the peripheral blood smear in Figure 17.6.**

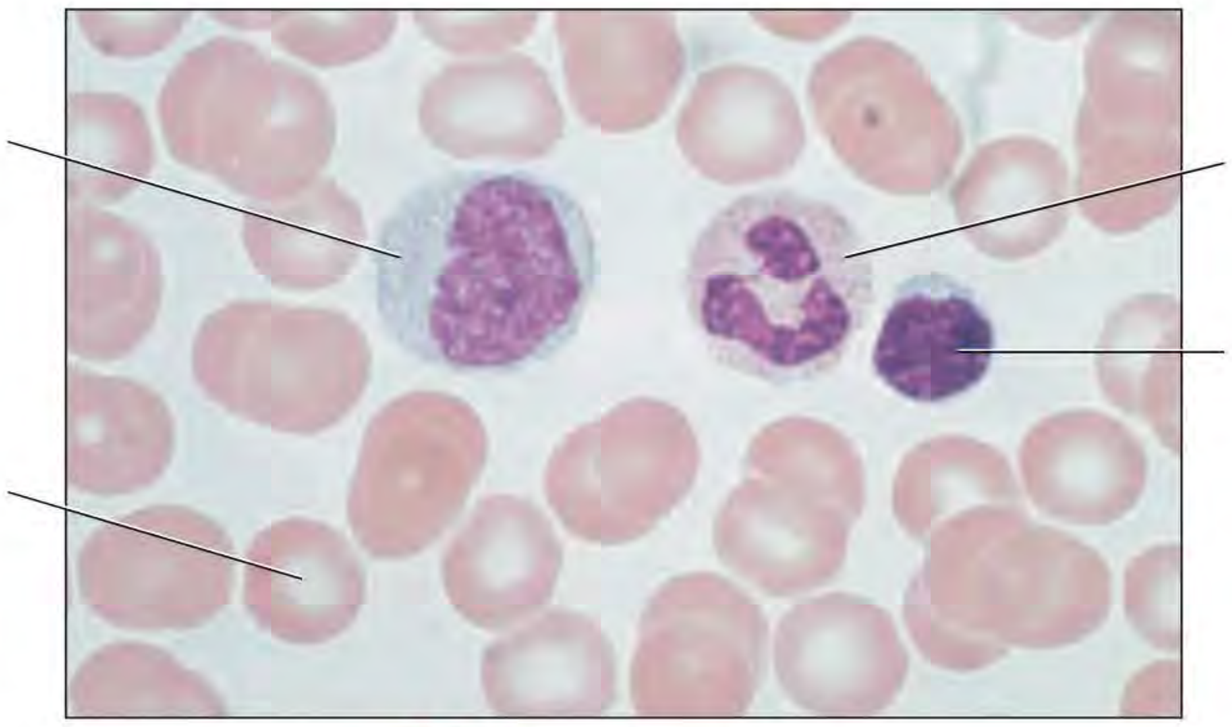


FIGURE **17.6** Peripheral blood smear.

3 **Which of the following is not an antigen that may be found on the surface of an erythrocyte?**

a. A antigen
b. B antigen
c. O antigen
d. Rh antigen

4 **Antibodies cause _____ of the antigens on erythrocytes.**

a. agglutination
b. aggregization
c. neutralization
d. They have no effect on erythrocytes.

5 State which antigens are present on the surface of erythrocytes of the following blood types:

a B– _____

b O+ _____

c AB– _____

d A+ _____

6 A person with type A blood has

a. anti-A antibodies.
b. anti-B antibodies.
c. anti-O antibodies.
d. no antibodies.

7 *Circle all that apply.* A person with type B– blood has which of the following antibodies? (Assume the person has been exposed to Rh antigens.)

a. anti-A antibodies
b. anti-B antibodies
c. anti-Rh antibodies
d. no antibodies

8 List all of the blood types to which the following people could donate, assuming the recipients have been exposed to Rh antigens:

a Person 1: Type A– _____

_____

b Person 2: Type O+ _____

_____

c Person 3: Type AB– _____

_____

d Person 4: Type B+ _____

_____

9 Which blood type is considered the universal donor? Why can this blood type be given to all other blood types?

_____

_____

_____

_____

10 Which blood type is considered the universal recipient? Why can people with this blood type receive blood from all other blood types?

_____

_____

_____

_____

Name _____

Section _____ Date _____

Check Your Understanding

Critical Thinking and Application Questions

1 When someone is admitted to the hospital, one of the first procedures health-care professionals perform is a blood draw. One lab value checked is a white blood cell (WBC) count. If the WBC count is elevated (normal range = 4,000–11,000/mm^3), this could indicate the presence of inflammation. Further analysis (called a differential) is performed to determine the relative prevalence of different types of white blood cells and the potential cause of the inflammation. What might be causing the inflammation if . . . (use your textbook for reference):

a neutrophils were elevated? Explain your reasoning.

b lymphocytes were elevated? Explain your reasoning.

c eosinophils were elevated? Explain your reasoning.

2 Another lab value monitored routinely is the total red blood cell (RBC) count. A normal RBC count is typically 4.2–5.9 million/mm^3. Having a low RBC count is called *anemia*. Predict the possible effects of having anemia, considering the functions of erythrocytes.

3 The poison ricin, derived from the castor bean plant, interferes with protein synthesis. Which formed elements of blood would ricin affect directly? Are there any mature formed elements in the blood that ricin would not affect? Explain.

4 The disease *erythroblastosis fetalis* (also called *hemolytic disease of the newborn*) develops in a fetus or a newborn infant with Rh-positive blood and an Rh-negative mother. Symptoms result when maternal anti-Rh antibodies cross the placenta and interact with the fetus' erythrocytes. Why are the children of Rh-positive mothers not at risk for this disease? Why are Rh-negative fetuses not at risk for this disease?

5 Explain why a person who is blood type AB+ can receive blood from any blood type but can only donate to individuals who are also blood type AB+.

6 When Col. Lemon arrived at the hospital, the staff determined that his blood had been mistyped, and he was in fact blood type AB–. Which of our three suspects (Mrs. Blanc, Ms. Feather, and/or Professor Purple) could safely donate blood to Col. Lemon now? (Refer to p. 441 for their blood types.)

7 What would have happened to Col. Lemon if he had received blood from an incompatible donor?

Lymphatics and Immunity

18

OBJECTIVES

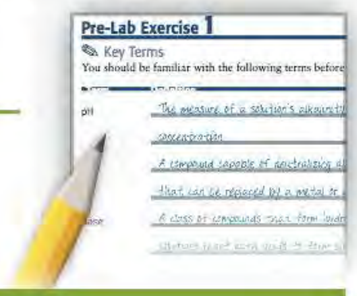
Once you have completed this unit, you should be able to:

1. Identify structures of the lymphatic system.
2. Describe the role of the immune system in processing lymph as it is returned to the heart.
3. Trace the pathway of lymph as it is returned to the cardiovascular system.
4. Identify features of lymphoid organs on microscope slides.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 18-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Lymphatic Structures

Lymphatic capillary _____

Lymph _____

Lymph-collecting vessel _____

Lymph trunk _____

Thoracic duct _____

Right lymphatic duct _____

Spleen _____

Thymus _____

Tonsil _____

Mucosa-associated lymphatic tissue _____

Lymph node _____

Pre-Lab Exercise 18-3

Anatomy of the Lymphatic System

Label and color the structures of the lymphatic system in Figure 18.1 with the terms from Exercise 18-1 (p. 453). Use your text and Exercise 18-1 in this unit for reference.

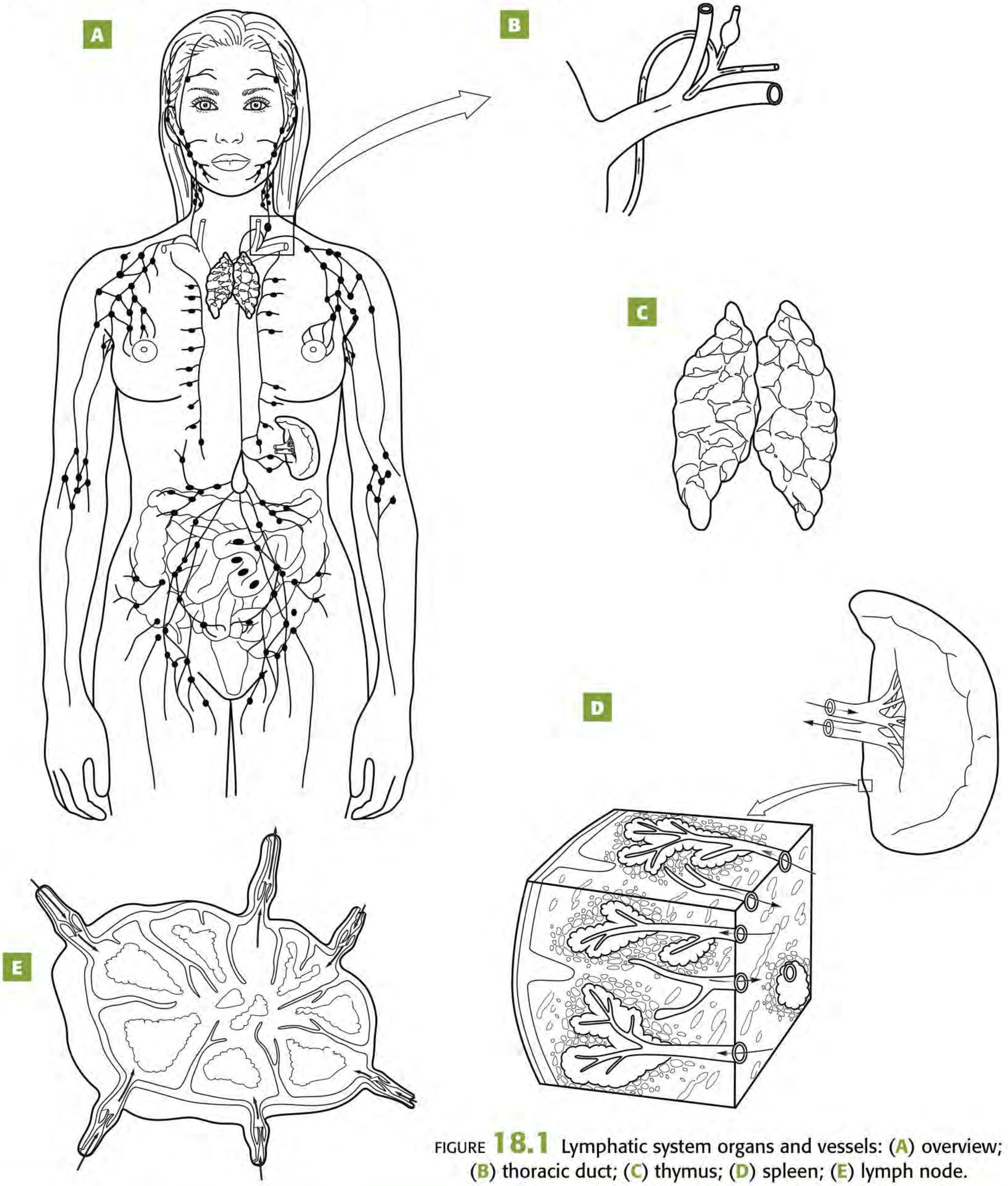


FIGURE **18.1** Lymphatic system organs and vessels: (**A**) overview; (**B**) thoracic duct; (**C**) thymus; (**D**) spleen; (**E**) lymph node.

EXERCISES

The **lymphatic system** (limf-AEH-tik) serves numerous homeostatic functions in the body. For one, it is an important part of the immune system and combats harmful agents in the internal and external environments. It also works with the cardiovascular system to maintain fluid homeostasis in the extracellular fluid and with the gastrointestinal system to absorb fats.

The exercises in this unit introduce you to this important system. In the first exercise, you will study the lymphatic system's anatomy, and trace the flow of lymph throughout the body. In the second exercise, you will examine three types of lymph tissue on microscope slides.

Exercise 18-1

Lymphatic System Anatomy

MATERIALS

- ❑ Human torso models
- ❑ Head and neck models
- ❑ Intestinal villus model
- ❑ Laminated outline of the human body
- ❑ Water-soluble marking pens

As you have learned, the lymphatic system consists of a diverse group of organs that have three primary functions:

1. **Transporting excess interstitial fluid back to the heart.** Hydrostatic pressure is stronger than colloid osmotic pressure in blood capillaries, which forces fluid out of the blood capillaries and into the interstitial space. Approximately 1.5 ml/min. of fluid is lost from the circulation in this manner. This may not sound like a lot, but if this fluid were not returned to the blood vessels, we could lose our entire plasma volume in about a day. Fortunately, the lymphatic system picks up this lost fluid, carries it through lymphatic vessels, and returns it to the cardiovascular system.

   The fluid is picked up first by small, blind-ended **lymph capillaries** that surround blood capillary beds. These lymph capillaries are distinct from blood capillaries and contain highly permeable walls that allow large substances and large volumes of fluid to enter and exit. Once inside the lymph capillaries, the fluid is called **lymph** (LIMF) and is delivered to larger **lymph-collecting vessels**. Lymph-collecting vessels drain the fluid into larger **lymph trunks**. There are nine main lymph trunks that drain lymph from major body regions (Figure 18.2): the **jugular trunks**, which drain the head and the neck; the **subclavian trunks**, which drain the upper limbs; the **bronchomediastinal trunks** (brongk-oh-mee-dee-ah-STYN-uhl), which drain the thorax; the **intestinal trunk**, which drains the abdomen; and the **lumbar trunks**, which drain the pelvis and lower limbs.

   The lymph trunks then drain into **lymph ducts** that return the lymph to the cardiovascular system. Note in Figure 18.2 that there are two lymph ducts—the **right lymphatic duct**, which drains the right arm and the right side of the head, neck, and thorax, and the **thoracic duct**, which drains lymph from the remainder of the body. The right lymphatic and thoracic ducts drain lymph into the blood at the junctions of the right and left subclavian and internal jugular veins, respectively.
2. **Activating the immune system.** Several of the lymphatic organs activate the immune system. These include the following:
   a. **Thymus.** The **thymus** is a bilobed organ located in the anterior mediastinum in which T lymphocytes mature. Recall from the endocrine unit that it secretes hormones, thymosin and thymopoietin, that stimulate this maturation. The thymus is largest and most active in infants and young children. In adults, it atrophies and becomes filled with adipose and other connective tissue.
   b. **Spleen.** The **spleen** is a lymphatic organ that resides in the upper left quadrant of the abdominopelvic cavity that filters the blood and houses phagocytes. As you can see in Figure 18.2, it has two histologically distinct regions: red pulp and white pulp. **Red pulp** contains macrophages surrounding *trabecular veins* and sinusoids that destroy old or damaged erythrocytes. **White pulp** contains T lymphyocytes, B lymphocytes, macrophages, and dendritic cells that surround branches of the splenic artery called **central arteries**.

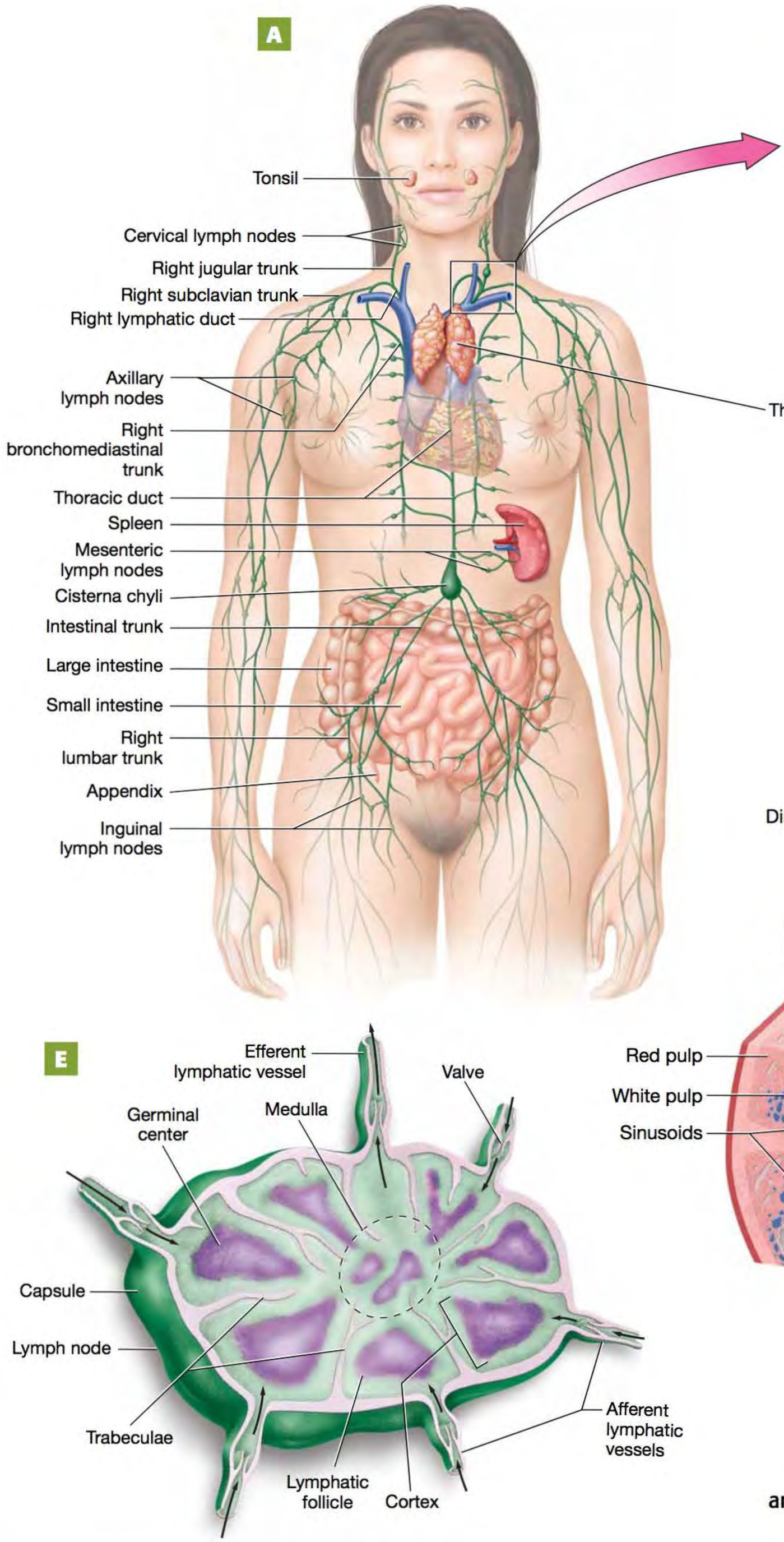


FIGURE **18.2** Lymphatic system organs and vessels: (**A**) overview; (**B**) thoracic duct; (**C**) thymus; (**D**) spleen; (**E**) lymph node.

c. **Lymph nodes.** The lymphatic organs called **lymph nodes** are clusters of lymphatic tissue surrounded by a connective tissue capsule (note that lymph nodes are often called "lymph glands," but this is a misnomer—they are not glands because they do not secrete any products). Lymph nodes are found along lymphatic vessels, where lymph is delivered by *afferent lymphatic vessels* and drained by an *efferent lymphatic vessel*. Within the node, lymph is filtered, and pathogens, toxins, and cells (such as cancer or virally infected cells) are removed. We find lymph nodes in clusters in specific areas, including the **cervical, axillary, inguinal** (IN-gwih-nuhl), and **mesenteric** (or intestinal) **lymph nodes.** As you can see in Figure 18.2, internally a lymph node consists of an outer **cortex** and an inner **medulla.** The cells are arranged into clusters called **lymphatic follicles,** in the center of which are lighter areas called **germinal centers.**

d. **Mucosa-associated lymphatic tissue and tonsils.** Clusters of loosely-organized lymphatic tissue is scattered throughout mucous membranes in locations such as the gastrointestinal tract, where it is called **mucosa-associated lymphatic tissue,** or **MALT.** Most MALT lacks a connective tissue capsule; however some types of MALT, known as specialized MALT, are partially encapsulated. The most prominent example of specialized MALT are the **tonsils,** which are found in the oropharynx and nasopharynx (Figure 18.3). As you can see in the figure, there are three main sets of tonsils: the **pharyngeal tonsil (or adenoid),** located in the posterior nasopharynx; the **palatine tonsils** (PAL-ah-teen), located in the posterior oropharynx; and the **lingual tonsil** (LING-yoo-uhl), located at the base of the tongue.

3. **Absorbing dietary fats.** Fats are not absorbed from the small intestine directly into the blood capillaries because they are too large to enter these small vessels. Instead, fats enter a lymphatic capillary called a **lacteal** (lak-TEEL). The lacteal delivers the fats to the lymph in a large lymphatic vessel called the **cisterna chyli** (sis-TER-nah KY-lee; see Figure 18.2), which then drains into the thoracic duct.

In the following activities you will identify structures of the lymphatic system, and then trace the flow of lymph through the vessels on its way back to the cardiovascular system. Your instructor may also wish you to dissect a preserved small mammal to identify some of the structures difficult to see on models, such as the thymus. If so, follow the procedure outlined in Unit 1 (p. 11) to open the animal and identify the required structures.

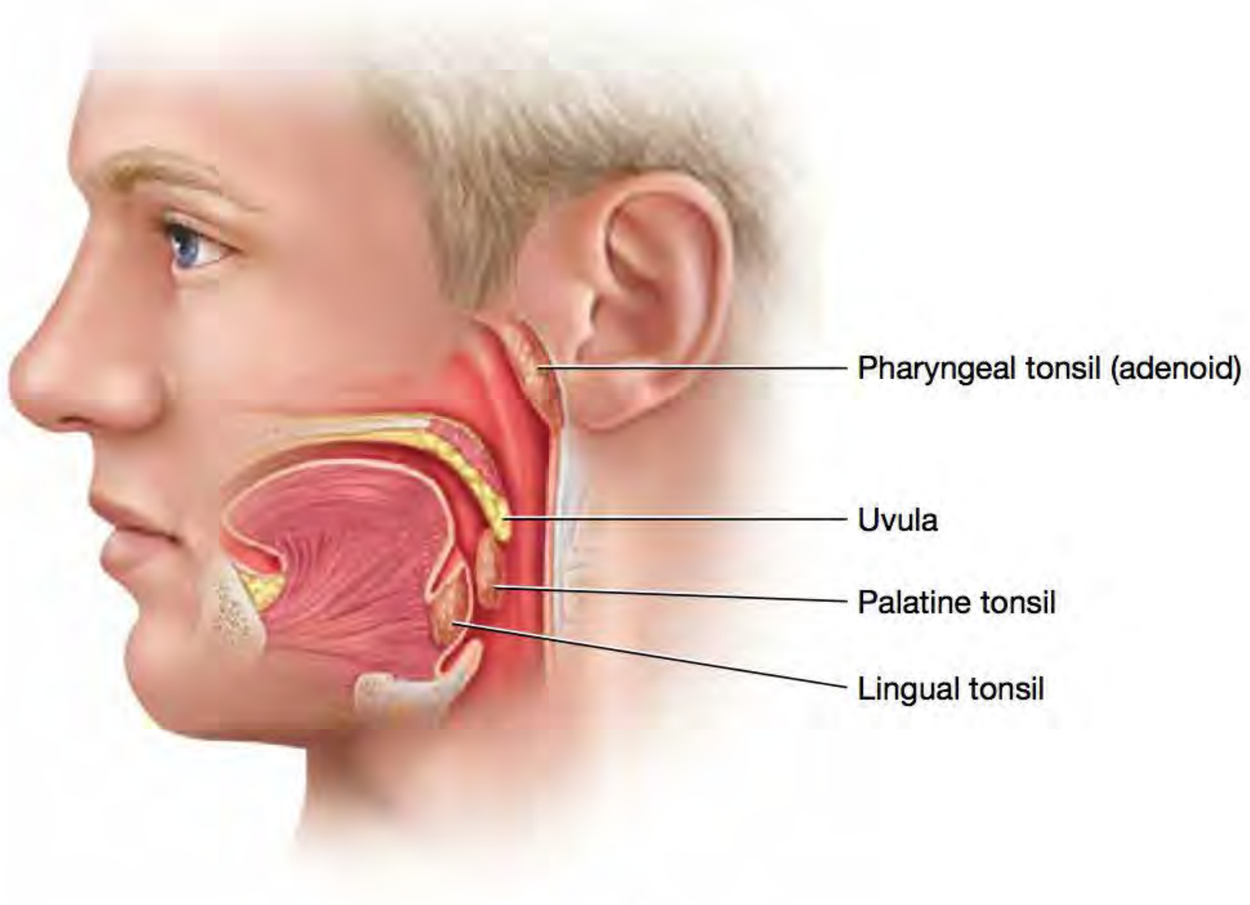


FIGURE **18.3** Tonsils.

Procedure 1 Model Inventory for the Lymphatic System

Identify the following structures of the lymphatic system on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 18.1. When you have completed this activity, answer Check Your Understanding questions 1 through 5 (pp. 463–464).

1. Lymph vessels
   a. Lymph-collecting vessels
   b. Lymph trunks: jugular, subclavian, bronchomediastinal, intestinal, lumbar
   c. Thoracic duct
   d. Right lymphatic duct
   e. Lacteal
   f. Cisterna chyli
2. Thymus (this may be best viewed on a fetal pig)
3. Spleen
4. Lymph nodes
   a. Cervical lymph nodes
   b. Axillary lymph nodes
   c. Inguinal lymph nodes
   d. Mesenteric lymph nodes
5. Mucosa-associated lymphatic tissue (MALT)
6. Tonsils
   a. Palatine tonsils
   b. Pharyngeal tonsil
   c. Lingual tonsil

TABLE 18.1 Model Inventory for the Lymphatic System

Model	Structures Identified

Procedure 2 Tracing the Flow of Lymph through the Body

In this exercise you will trace the pathway of lymph flow from the starting point to the point at which the lymph is delivered to the cardiovascular system. You will trace the flow through the major lymph-collecting vessels, trunks, and ducts, and highlight clusters of lymph nodes through which the lymph passes as it travels.

1. Write the sequence of the flow.
2. Then use differently colored water-soluble markers to draw the pathway on a laminated outline of the human body. If no outline is available, use colored pencils and Figure 18.4.
3. Trace the flow from the following locations:

Start: Right foot _____

Start: Right arm _____

Start: Intestines (with fat) _____

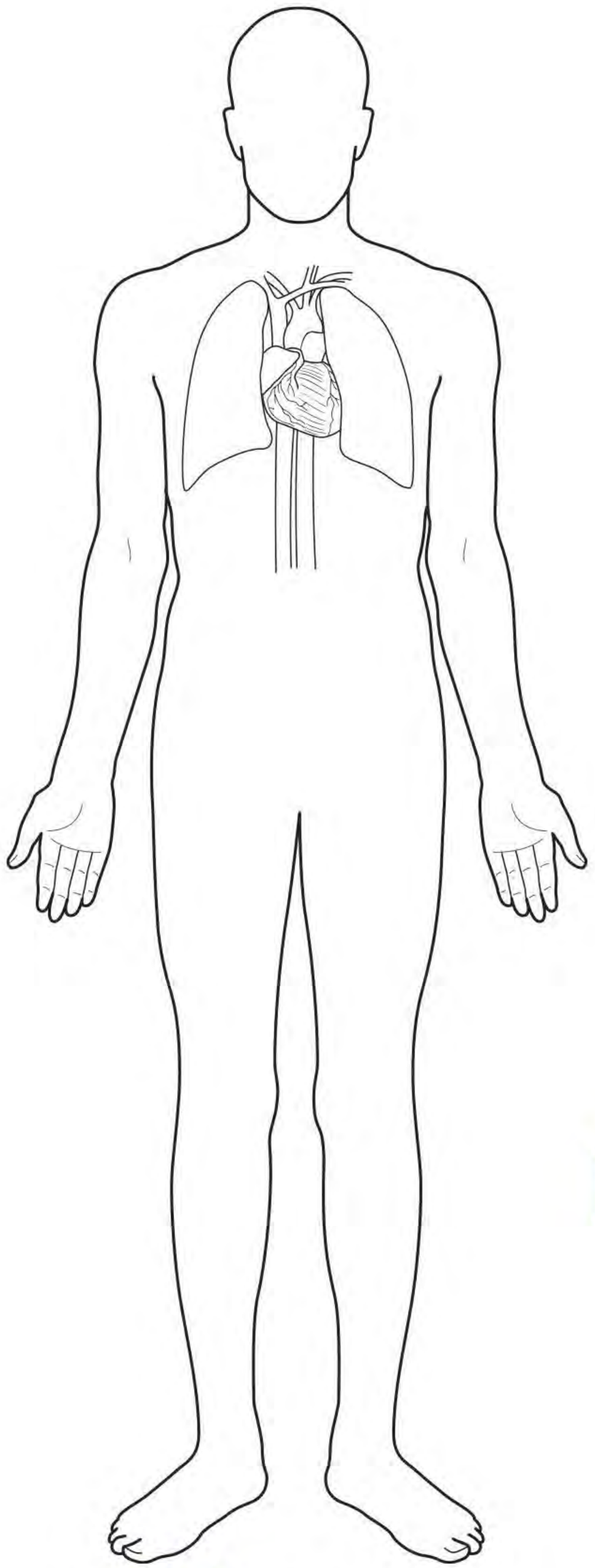


FIGURE **18.4** Outline of human body, anterior view.

Exercise 18-2

Lymphatic Organ Histology

MATERIALS

- ❑ Spleen section slide
- ❑ Lymph node slide
- ❑ Peyer's patch slide
- ❑ Palatine tonsil slide
- ❑ Light microscope
- ❑ Colored pencils

In this exercise, you will examine the microscopic anatomy of four different lymphoid organs: the spleen, a lymph node, a special type of MALT found in the terminal portion of the small intestine called a **Peyer's patch**, and the **palatine tonsil**. Following are some hints regarding what to look for on each slide.

1. **Spleen.** As you read in Exercise 18-1, the spleen consists of two types of tissue:
   a. **red pulp**, which is involved in the destruction of old and worn-out red blood cells, and
   b. **white pulp**, which contains phagocytes and lymphocytes that play a role in the immune system.

   Notice in Figure 18.5A that the red pulp is reddish in color, but the white pulp doesn't show up on the slide as white; instead, it appears as purplish "islands" within the red pulp. The purple color is caused by the presence of white blood cells, which have prominent nuclei that stain purple with commonly used stains.
2. **Lymph node.** When looking at the lymph node, remember that lymph nodes consist of an outer **cortex** that contains spherical clusters of cells (primarily B lymphocytes) called lymphatic follicles. In the center of the follicle is a lighter-staining region consisting of B lymphocytes, dendritic cells, and macrophages called a **germinal center** (Figure 18.5B). Deep to the lymphatic follicles we find an area of the cortex that houses primarily T lymphocytes. The innermost region of the node, called the **medulla**, houses primarily macrophages. The entire lymph node is surrounded by a capsule made of dense irregular collagenous connective tissue. Start first on low power and find the lymphatic follicles, then advance to higher powers to see them in greater detail.
3. **Peyer's patch. Peyer's patches** are clusters of MALT located in the terminal portion of the small intestine called the *ileum*. This portion of the small intestine is continuous with the large intestine, which contains a large number of bacteria. The small intestine is sterile, meaning it normally contains no bacteria, so these Peyer's patches play an important role in protecting it from any bacteria that migrate in from the large intestine. The Peyer's patches somewhat resemble lymph nodes, although their lymphatic follicles and germinal centers are less well defined, and their capsules are incomplete or absent (Figure 18.5C). To have the best chance of finding them, examine your section on low power, and look for the epithelial lining of the small intestine. Scroll downward (deep to the epithelium) into the connective tissue, where you will note large, oval or teardrop-shaped, purplish clusters. These are Peyer's patches.

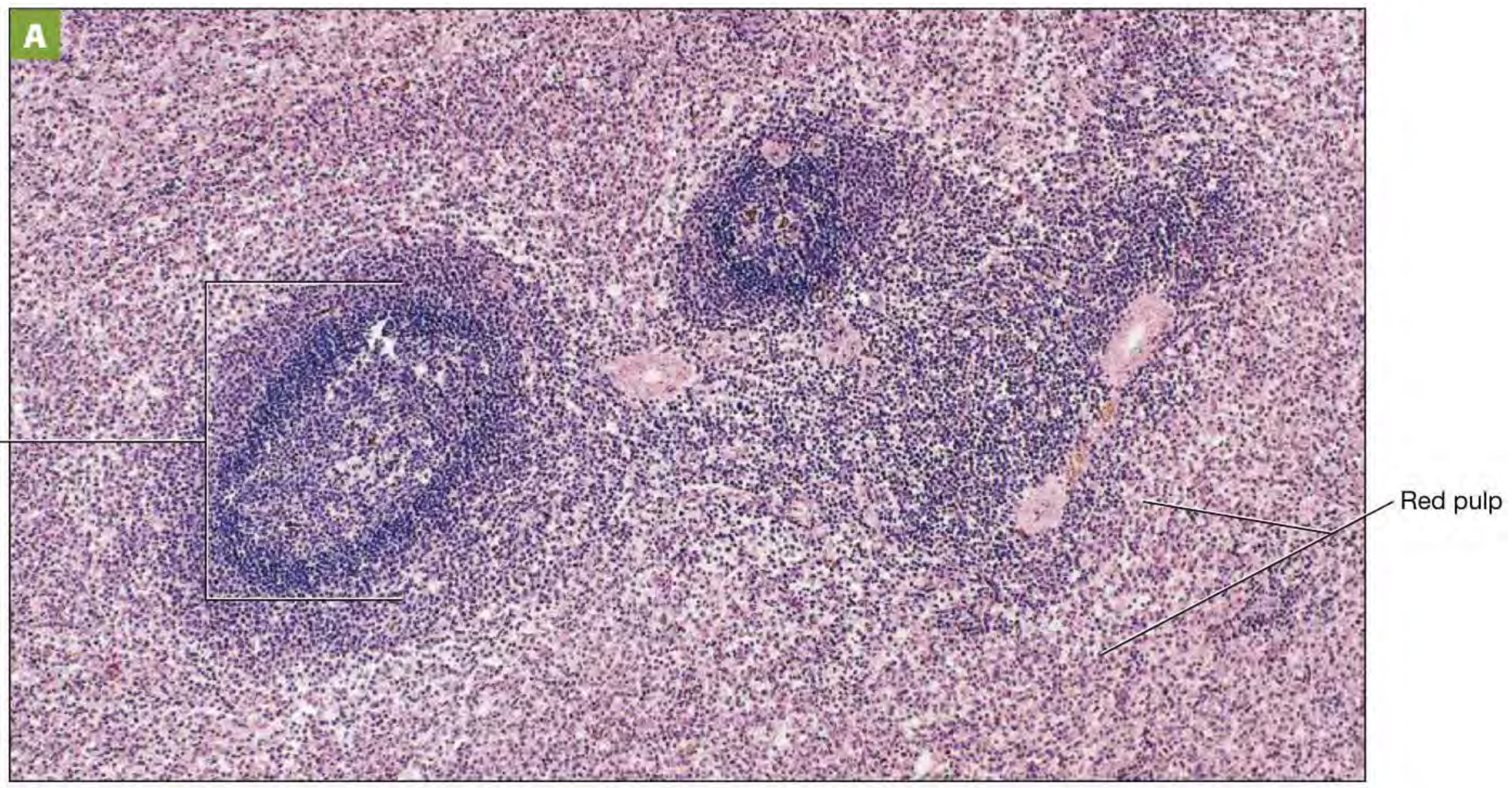


FIGURE **18.5** Lymphatic organs, photomicrographs: (**A**) spleen *(continues)*

4. **Tonsil.** As tonsils have similar functions to MALT and lymph nodes, they also have a similar structure (Figure 18.5D). Internally, they also consist of lymphatic follicles with germinal centers. Externally, however, they are lined with stratified squamous epithelium and feature deep indentations called **tonsillar crypts** that help to trap pathogens in the oral cavity. You will have the best chance of finding all of these structures by examining your slide on low power.

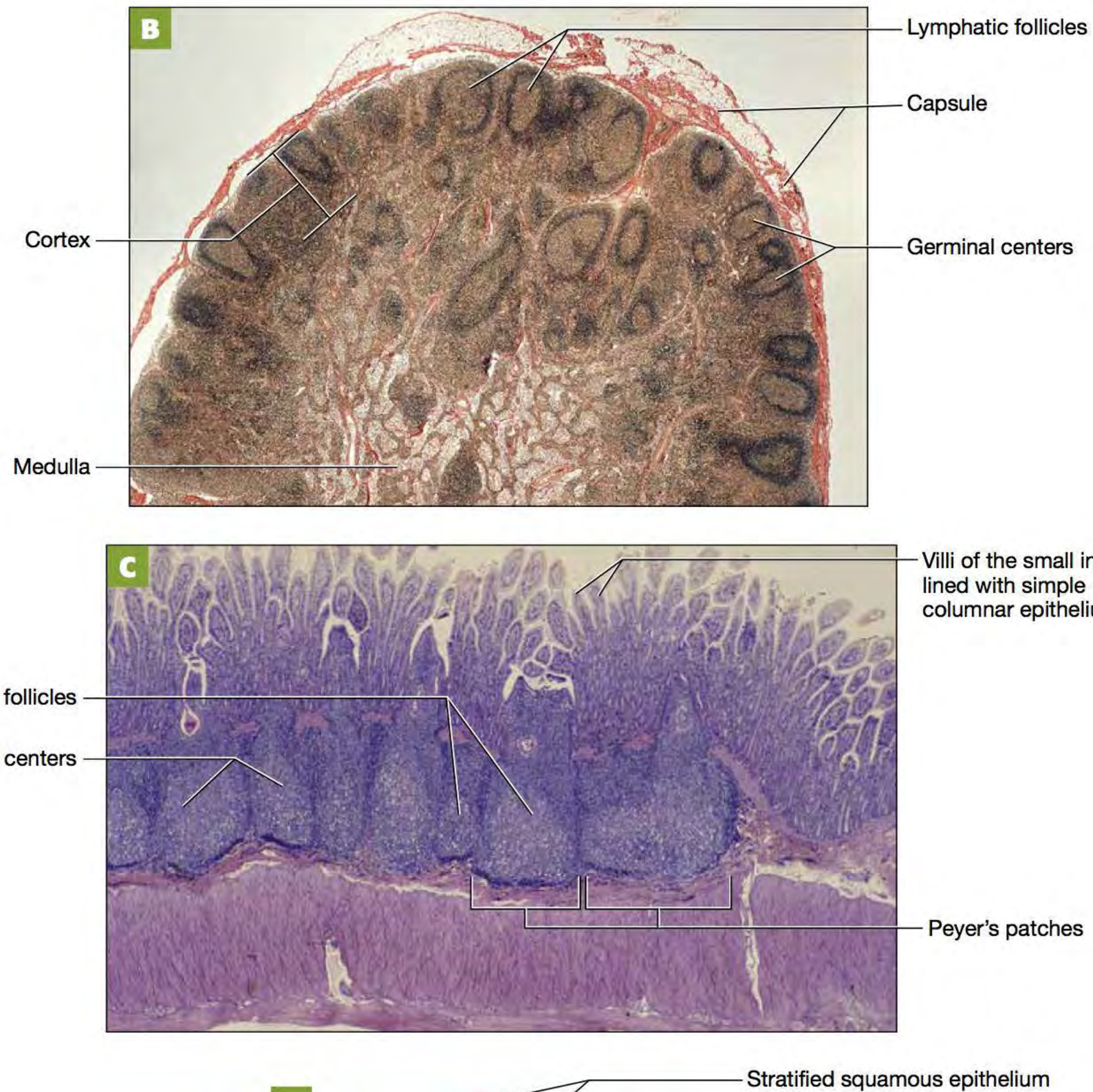


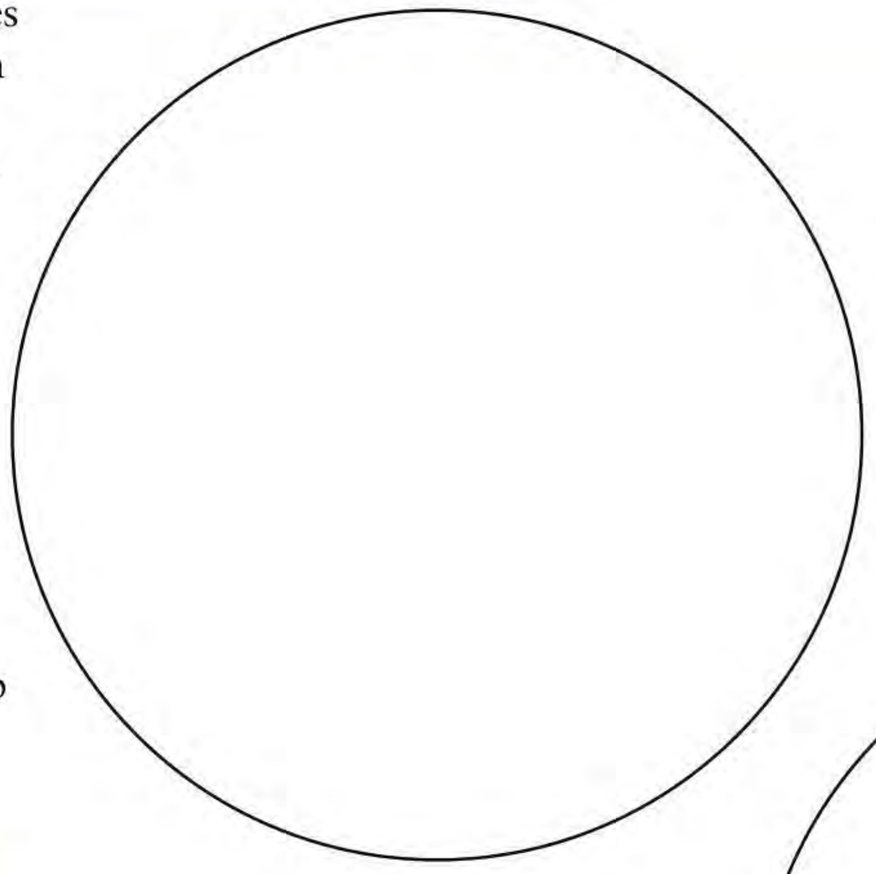
FIGURE **18.5** Lymphatic organs, photomicrographs *(cont.)*: (**B**) lymph node; (**C**) Peyer's patches in the ileum; (**D**) palatine tonsil.

Procedure 1 Microscopy

Obtain prepared slides of the spleen, a lymph node, the small intestine (the *ileum*), and the palatine tonsil. Use your colored pencils to draw what you see in the field of view, and label your drawing with the terms below.

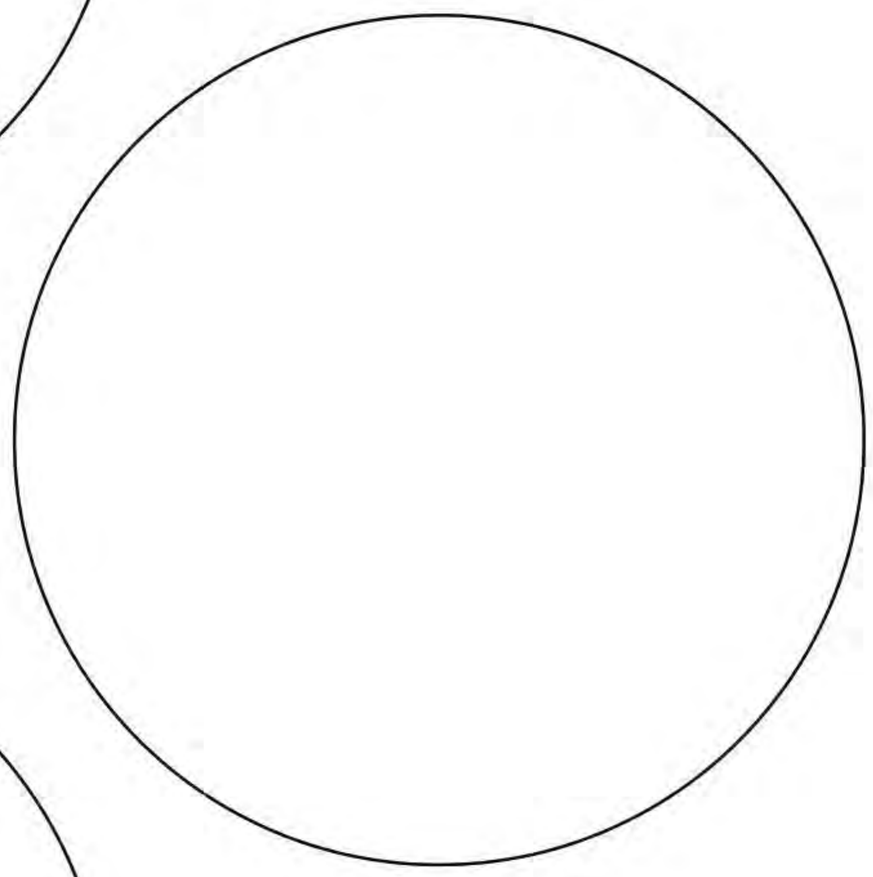
Spleen

1. Red pulp
2. White pulp



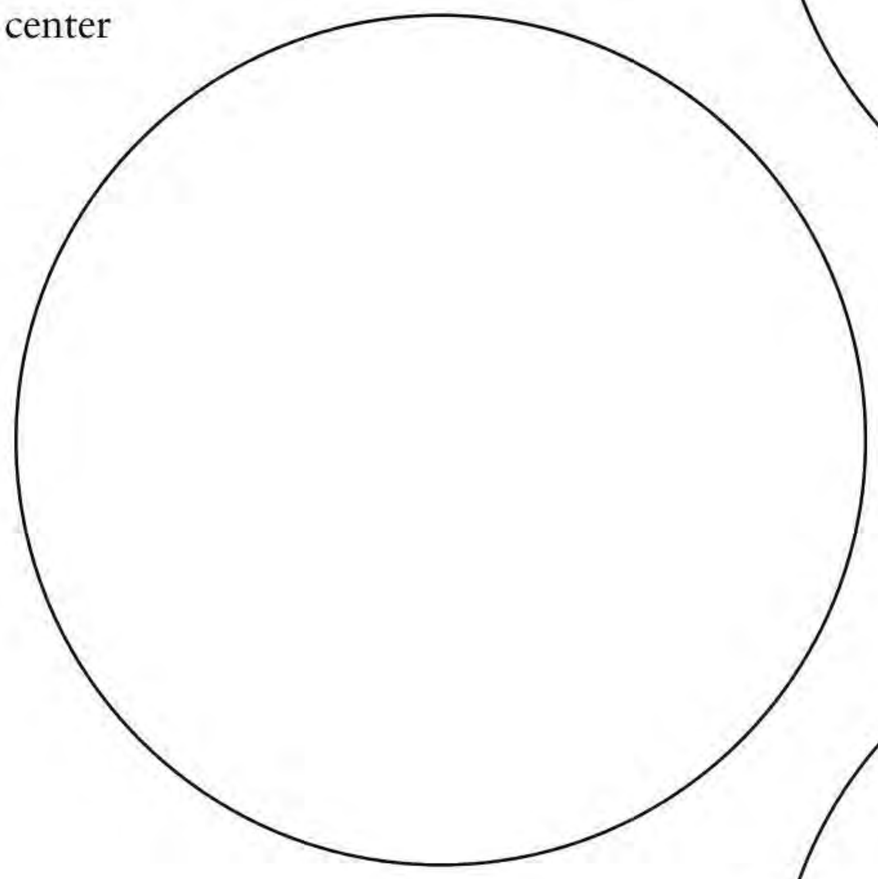
Lymph Node

1. Capsule
2. Cortex
3. Medulla
4. Lymphatic follicle
5. Germinal center



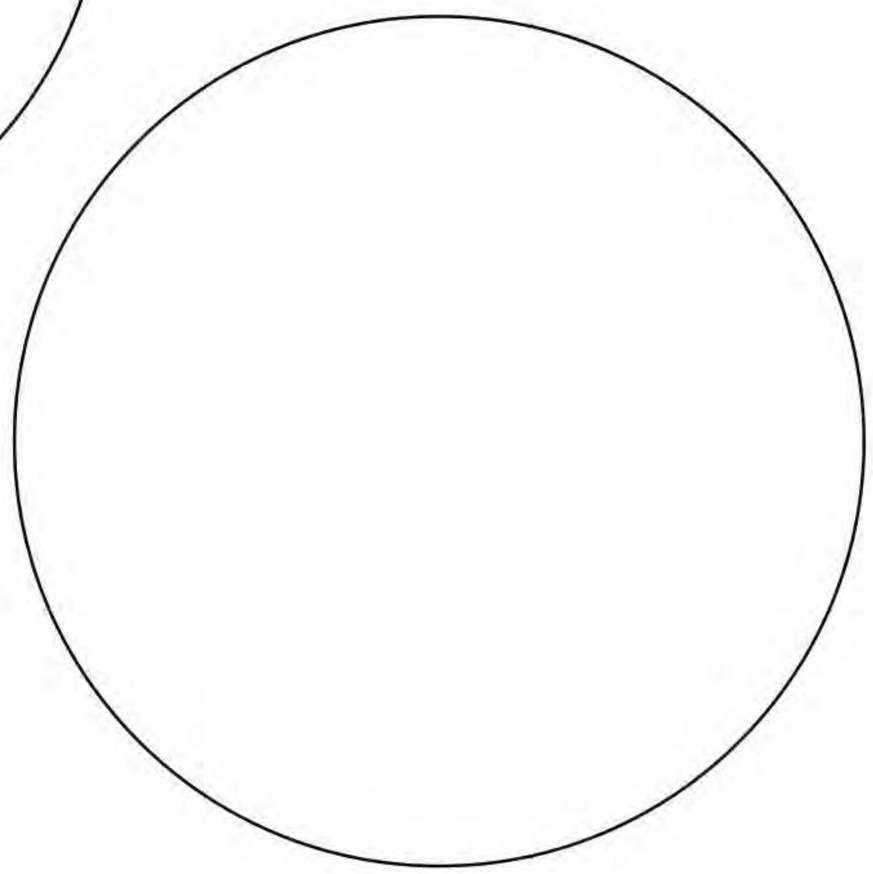
Peyer's Patch

1. Mucosa (simple columnar epithelium)
2. Peyer's patch
3. Lymphatic follicle
4. Germinal center



Palatine Tonsil

1. Stratified squamous epithelium
2. Tonsillar crypt
3. Lymphatic follicle
4. Germinal center



Name _____

Section _____ Date _____

UNIT 18 REVIEW

Check Your Recall

1 Label Figure 18.6 with the terms below.

- ❑ Cisterna chyli
- ❑ Lymph nodes: cervical, axillary, and inguinal
- ❑ Spleen
- ❑ Thoracic duct
- ❑ Thymus
- ❑ Right lymphatic duct

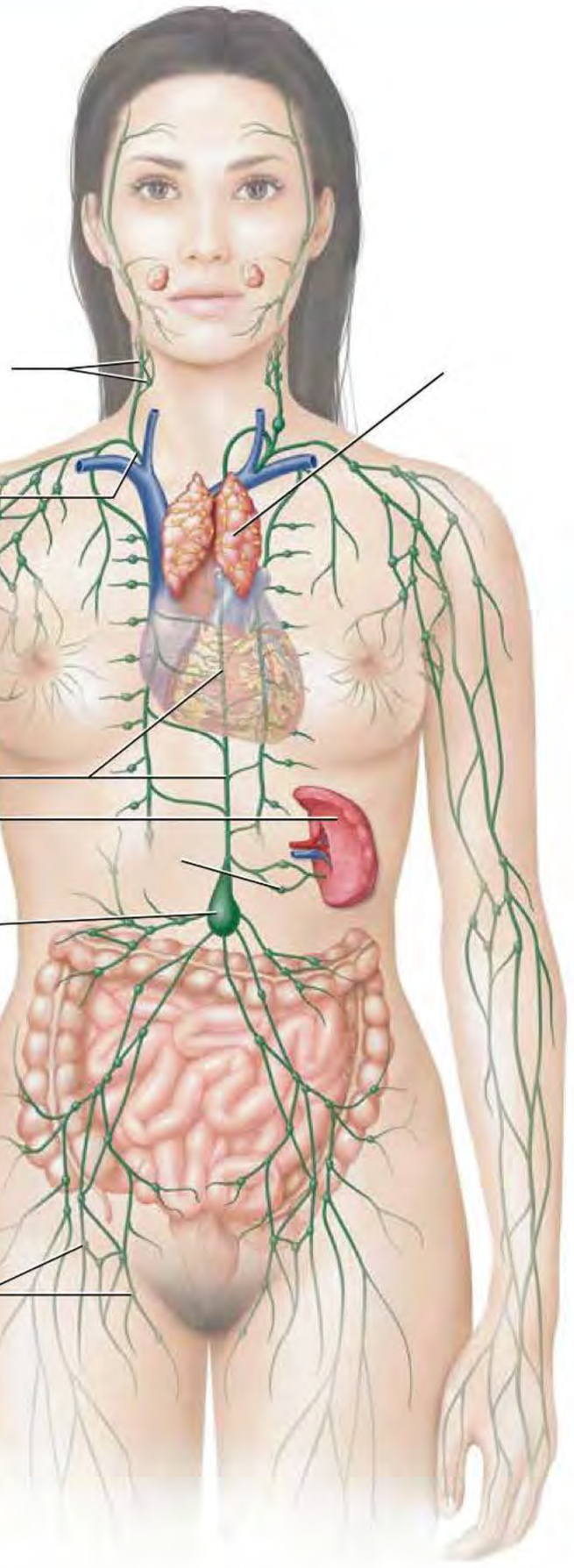


FIGURE **18.6** Overview of the lymphatic organs and vessels.

2 Label Figure 18.7 with the terms below.

- ❑ Lingual tonsil
- ❑ Palatine tonsil
- ❑ Pharyngeal tonsil

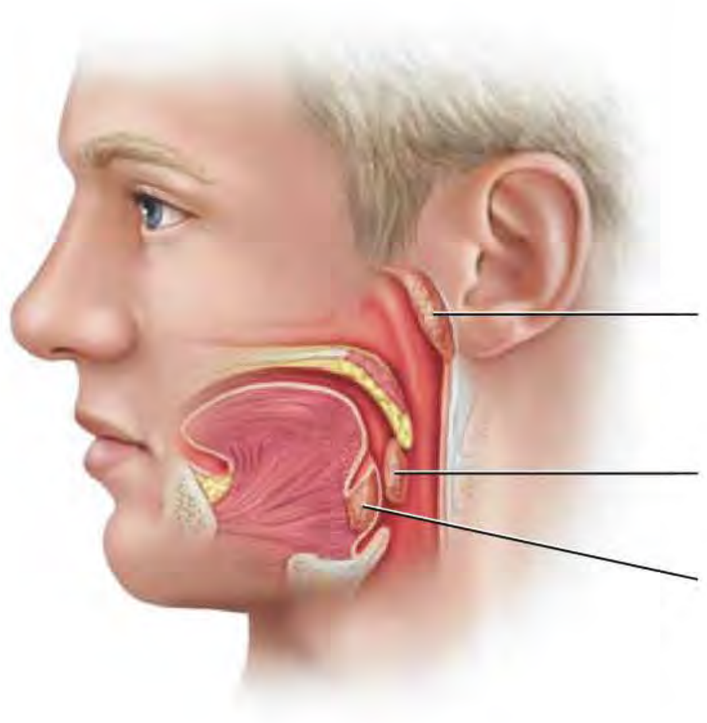


FIGURE **18.7** Tonsils.

3 **Which of the following is not a function of the lymphatic system?**

a. Maintaining blood pressure
b. Absorbing dietary fats
c. Activating the immune system
d. Transporting excess interstitial fluid back to the heart

4 **Which regions of the body are drained by the right lymphatic duct? Which regions are drained by the thoracic duct?**

_____

_____

_____

5 **Lymph nodes filter _____, and the spleen filters _____.**

a. lymph; lymph
b. blood; blood
c. lymph; blood
d. blood; lymph

6 **The vessels into which fats are absorbed are called**

a. blood capillaries.
b. lymph ducts.
c. lacteals.
d. Fats are not absorbed.

7 **Describe the structure and location of the tonsils, lymph nodes, and MALT.**

_____

_____

_____

_____

_____

8 **The cortex of a lymph node contains spherical clusters called _____ that contain primarily _____.**

a. lymphoid follicles; T lymphocytes
b. lymphoid follicles; B lymphocytes
c. medullary centers; T lymphocytes
d. medullary centers; B lymphocytes

9 **What is the function of the thymus?**

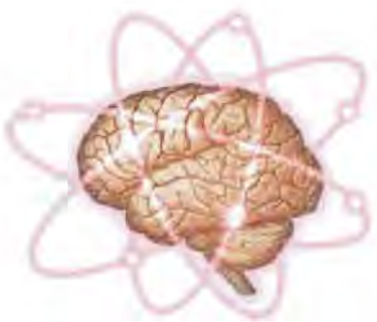
a. Traps pathogens in lymph
b. Filters the blood
c. It mediates inflammation
d. The site of T lymphocyte maturation

10 ***Fill in the blanks:*** **The spleen has two functionally distinct areas known as _____**

and _____.

Name _____

Section _____ Date _____



Check Your Understanding

Critical Thinking and Application Questions

1 Predict some potential consequences of removing the spleen.

2 In a condition called DiGeorge syndrome, infants are born with either an absent thymus or a thymus that isn't functional. Predict the consequences of this disease.

3 Explain why blockage or removal of the lymphatic vessels can result in significant edema (accumulation of fluid in a limb or body part).

4 A common symptom of pharyngitis is swelling of the cervical lymph nodes. Why might lymph nodes swell in the presence of an infection? What else may cause swollen lymph nodes? (*Hint:* What part of the immune response causes swelling?)

5 As you learned, the tonsils are only partially encapsulated. How does this better enable them to perform their function? How does this also place them at greater risk for infection?

Respiratory System

19

OBJECTIVES

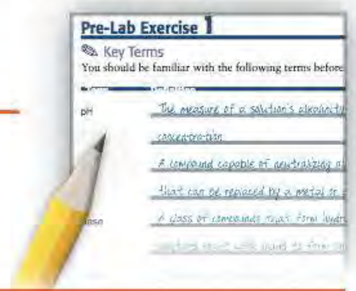
Once you have completed this unit, you should be able to:

1. Identify structures of the respiratory system.
2. Trace the pathway of gases through the respiratory system.
3. Identify histological structures of the respiratory system on microscope slides.
4. Describe the anatomical and pressure changes associated with inhalation and exhalation.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 19-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

General Structures of the Respiratory System

Respiratory tract _____

Parietal pleura _____

Visceral pleura _____

Pleural cavity _____

Lungs and lobes _____

Structures of the Respiratory Tract

Nasal cavity _____

Pharynx _____

Larynx _____

Trachea _____

Primary bronchi _____

Secondary bronchi _____

Name _____ Section _____ Date _____

Terminal bronchioles _____

Respiratory bronchioles _____

Alveolar ducts _____

Alveoli _____

Pulmonary Ventilation Terms

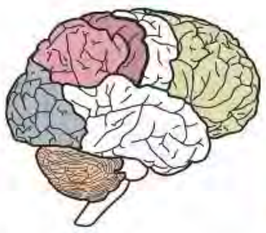
Inspiration _____

Expiration _____

Boyle's law _____

Intrapulmonary pressure _____

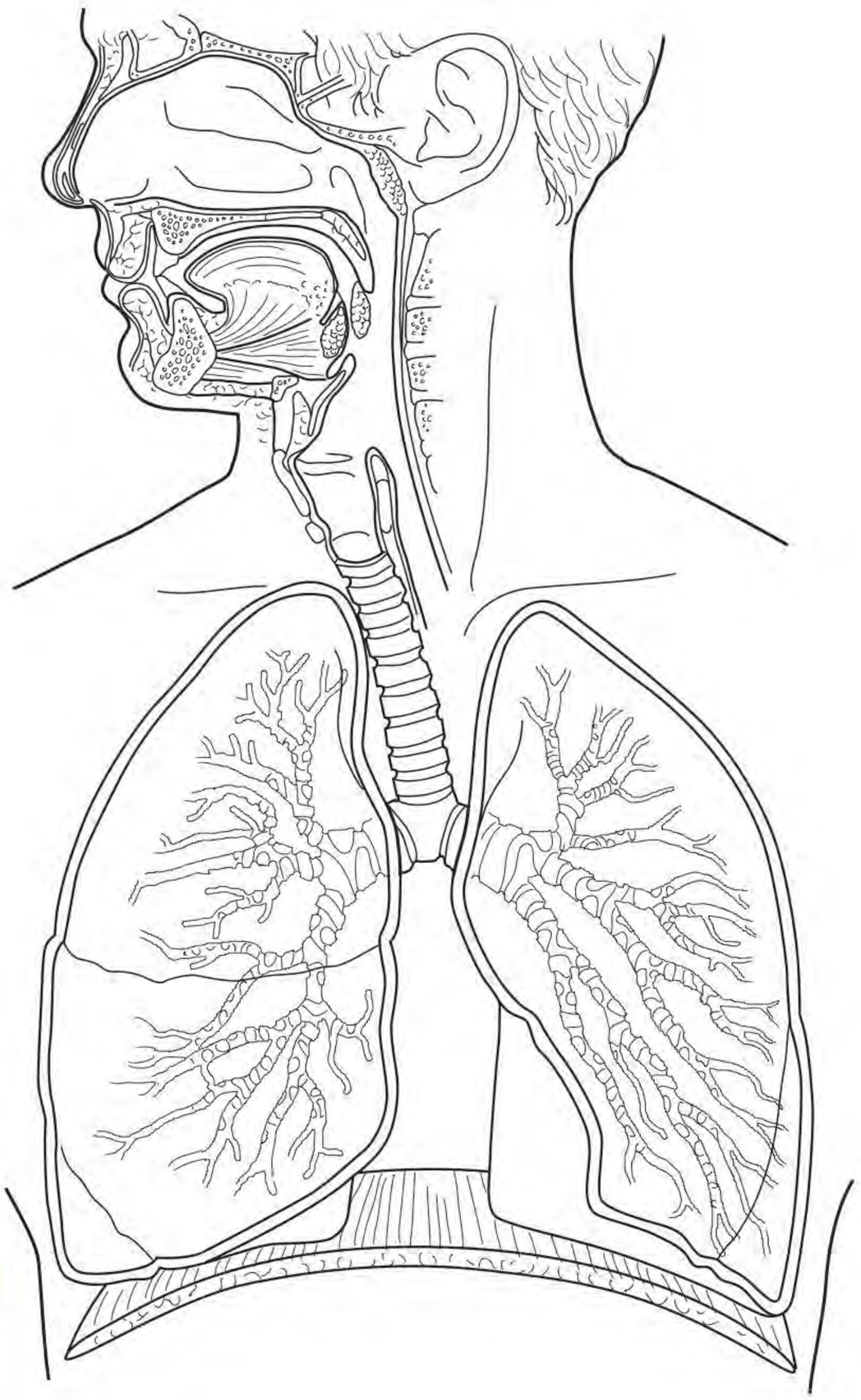
Atmospheric pressure _____



Pre-Lab Exercise 19-2

Respiratory System Anatomy

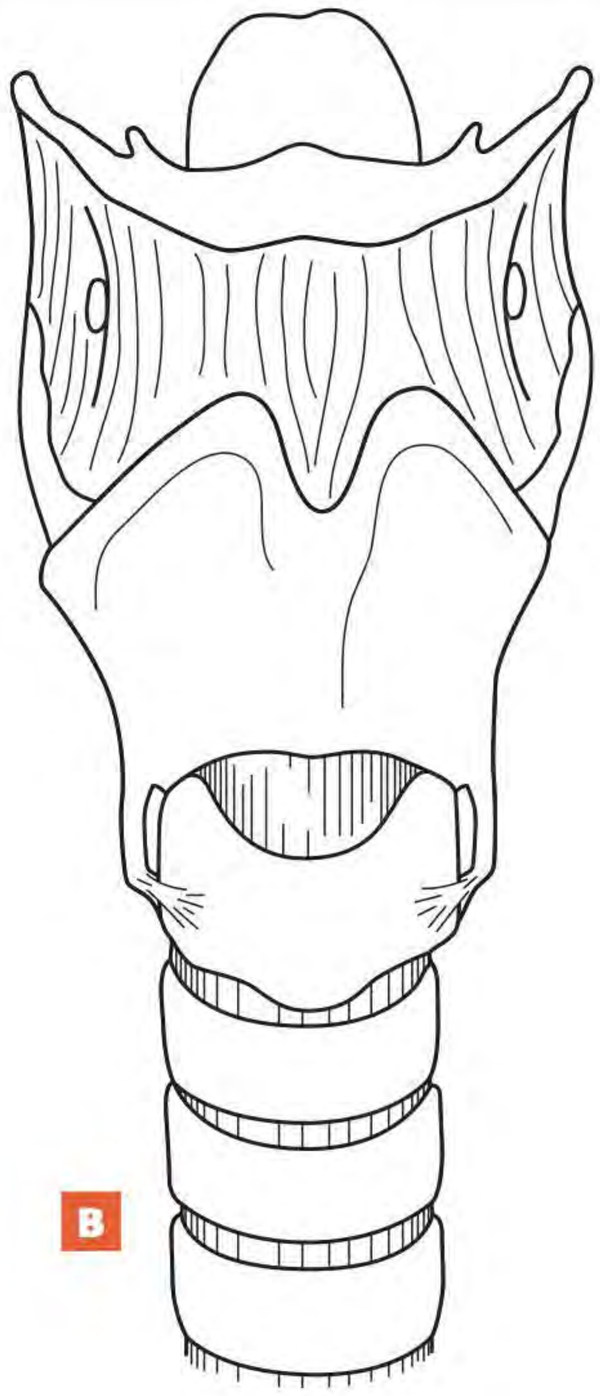
Label and color the diagrams of the structures of the respiratory system in Figure 19.1 with the terms from Exercise 19-1 (p. 471). Use your text and Exercise 19-1 in this unit for reference.



A

FIGURE 19.1 Structures of the respiratory system: (A) lungs and respiratory tract *(continues)*

Name _____ Section _____ Date _____



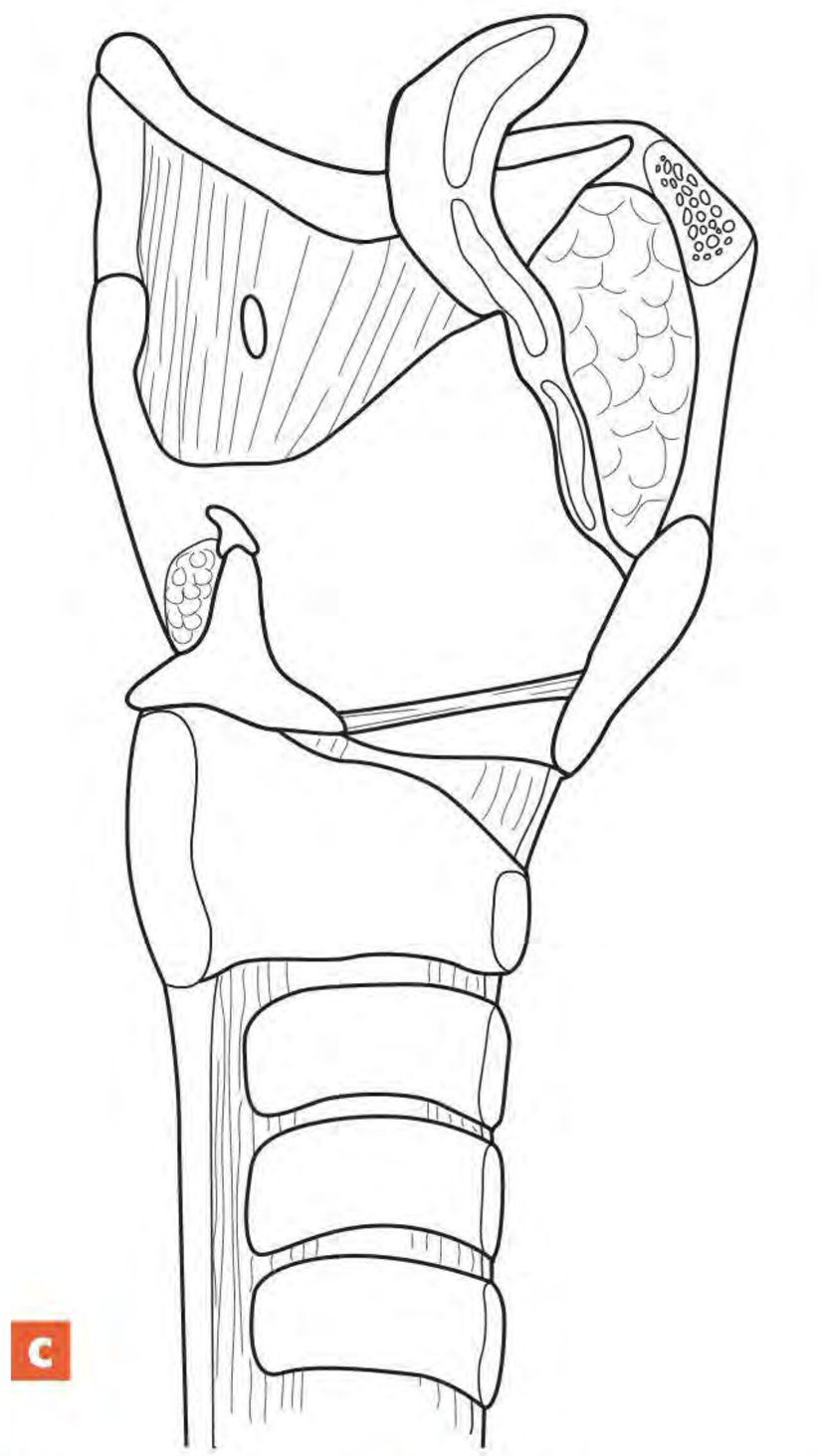
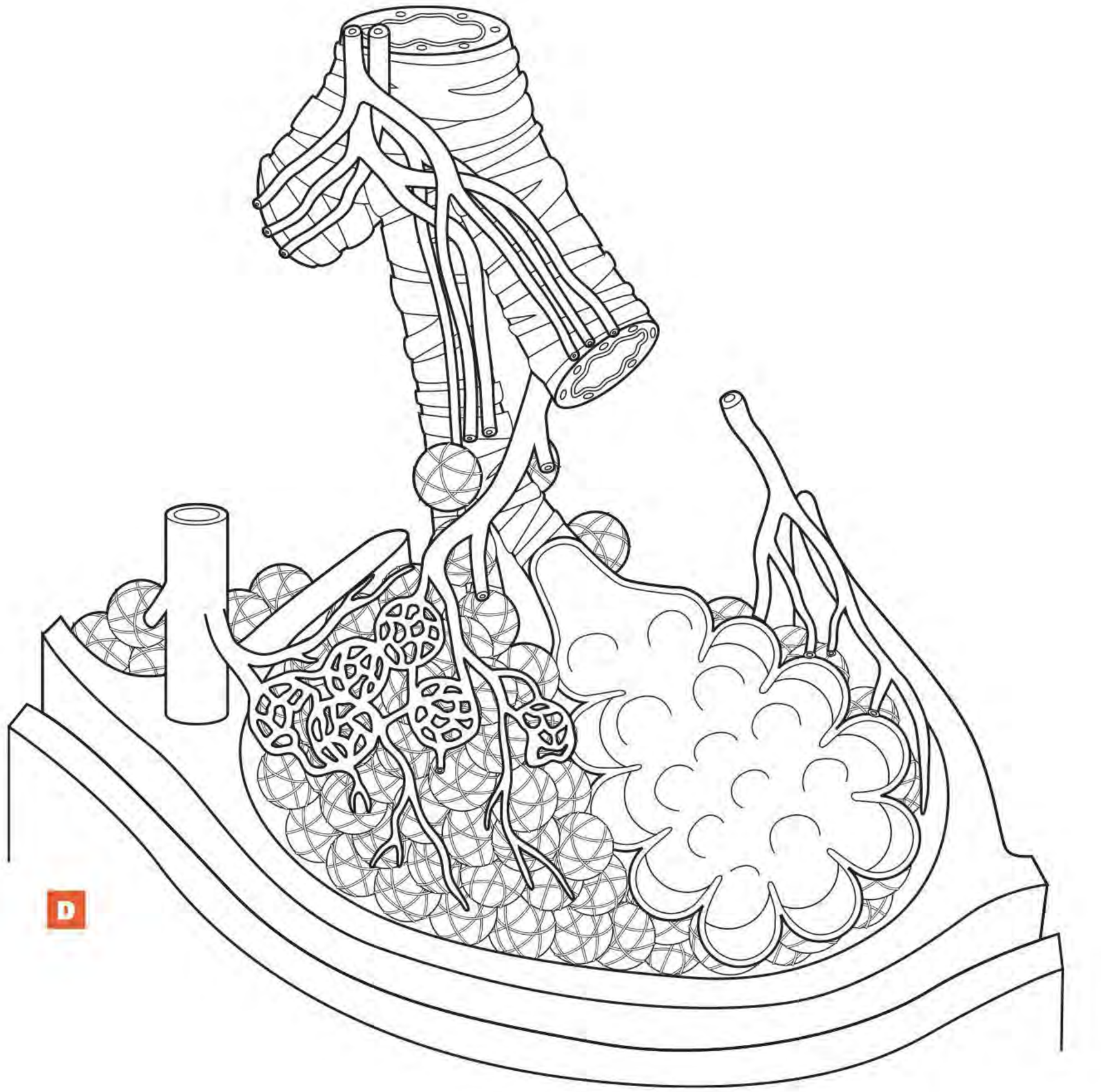


FIGURE **19.1** Structures of the respiratory system *(cont.)*: (**B**) larynx, anterior view; (**C**) larynx, midsagittal section *(continues)*



19

FIGURE **19.1** Structures of the respiratory system *(cont.)*: (**D**) bronchiole and alveolar sac.

EXERCISES

Cells require oxygen in the processes that synthesize ATP, and these reactions produce carbon dioxide as a waste product. The respiratory system and the cardiovascular system work together to supply the cells with the oxygen they need and to rid them of carbon dioxide.

The exercises in this unit will familiarize you with the organs and histology of the respiratory system, including the paired **lungs** and the collection of airway passages known as the **respiratory tract**. In the final exercise you will observe how the changes in pressure of the thoracic cavity lead to changes in lung volume with the process known as **ventilation**.

Exercise 19-1

Respiratory System Anatomy

MATERIALS

- ❑ Lung models
- ❑ Larynx models
- ❑ Alveolar sac model
- ❑ Head and neck model

The lungs are composed of elastic connective tissue and tiny air sacs called **alveoli** (al-vee-OH-lye), where gas exchange takes place. Each lung is divided into smaller structures called **lobes**. The right lung has three lobes (upper, middle, and lower), and the left lung has two lobes (upper and lower) (Figure 19.2A). The lobes are separated from one another by deep indentations called **fissures**. The **horizontal fissure** separates the right upper and right middle lobes; the **right oblique fissure** separates the right middle and right lower lobes; and the **left oblique fissure** separates the left upper and left lower lobes. The left upper lobe has a groove on its inferior, medial surface called the **cardiac notch** where it comes into contact with the heart. Each lung has an **apex** that sits just above the clavicle, and a **base** that rests on the **diaphragm**, the main muscle for breathing.

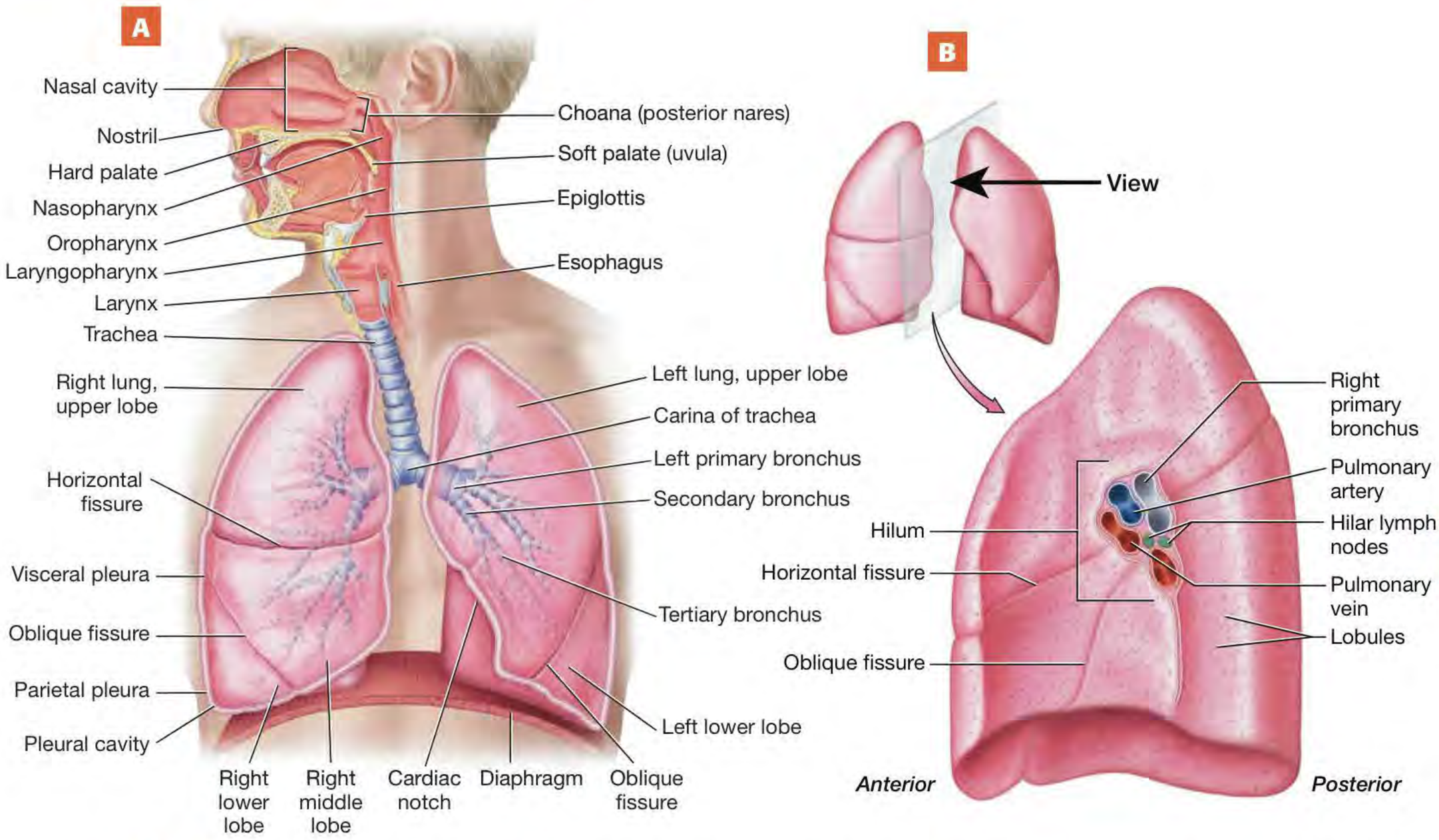


FIGURE **19.2** The respiratory system: (**A**) the lungs and respiratory tract; (**B**) mediastinal surface of the right lung.

Each lung is surrounded by serous membranes similar to the pericardial membranes called the **pleural membranes** (PLOO-ruhl). There are two layers of the pleural membranes:

1. **Parietal pleura.** The outer **parietal pleura** lines the interior of the thoracic cavity and the superior surface of the diaphragm.
2. **Visceral pleura.** When the parietal pleura reaches the structures of the mediastinum, it folds inward to become the **visceral pleura**. The visceral pleura adheres tightly to the surface of the lung.

There is a very thin potential space between the parietal and visceral pleurae called the **pleural cavity.** The space is only a "potential" space because it is filled with a thin layer of serous fluid that reduces friction as the lungs change in shape and size during ventilation.

If we flip a lung on its side and examine its medial or mediastinal surface (the surface that faces the mediastinum), as we do in Figure 19.2B, we can see an area called the **hilum** (HY-lum) of the lung. This is an indentation where the pulmonary vessels, nerves, lymphatic vessels, and airway passages called *primary bronchi* enter and exit the lungs.

Air is delivered to the lungs' alveoli through the passageways of the **respiratory tract.** The respiratory tract may be divided into two regions according to both structure and function. Structurally, it is divided into:

1. The **upper respiratory tract,** which consists of the passages superior to the thoracic cavity, and
2. the **lower respiratory tract,** which consists of the passages within the thoracic cavity.

Functionally, it is divided into:

1. The **conducting zone,** which consists of passages that carry, or "conduct," air to the lower passages where gas exchange takes place. The majority of the passages of the respiratory tract belong to the conducting zone.
2. The **respiratory zone,** which consists of the passages in which gas exchange takes place, located in the terminal respiratory tract.

The conducting zone begins with the **nasal cavity. Air first enters through the nares (or nostrils) and the hair-lined vestibule, then enters the actual nasal cavity.** Lining the walls of the nasal cavity are three projections known as the **superior, middle,** and **inferior nasal conchae** (KAHN-kee). These projections make airflow turbulent, which helps to filter the incoming air of dust and other debris. The nasal cavity is lined with pseudostratified ciliated columnar epithelium with copious mucus-secreting **goblet cells,** a type of tissue known as **respiratory epithelium.**

Air flow is continuous between the nasal cavity and the **paranasal sinuses,** which assist in filtering, warming, and humidifying the inhaled air (Figure 19.3). Recall from Unit 7 that there are four paranasal sinuses: the frontal, maxillary, ethmoid, and sphenoid sinuses (see Figure 7.11, p. 148, for a review).

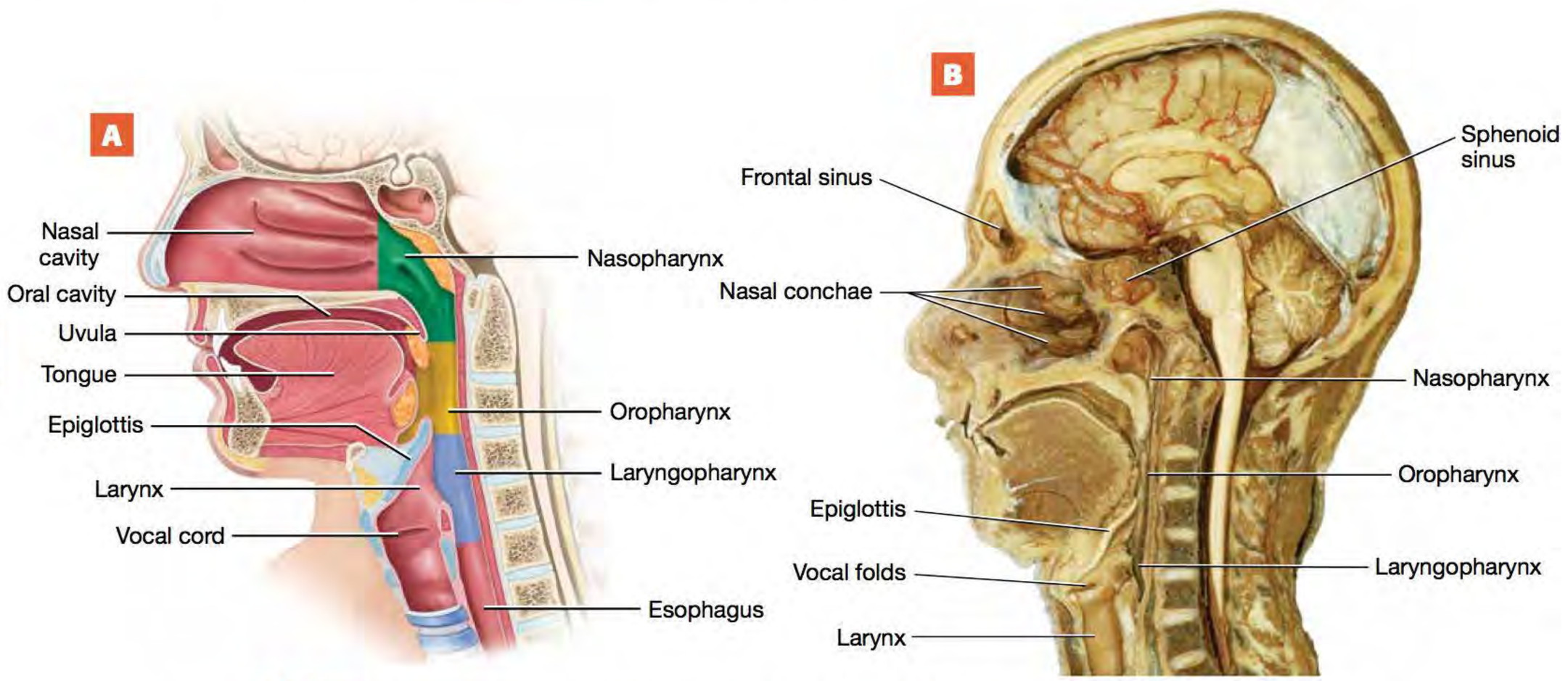


FIGURE **19.3** Midsagittal section of the head and neck: (A) illustration; (B) cadaver dissection.

Air from the nasal cavity next enters the **pharynx** (FEHR-inks), also known as the throat, which has the following three divisions:

1. **Nasopharynx.** The **nasopharynx** (NAYZ-oh-fehr-inks) is the region posterior to the nasal cavity. The muscles of the soft palate and *uvula* move superiorly to close off the nasopharynx during swallowing to prevent food from entering the passage. Sometimes this mechanism fails (such as when a person is laughing and swallowing simultaneously), and the unfortunate result is that food or liquid comes out of the nose. Like the nasal cavity, the nasopharynx is lined with respiratory epithelium.
2. **Oropharynx.** The **oropharynx** (OHR-oh-fehr-inks) is the region posterior to the oral cavity. Both food and air pass through the oropharynx, and it is therefore lined with stratified squamous epithelium. This tissue provides more resistance to mechanical and thermal stresses.
3. **Laryngopharynx.** The **laryngopharynx** (lah-RING-oh-fehr-inks) is the intermediate region between the larynx and the esophagus. As with the oropharynx, both food and air pass through the laryngopharynx, and it is lined with stratified squamous epithelium.

Air passes from the pharynx to the **larynx** (LEHR-inks), a short passage framed by nine cartilages (Figure 19.4). The "lid" of the larynx is a piece of elastic cartilage called the **epiglottis** (ep-ih-GLAH-tiss). During swallowing, muscles of the pharynx and larynx move the larynx superiorly, and the epiglottis seals off the larynx from food and liquids. The largest cartilage of the larynx is the shield-like **thyroid cartilage**, which forms the larynx's anterior and lateral walls. Inferior to the thyroid cartilage is a smaller cartilage called the **cricoid cartilage** (KRY-koyd). Between the two is a soft piece of connective tissue called the **cricothyroid ligament** (kry-koh-THY-royd). The smaller cartilages of the larynx include the **arytenoid** (ah-RIT-eh-noyd), **corniculate** (kor-NIK-yoo-layt), and **cuneiform cartilages** (kyoo-NEE-ih-form), which are found in its posterior and lateral walls.

As its common name "voice box" implies, the larynx is the structure where sound is produced. It contains two sets of elastic ligaments known as the **vocal folds** or **vocal cords**. The superior set of vocal folds, the **false vocal cords** (also called the *vestibular folds*), plays no role in sound production. They do, however, serve an important sphincter function and can constrict to close off the larynx. The inferior set of vocal folds, called the **true vocal cords**, vibrates as air passes over it to produce sound. Superior to the vocal cords, the larynx is lined with stratified squamous epithelium; inferior to the vocal cords, it is lined with respiratory epithelium, as is the remainder of the respiratory tract until we reach much smaller passageways.

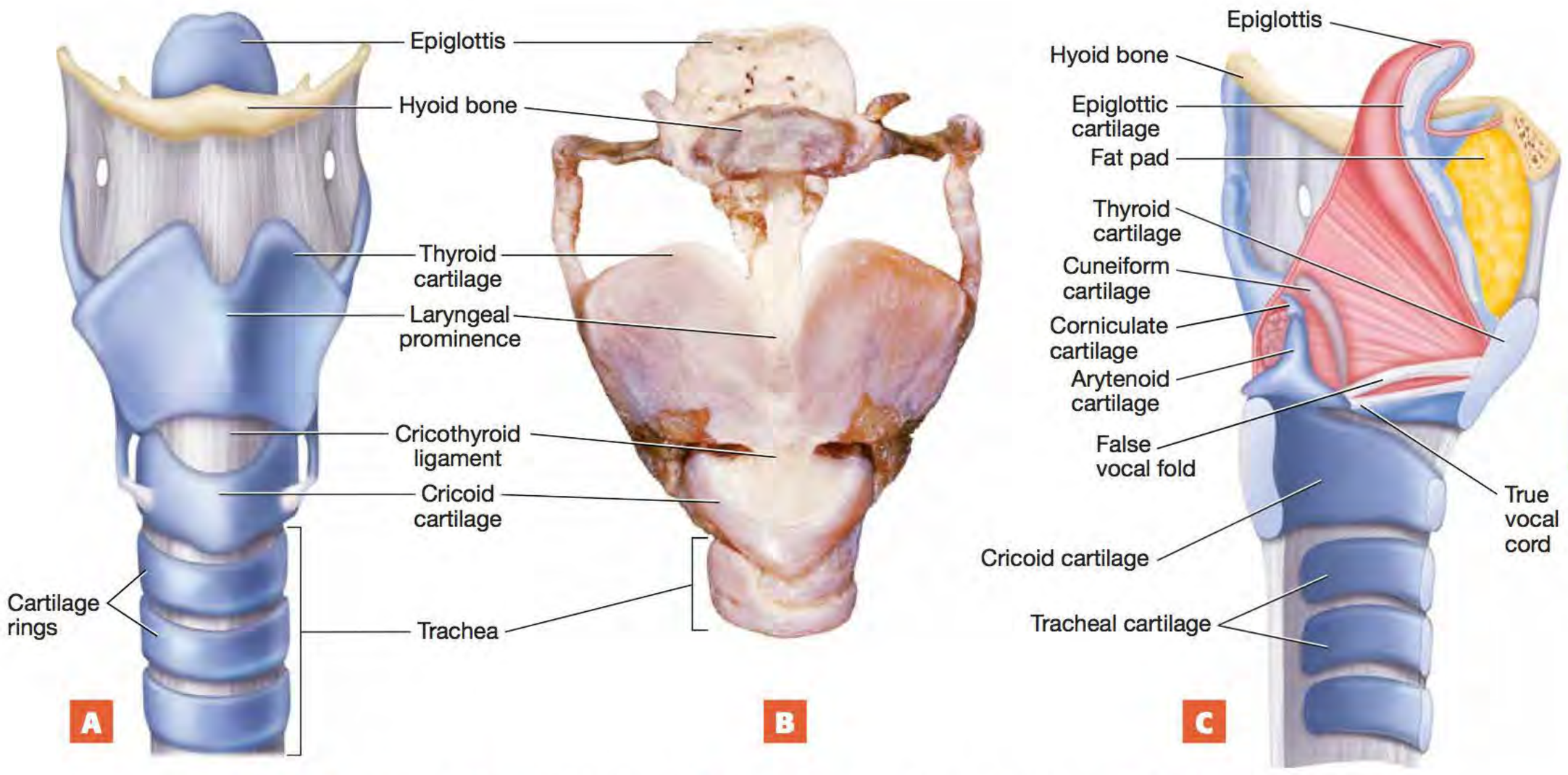


FIGURE **19.4** Larynx: (A) anterior view; (B) anterior view from a cadaver; (C) midsagittal section.

Inspired air passes from the larynx into a tube supported by C-shaped rings of hyaline cartilage called the **trachea** (TRAY-kee-uh; Figure 19.5). The trachea bifurcates in the mediastinum at its final cartilage ring, called the **carina** (kar-EYE-nah), into two **primary bronchi** (BRONG-kye) that begin the large and branching **bronchial tree** (BRONG-kee-uhl). The right primary bronchus is short, fairly straight, and wide, and the left primary bronchus is long, more horizontal, and narrow because of the position of the heart.

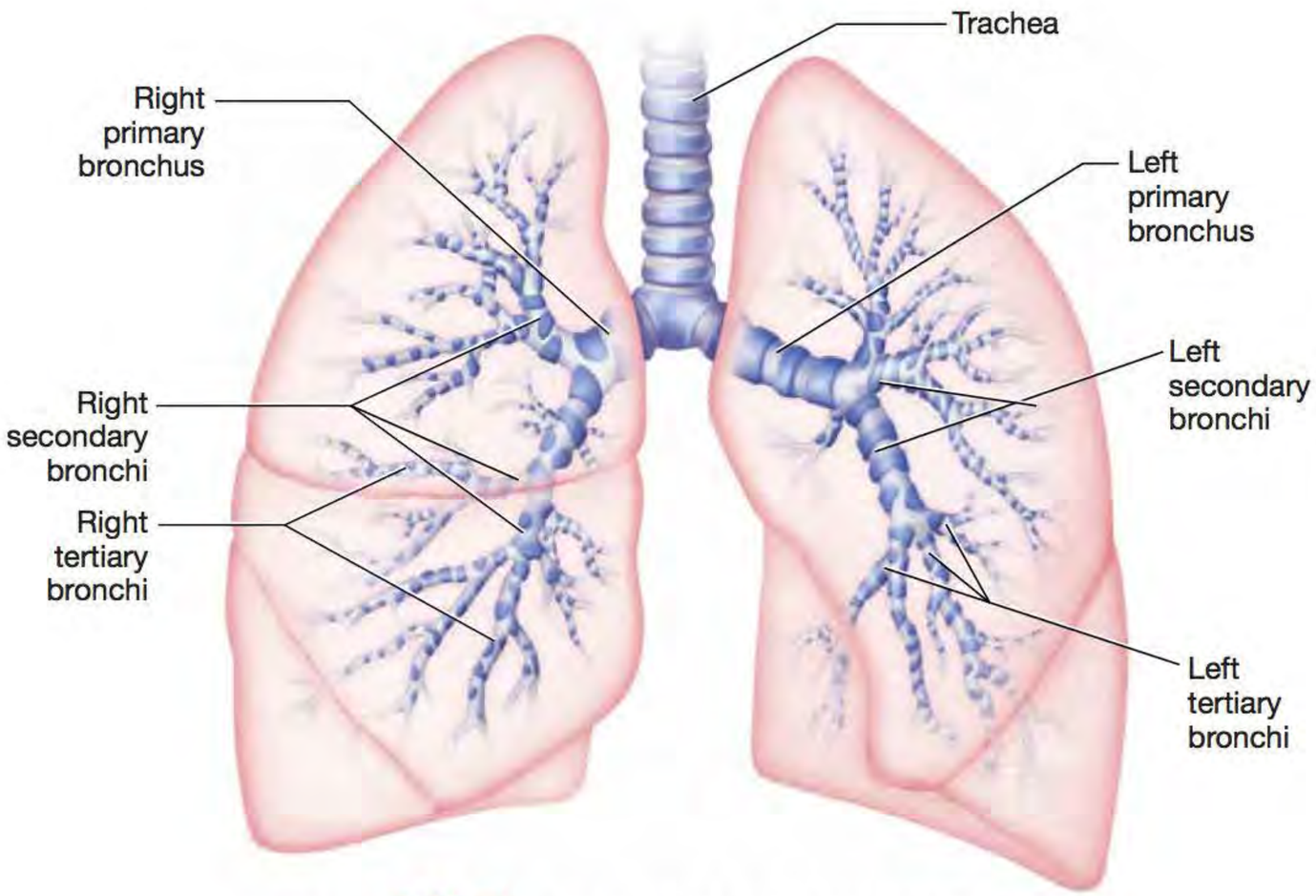


FIGURE **19.5** The trachea and bronchial tree.

Each primary bronchus divides into smaller **secondary bronchi**, each of which serves one lobe of the lung. The two left secondary bronchi serve the two lobes of the left lung, and the three right secondary bronchi serve the three lobes of the right lung. The bronchi continue to branch and become tertiary bronchi, quaternary bronchi, and so on until the air reaches tiny air passages smaller than 1 millimeter in diameter called **bronchioles** (BRONG-kee-ohlz; Figure 19.6). At this level, the epithelium changes to simple cuboidal epithelium.

Bronchioles smaller than 0.5 mm in diameter are called the **terminal bronchioles**, and these mark the end of the conducting zone. The respiratory zone begins with small branches called **respiratory bronchioles** that have alveoli in their walls. As the respiratory bronchioles progressively branch, the number of alveoli in their walls increases until the wall is made up exclusively of alveoli, at which point it is termed an **alveolar duct** (al-vee-OH-lahr). The terminal portions of the respiratory zone, called **alveolar sacs**, are grape-like clusters of alveoli.

The alveoli are surrounded by **pulmonary capillaries**, which are fed by pulmonary arterioles and drained by pulmonary veins. The capillary-alveolus junction is where pulmonary gas exchange takes place: Oxygen from the alveoli diffuses into the blood, and carbon dioxide in the blood diffuses into the alveoli to be exhaled. Alveolar walls and capillary walls are both composed of simple squamous epithelium, so the gases have only a short distance to diffuse. In addition, the structure of the alveolar sacs creates a huge surface area (around 1,000 square feet on average). Both factors allow for gas exchange to take place rapidly and efficiently.

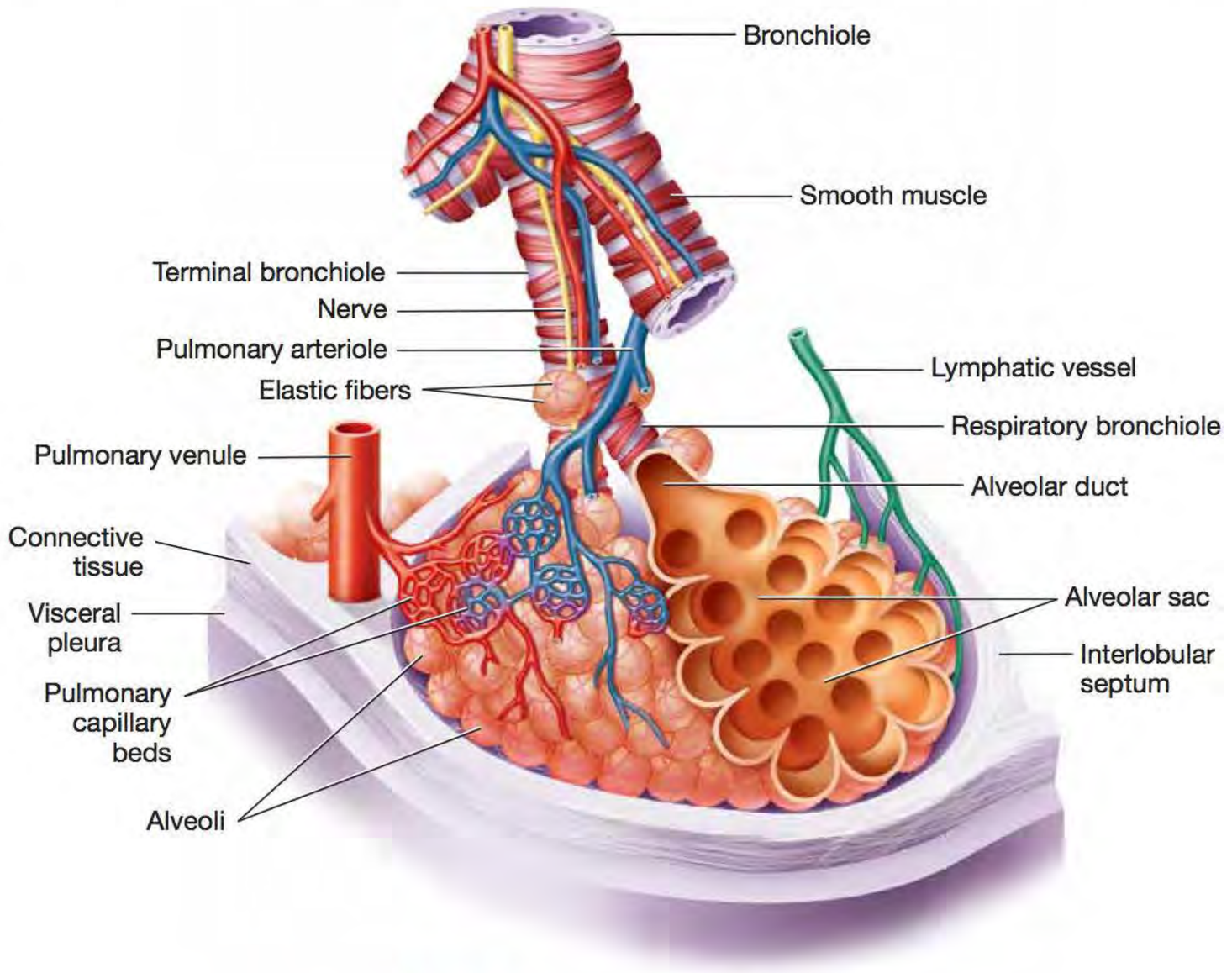
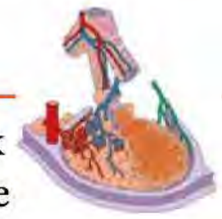


FIGURE **19.6** Bronchiole and alveolar sac.

Procedure 1 Model Inventory for the Respiratory System



Identify the following structures of the respiratory system on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 19.1. After you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 486).

1. Right lung
   a. Upper, middle, lower lobes
   b. Horizontal fissure
   c. Oblique fissure
2. Left lung
   a. Upper and lower lobes
   b. Oblique fissure
   c. Cardiac notch
3. Lungs, general
   a. Apex
   b. Base
   c. Diaphragm
   d. Parietal pleura
   e. Visceral pleura
   f. Pleural cavity
   g. Hilum
4. Respiratory tract, general
   a. Upper respiratory tract
   b. Lower respiratory tract
   c. Conducting zone
   d. Respiratory zone
5. Nasal cavity
   a. Nares
   b. Nasal conchae
      (1) Superior nasal conchae
      (2) Middle nasal conchae
      (3) Inferior nasal conchae
   c. Paranasal sinuses
      (1) Sphenoid sinus
      (2) Ethmoid sinus
      (3) Frontal sinus
      (4) Maxillary sinus
6. Pharynx
   a. Nasopharynx
   b. Oropharynx
   c. Laryngopharynx
7. Larynx
   a. Epiglottis
   b. Thyroid cartilage
   c. Cricoid cartilage
   d. Cricothyroid ligament
   e. Arytenoid cartilages
   f. Corniculate cartilages
   g. Cuneiform cartilages
   h. False vocal cords
   i. True vocal cords
8. Trachea
   a. Hyaline cartilage rings
   b. Carina
9. Bronchi
   a. Right and left primary bronchi
   b. Secondary bronchi
   c. Tertiary bronchi
10. Bronchioles
    a. Terminal bronchioles
    b. Respiratory bronchioles
    c. Alveolar duct
11. Alveoli and alveolar sacs
12. Vascular structures
    a. Pulmonary arteries
    b. Pulmonary arterioles
    c. Pulmonary capillaries
    d. Pulmonary venules
    e. Pulmonary veins

TABLE 19.1 Model Inventory for the Respiratory System

Model/Diagram	Structures Identified

Procedure 2 Time to Draw

In the space below, draw, color, and label one of the respiratory system models that you examined. In addition, write the function of each structure that you label.

Procedure 3 Time to Trace

Part 1

You are a molecule of oxygen floating happily through the atmosphere when all of a sudden you are inhaled by Ms. Magenta.

1 Trace your pathway through Ms. Magenta's respiratory tract beginning in her nasal cavity to the point at which you enter the pulmonary capillaries.

19

Start: _____

_____

_____

_____

_____

_____

_____ **End**

2 Trace your pathway from Ms. Magenta's pulmonary capillaries through the blood, beginning in the pulmonary circuit in her lungs, going through her heart, then through her systemic arteries to your final destination in a hepatocyte (liver cell). You likely will have to review Unit 16 (p. 391) for some help with this.

Start: _____

_____

_____

_____

_____

_____

_____

_____ **End**

Part 2

While in her hepatocyte, you notice that a molecule of carbon dioxide has just been produced.

1 Trace the carbon dioxide's pathway from Ms. Magenta's hepatocyte through the systemic veins to her heart, then through her heart to the pulmonary circuit, and finally through the pulmonary circuit to her pulmonary capillaries. You will likely need to review Unit 16 (p. 391) for some help with this.

Start: _____

_____

_____

_____

_____

_____

_____

_____

_____ **End**

2 Trace the pathway of the carbon dioxide molecule from the pulmonary capillaries through the respiratory tract to the point at which it exits from Ms. Magenta's body through her nares.

Start: _____

_____

_____

_____

_____

_____

_____

_____

_____ **End**

Exercise 19-2

Histology of the Respiratory Tract

MATERIALS

- ❑ Trachea slide
- ❑ Lung tissue slide
- ❑ Bronchiole slide
- ❑ Light microscope
- ❑ Colored pencils

As you learned in Exercise 19-1, the respiratory tract is a series of branching tubes that conduct air to and from the respiratory zone for gas exchange. The "tubes" of the respiratory tract are similar in structure histologically to other hollow organs of the body and consist of three tissue layers. Figure 19.7A uses the example of the trachea to show these layers: the mucosa, the submucosa, and the adventitia.

1. **Mucosa**. Mucous membranes, or **mucosae**, line all passageways that open to the outside of the body, including the passages of the respiratory tract. Mucosae consist of epithelial tissue overlying the basement membrane. As we have seen elsewhere in the body, there is a clear relationship of structure and function in the respiratory tract, because the epithelial tissue of the mucosae is adapted for each region's function. Some examples of the epithelia found in different regions include the following:
   a. The nasopharynx, larynx (inferior to the vocal cords), trachea, and bronchi are lined with pseudostratified ciliated columnar epithelium with mucus-secreting cells called **goblet cells**, otherwise known as **respiratory epithelium**. Figure 19.7B shows you an example of respiratory epithelium from the nasal cavity, but note that you can see respiratory epithelium in Figure 19.7A in the trachea, as well. The cilia of respiratory epithelium sweep dust and other particulates that become trapped in the mucus out of the respiratory tract. This helps to prevent this material from reaching the deeper parts of the respiratory tract.
   b. The oropharynx, laryngopharynx, and larynx (superior to the vocal cords) are lined with stratified squamous epithelium. This helps to protect these areas from mechanical abrasion from food.
   c. The bronchioles are lined with simple cuboidal epithelium, which is shown in Figure 19.7C. These small passageways need fewer goblet cells and cilia because most dust and debris have already been removed by the time air reaches them.
   d. Alveoli are lined with simple squamous epithelium. Note in Figure 19.7D that the alveoli consist of a mucosa only and have no other tissue layers. As you read earlier, this minimizes the distances gases must diffuse across the alveoli and into the pulmonary capillaries. The structure through which gases must diffuse, called the **respiratory membrane**, consists of the squamous epithelial cells, the endothelial cells of the pulmonary capillaries, and their shared basal lamina.
2. **Submucosa**. Deep to the mucosa we find the **submucosa**, a layer of loose connective tissue. The submucosa contains specialized **seromucous glands** (seer-oh-MYOO-kuss) that secrete watery mucus. The submucosa of larger passages contains hyaline cartilage for support; it also contains smooth muscle that controls the diameter of the airways.
3. **Adventitia**. The outermost layer of the respiratory tract, the **adventitia** (ad-ven-TISH-uh), consists of dense irregular collagenous connective tissue with elastic fibers for support.

As you examine different regions of the respiratory tract, you will note a few trends:

- The epithelial tissue changes from taller (pseudostratified) in the upper passages to shorter (cuboidal) in the lower passages and finally to flat (squamous) in the alveoli.
- The amount of hyaline cartilage gradually decreases (it is absent in bronchioles), as does the number of goblet cells.
- The amount of smooth muscle and elastic fibers increases as we move deeper into the respiratory tract.

These trends can help you to determine the portion of the respiratory tract from which the section on your slide was taken. In the following exercise you will be able to see these trends as you examine photomicrographs of the trachea, a bronchiole, and the alveoli.

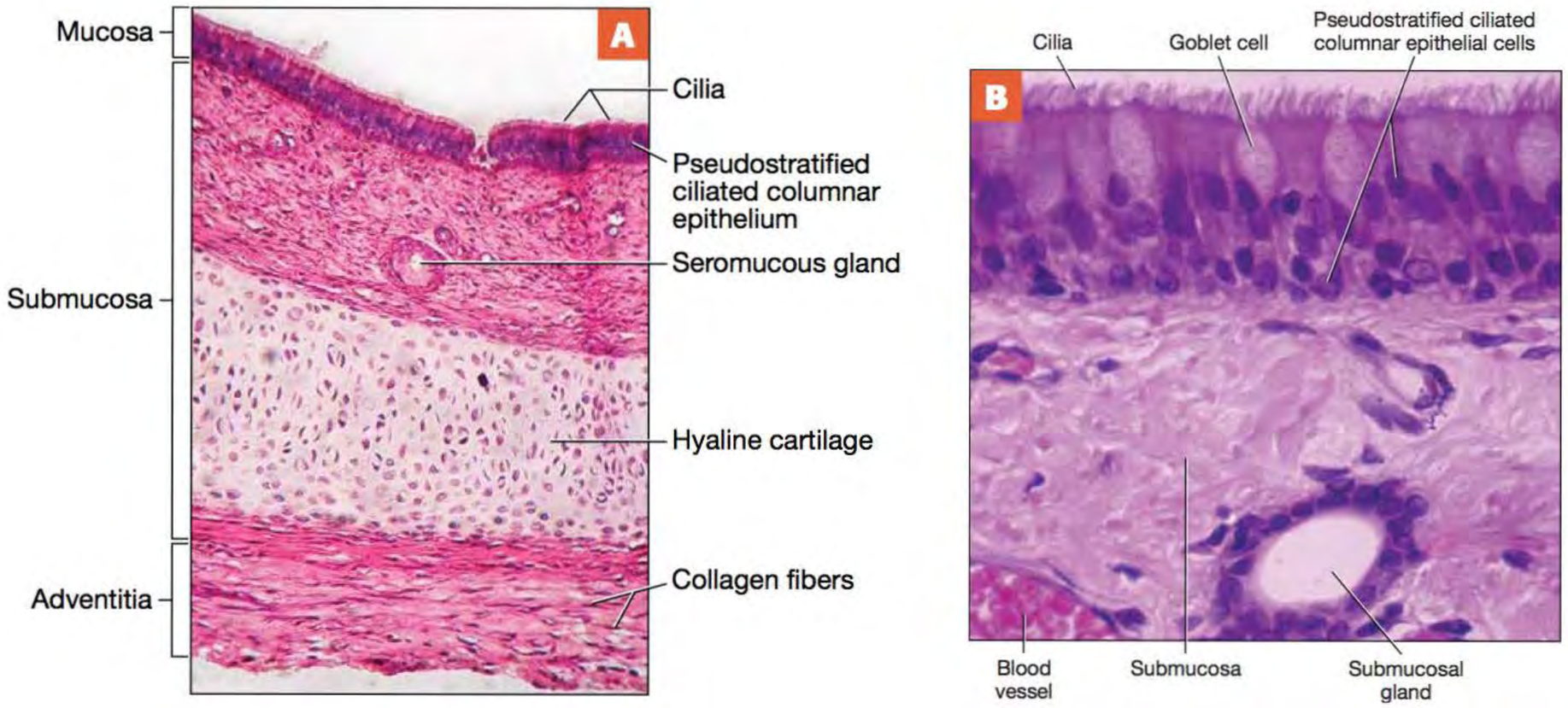


FIGURE **19.7** Photomicrograph of: (**A**) the trachea; (**B**) nasal mucosa with goblet cell; (**C**) bronchiole; (**D**) lung tissue.

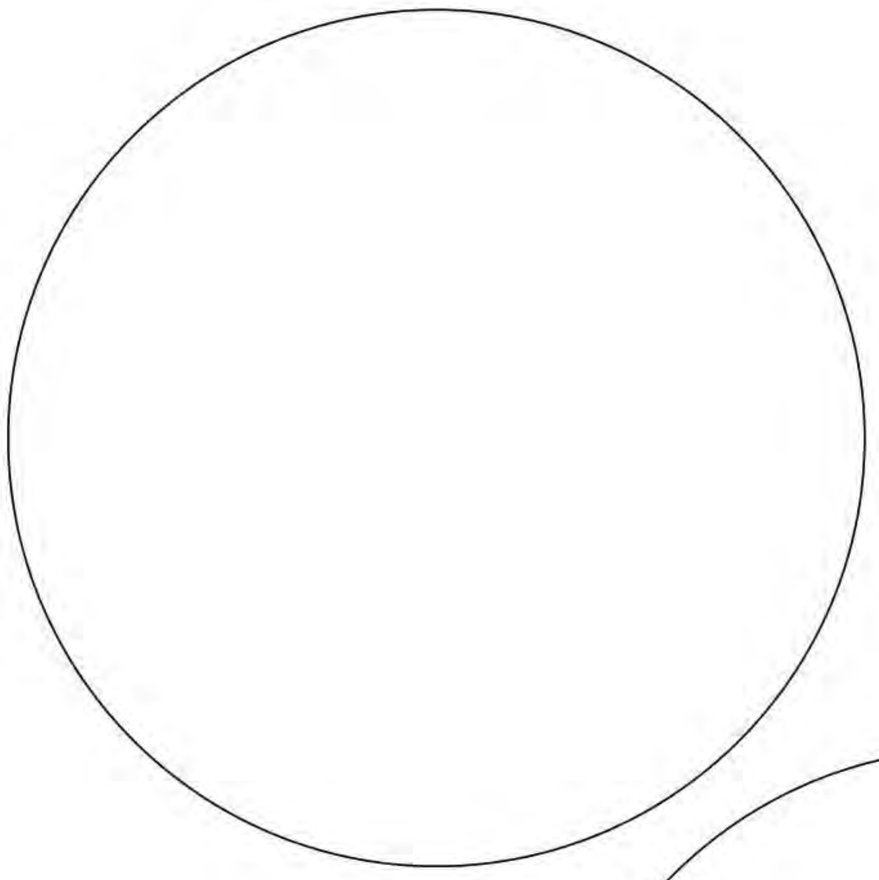
Procedure 1 Microscopy

View prepared slides of a section of the trachea, a bronchiole, and alveoli. Note that the bronchiole may be on the same slide as the alveoli. Begin your examination of the slides on low power, and advance to medium and high power to observe details. Use colored pencils to draw what you see under the microscope, and label your drawing with the terms indicated. When you have completed the activity, answer Check Your Understanding questions 4 through 6 (p. 490).

1. Trachea

Label the following on your drawing:

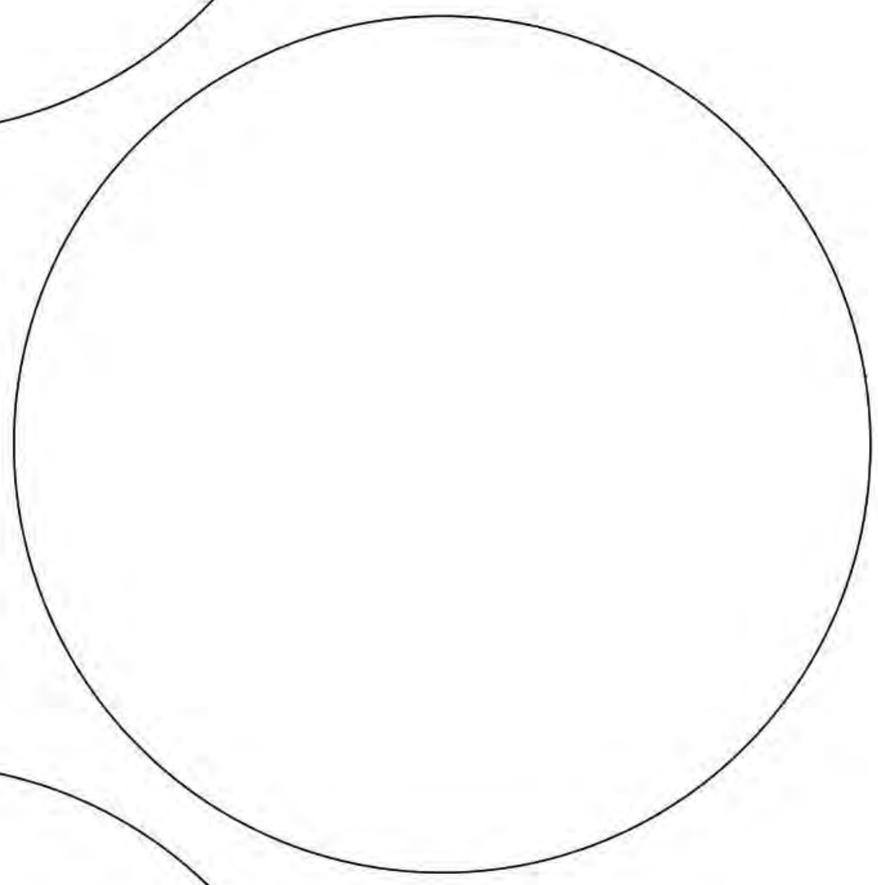
- ❑ Pseudostratified columnar epithelium
- ❑ Cilia
- ❑ Goblet cells
- ❑ Submucosa
- ❑ Seromucous glands
- ❑ Hyaline cartilage



2. Bronchioles

Label the following on your drawing:

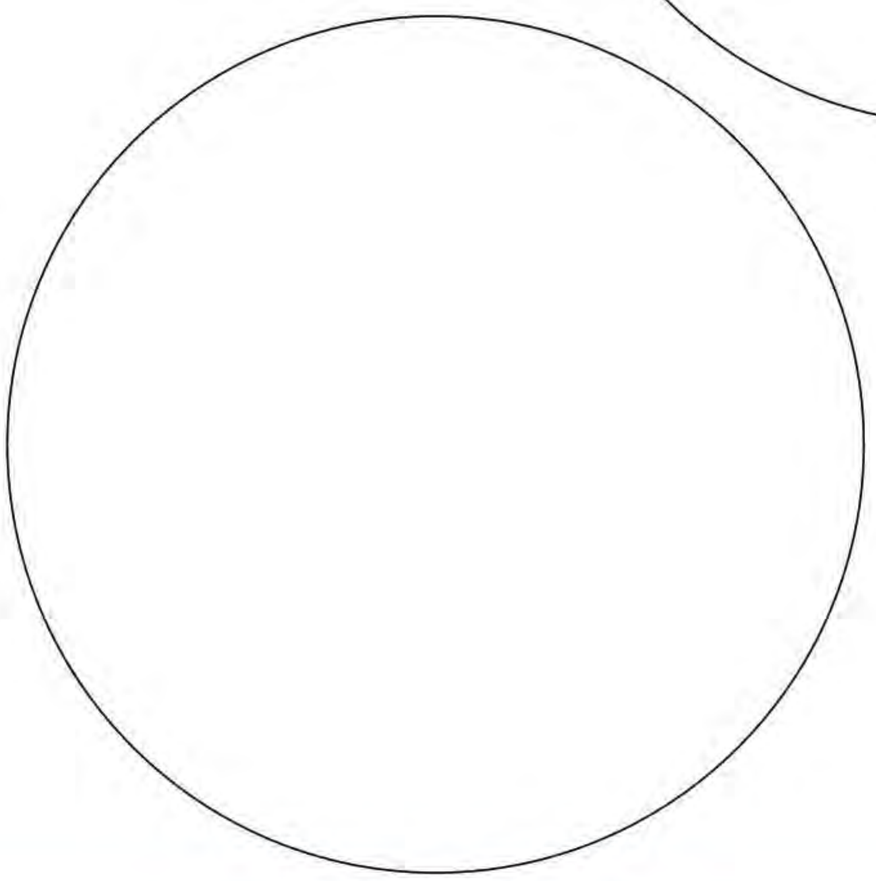
- ❑ Simple columnar or cuboidal epithelium
- ❑ Smooth muscle
- ❑ Pulmonary arteriole



3. Alveoli

Label the following on your drawing:

- ❑ Simple squamous epithelium
- ❑ Alveolar duct
- ❑ Alveolus



Exercise 19-3

Lung Inflation

MATERIALS

- ❑ Preserved small mammal
- ❑ Dissection equipment
- ❑ Dissection trays
- ❑ Straw
- ❑ Air hose
- ❑ Fresh lungs

In movies or television programs you may have seen a hero rescuing a choking victim by poking a hole in the victim's neck (usually with a pocketknife) and inserting a straw (or pen) into the hole to restore the airway and save the victim's life. This is actually a somewhat crude version of a legitimate procedure called a **cricothyroidotomy** (kry-koh-thy-royd-AH-toh-mee)—but don't try this at home!

A cricothyroidotomy is performed when the upper respiratory tract is blocked and air is prevented from moving into the lungs. The first step in the procedure is to place an incision (hopefully with a scalpel, not a pocketknife) in the cricothyroid ligament, the soft spot between the thyroid and cricoid cartilages. A tube is then inserted into the opening, and the patient is ventilated artificially. This restores the patient's airway by bypassing the upper respiratory tract.

In the following procedure you will be able to see the effects of a cricothyroidotomy firsthand by performing the procedure on a fetal pig (or other preserved small mammal) and inflating its lungs. You will also inflate fresh lungs from a sheep, a pig, or a cow. As you perform both procedures, note the difference in the textures and appearances of the preserved lungs and fresh lungs. After you have completed both procedures, answer Check Your Understanding question 7 (p. 490).

Procedure 1 Cricothyroidotomy and Inflating Preserved Lungs

1. Obtain a fetal pig or other preserved small mammal and dissection equipment.
2. Carefully dissect the animal's neck and remove tissue so the larynx is clearly visible.
3. Locate the cricothyroid ligament, and make a small incision with a scalpel into its anterior surface.
4. Insert a small straw into the hole you have just made.
5. Attach the straw to a small hose, and attach the hose to an air outlet.
6. Turn on the air slowly and watch the lungs inflate. Crimp the hose to cut off the airflow, and watch the lungs deflate.

Procedure 2 Inflating Fresh Lungs

1 Obtain a fresh specimen and a large air hose.

2 Examine the specimen for structures covered in Exercise 19-1 (p. 471), in particular the epiglottis and vocal folds, the other laryngeal cartilages, the trachea and its hyaline cartilage rings, and the pleural membranes.

Safety Note

Safety glasses and gloves are required!

3 Squeeze the deflated lungs between your fingertips and note their texture. Deflated lungs are shown in Figure 19.8A. Compare their texture with that of the lungs of the preserved mammal:

4 Insert the air hose into the larynx and feed it down into the trachea. Take care not to get the hose stuck in one of the primary bronchi.

5 Attach the hose to the air outlet and turn it on slowly. You may have to squeeze the trachea and the hose to prevent air leakage.

6 Observe the lungs as they inflate, shown in Figure 19.8B. You may inflate the lungs quite fully. Don't worry—they're very unlikely to pop.

7 Squeeze the inflated lungs between your fingers and note their texture:

8 Crimp the air hose and watch the lungs deflate. Again feel the lungs, and note changes in texture:

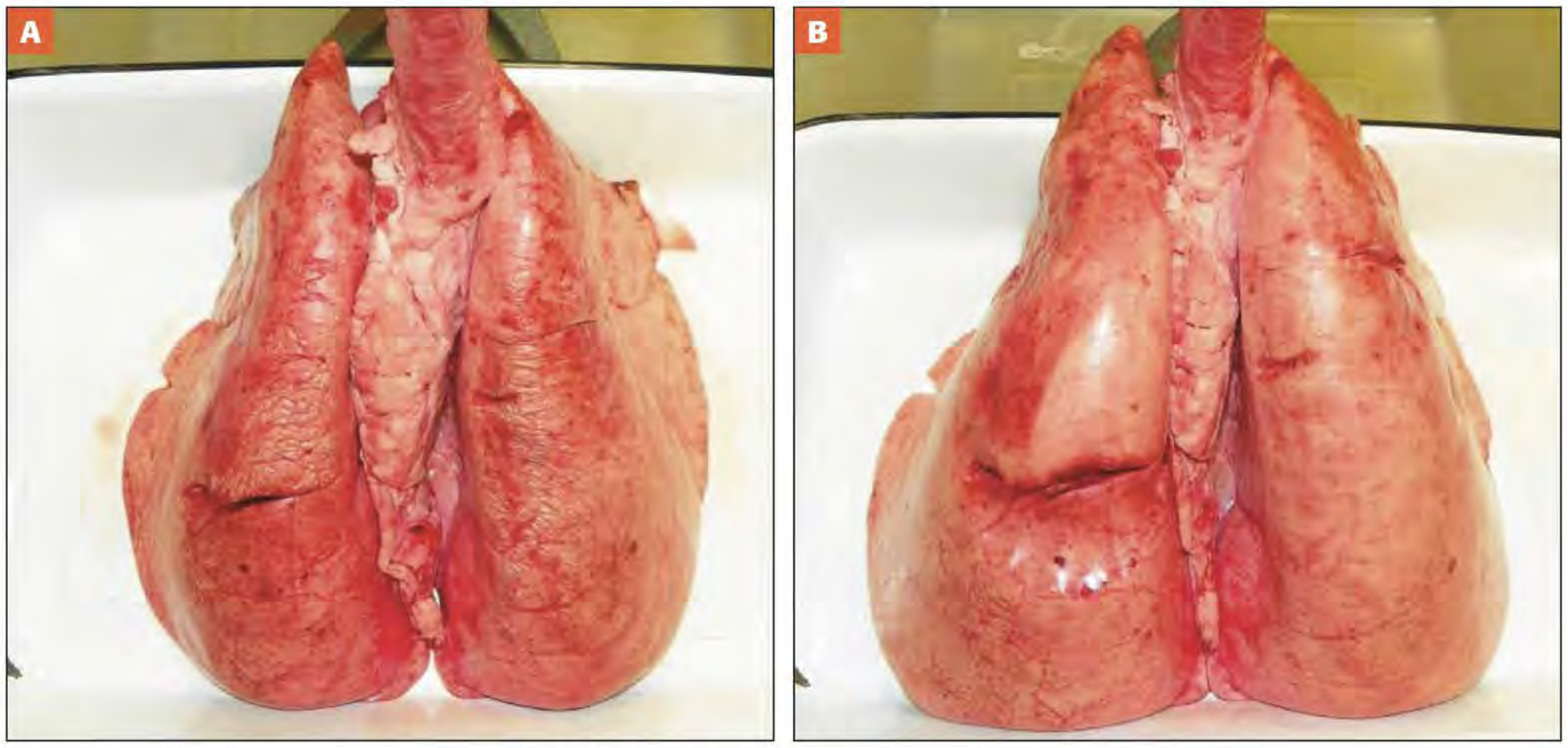


FIGURE **19.8** Fresh lungs: (**A**) deflated; (**B**) inflated.

Exercise 19-4

Pressure-Volume Relationships in the Lungs

MATERIALS

- ❑ Bell-jar model of the lungs

Pulmonary ventilation, the physical movement of air into and out of the lungs, consists of two phases:

1. **inspiration**, during which air is brought into the lungs, and
2. **expiration**, during which air is expelled from the lungs.

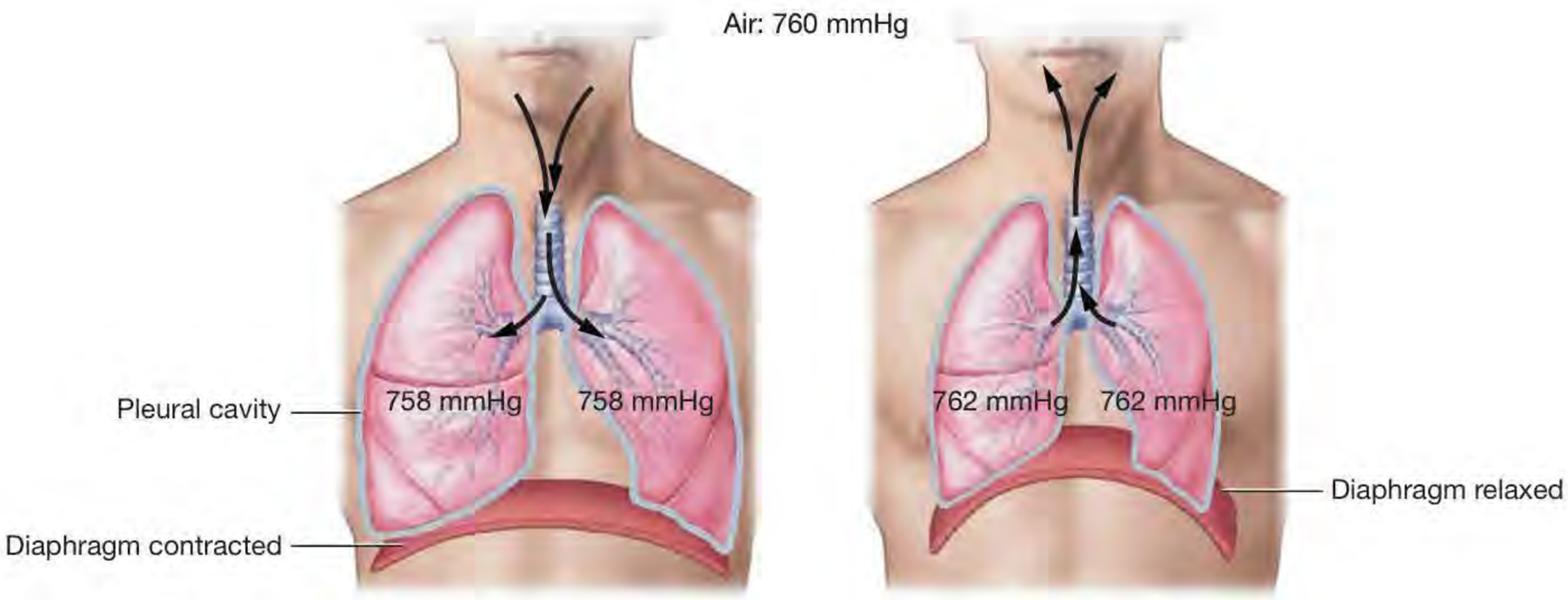
The movement of air during inspiration and expiration is driven by changes in the lungs' volume and pressure (Figure 19.9). The relationship of gas pressure and volume is expressed in what is known as **Boyle's law**, expressed mathematically as:

$$P_1V_1 = P_2V_2 \text{ or } P = 1/V$$

Stated simply, this means that pressure and volume are inversely proportional: As the volume of a container increases, the pressure decreases, and as the volume of a container decreases, the pressure increases.

The changes in volume during the phases of ventilation are driven by the **inspiratory muscles**. The main inspiratory muscle is the **diaphragm**, and it is assisted by the **external intercostal muscles**. During forced inspiration, several other muscles, termed *accessory muscles of inspiration*, assist the diaphragm and external intercostal muscles. When the inspiratory muscles contract, they increase both the height and the diameter of the thoracic cavity, which increases its volume. Recall that the lungs are attached to the thoracic cavity directly by the pleural membranes. Therefore, the lungs increase in volume when the thoracic cavity increases in volume. As the lungs' volume increases, their pressure, called the **intrapulmonary pressure**, decreases. When intrapulmonary pressure is lower than the **atmospheric pressure**, inspiration occurs, and air rushes into the lungs.

Expiration is achieved primarily by the elastic recoil of the lungs. As the inspiratory muscles relax, the lungs' elastic tissue causes them to recoil to their original, smaller size. This decreases the volume of the lungs and increases the intrapulmonary pressure. Once the intrapulmonary pressure is higher than the atmospheric pressure, air exits the lungs, and expiration occurs. In the event of forced expiration, several accessory muscles of expiration, including the **internal intercostal muscles**, will decrease the height and diameter of the thoracic cavity.



Inspiration: Lung volume increases and intrapulmonary pressure decreases.

Expiration: Lung volume decreases and intrapulmonary pressure increases.

FIGURE **19.9** Pressure-volume relationships in the lungs during inspiration and expiration.

Procedure 1 Model Ventilation with the Bell-Jar Model

In this procedure we will use a bell-jar model of the lungs, shown in Figure 19.10, to view the effects of pressure and volume on ventilation. The bell-jar model has two balloons, each representing one lung, and a flexible membrane on the bottom that represents the diaphragm.

FIGURE **19.10** Bell-jar model of the lungs, simulated inspiration.

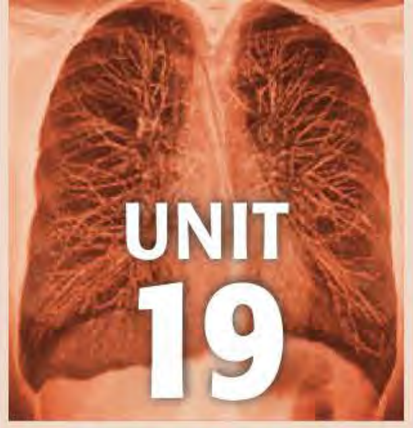
1 Apply upward pressure to the diaphragm. This represents how the diaphragm looks when it is relaxed. What has happened to the pressure of the system (has it increased or decreased)? What happened to the volume of the lungs?

2 Now slowly release the diaphragm. This represents the diaphragm flattening out as it contracts. What is happening to the pressure as you release the diaphragm? What happened to the volume of the lungs?

3 If your bell-jar model has a rubber stopper in the top, you can use it to demonstrate the effects of a **pneumothorax** (noo-moh-THOHR-ax) on lung tissue. A pneumothorax generally is caused by a tear in the pleural membranes that allows air to enter the pleural cavity. With the diaphragm flat and the lungs (balloons) inflated, loosen the rubber stopper. What happens to the lungs? Why?

Name _____

Section _____ Date _____



REVIEW

Check Your Recall

1 Label Figure 19.11A and 19.11B with the terms below.

- ❑ Laryngopharynx
- ❑ Larynx
- ❑ Left primary bronchus
- ❑ Nasal cavity
- ❑ Nasopharynx
- ❑ Oropharynx
- ❑ Pleural cavity
- ❑ Right primary bronchus
- ❑ Secondary bronchi
- ❑ Cricoid cartilage
- ❑ Epiglottis
- ❑ Hyoid bone
- ❑ Thyroid cartilage

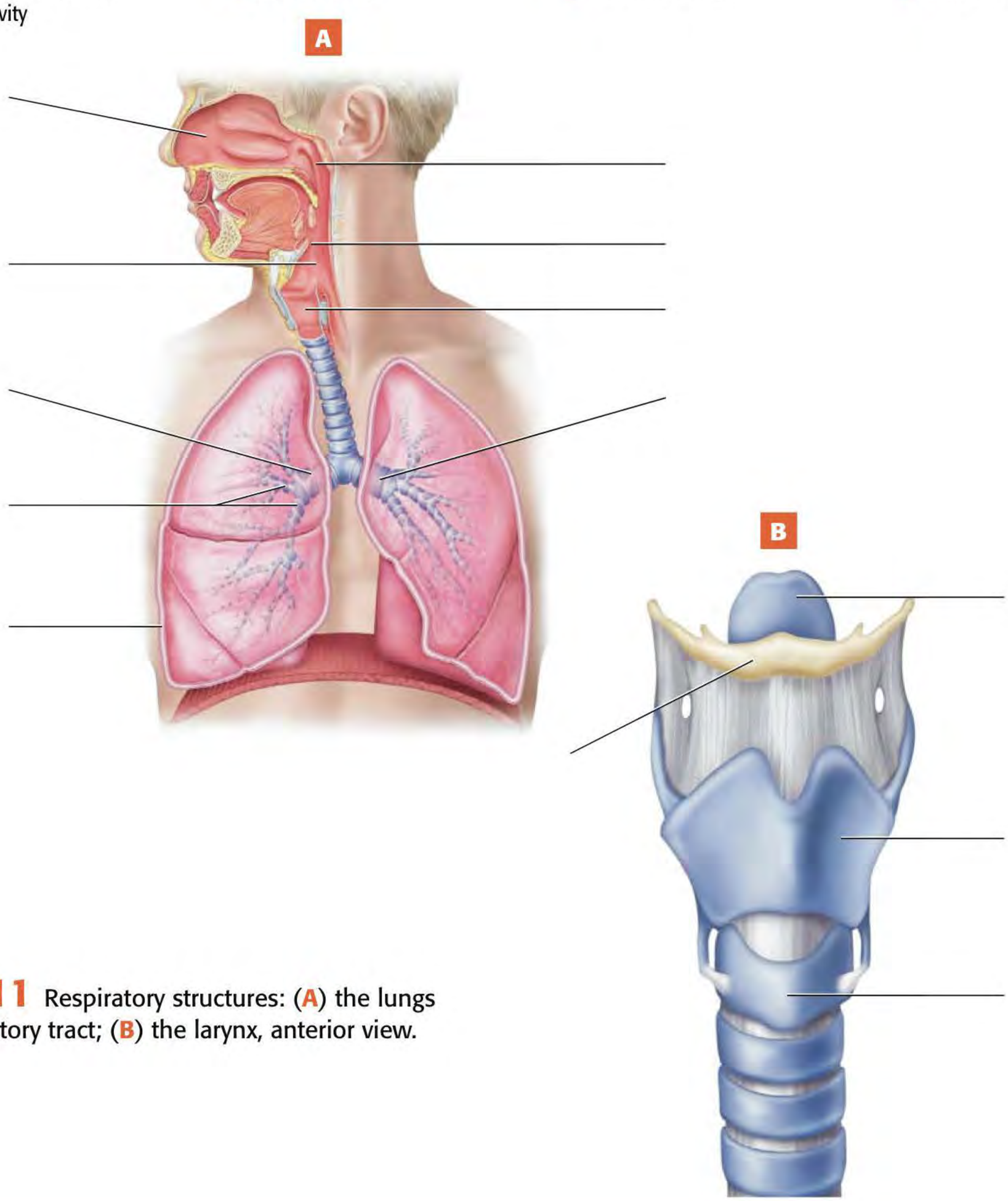


FIGURE **19.11** Respiratory structures: (**A**) the lungs and respiratory tract; (**B**) the larynx, anterior view.

2 Label Figure 19.12 with the terms below.

- ❑ Alveolar duct
- ❑ Alveolar sac
- ❑ Alveolus
- ❑ Pulmonary arteriole
- ❑ Pulmonary capillaries
- ❑ Pulmonary venule
- ❑ Respiratory bronchiole
- ❑ Terminal bronchiole

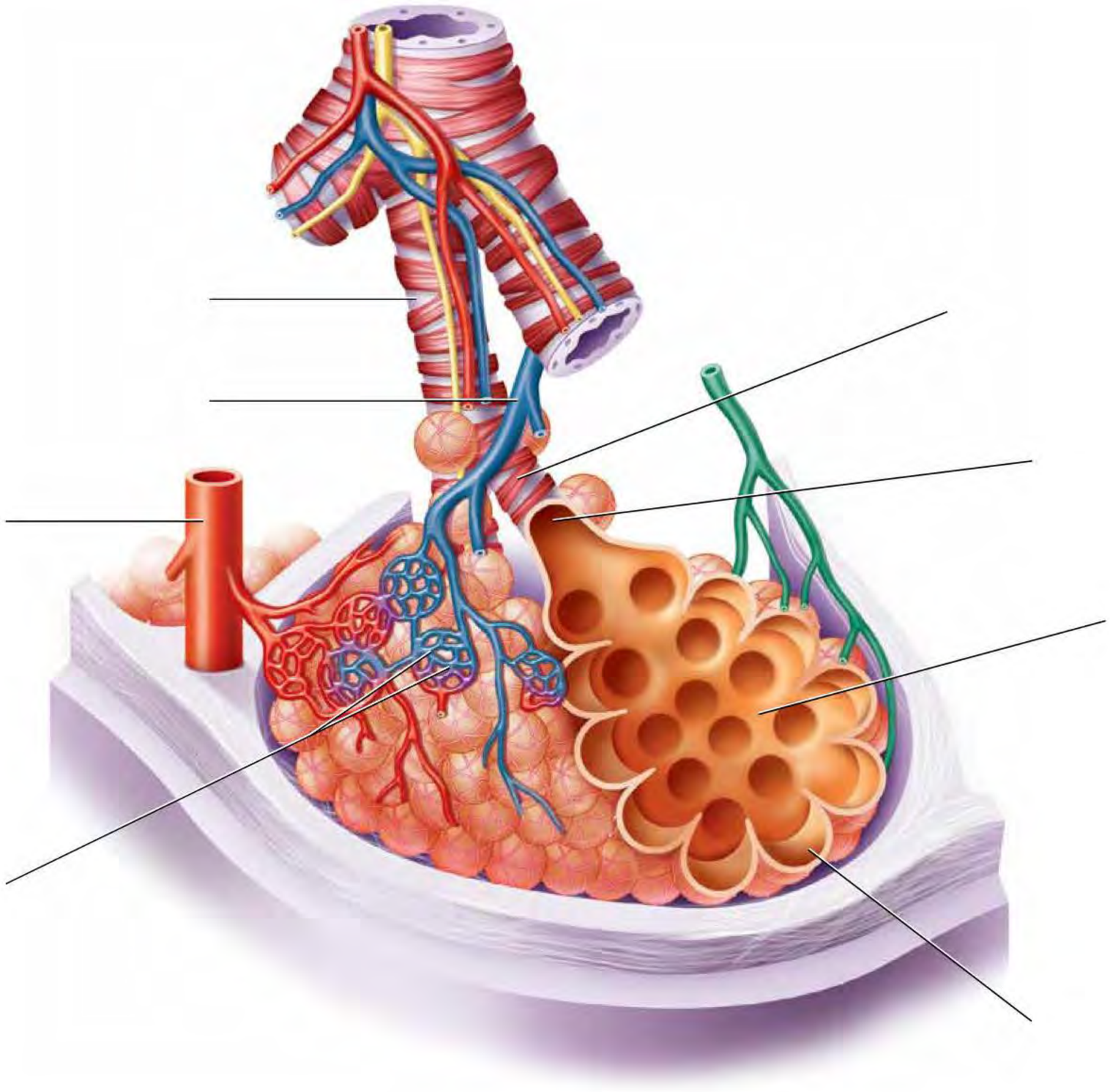


FIGURE **19.12** Bronchiole and alveolar sac.

3 *Fill in the blanks:* The _____ is the lungs' outer membrane, which adheres to the inner wall of the thoracic cavity. It folds inward on itself to become the inner membrane called the _____, which adheres to the lungs' surface. Between the two layers of membrane is the _____.

4 How do the respiratory zone and the conducting zone differ?

_____

_____

_____

Name _____

Section _____ Date _____

UNIT 19

5 Number the following structures of the respiratory tract in the proper order. The structure that comes into contact with oxygenated air first should be number 1, and the structure(s) where gas exchange takes place should be number 11.

_____ Oropharynx

_____ Trachea

_____ Nasal cavity

_____ Bronchiole

_____ Alveolar sac

_____ Larynx

_____ Nasopharynx

_____ Bronchi

_____ Terminal bronchiole

_____ Laryngopharynx

_____ Respiratory bronchiole

6 The piece of elastic cartilage that seals off the larynx during swallowing is called the

a. uvula.
b. false vocal cord.
c. true vocal cord.
d. epiglottis.

7 Passages in the respiratory tract smaller than 1 mm in diameter are called

a. bronchi.
b. bronchioles.
c. alveolar ducts.
d. paranasal sinuses.

8 Which of the following is *not* one of the tissue layers of the respiratory tract?

a. Muscularis
b. Mucosa
c. Adventitia
d. Submucosa

9 What three structures make up the respiratory membrane?

a _____

b _____

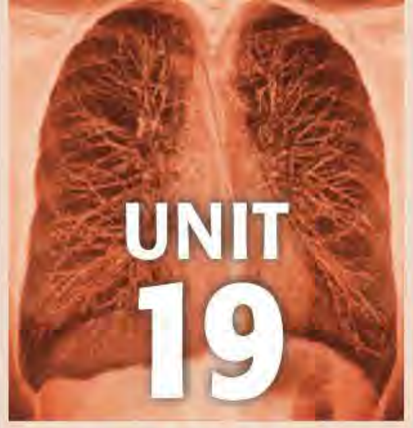
c _____

10 Which of the following is *not* a trend we find within the respiratory tract?

a. The epithelium gets progressively shorter in the lower passages.
b. The amount of hyaline cartilage gradually increases as we move to smaller passages.
c. The amount of smooth muscle increases in the smaller passages.
d. The amount of elastic fibers increases in the smaller passages.

Name _____

Section _____ Date _____



UNIT 19 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Why do you think the hyaline cartilage rings of the trachea are "C"-shaped rather than "O"-shaped? (*Hint:* Think about the structure posterior to the trachea.)

2 Conditions such as pneumonia and lung cancer can result in what is known as a *pleural effusion*, in which the pleural cavity becomes filled with a large amount of fluid. What effects do you think a pleural effusion would have on ventilation? Explain.

3 Diseases such as emphysema cause the destruction of the walls between the alveoli, reducing the alveolar surface area. What effect might this have on gas exchange? Explain.

4 Explain how the epithelium in each of the following regions of the respiratory tract is adapted so its structure follows its function:

a Nasal cavity: _____

_____

b Bronchiole: _____

_____

c Alveolus: _____

_____

5 Why do you think goblet cells are more numerous in the upper respiratory passages than in the lower respiratory passages?

6 Cigarette smoke has a number of harmful effects on the lungs, one of which is the destruction of the cilia lining the respiratory tract. Predict how this will affect the functions of the respiratory epithelium.

7 The most common site for obstruction in a choking victim is the right primary bronchus. Explain why the obstruction tends to lodge in the right primary bronchus rather than the left primary bronchus. (*Hint:* Consider the structure and position of the right versus the left primary bronchus.)

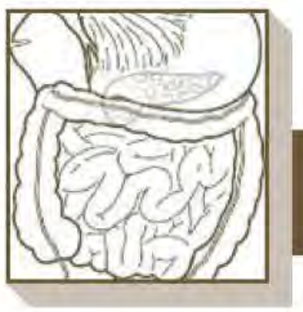
Digestive System

20

OBJECTIVES

Once you have completed this unit, you should be able to:

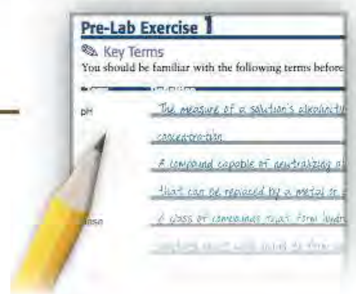
1. Identify structures of the digestive system.
2. Identify histological structures of the digestive system.
3. Trace the anatomical pathway of digestion and absorption of carbohydrates and lipids.



Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 20-1

✎ Key Terms

You should be familiar with the following terms before coming to lab. Please note that this list is not all-inclusive, because the terminology for the digestive system is extensive.

Term	Definition

Digestive System Structures

Alimentary canal _____

_____

Accessory organ _____

_____

Peritoneal cavity _____

_____

Gastroesophageal sphincter _____

_____

Pyloric sphincter _____

_____

Duodenum _____

_____

Jejunum _____

_____

Ileum _____

_____

Colon _____

_____

Salivary glands _____

_____

Pancreas _____

_____

Liver _____

_____

Name _____ Section _____ Date _____

Gallbladder _____

_____

Digestive Histology

Mucosa _____

_____

Submucosa _____

_____

Muscularis externa _____

_____

Serosa _____

_____

Acinar cells _____

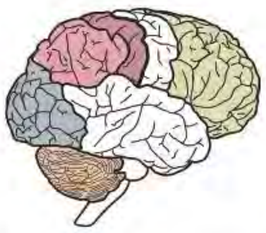
_____

Pancreatic islet _____

_____

Liver lobule _____

_____



Pre-Lab Exercise 20-2

Anatomy of the Digestive System

Label and color the structures of the digestive system in Figures 20.1–20.4 with the terms from Exercise 20-1 (p. 497). Use your text and Exercise 20-1 in this unit for reference.

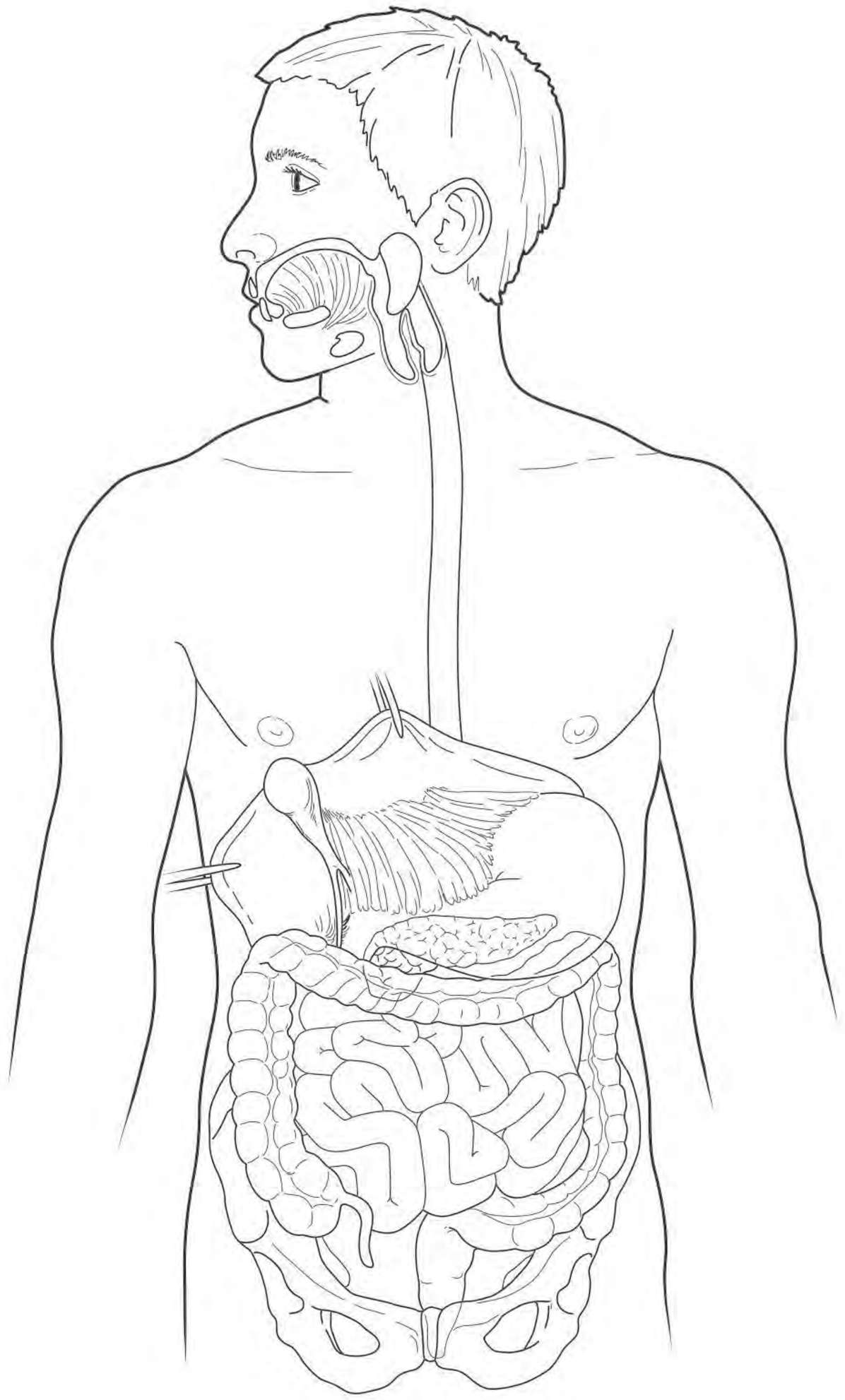


FIGURE **20.1** Organs of the digestive system.

Name _____ Section _____ Date _____

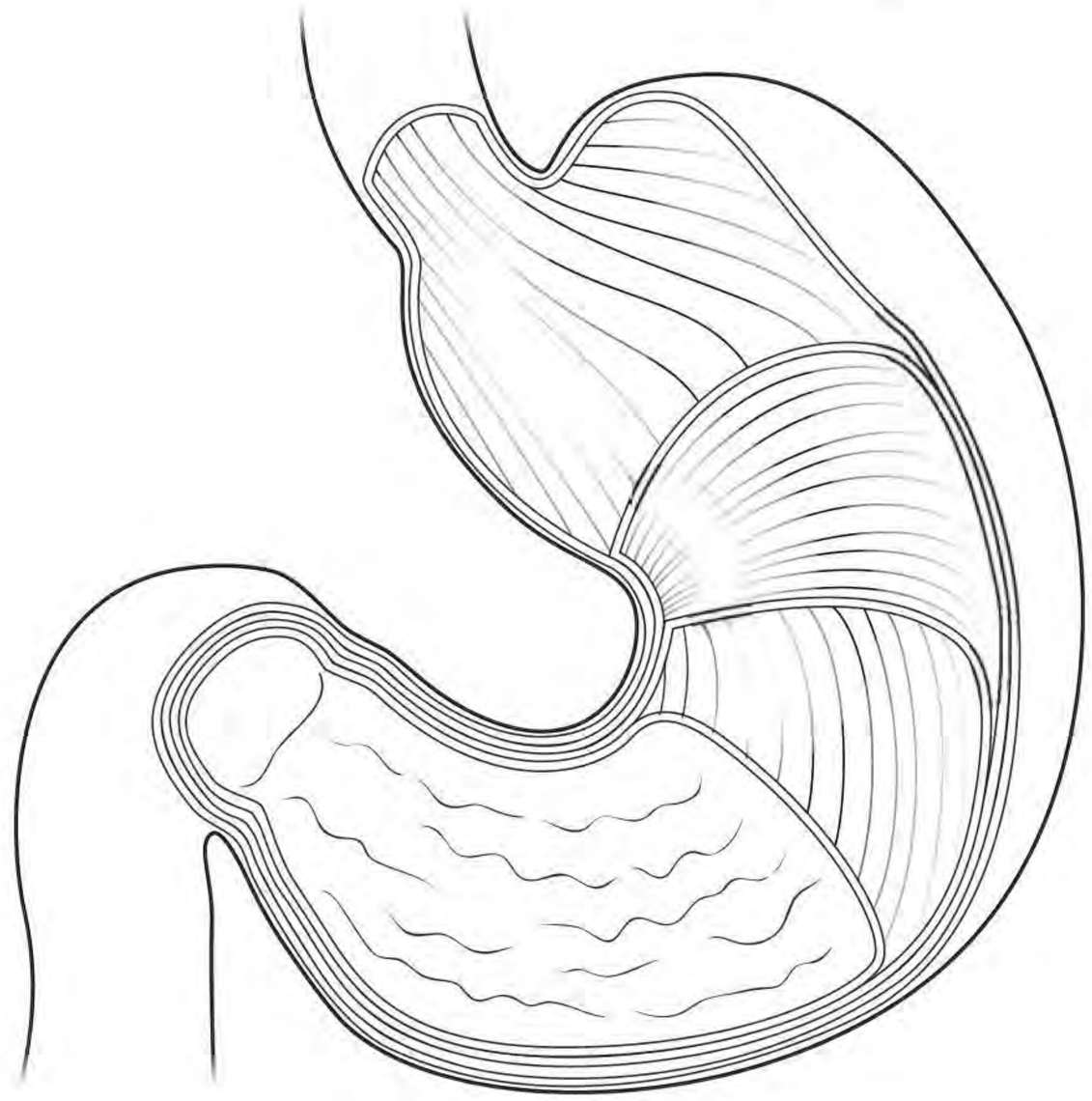


FIGURE **20.2** Stomach.

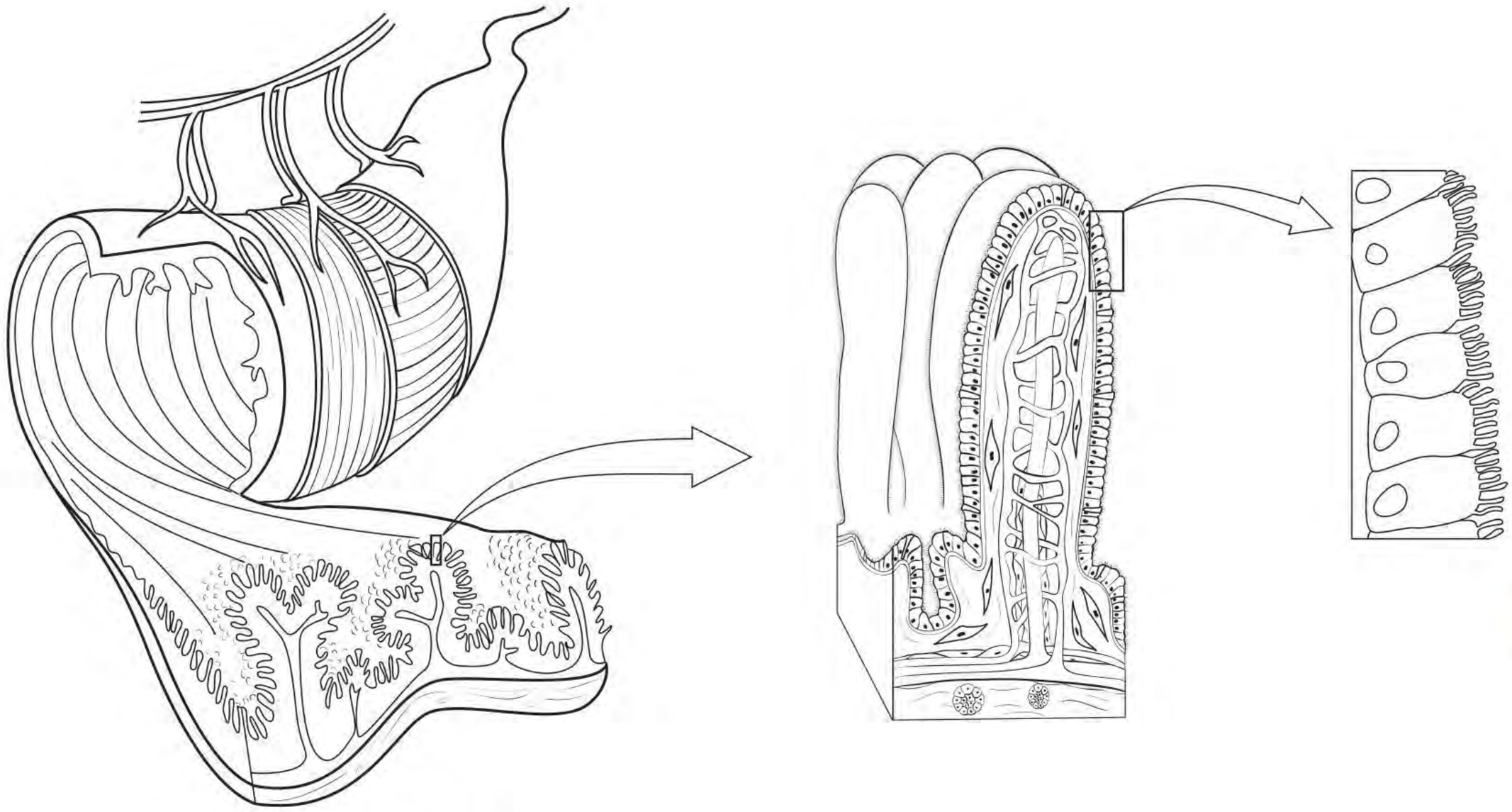


FIGURE **20.3** Gross and microscopic anatomy of the small intestine.

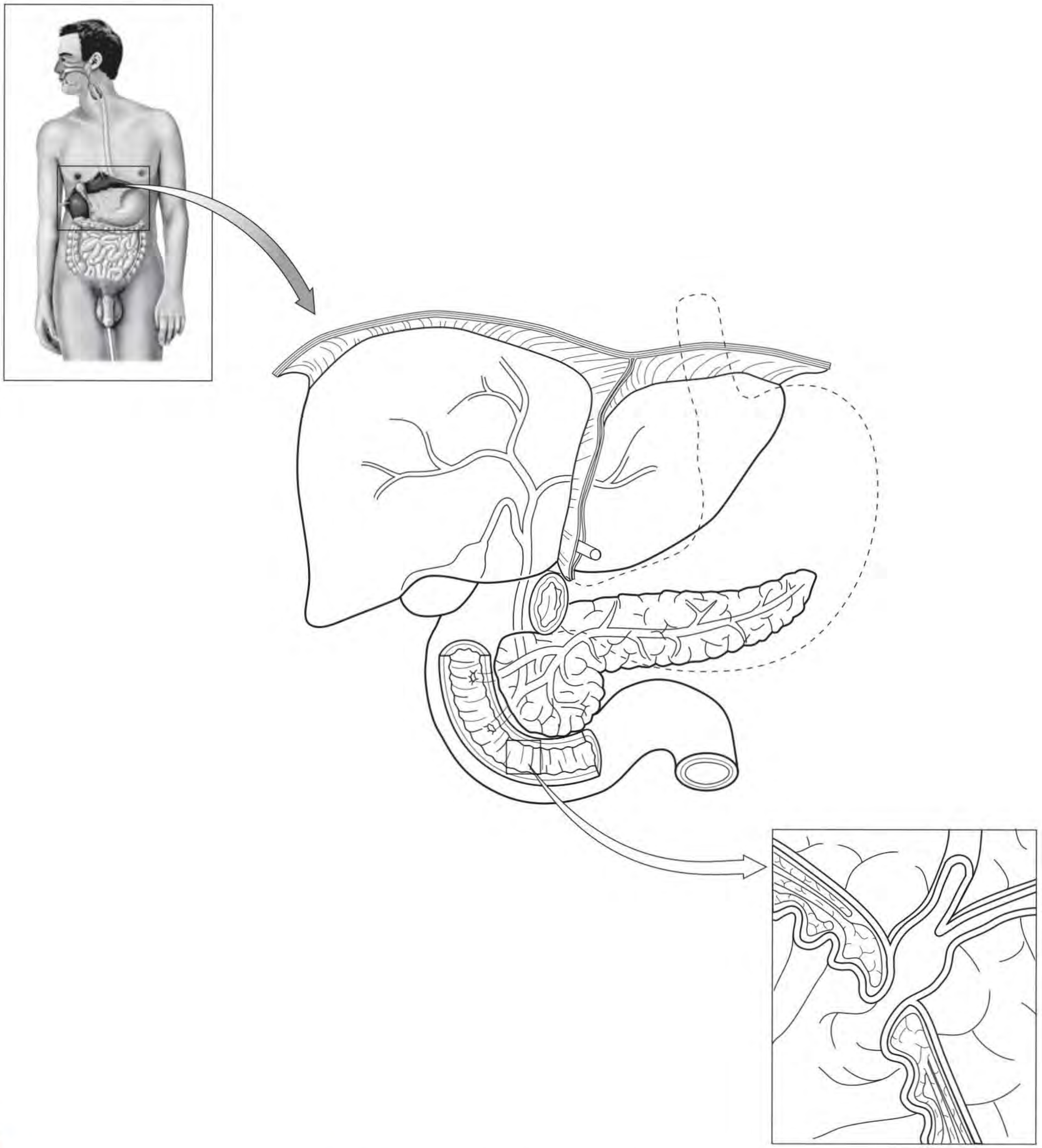


FIGURE **20.4** Liver, gallbladder, pancreas, and duodenum.

EXERCISES

The food we eat contains nutrients our cells use to build and repair body tissues and to make ATP. Food macromolecules, however, are typically too large for the body to absorb and utilize, so the body must break them down into smaller molecules. This process of breaking down foods into smaller substances that can enter body cells is called **digestion** and is carried out by the **digestive system**. In general, the functions of the digestive system include ingesting food, breaking down food mechanically and chemically into nutrients, absorbing these nutrients into the bloodstream, and eliminating indigestible substances.

We begin this unit with an introduction to the anatomy and histology of the organs of the digestive system. We conclude with a "big picture" view of digestive anatomy through a tracing exercise.

Exercise 20-1

Digestive System Anatomy

MATERIALS

- ❑ Digestive system models
- ❑ Head and neck models
- ❑ Human torso models
- ❑ Human skulls with teeth
- ❑ Intestinal villus model
- ❑ Models of the tissue layers of the alimentary canal
- ❑ Digestive organ models (stomach, pancreas, liver, and duodenum)

The digestive system is composed of two groups of organs: (1) the organs of the **alimentary canal**, also known as the **gastrointestinal** or **GI tract**, through which food travels, and (2) the **accessory organs**, which assist in mechanical or chemical digestion (Figure 20.5). The organs of the alimentary canal include the *oral cavity*, *pharynx*, *esophagus*, *stomach*, *small intestine*, and *large intestine*. The accessory organs include the *teeth*, *tongue*, *salivary glands*, *liver*, *gallbladder*, and *pancreas*. We will discuss the structure of each in greater detail shortly.

Much of the alimentary canal and many of the accessory organs reside inside a cavity known as the **peritoneal cavity** (pehr-ih-toh-NEE-ul; Figure 20.6). Like the pleural and pericardial cavities, the

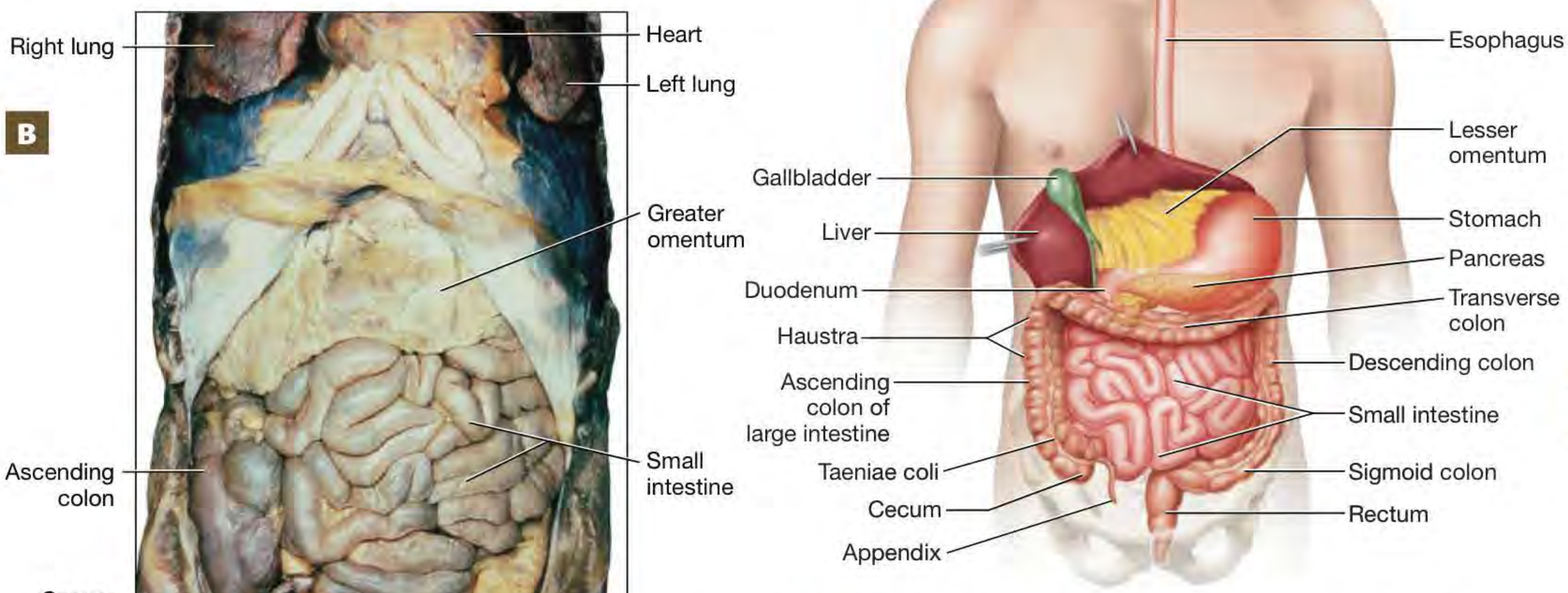


FIGURE **20.5** Overview of the digestive system: (**A**) illustration; (**B**) a dissected abdominopelvic cavity.

peritoneal cavity is found between a double-layered serous membrane, which secretes **serous fluid** that allows the organs to slide over one another without friction. Organs that are within the peritoneal cavity are known as *intraperitoneal*, while those that are behind the cavity are *retroperitoneal*. You can see in Figure 20.6 how widespread the peritoneal cavity is, and how many of the abdominal organs are located either partially or totally within it.

The two peritoneal layers are as follows:

1. **Parietal peritoneum.** The outer **parietal peritoneum** is a thin membrane functionally fused to the abdominal wall and certain organs.
2. **Visceral peritoneum.** The inner **visceral peritoneum** adheres to the surface of many digestive organs. The visceral peritoneum around the intestines folds over on itself to form a thick membrane known as the **mesentery** (MEZ-en-tehr-ee; Figure 20.7). The mesentery houses blood vessels, nerves, and lymphatic vessels and anchors these structures and the intestines in place. Some mesenteries have specific names, including the **greater omentum** (oh-MEN-tum), which covers the abdominal organs like an apron. The smaller **lesser omentum** runs from the liver to the lesser curvature of the stomach.

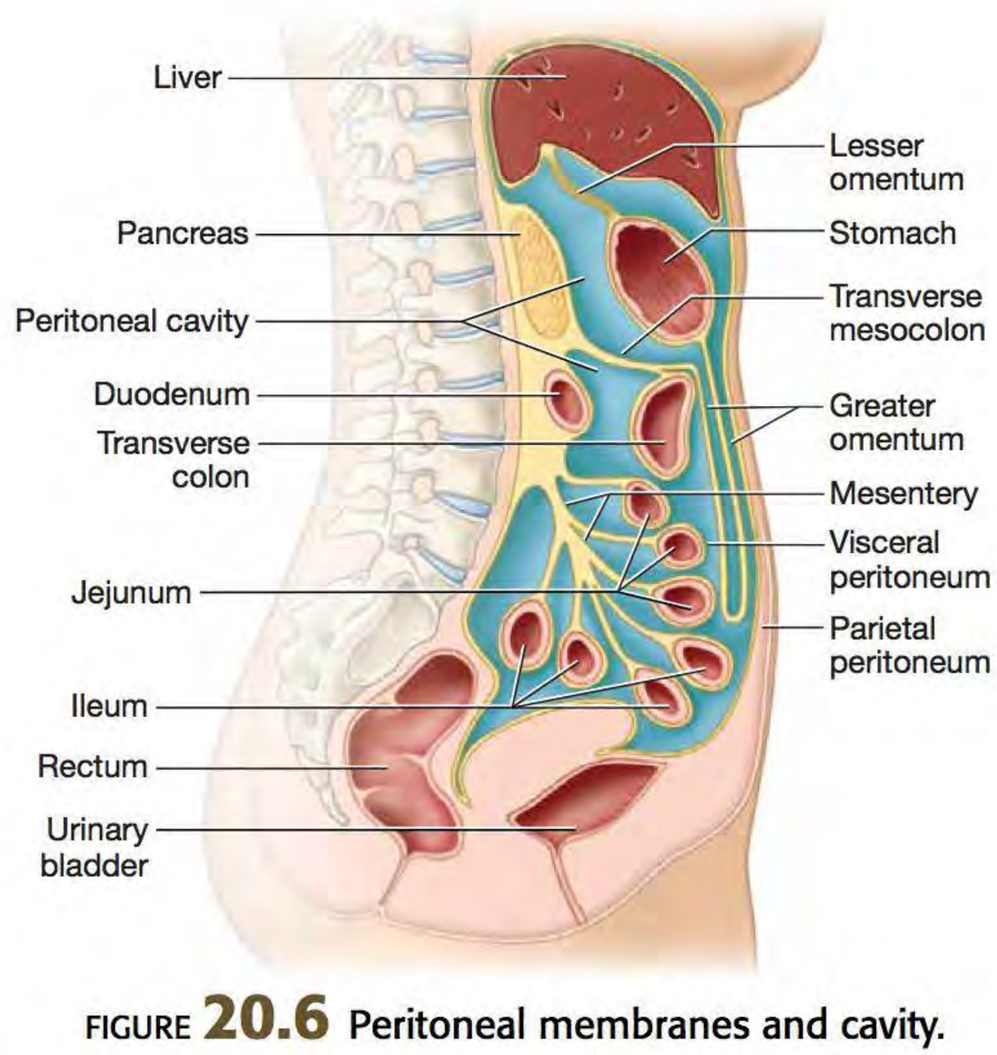


FIGURE **20.6** Peritoneal membranes and cavity.

The alimentary canal consists of the following organs:

1. **Mouth.** The alimentary canal begins with the mouth (Figure 20.8). The **oral cavity** is defined as the area posterior to the teeth and bounded by the palate, cheeks, and tongue. The "roof" of the mouth is the **palate** (PAL-it), which consists of two portions. The anterior two-thirds is the bony **hard palate**, which is formed by the palatine processes of the maxillary bones and the palatine bones. The posterior one-third is the muscular, arch-shaped **soft palate** (you can see this shape in Figure 20.8A). Extending inferiorly from the soft palate is the **uvula** (YOO-vyoo-luh). As we discussed

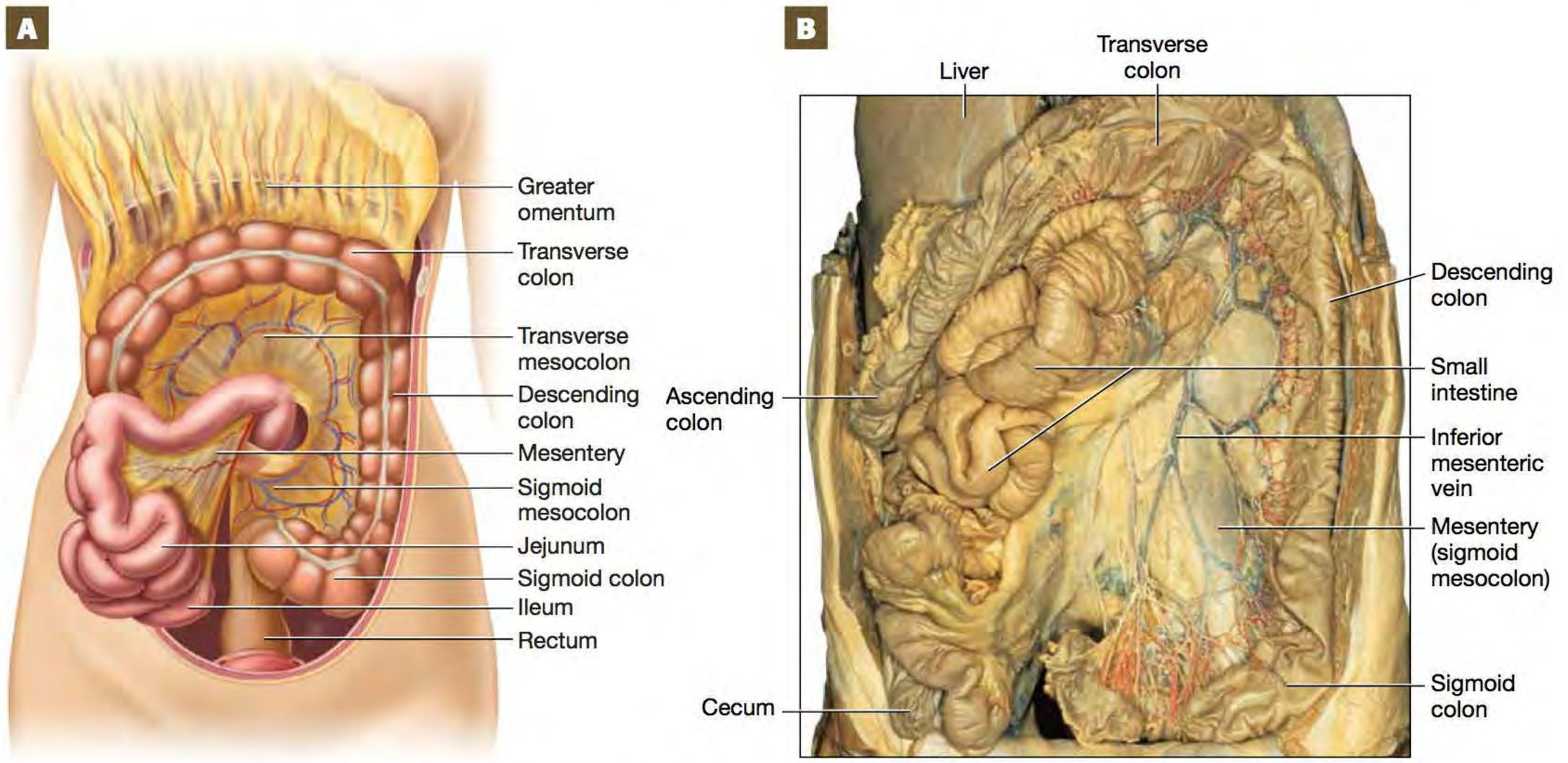


FIGURE **20.7** Mesentery and greater omentum; (**A**) illustration; (**B**) photograph.

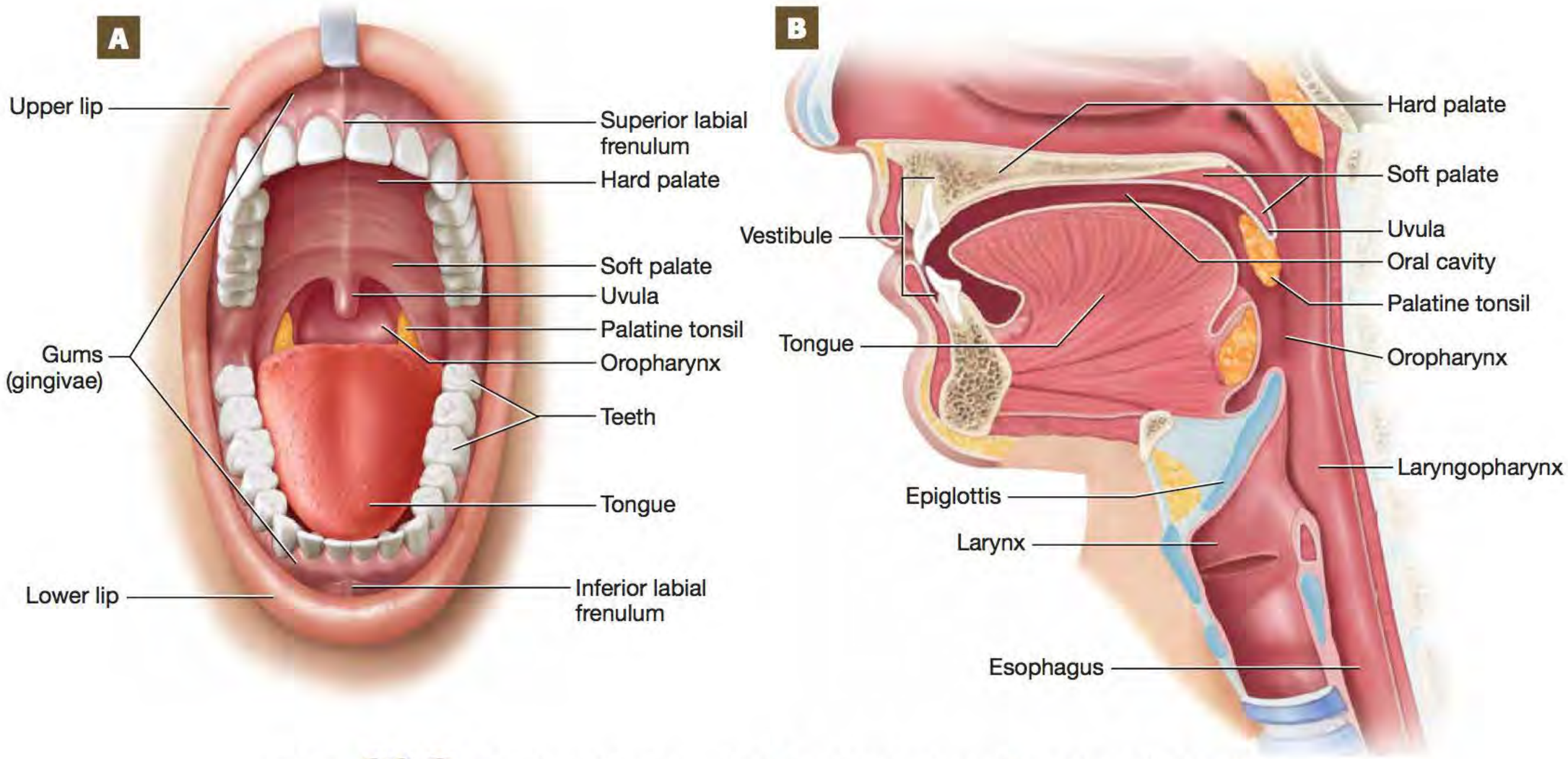


FIGURE **20.8** Mouth and oral cavity: (**A**) anterior view; (**B**) midsagittal section.

in Unit 19, the soft palate and uvula move posteriorly to prevent food from entering the nasopharynx and nasal cavity when we swallow.

The space between the lips and the teeth is not technically part of the oral cavity. Instead, this is a space called the **vestibule**. Within the vestibule we find the **gums** or *gingivae* (JIN-jih-vay) and the maxilla and mandible, where the teeth are housed. We also find a narrow band of mucosa called the **labial frenulum** on each of the upper and lower lips that attaches their internal surfaces to the upper and lower gums.

2. **Pharynx.** The food next enters the **pharynx** (FEHR-inks), also known as the throat. Food passes through two divisions of the pharynx: the **oropharynx** (OHR-oh-fehr-inks) and the **laryngopharynx** (lah-RING-oh-fehr-inks; Figure 20.8B). The muscles surrounding the pharynx propel swallowed food into the next portion of the alimentary canal.
3. **Esophagus.** The **esophagus** (eh-SOF-ah-gus) is a narrow tube posterior to the heart and the trachea in the thoracic cavity. The esophagus contains both smooth and skeletal muscle fibers that contract via rhythmic contractions called **peristalsis** (pehr-ih-STAHL-sis) that propel food into the stomach. A sphincter at the inferior end of the esophagus called the **gastroesophageal sphincter** (also known as the *lower esophageal sphincter*) prevents the contents of the stomach from regurgitating into the esophagus.
4. **Stomach.** The **stomach**, shown in Figure 20.9, has five regions:
   a. the **cardia** near the gastroesophageal sphincter,
   b. the dome-shaped **fundus**,
   c. the middle **body**,
   d. the inferior **pyloric antrum**, and
   e. the **pylorus** (py-LOHR-us). A sphincter called the **pyloric sphincter** separates the stomach from the initial portion of the small intestine.

Note in Figure 20.9 that the stomach has interior folds called **rugae** (ROO-ghee) that allow it to expand considerably when it is filled with food and/or liquid. In addition, note that the wall of the stomach has three layers of smooth muscle (inner oblique, middle circular, and outer longitudinal layers) that work together to pummel ingested food into a liquid material called **chyme** (KYME).

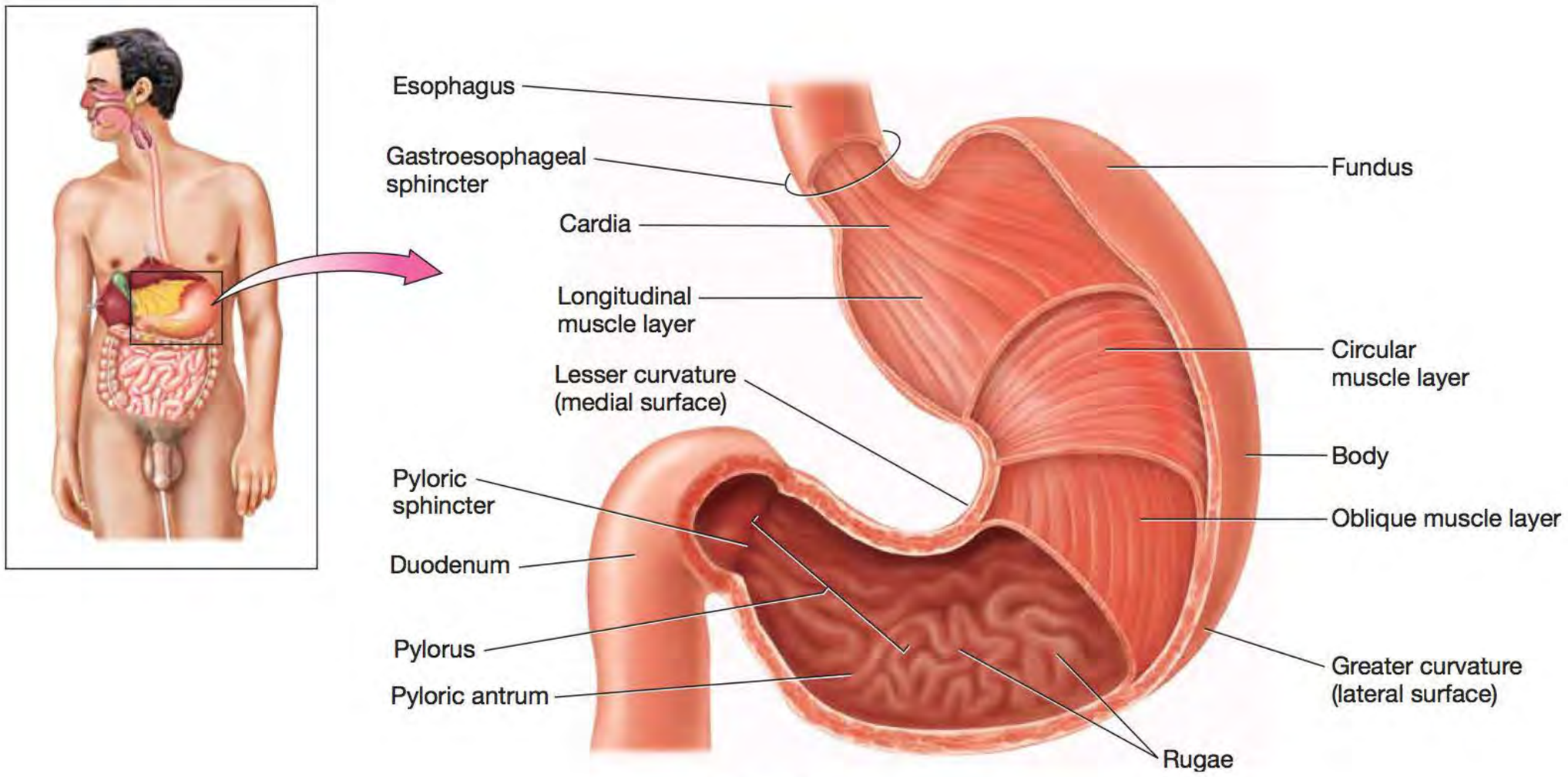


FIGURE **20.9** Stomach.

5. **Small intestine.** The **small intestine** is the portion of the alimentary canal where most chemical digestion and absorption take place. It has three portions (Figure 20.10):
   a. the initial **duodenum** (doo-AH-den-um),
   b. the middle **jejunum** (jeh-JOO-num), and
   c. the terminal **ileum** (ILL-ee-um).

   Of the three divisions, the duodenum is the shortest, measuring only about 10 inches. The jejunum and the ileum measure about 8 feet and 12 feet long, respectively. Notice in Figure 20.10 that at the terminal ileum there is a structure called the **ileocecal valve** (ill-ee-oh-SEE-kul) that abuts the first portion of the large intestine, the *cecum*. This valve helps to prevent bacteria in the large intestine from reaching the normally sterile small intestine.
6. **Large intestine.** The **large intestine** is named for its large diameter rather than its length, which only measures about 5.5 feet. Much of the large intestine features bands of longitudinal smooth muscle called **taeniae coli** (TEE-nee-ee KOHL-eye) that have a drawstring effect on the large intestine, pulling it into pouches called **haustra** (HAW-struh; Figure 20.11). Extending from the external surface of the large intestine are fat-filled pouches of visceral peritoneum called **epiploic appendages** (ep-ih-PLOH-ik).

   The large intestine may be divided into four regions:

   a. The **cecum** (SEE-kum) is the blind pouch that receives contents from the ileum, from which it is separated by the **ileocecal valve.** It features an extension called the **vermiform appendix**, also visible in Figure 20.11B, which is a blind-ended sac that contains lymphatic follicles.

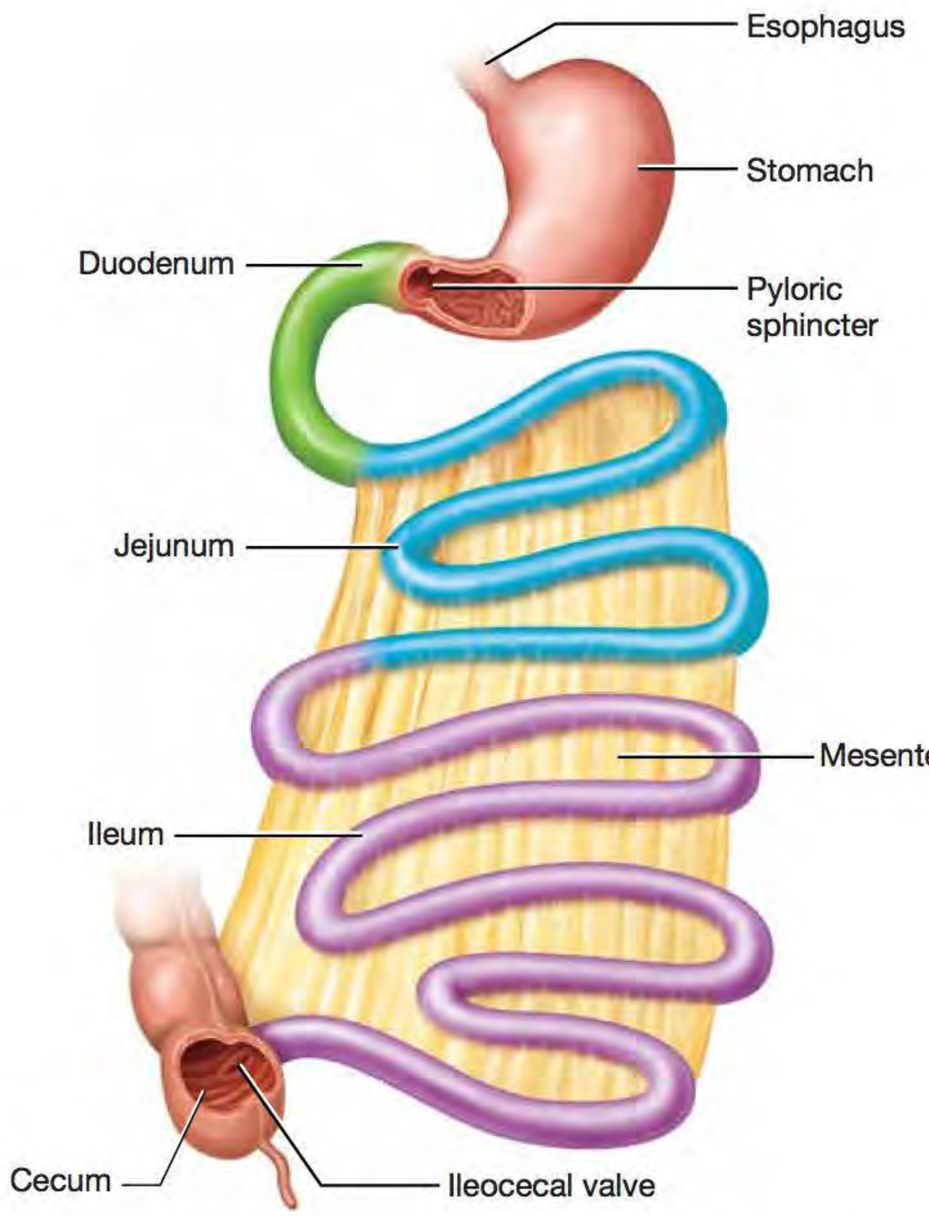
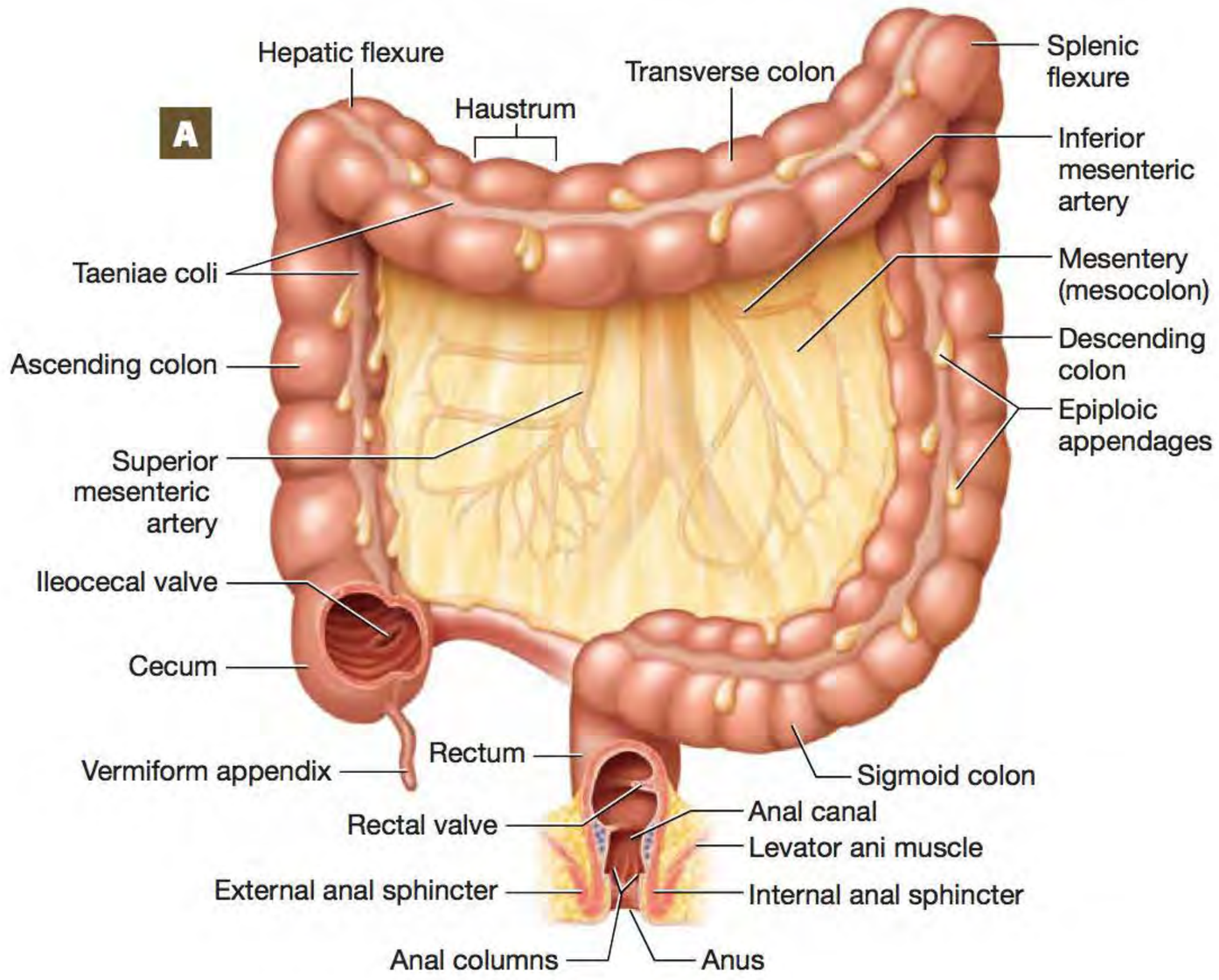


FIGURE **20.10** Small intestine, spread out to show the divisions.

b. The next segment is the **colon,** which itself has four divisions. It begins as the *ascending* **colon,** which turns left at the **hepatic flexure** and crosses the superior abdomen as the **transverse colon,** which then turns inferiorly at the **splenic flexure** to become the **descending colon,** and then finally becomes the S-shaped **sigmoid colon** as it passes toward the sacrum.

c. The **rectum** is the straight part of the large intestine that runs anterior to the sacrum.

d. The terminal portion of the large intestine is the **anal canal.** It has two sphincters: the involuntary **internal anal sphincter** and the voluntary **external anal sphincter.**



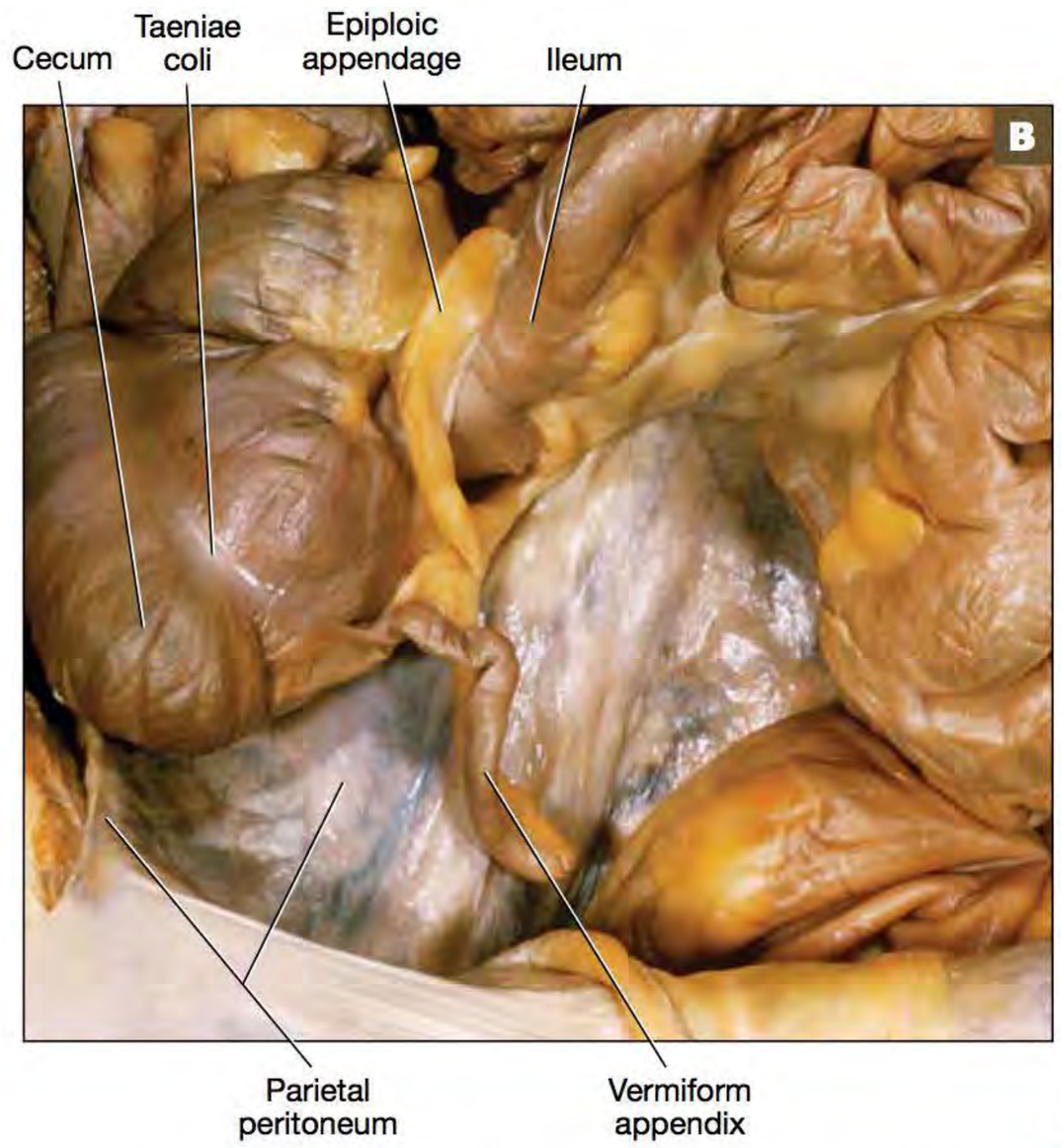


FIGURE **20.11** Large intestine: (A) illustration; (B) cadaver dissection of the cecum and vermiform appendix.

The accessory digestive organs generally do not come into direct contact with the ingested food (the teeth and tongue are exceptions). Most of them instead secrete substances such as bile salts and enzymes that travel through a duct to the alimentary canal. The accessory digestive organs are as follows:

1. **Teeth and tongue.** The **teeth** and the **tongue** are accessory organs located in the mouth that assist in mechanical digestion of ingested food. The tongue contains keratinized papillae called **filiform papillae** that provide a rough surface that helps to break down food physically. Note that filiform papillae do not contain taste buds, which are located only on circumvallate, foliate, and fungiform papillae (for a review of tongue anatomy, see Unit 13, p. 332).

   The **teeth** are located in their bony sockets, called *alveoli*, within the mandible and maxilla. They are held in place by bands of collagen fibers known collectively as the **periodontal ligament** (pehr-ee-oh-DAHN-tuhl). There are three classes of teeth:

   - **Incisors.** The **incisors** are the broad and flat central teeth. There are four incisors: the two *central incisors*, and the two *lateral incisors*.
   - **Canines.** The **canines** (KAY-nynz), also known as *cuspids*, are two pointed teeth located to the sides of the lateral incisors.
   - **Molars.** There are two sets of **molars.** First are the premolars, located lateral to the canines, and second are the larger molars, which are the posterior teeth.

As you are no doubt aware, humans normally have two sets of teeth: one set of "baby teeth" and one set of "permanent teeth." The "baby teeth" are known as the **primary dentition** or **deciduous teeth** (dih-SIJ-oo-us), and are shown in Figure 20.12A. Notice that there are 20 deciduous teeth: 4 incisors, 2 canines, and 4 molars in both the maxilla and mandible. The **secondary dentition,** or **permanent teeth,** generally begin to erupt at about 6 years of age when these teeth enlarge and cause the roots of the deciduous teeth to dissolve. There are 32 permanent teeth, shown in Figure 20.12B: 4 incisors, 2 canines, 4 premolars, and 6 molars in both the maxilla and mandible. Generally by age 12 all of the deciduous teeth have fallen out and all but the third set of molars, or the "wisdom teeth," have erupted. These third molars tend to erupt later, around age 17, although they often remain embedded in the bone, a condition called *impaction.*

2. **Salivary glands.** The **salivary glands** are exocrine glands located around the mouth, and their secretions pass through a duct into the oral cavity (Figure 20.13).
   a. The largest salivary glands are the paired **parotid glands** (pah-ROT-id) located superficial to the masseter muscles. The secretions of the parotid gland pass through a duct called the **parotid duct,** which enters the oral cavity by piercing the buccinator muscle.
   b. The smaller **submandibular glands** are located just medial to the mandible. They secrete saliva through the **submandibular ducts,** which open into the floor of the oral cavity under the tongue.
   c. The **sublingual glands** (sub-LING-gwuhl) are located under the tongue, as their name implies. They secrete saliva through multiple **sublingual ducts.**

All three types of glands secrete **saliva,** which contains water, mucus, an enzyme called *salivary amylase*, and antimicrobial molecules such as *lysozyme*.

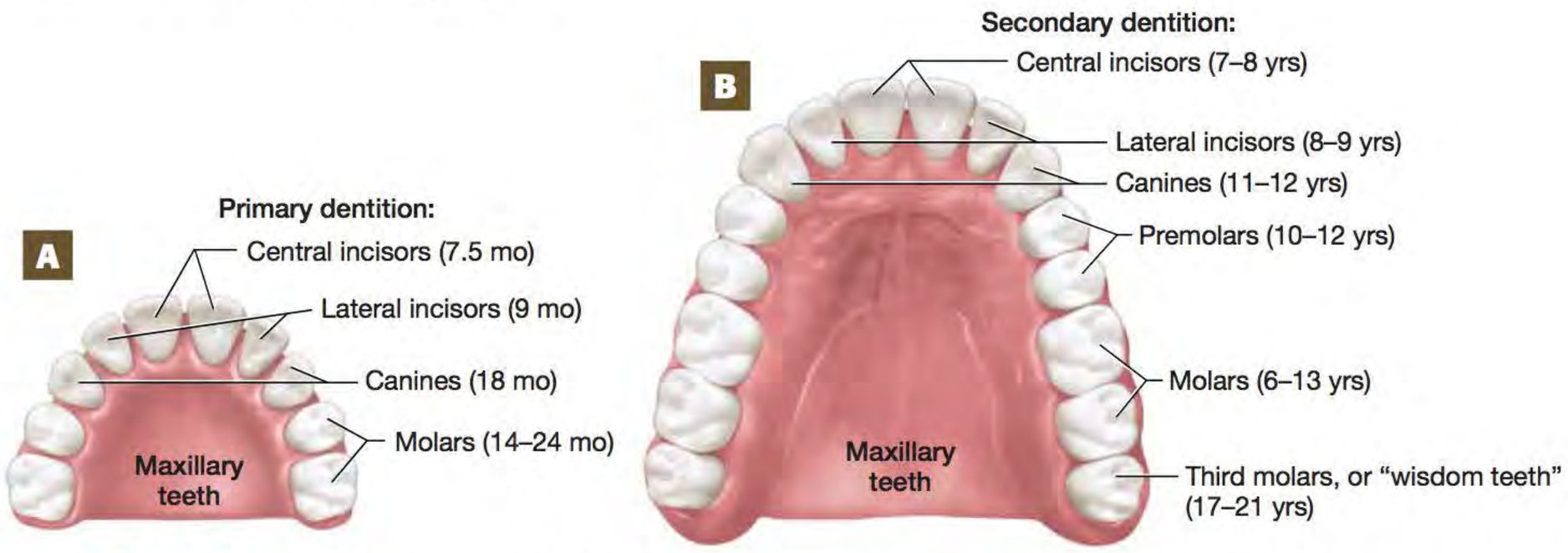


FIGURE **20.12** Teeth: (A) primary dentition of the maxilla; (B) secondary dentition of the maxilla.

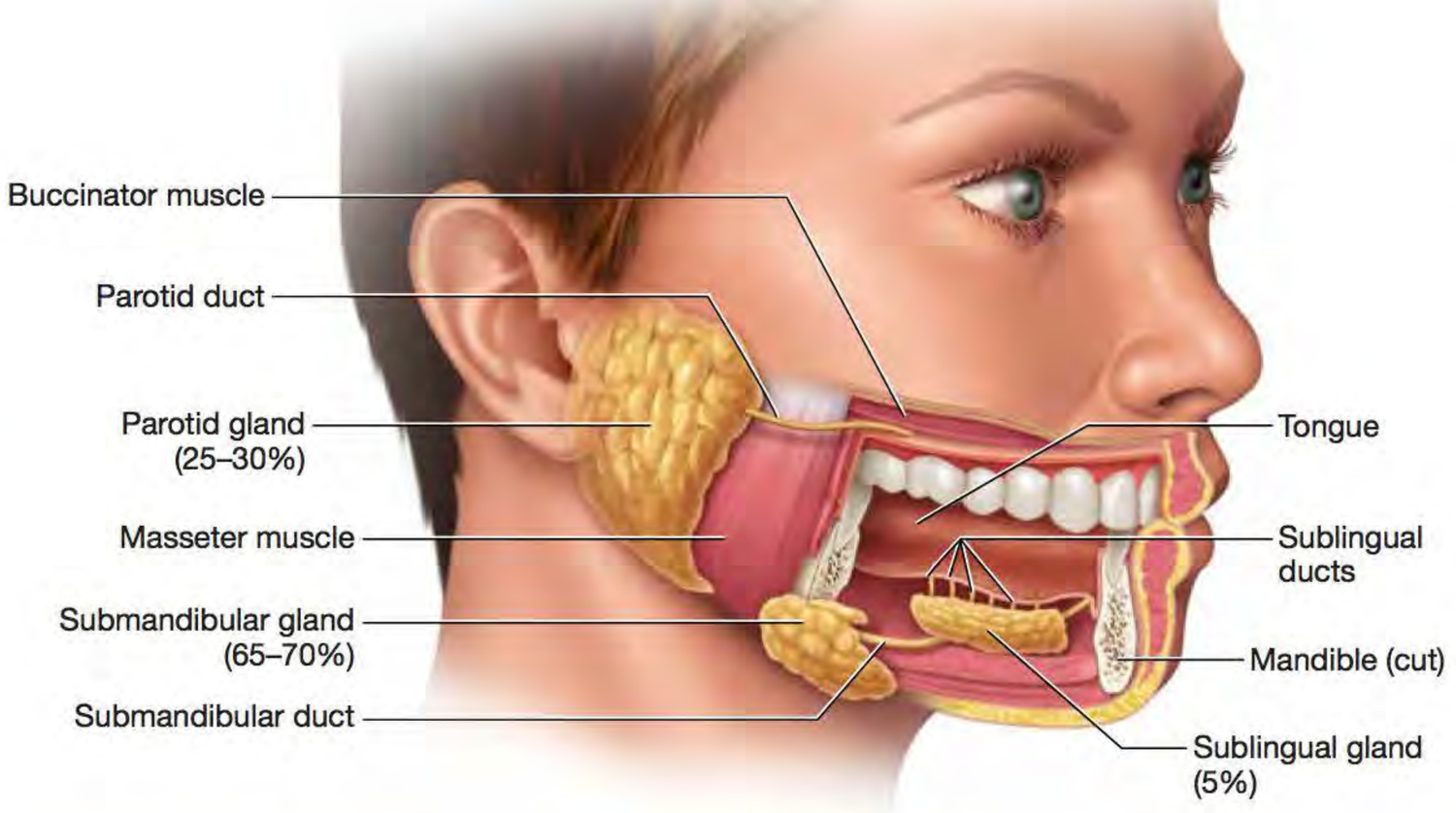


FIGURE **20.13** Salivary glands.

3. **Liver and gallbladder.** The liver and gallbladder are organs located on the right side of the abdominal cavity.

   a. The **liver** consists of four lobes: the large *right* and *left lobes,* and the small *caudate* and *quadrate lobes*, which are located on the posterior side of the right lobe (Figure 20.14). The liver is wrapped in a thin connective tissue capsule, and most of it is covered by the visceral peritoneum. On the liver's anterior side, shown in Figure 20.14A, we find the **falciform ligament** (FALL-sih-form), which is a fold of visceral peritoneum that separates the right and left lobes and anchors the liver to the abdominal wall. Inferior to the falciform ligament is the **round ligament.** This is a remnant of a structure called the *umbilical vein* that brought oxygenated blood to the fetus.

   On the liver's posterior side near the quadrate lobe, shown in Figure 20.14B, is an area called the **porta hepatis** (POR-tuh heh-PAH-tis). This area serves as a main "gateway" into and out of the liver, as the hepatic artery, the hepatic portal vein, and the common hepatic duct all enter and exit via the porta hepatis. Note that the exception are the hepatic veins, which exit at the superior side of the liver, where they drain into the inferior vena cava.

   The liver has multiple functions in the body, most of which are metabolic in nature. For example, recall from Unit 16 that all blood from the digestive organs and the spleen travels via the hepatic portal vein to the hepatic portal system of the liver. There, the absorbed nutrients and chemicals are processed before they enter the general circulation. One of the liver's main digestive functions is to produce a chemical called *bile*, required for the digestion and absorption of fats.

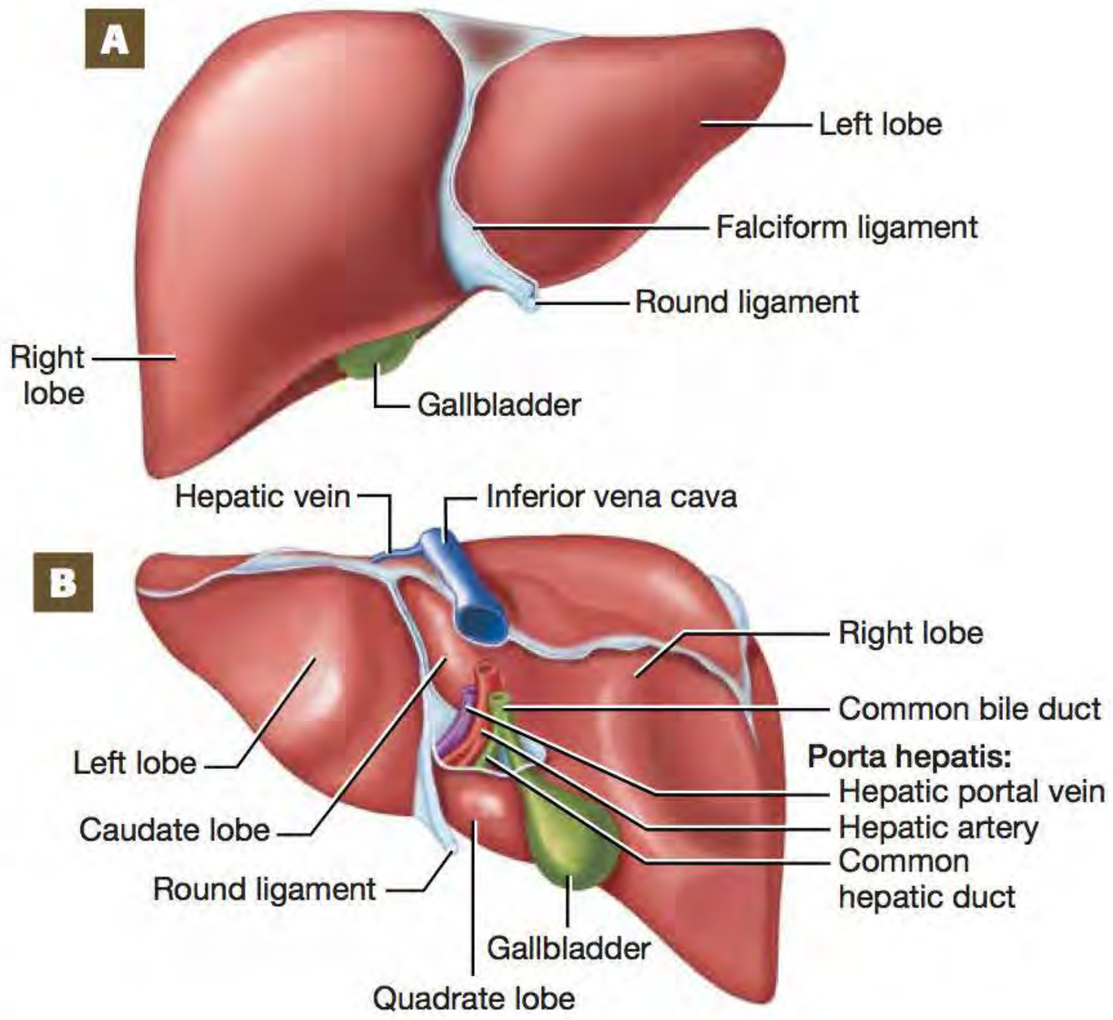


FIGURE **20.14** Liver: (A) anterior view; (B) posterior view.

   b. The **gallbladder** is a small, saclike organ on the posterior side of the liver that stores and concentrates bile. Bile leaves the liver via a duct called the **common hepatic duct,** after which much of it enters the gallbladder (Figure 20.15). When stimulated by certain hormones, the gallbladder contracts, and the bile contained within it is ejected through the **cystic duct** (SIS-tik). Note that the cystic duct joins with the common hepatic duct to form the **common bile duct,** which empties into the duodenum at the **hepatopancreatic ampulla** (heh-PAH-toh-payn-kree-at-ik am-POOL-ah).

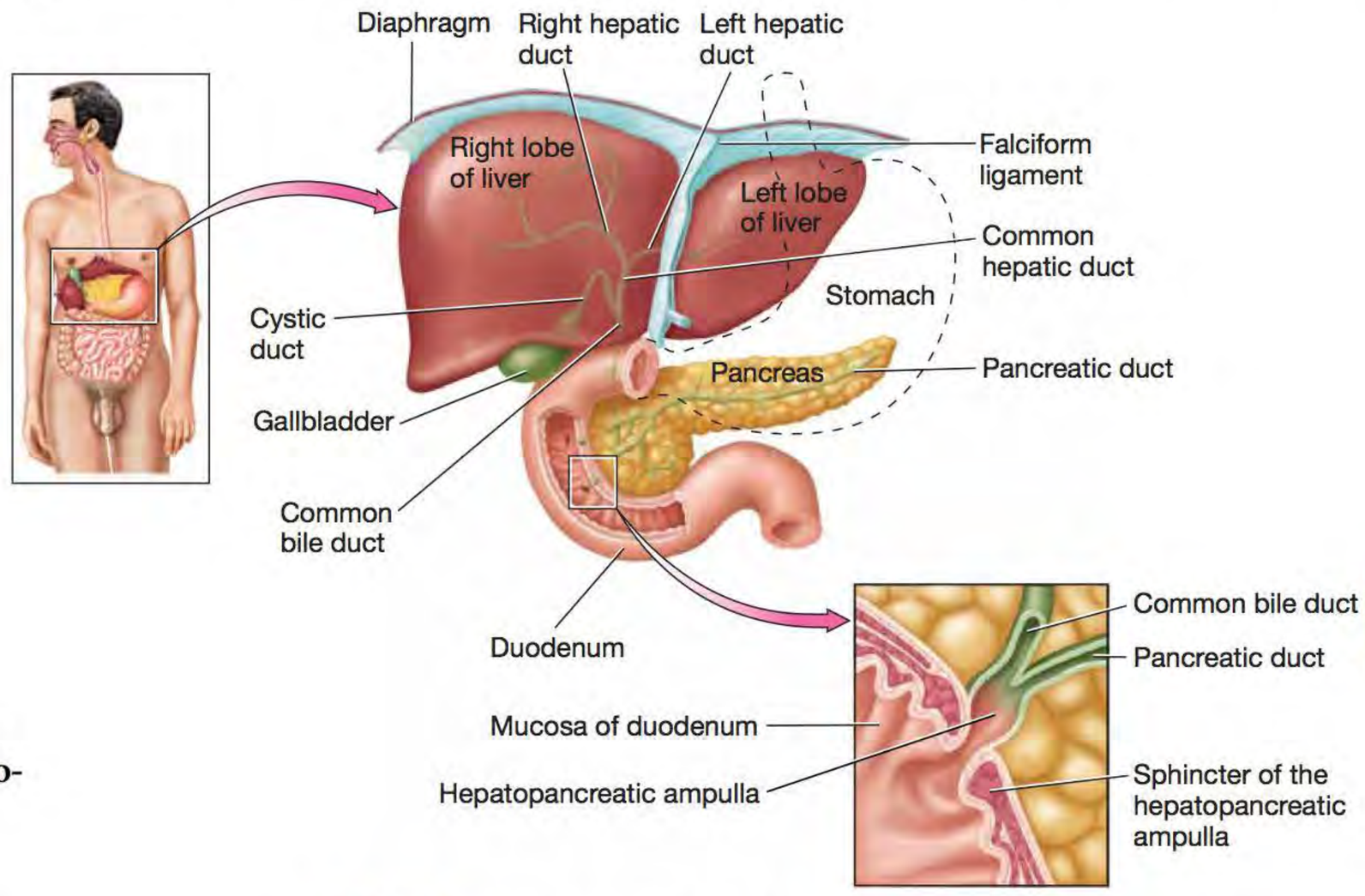


FIGURE **20.15** Liver, gallbladder, pancreas, and duodenum.

4. **Pancreas.** The **pancreas** (PAYN-kree-iss) is an exocrine and endocrine gland that sits posterior and inferior to the stomach. Its exocrine functions are digestive, whereas its endocrine functions are metabolic. The exocrine portion of the pancreas produces a fluid called **pancreatic juice** that contains water, bicarbonate ions to neutralize the acid produced by the stomach, and multiple digestive enzymes. Pancreatic juice is released through the **pancreatic duct** and enters the duodenum at the hepatopancreatic ampulla.

Procedure 1 Model Inventory for the Digestive System

Identify the following structures of the digestive system on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 20.1. After you have completed the activity, answer Check Your Understanding questions 1 and 2 (p. 521).

Peritoneum

1. Visceral peritoneum
2. Parietal peritoneum
3. Peritoneal cavity
4. Mesentery
5. Greater omentum
6. Lesser omentum

Alimentary Canal

1. Mouth:
   a. Oral cavity
   b. Hard palate
   c. Soft palate
   d. Uvula
   e. Vestibule
   f. Gums (gingivae)
   g. Labial frenulum
2. Pharynx
   a. Oropharynx
   b. Laryngopharynx
3. Esophagus
   a. Gastroesophageal sphincter (or lower esophageal sphincter)
4. Stomach
   a. Cardia
   b. Fundus
   c. Body
   d. Pyloric antrum
   e. Pylorus
   f. Pyloric sphincter
   g. Rugae
5. Small intestine
   a. Duodenum
   b. Jejunum
   c. Ileum
   d. Ileocecal valve
6. Large intestine
   a. Haustra
   b. Taeniae coli
   c. Cecum
   d. Vermiform appendix
   e. Ascending colon
   f. Hepatic flexure
   g. Transverse colon
   h. Splenic flexure
   i. Descending colon
   j. Sigmoid colon
   k. Rectum
   l. Anal canal
   m. Internal anal sphincter
   n. External anal sphincter

Accessory Organs

1. Tongue
   a. Filiform papillae
   b. Fungiform papillae
   c. Circumvallate papillae
   d. Foliate papillae
2. Teeth
   a. Incisors
   b. Canines
   c. Premolars
   d. Molars
   e. Primary dentition
   f. Secondary dentition
3. Salivary glands
   a. Parotid gland with parotid duct
   b. Submandibular gland with submandibular duct
   c. Sublingual gland with sublingual ducts
4. Liver
   a. Right lobe, left lobe, caudate lobe, and quadrate lobe
   b. Falciform ligament
   c. Round ligament
   d. Porta hepatis
   e. Hepatic arteries
   f. Hepatic portal vein
   g. Common hepatic duct
   h. Hepatic veins
5. Gallbladder
   a. Cystic duct
   b. Common bile duct
   c. Hepatopancreatic ampulla
6. Pancreas
   a. Pancreatic duct

Note: Your instructor may wish to omit certain structures or add structures not included in these lists. List any additional structures below:

TABLE **20.1** Model Inventory for the Digestive System

Model	Digestive Structures Identified

Procedure 2 Time to Draw

In the space below, draw, color, and label the arrangement of the liver, gallbladder, pancreas, and duodenum. In addition, write the function of each structure that you label.

Exercise 20-2

Digestive System Histology

MATERIALS

- ❑ Model of the layers of the alimentary canal
- ❑ Esophagus slide
- ❑ Stomach slide
- ❑ Duodenum slide
- ❑ Pancreas slide
- ❑ Liver slide
- ❑ Tooth slide
- ❑ Light microscope
- ❑ Colored pencils

The organs of the alimentary canal follow the same basic pattern we have seen for other hollow organs: an inner layer of epithelial tissue that rests on connective tissue, a middle layer of smooth muscle, and an outer layer of supportive connective tissue. The tissue layers of the alimentary canal, shown in Figure 20.16, are named as follows:

1. **Mucosa.** The inner epithelial tissue lining of the alimentary canal is called the **mucosa.** Throughout most of the alimentary canal, it consists of simple columnar epithelium overlying a lamina propria and a thin layer of smooth muscle called the **muscularis mucosa.** The mucosa contains a collection of lymphoid nodules called **mucosa-associated lymphatic tissue** (**MALT**), mucus-secreting goblet cells, and other glands that secrete products such as hydrochloric acid and enzymes. The mucosa is generally covered with a layer of mucus that helps protect the underlying epithelium from the effects of the acid and digestive enzymes.
2. **Submucosa.** Deep to the mucosa we find the **submucosa,** a layer of connective tissue that houses blood vessels, nerves, lymph vessels, and elastic fibers.
3. **Muscularis externa.** The **muscularis externa** in most regions of the alimentary canal contains two layers of smooth muscle—an inner circular layer and an outer longitudinal layer. These two layers contract alternately to produce the rhythmic contractions of **peristalsis.** Recall from Exercise 20-1 that the muscularis externa of the stomach has three layers of smooth muscle, with an additional oblique layer.
4. **Serosa or adventitia.** The outer layer is called the **serosa** where it is composed of the visceral peritoneum, and the **adventitia** where it is composed of dense irregular collagenous connective tissue.

Although this pattern is followed throughout most of the alimentary canal, there are some notable differences, particularly in the esophagus (Figure 20.17). The mucosa of the esophagus is composed of stratified squamous epithelium with no goblet cells or thick mucus layer. The esophagus' muscularis externa changes as it progresses toward the stomach. The upper one-third of the esophagus is *skeletal muscle*, the middle one-third is about *half skeletal muscle and half smooth muscle*, and the lower one-third is *smooth muscle*. These differences in the muscularis externa allow you to determine the location of the section you are examining.

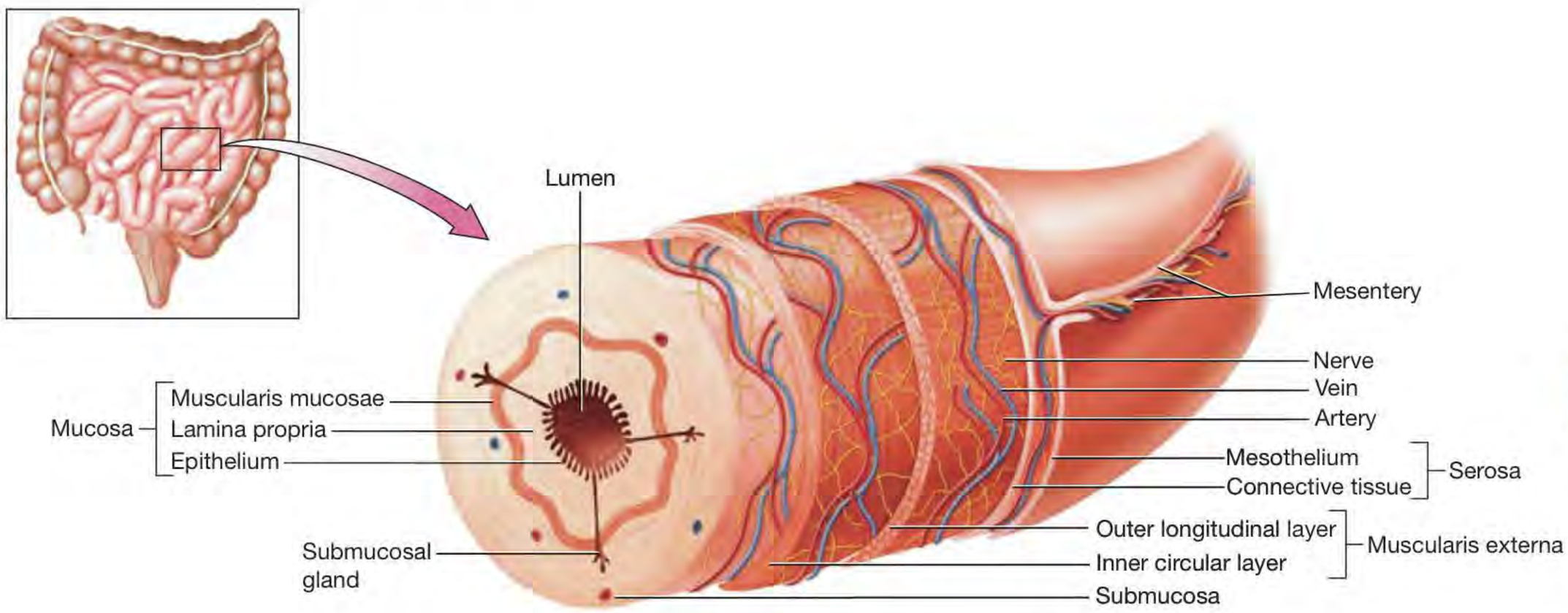


FIGURE **20.16** Tissue layers of the alimentary canal.

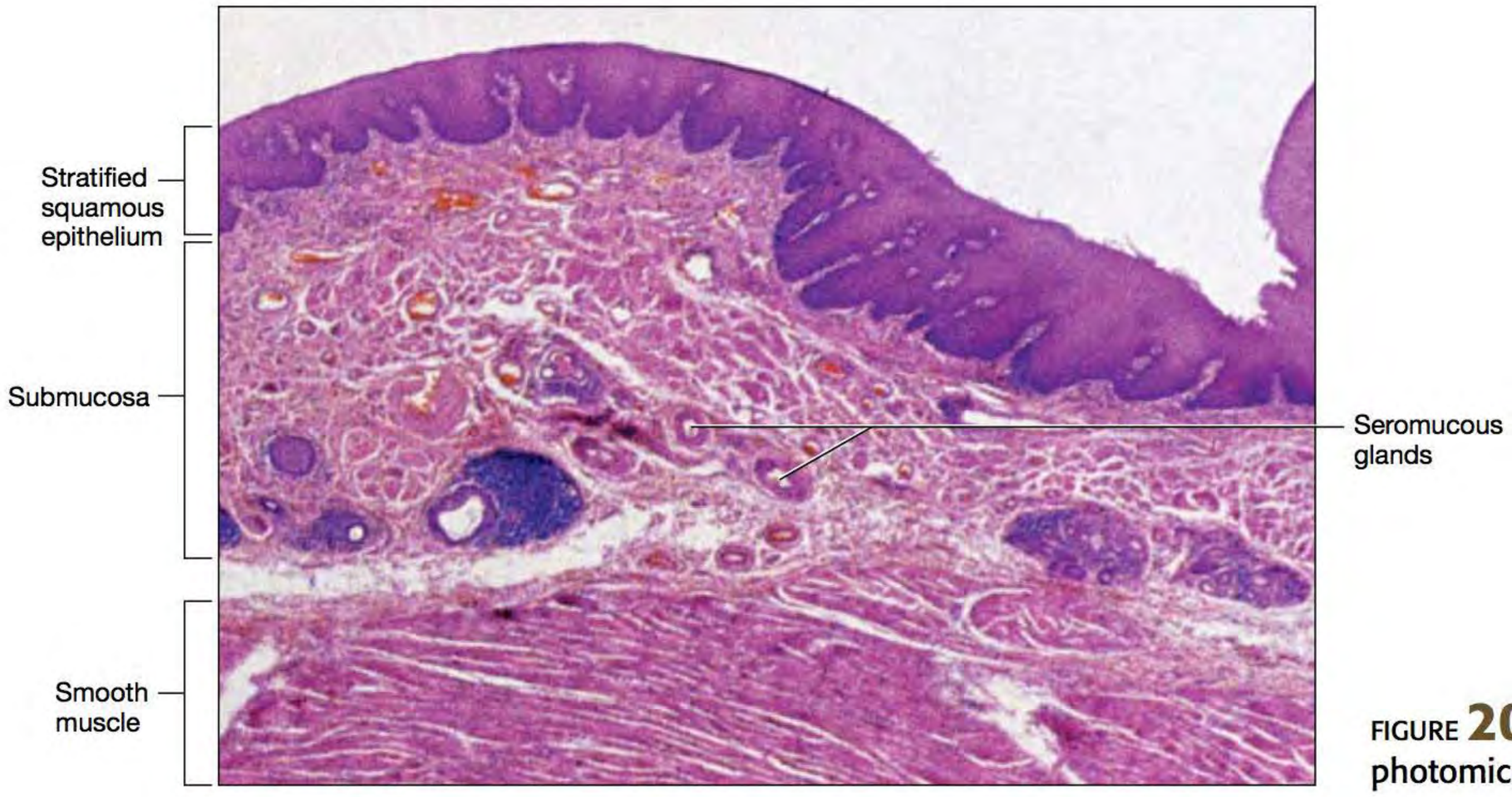


FIGURE **20.17** Esophagus, photomicrograph.

The mucosae of both the stomach and the small intestine are folded into ridges. The stomach mucosa is heavily indented, which reflects the presence of numerous **gastric pits** that house **gastric glands** (Figure 20.18). These glands secrete products for digestion known collectively as **gastric juice**. The stomach mucosa between the gastric pits contains a large number of goblet cells.

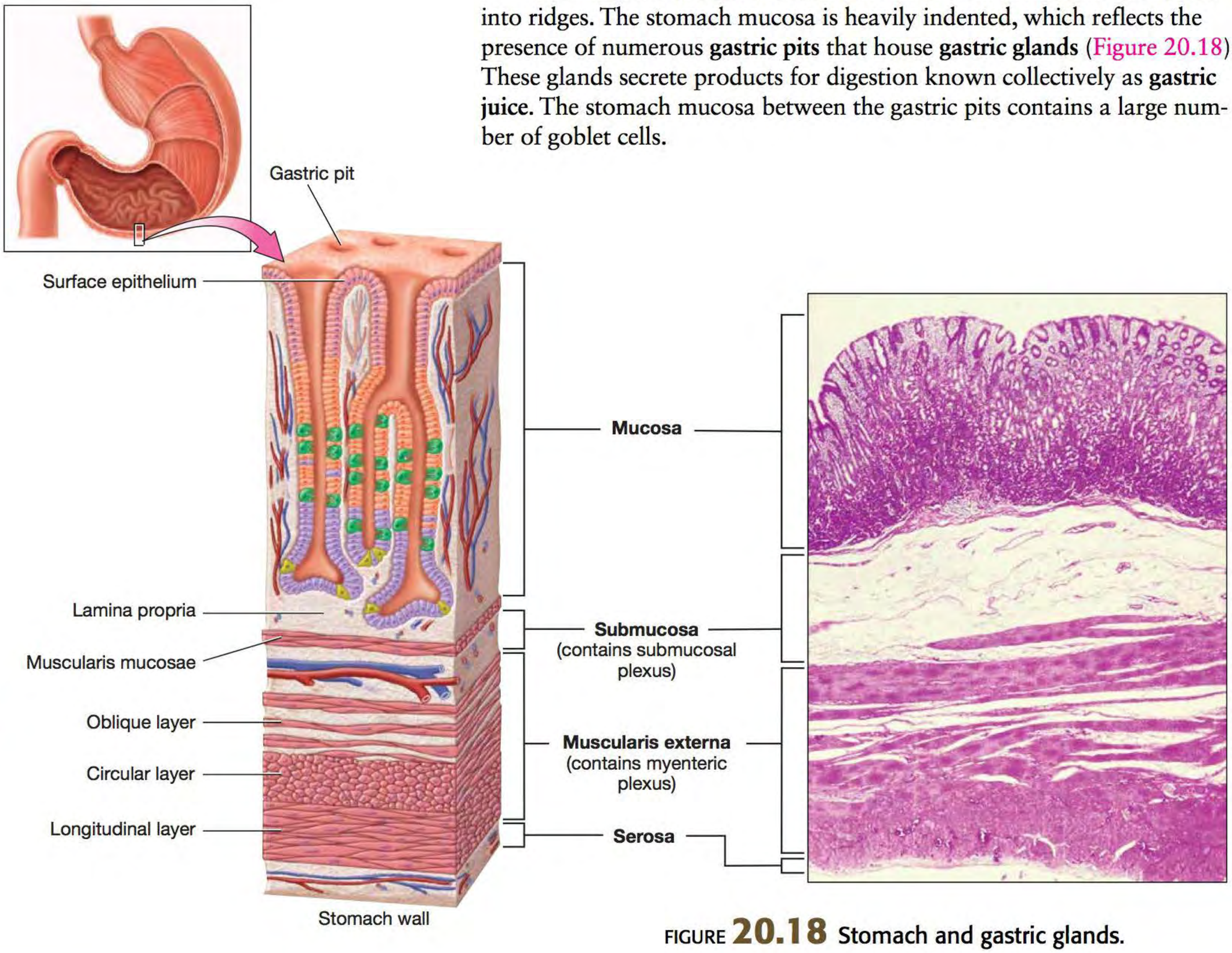


FIGURE **20.18** Stomach and gastric glands.

The small intestinal mucosa is also highly folded, but its submucosa is folded as well. These folds are done in a different manner and with a different purpose, which is to increase the surface area available for absorption. The three sets of folds in the small intestine, shown in Figure 20.19, include the:

1. **Circular folds.** The **circular folds,** also known as *plicae circulares*, are folds of the mucosa and submucosa.
2. **Villi.** The fingerlike **villi** (VILL-eye) are the "fringe" on the circular folds and are foldings of the mucosa. Note in Figure 20.19 that between the villi are glands called **intestinal crypts.** Each villus is lined with intestinal cells called **enterocytes** that surround a core containing blood vessels and a lymphatic vessel called a **lacteal** (LAK-teel).
3. **Microvilli. Microvilli** are folds of the enterocytes' plasma membranes.

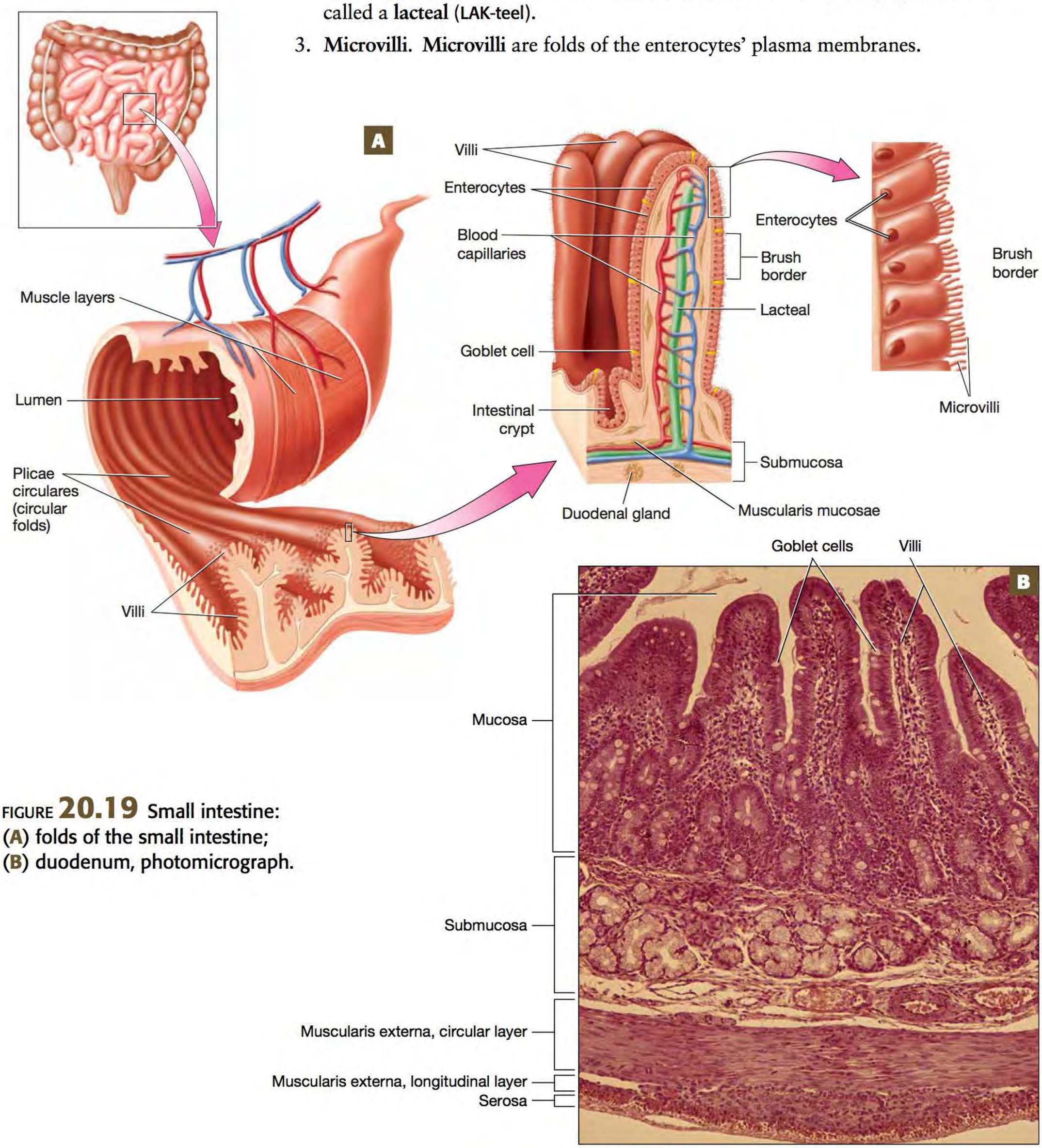


FIGURE **20.19** Small intestine: (**A**) folds of the small intestine; (**B**) duodenum, photomicrograph.

The three accessory digestive organs we will examine in this exercise—the pancreas, liver, and a tooth—are not hollow organs, so they do not follow the same histological pattern as the alimentary canal. The pancreas is a gland that consists of clusters of cells that produce both exocrine and endocrine secretions (Figure 20.20). The exocrine cells of the pancreas, called **acinar cells** (AY-sin-ahr), produce and secrete pancreatic juice (digestive enzymes, bicarbonate ions, and water) into ducts. The endocrine cells of the pancreas, called **pancreatic islets** (EYE-lets), secrete hormones such as insulin into the bloodstream. They are visible as small, circular groups of cells that stain less darkly than the surrounding acinar cells.

The liver consists of hepatocytes organized into hexagonal plates of cells called **liver lobules** (Figure 20.21). At the center of each lobule is a central vein that will eventually drain into the hepatic veins. At each of the six corners of a liver lobule we find three small vessels collectively called **portal triads**. The three vessels are: (1) a **bile duct,** which carries bile made by hepatocytes and drains into the hepatic duct; (2) a **portal venule,** a tiny branch off the hepatic portal vein that delivers nutrient-rich blood to the liver for processing and detoxification; and (3) a **hepatic arteriole,** which delivers oxygen-rich blood to the hepatocytes.

The last slide you will examine is a tooth, which consists of two components: the **crown,** which is the visible portion above the gum line, and the **root,** which is embedded within the bone (Figure 20.22). The outer layer of the tooth in the crown is composed of the hardest substance in the body, called **enamel,** which is composed almost completely of calcium hydroxyapatite crystals. The outer layer of the tooth in the root is called **cementum;** its composition is similar to bone, and so it is about as hard as bone tissue. Collagen fibers from the *periodontal ligament* extend into the cementum to help hold the tooth in place. Both enamel and cementum cover the next layer of the tooth, the **dentin,** which is the second hardest material in the body. Dentin covers the soft, inner **pulp** that resides in the **pulp cavity,** along with nerves and blood vessels. The pulp cavity, along with the blood vessels and nerves, extends into the root of the tooth via the **root canal.**

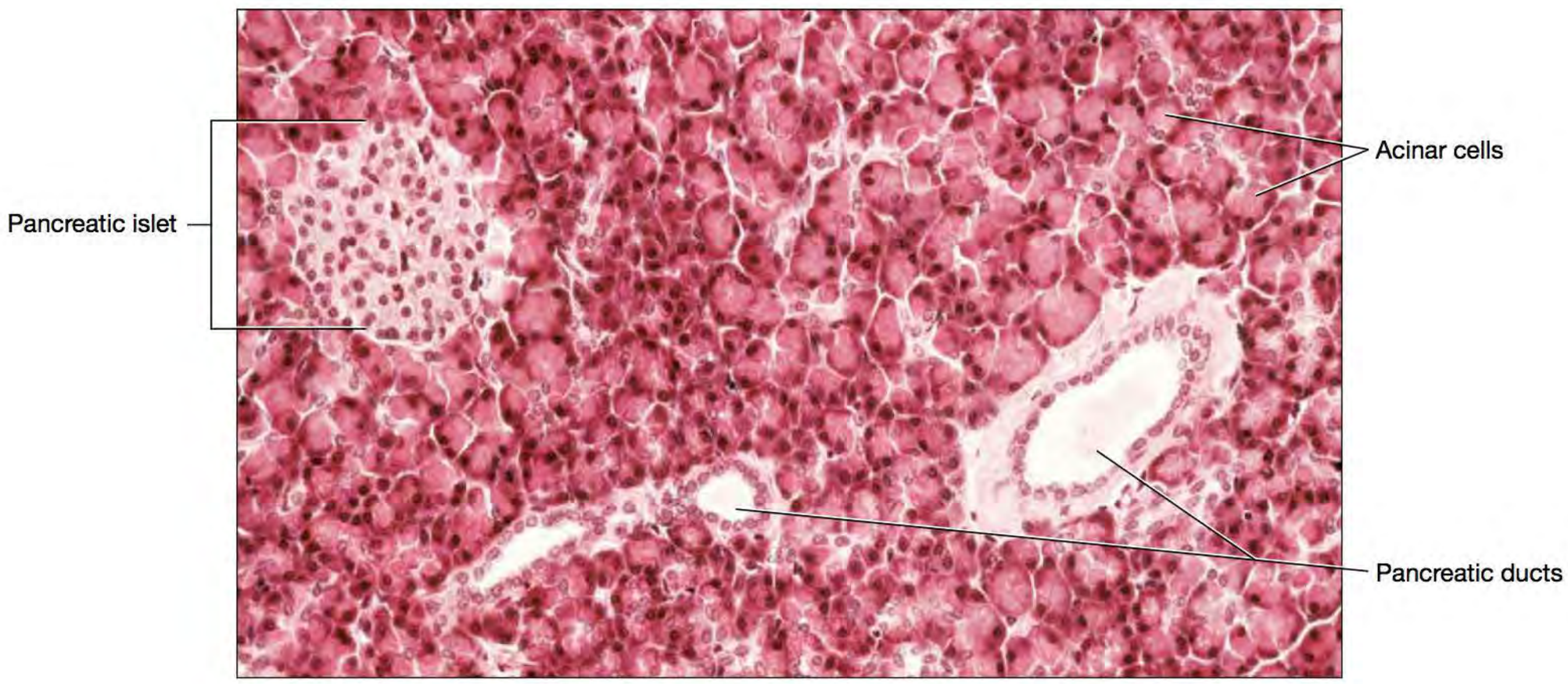


FIGURE **20.20** Pancreas, photomicrograph.

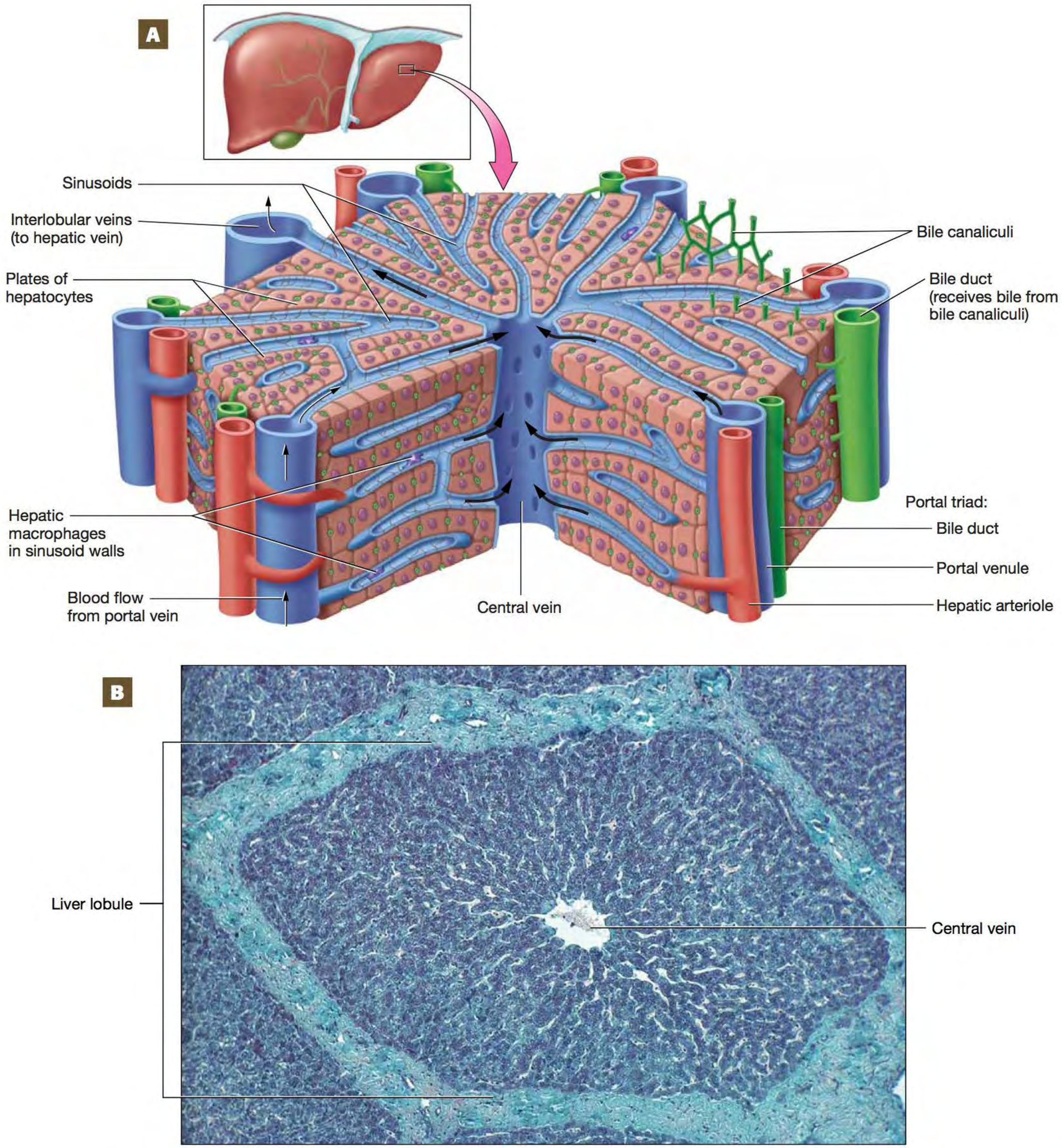


FIGURE **20.21** Microscopic structure of the liver: (**A**) liver lobule; (**B**) liver, photomicrograph.

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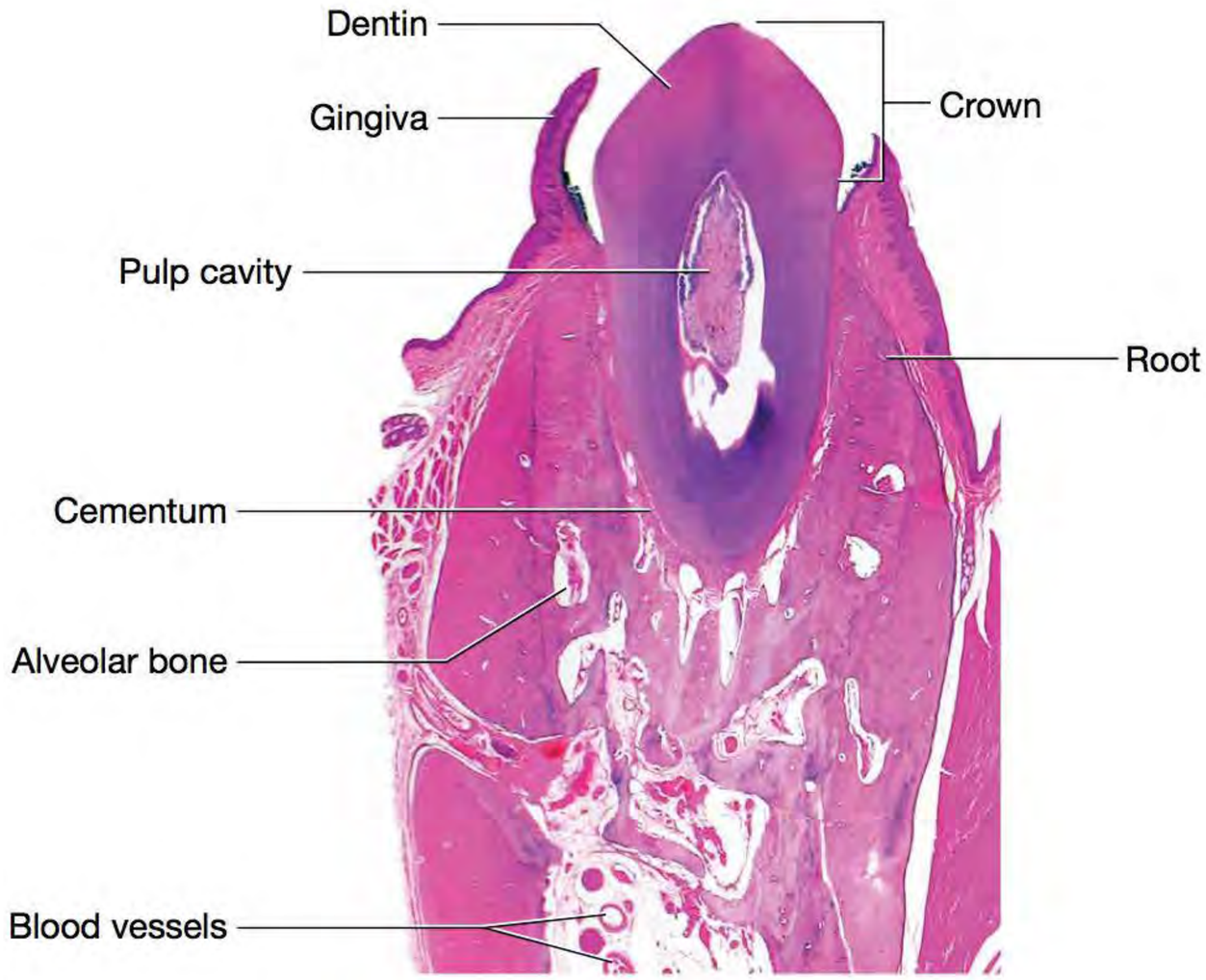


FIGURE **20.22** Microscopic structure of a human tooth.

Procedure 1 Model Inventory for the Histologic Structures of the Digestive System

Identify on models and diagrams the following histologic structures of the digestive system, using your textbook and this unit for reference. As you examine the models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 20.1 (p. 505—note that this is the model inventory in Exercise 20-1).

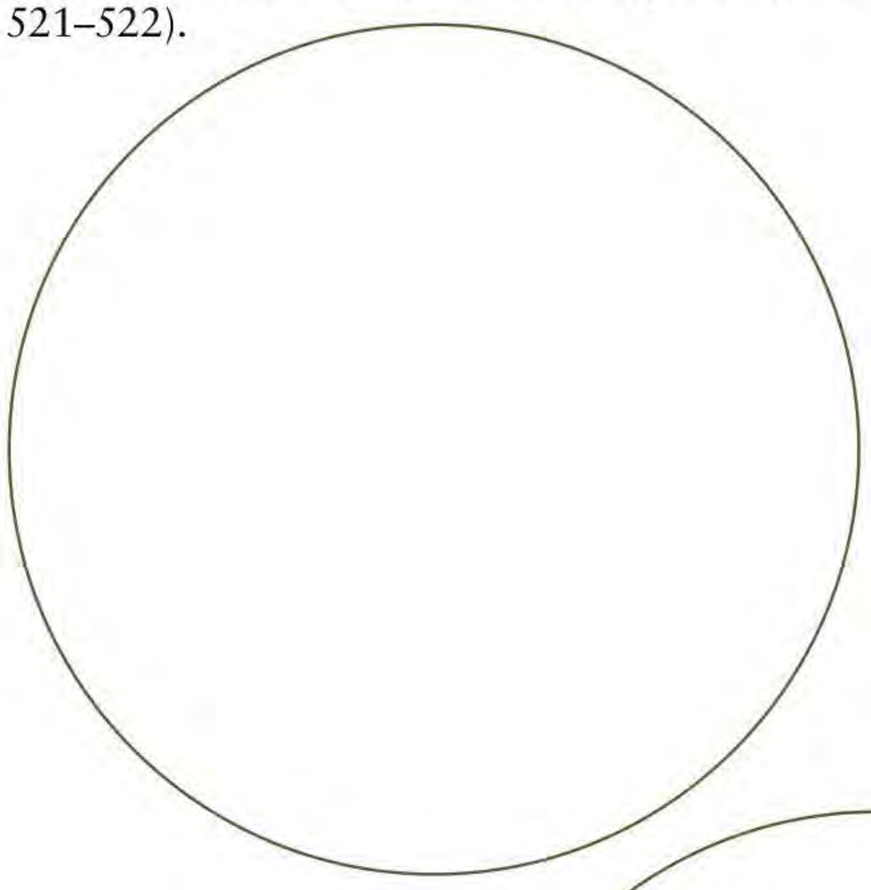
1. Mucosa
   a. Epithelial tissue (simple columnar epithelium)
   b. Glands
   c. MALT
   d. Muscularis mucosae
2. Submucosa
   a. Blood vessels
   b. Nerves
   c. Lymphatic vessels
3. Muscularis externa
   a. Inner circular layer
   b. Outer longitudinal layer
   c. Inner oblique layer (stomach only)
4. Serosa or adventitia
5. Intestinal villi
   a. Lacteal
   b. Enterocytes
   c. Microvilli

Procedure 2 Microscopy of Digestive Organs

Obtain prepared slides of the esophagus, the fundus of the stomach, the duodenum, the pancreas, the liver, and a tooth. You will have the best results viewing most of the slides on low power. Use your colored pencils to draw what you see, and label your drawing with the following terms. When you have completed the activity, answer Check Your Understanding questions 3 through 5 (pp. 521–522).

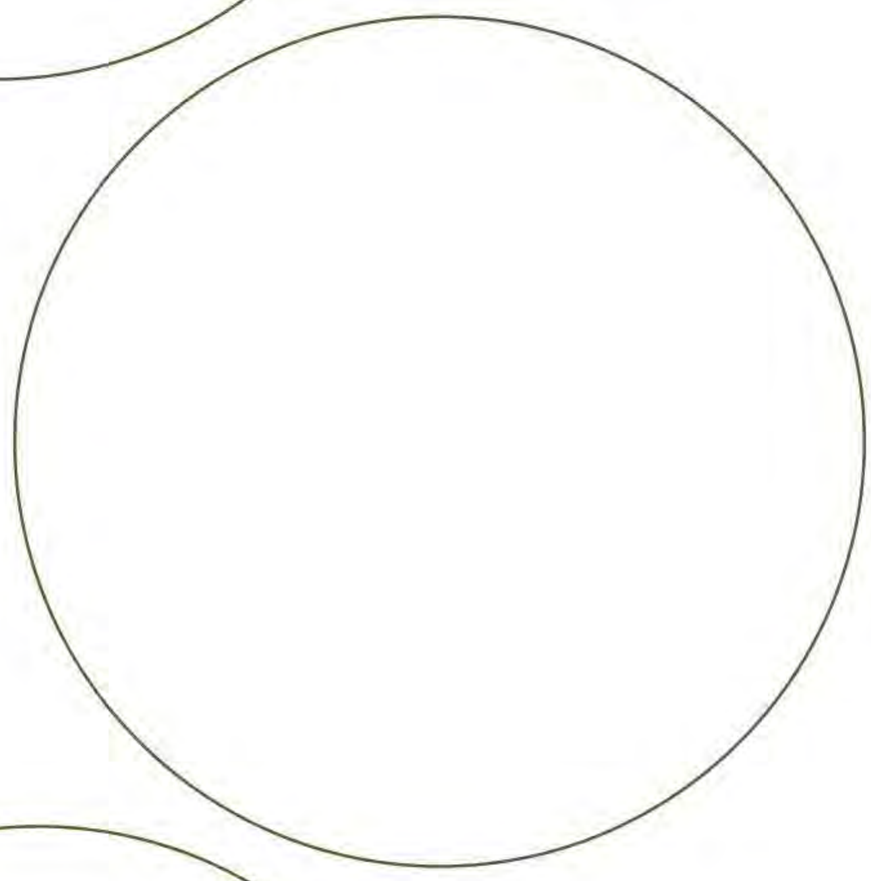
Esophagus

1. Stratified squamous epithelium
2. Submucosa with blood vessels
3. Muscularis externa
   a. Smooth muscle
   b. Skeletal muscle
4. Adventitia



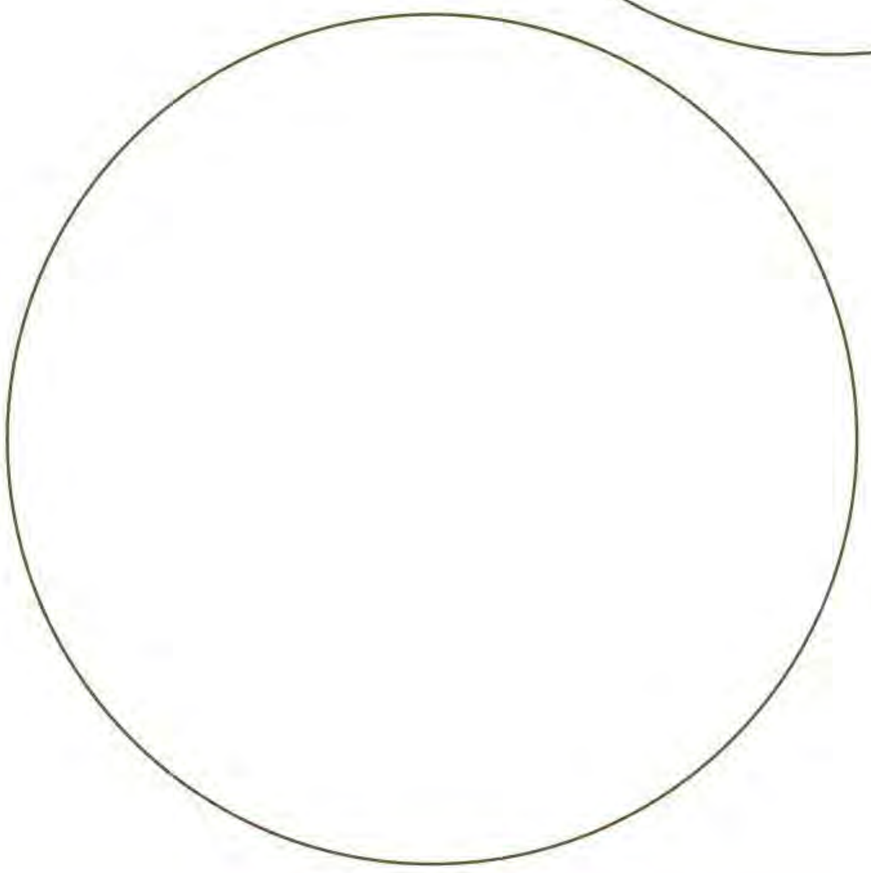
Fundus of the Stomach

1. Mucosa with goblet cells and gastric glands
2. Submucosa with blood vessels
3. Muscularis externa with smooth muscle layers
4. Serosa



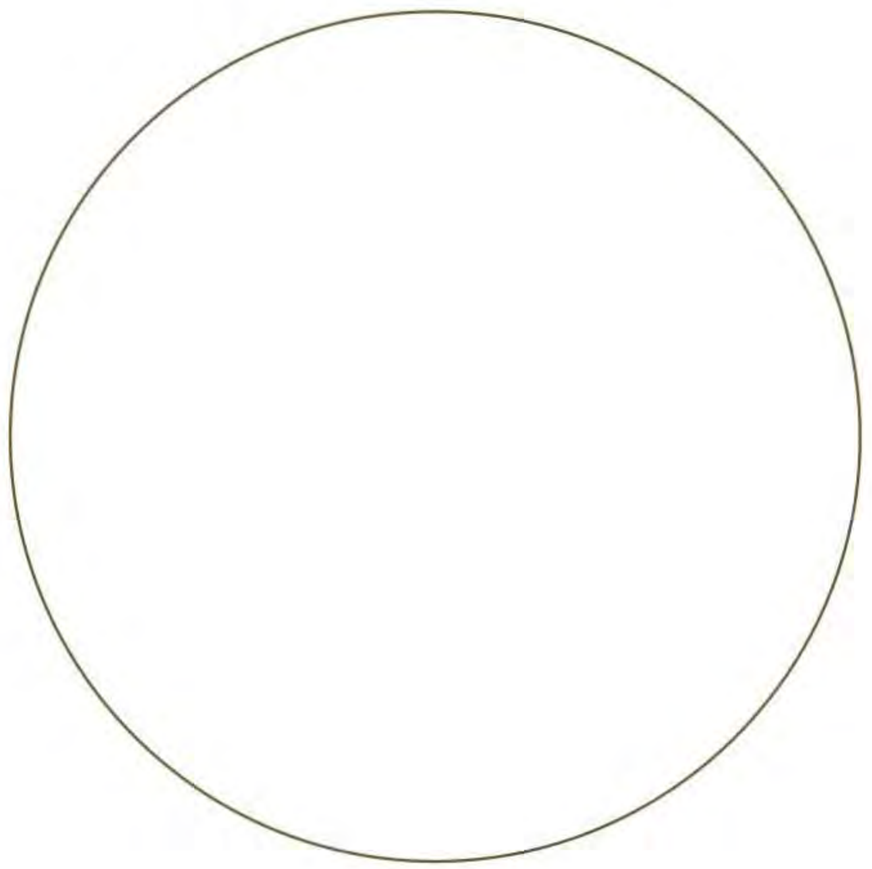
Duodenum

1. Villi
2. Mucosal-associated lymphoid tissue
3. Microvilli (visible as small "hairs" projecting from the cells); may only be visible on oil immersion
4. Intestinal glands



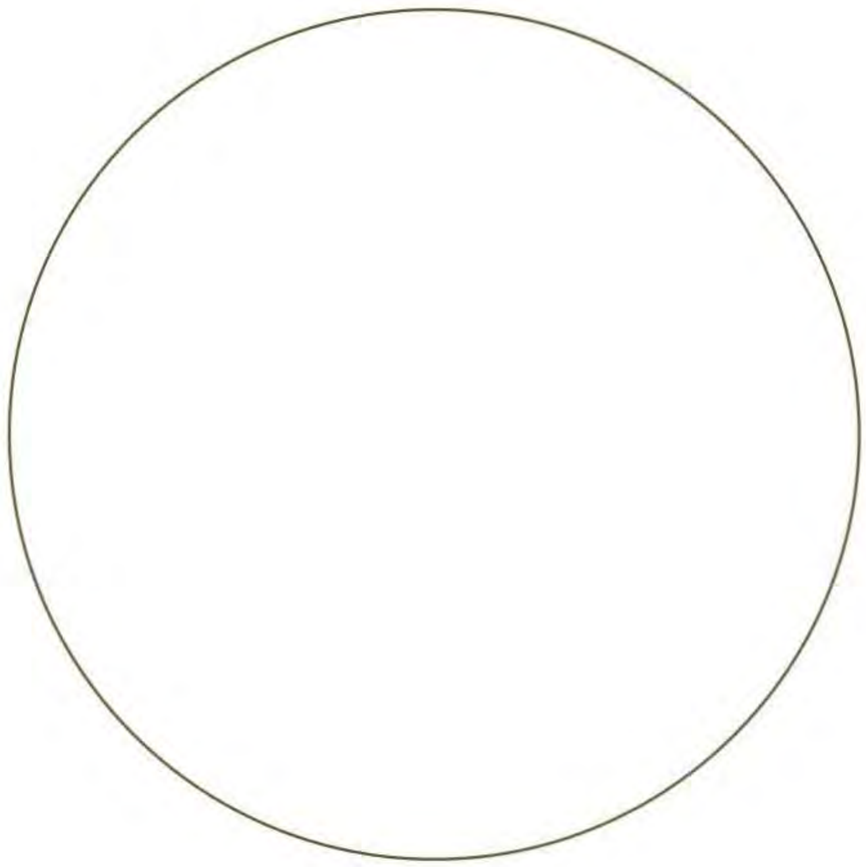
Pancreas

1. Acinar cells
2. Pancreatic ducts
3. Pancreatic islets (islets of Langerhans)



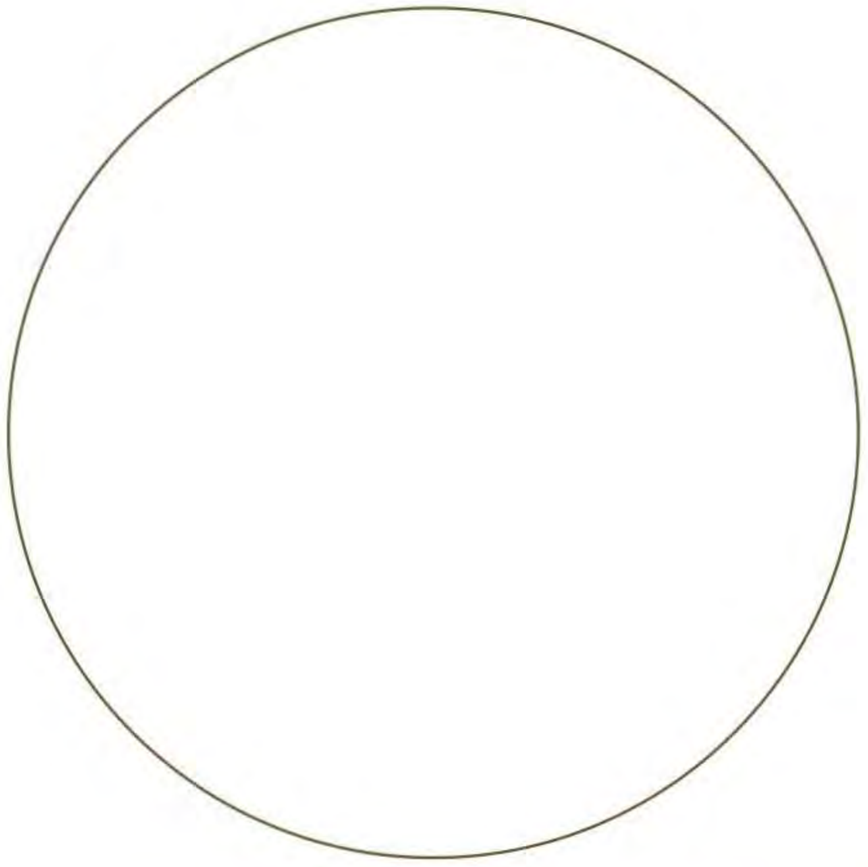
Liver

1. Liver lobule
2. Portal triad
3. Central vein



Tooth (best viewed on low power)

1. Crown
2. Root
3. Dentin
4. Pulp cavity
5. Cementum



Exercise 20-3

Time to Trace!

MATERIALS

- ❑ Laminated outline of the human body
- ❑ Water-soluble marking pens

Now it's time to put all of the digestive anatomy together to get a "big picture" view of the digestive system. In this exercise you will trace the pathways two different nutrients take from their ingestion at the mouth to their arrival at the heart. You will trace a cookie (primarily carbohydrates) and greasy fried food (primarily lipids). Along the way, detail the *anatomical pathway* each takes from ingestion through its passage through the alimentary canal, to its absorption into the blood, and finally to its passage through the blood until it reaches the heart.

Some hints:

- Don't forget that carbohydrates travel through the hepatic portal system before they enter the general circulation.
- Remember that lipids are not absorbed into the same structures as carbohydrates.
- Refer to the tracing exercises from Unit 16 (p. 409) and Unit 18 (p. 457) to review the pathway of blood and lymph flow through the body.

Tracing Steps

1 Cookie: **Start:** mouth → _____

_____ heart **End**

2 Greasy fried food: **Start:** mouth → _____

_____ heart **End**

Name _____

Section _____ Date _____

UNIT 20 REVIEW

Check Your Recall

1 Label the following structures on Figure 20.23.

- ❑ Cecum
- ❑ Esophagus
- ❑ Gallbladder
- ❑ Liver
- ❑ Parotid gland
- ❑ Sigmoid colon
- ❑ Sublingual gland
- ❑ Submandibular gland
- ❑ Transverse colon

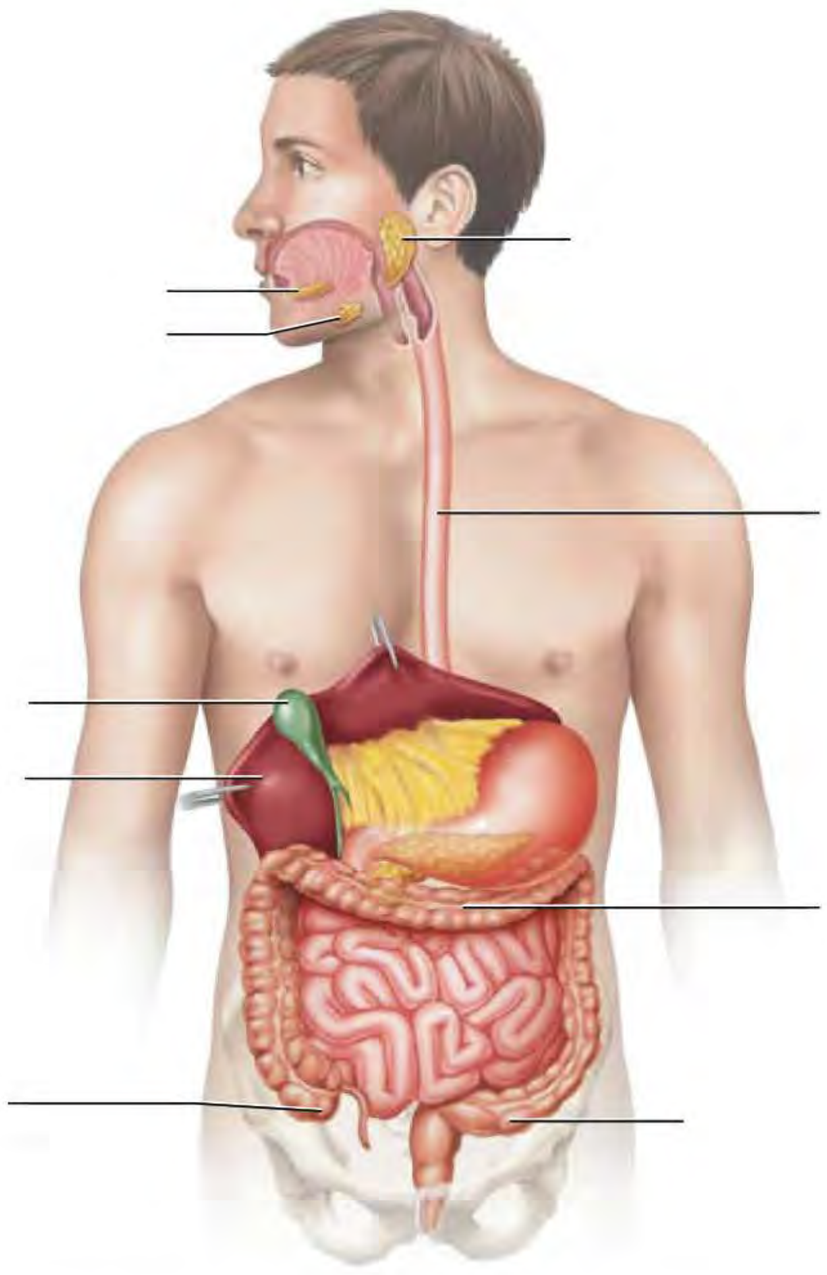


FIGURE **20.23** Overview of the digestive system.

20

2 Label the following structures on Figure 20.24.

- ❑ Body
- ❑ Cardia
- ❑ Circular muscle layer
- ❑ Duodenum
- ❑ Fundus
- ❑ Gastroesophageal sphincter
- ❑ Pyloric sphincter
- ❑ Pylorus
- ❑ Rugae
- ❑ Esophagus

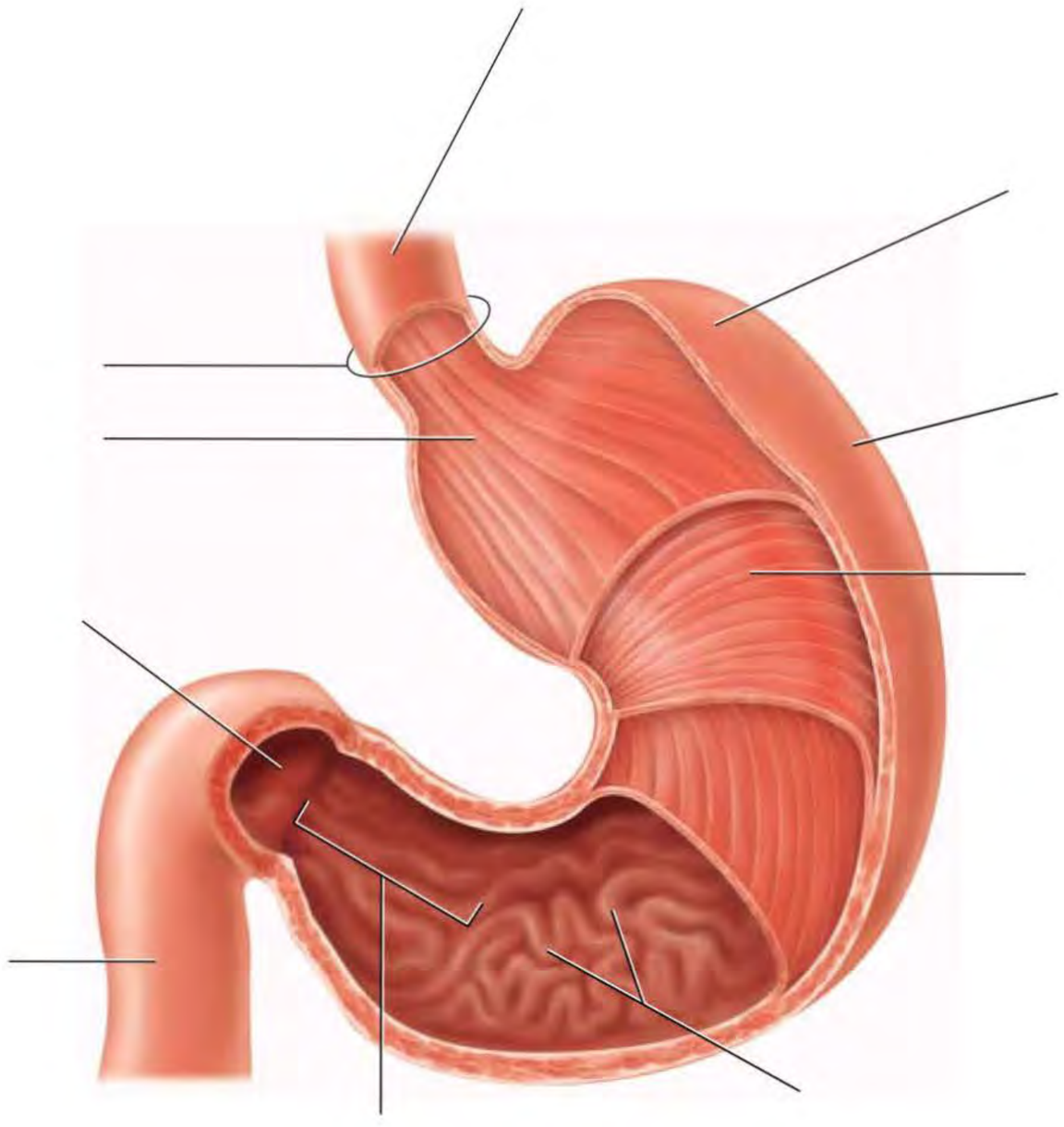


FIGURE **20.24** Stomach.

Name _____

Section _____ Date _____

3 Label the following structures on Figure 20.25.

- ❑ Common bile duct
- ❑ Common hepatic duct
- ❑ Cystic duct
- ❑ Duodenum
- ❑ Gallbladder
- ❑ Hepatopancreatic ampulla
- ❑ Liver
- ❑ Pancreas
- ❑ Pancreatic duct

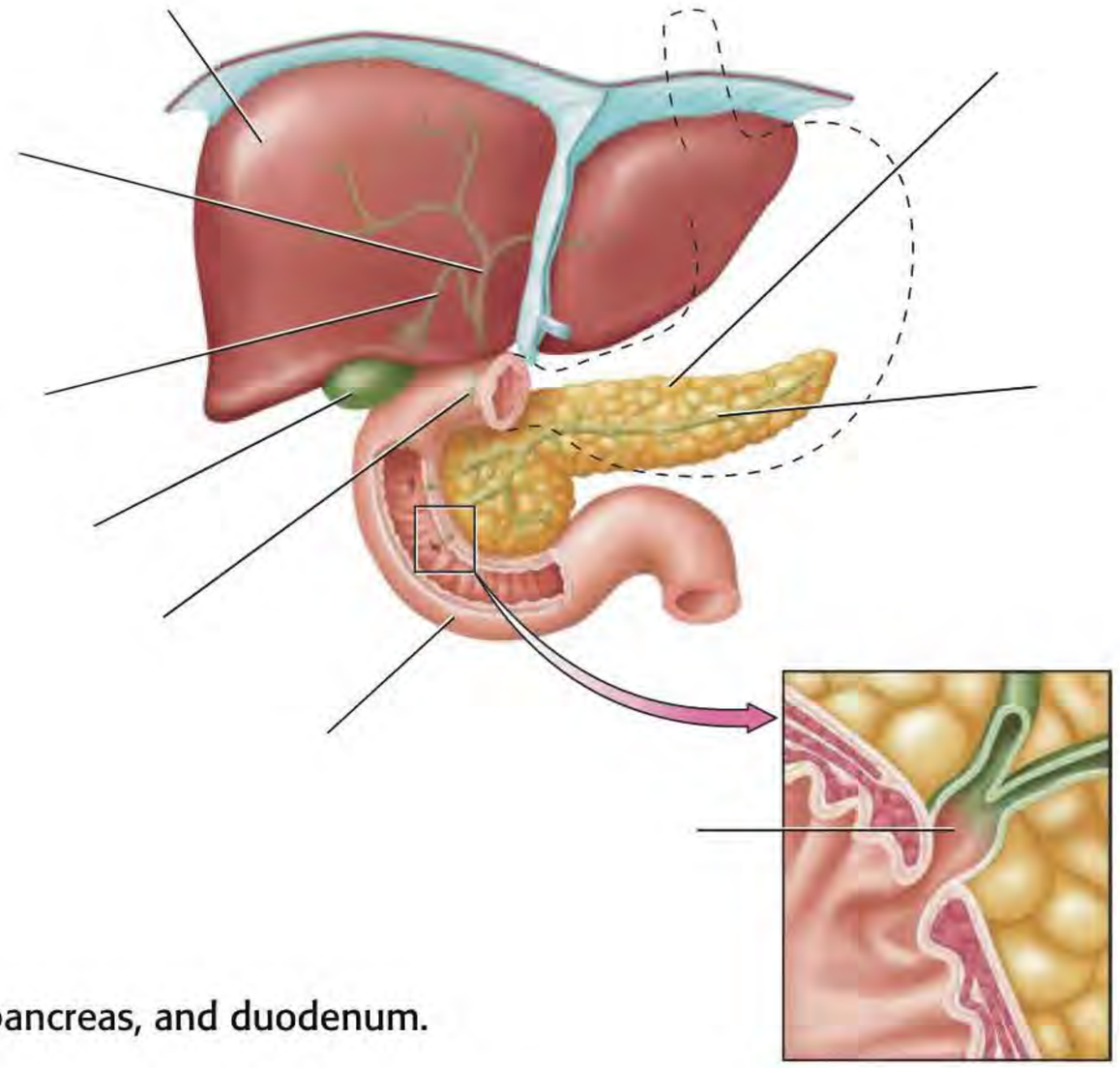


FIGURE **20.25** Liver, gallbladder, pancreas, and duodenum.

4 Which of the following organs is *not* part of the alimentary canal?

a. Esophagus
b. Gallbladder
c. Cecum
d. Ileum

5 *Mark the following statements as true (T) or false (F).* **If the statement is false, correct it so it becomes a true statement.**

_____ a. The peritoneal cavity is located between the visceral peritoneum and the mesentery.

_____ b. The longest segment of the small intestine is the duodenum.

_____ c. The stomach has three layers of smooth muscle that contract to churn food into chyme.

_____ d. The gallbladder produces and stores bile.

_____ e. The small intestine features three sets of progressively smaller folds that increase surface area for absorption.

_____ f. The liver consists of plates of hexagonal liver lobules.

6 Label the following structures on Figure 20.26.

- ❑ Circular layer of smooth muscle
- ❑ Longitudinal layer of smooth muscle
- ❑ Lumen
- ❑ Mucosa
- ❑ Muscularis mucosae
- ❑ Serosa
- ❑ Submucosa

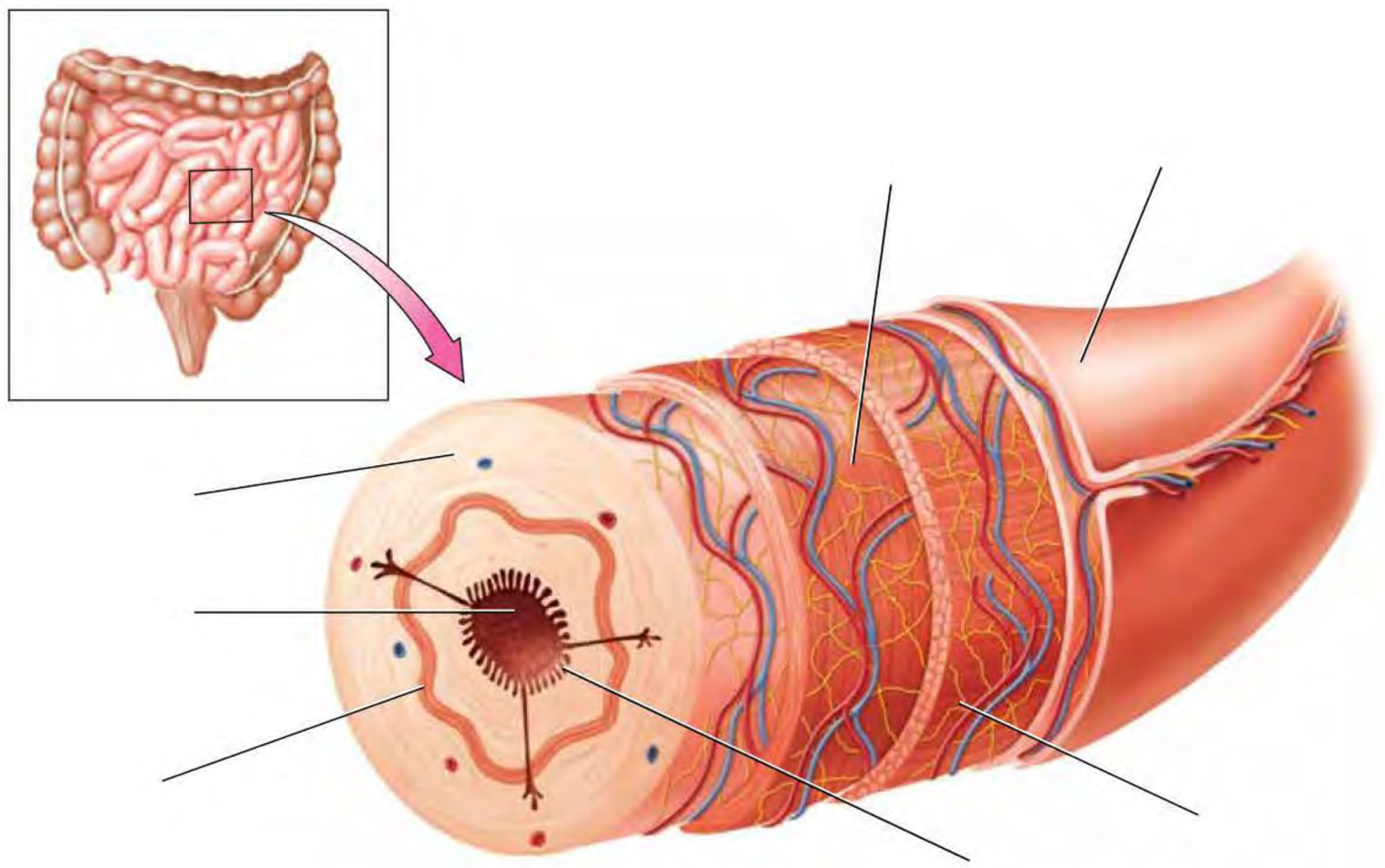


FIGURE **20.26** Tissue layers of the alimentary canal.

7 *Fill in the blanks:* The exocrine cells of the pancreas are called _____ and secrete _____.

The endocrine cells of the pancreas are called _____ and secrete _____.

8 The hardest substance in the body is known as

a. enamel.
b. cementum.
c. bone.
d. pulp.

9 What is the function of the ileocecal valve?

10 What is different about the muscularis externa of the stomach? What is the function of this adaptation?

Name _____

Section _____ Date _____

UNIT 20 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Will removal of the gallbladder prevent bile from being produced and released into the duodenum? Explain your answer.

2 The condition known as *appendicitis* is an acute inflammation of the appendix, usually due to bacterial infection. What anatomical or histological feature does the appendix contain that makes it at risk for this type of condition? How does its location and shape complicate this? Explain.

3 The condition known as heartburn is most often caused by acid regurgitating from the stomach into the esophagus. Why do you think the acid tends to burn the esophagus and produce pain but does not similarly burn the stomach under normal conditions?

4 If you go into your local grocery store, you are bound to find a host of gluten-free products made with synthetic proteins instead of the natural wheat-based protein gluten. About 1–3% of the population is sensitive to gluten. The most severe form of gluten intolerance is the autoimmune disease *celiac disease* (note that it is not caused by gluten, and you cannot get it from eating gluten). In individuals with celiac disease, the immune response to gluten antigens causes the flattening of the villi in the small intestine. How would this affect the ability of the small intestine to function? Predict the symptoms you would expect to see from celiac disease.

5 Your patient has an ulcer of his large intestine that has perforated, meaning that it has developed a hole that has gone **through all tissue layers.**

a Through which tissue layers would the ulcer have had to pass to perforate completely?

b A major concern with large intestine perforation is *peritonitis*, or infection of the peritoneal fluid. Why is this a particular concern with the large intestine?

c Why could peritonitis have wide-ranging effects on other organs of the abdomen and digestive system? Are there any organs that would be unlikely to be directly affected by peritonitis? Explain.

Urinary System

21

OBJECTIVES

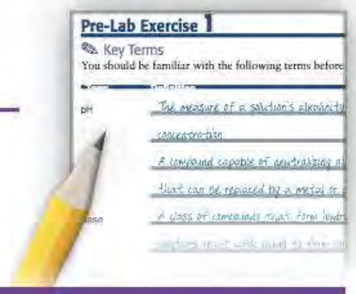
Once you have completed this unit, you should be able to:

1. Identify gross structures of the urinary system.
2. Identify structures of the nephron.
3. Identify histological structures of the urinary system.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 21-1

✎ Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Gross Structures of the Kidney

Renal cortex _____

Renal medulla _____

Renal pyramid _____

Renal column _____

Renal pelvis _____

Major and minor calyces _____

Other Structures of the Urinary System

Ureter _____

Urinary bladder _____

Urethra _____

Blood Vessels and Tubules of the Nephron

Nephron _____

Name _____ Section _____ Date _____

Glomerulus _____

_____

Peritubular capillaries _____

_____

Proximal tubule _____

_____

Nephron loop _____

_____

Distal tubule _____

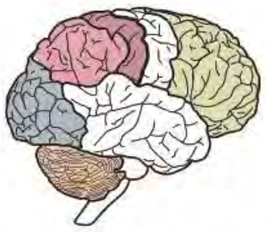
_____

Cortical collecting duct _____

_____

Medullary collecting duct _____

_____



Pre-Lab Exercise 21-2

Structures of the Urinary System

Label and color the structures of the urinary system in Figures 21.1 and 21.2 with the terms from Exercise 21-1 (p. 529). Use your text and Exercise 21-1 in this unit for reference.

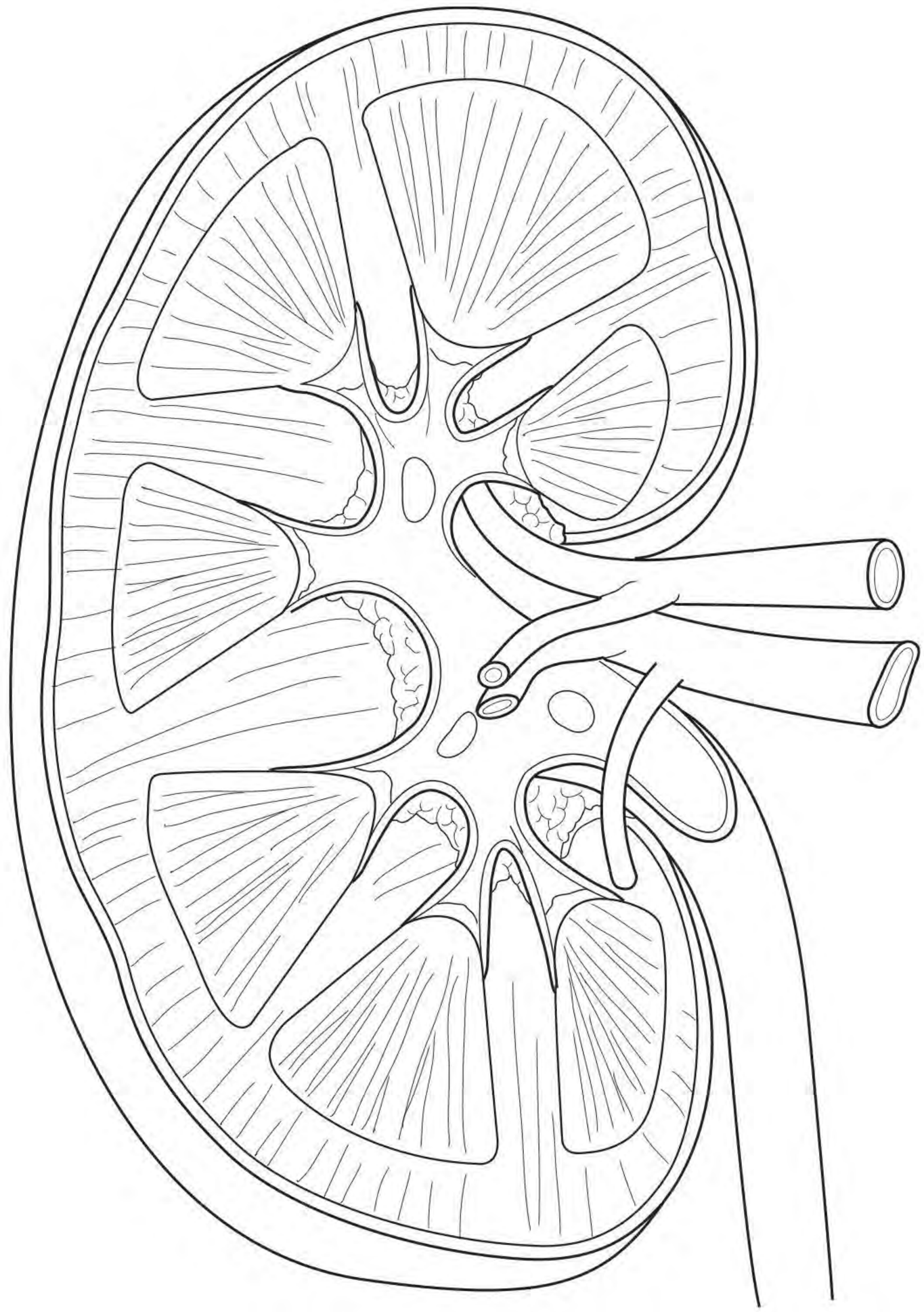


FIGURE **21.1** Right kidney, frontal section.

Name _____ Section _____ Date _____

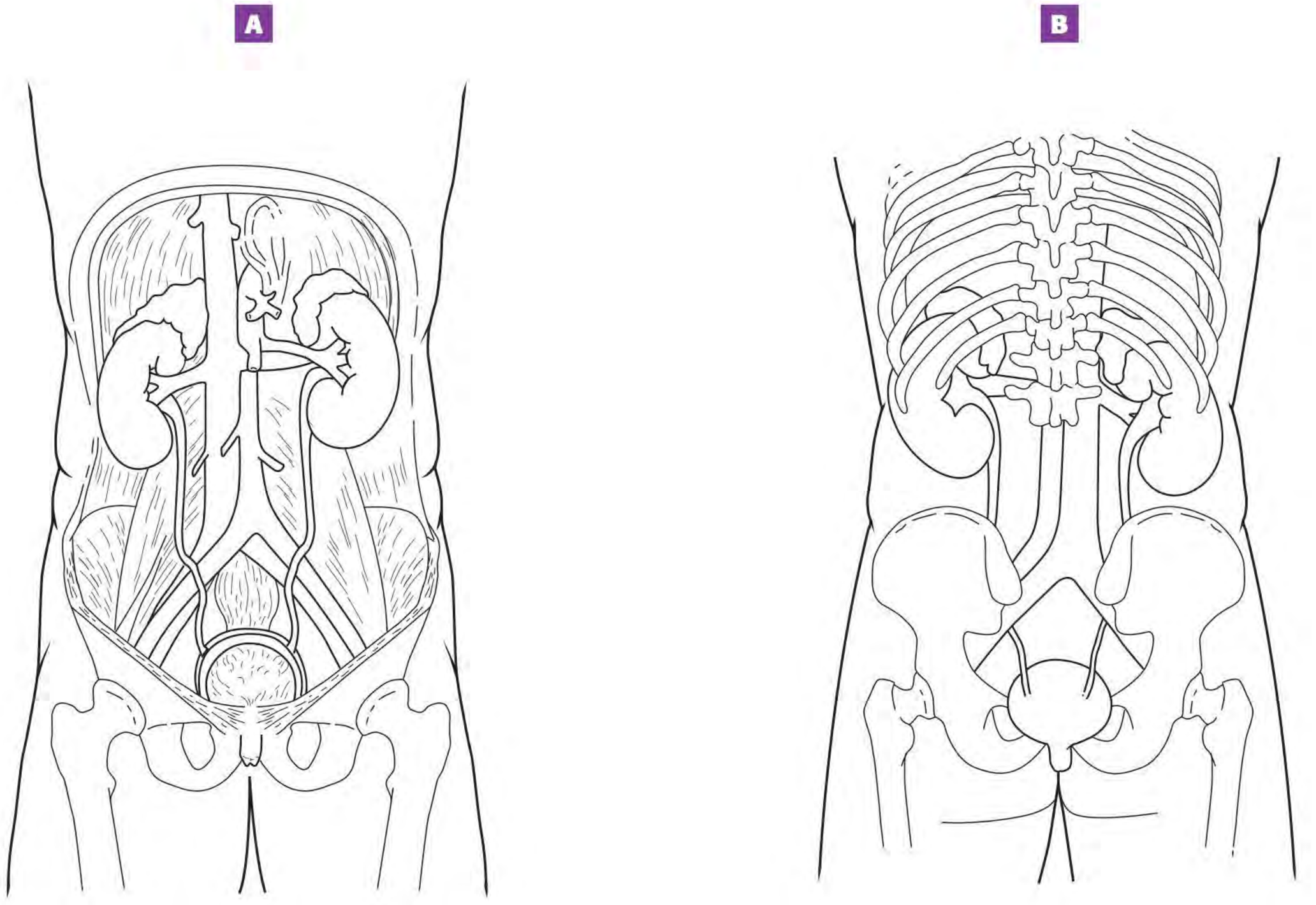


FIGURE **21.2** Organs of the urinary system: (**A**) anterior view; (**B**) posterior view.

Pre-Lab Exercise 21-3

Structures of the Nephron

Label and color the structures of the nephron in Figure 21.3 with the terms from Exercise 21-1 (p. 529). Use your text and Exercise 21-1 in this unit for reference.

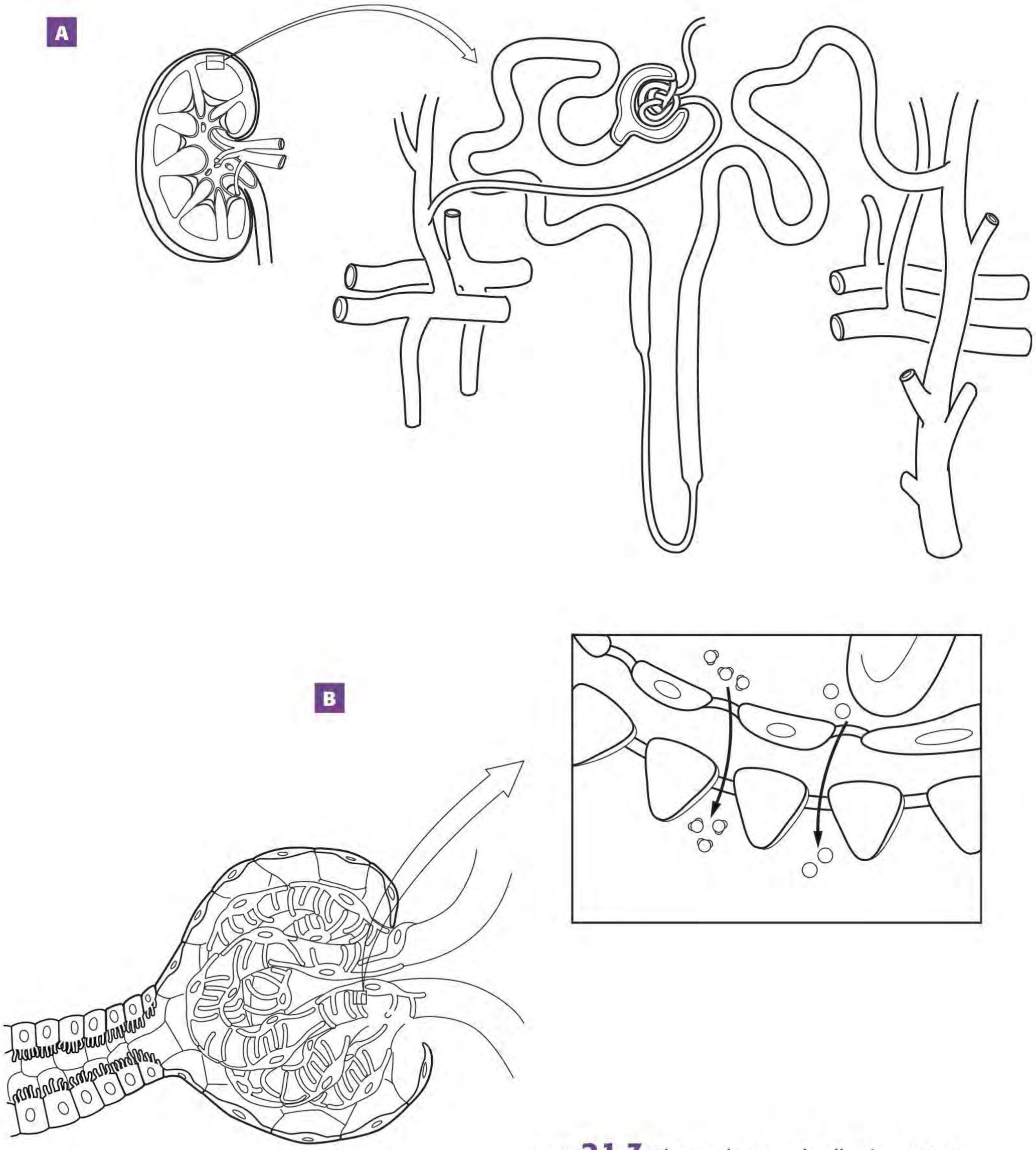


FIGURE **21.3** The nephron and collecting system.

EXERCISES

The **urinary system** is the group of organs that consists of the *kidneys* and the *urinary tract*—the *ureters*, *urinary bladder*, and *urethra*—that performs many functions critical to homeostasis. Some of these functions include removing waste products from the blood; regulating the body's fluid, electrolyte, and acid-base balance; and producing the hormone erythropoietin, which regulates blood cell formation. In addition to these roles, the urinary system helps the liver detoxify certain compounds and makes glucose during times of starvation. In this unit you will become acquainted with the anatomy and the histology of the urinary system. In the final exercise, you will trace an erythrocyte through the vasculature of the kidney and a molecule of urea through the kidney and urinary tract.

Exercise 21-1

Urinary System Anatomy

MATERIALS

- ❑ Urinary system models
- ❑ Kidney models
- ❑ Nephron models
- ❑ Preserved kidney
- ❑ Dissection equipment
- ❑ Dissecting tray
- ❑ Colored pencils

The paired **kidneys** are situated against the posterior body wall posterior to the peritoneal membranes, meaning they are *retroperitoneal*. Externally, they are encased within three layers of connective tissue: the superficial **renal fascia**, a layer of dense irregular collagenous connective tissue that anchors the kidneys to the posterior abdominal wall and the peritoneum; the **adipose capsule**, a thick layer of adipose tissue that wedges the kidneys in place; and the **renal capsule**, a very thin layer of dense irregular collagenous connective tissue that encases each kidney like plastic wrap (Figure 21.4). With the layers of connective tissue removed, the kidneys are bean-shaped; the medial indentation where blood vessels and the ureter enter and exit is known as the **hilum** (HY-lum).

Internally, each kidney has three distinct regions that can be seen in a frontal section (Figure 21.5):

1. **Renal cortex.** The most superficial region is known as the **renal cortex** (REE-nul). It is dark brown because it consists of many blood vessels that serve the tiny blood-filtering structures of the kidney, the **nephrons**.

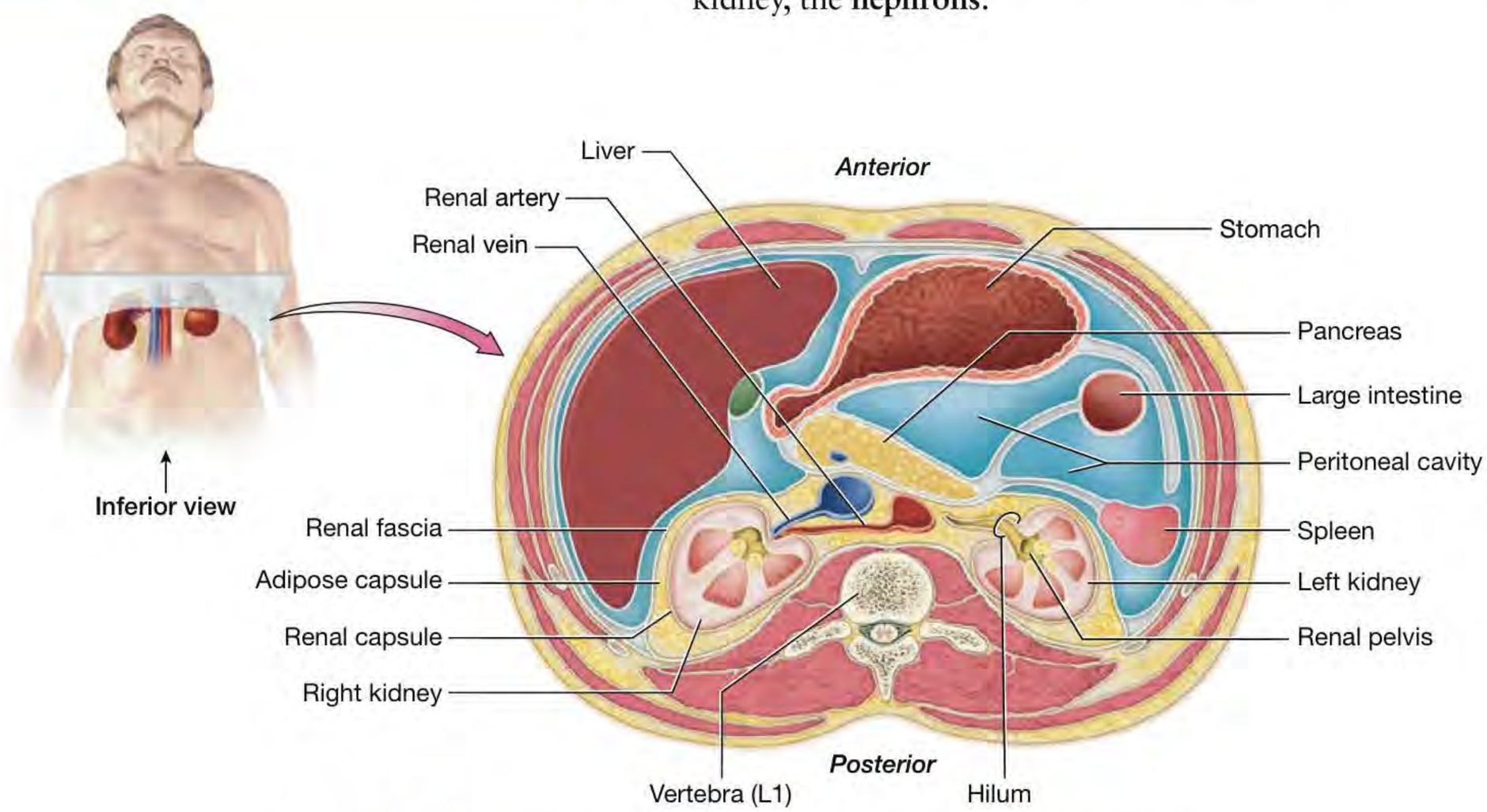


FIGURE **21.4** Transverse section of the abdomen and kidneys.

2. **Renal medulla.** The kidney's middle region is known as the **renal medulla,** which consists of triangular structures known as **renal pyramids.** The renal pyramids are separated from one another by inward extensions of the renal cortex called **renal columns.** Like the renal cortex, the renal columns contain many blood vessels. Each pyramid contains looping tubules of the nephron as well as structures that drain fluid from the nephron. These tubes give the pyramids a striped (or *striated*) appearance. The end or tip of a renal pyramid is known as a **renal papilla.**
3. **Renal pelvis.** The tubes that drain the fluid from the renal papilla drain into larger tubes called **minor calyces** that in turn drain into even larger **major calyces** (KAY-lih-seez). The major calyces drain into the kidney's innermost region, called the **renal pelvis,** which serves as a basin for collecting urine.

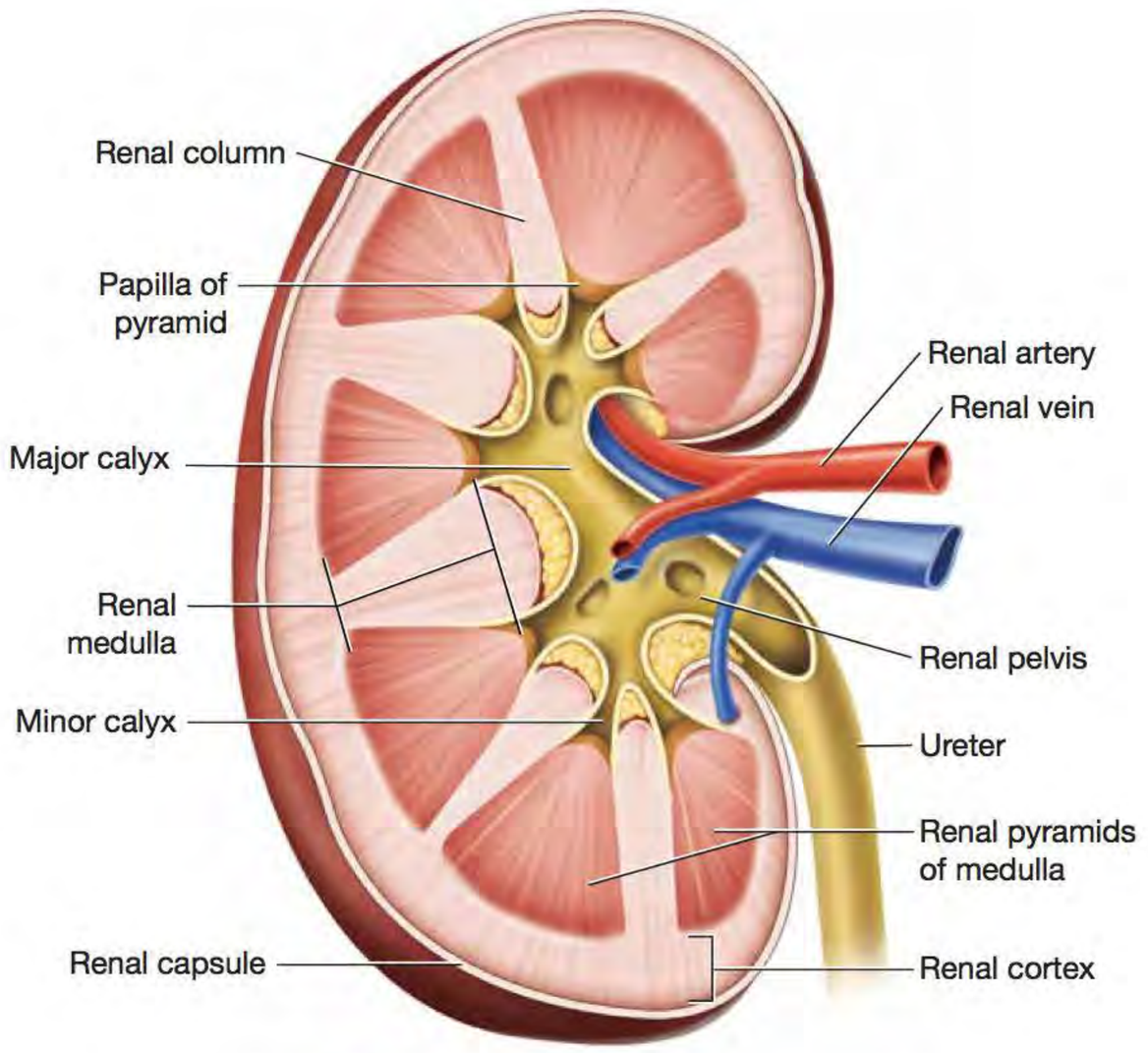


FIGURE **21.5** Right kidney, frontal section.

The blood flow through the kidney follows a unique pattern that allows it to carry out its function of maintaining the homeostasis of the blood. The large **renal arteries** deliver about 1,200 milliliters of blood per minute to the kidney to be filtered. The renal arteries branch into progressively smaller arteries as they pass through the medulla to the cortex, including the **segmental arteries** in the renal pelvis, the **interlobar arteries** between the medullary pyramids, the **arcuate arteries** (ARK-yoo-it) that curve around the top of the pyramids, and finally the small **interlobular arteries** in the renal cortex (Figure 21.6). The interlobular arteries branch into tiny **afferent arterioles,** each of which supplies a ball of capillaries known as the **glomerulus** (gloh-MEHR-yoo-lus). This is where the blood is filtered. Note that the glomerulus is not the primary site for gas and nutrient exchange for the tissues of the kidneys.

You learned in Unit 16 that a capillary bed generally drains into a venule, but note in Figure 21.6 that the capillaries of the glomerulus drain into a second *arteriole* called the **efferent arteriole.** The efferent arteriole then branches to form a second capillary bed known as the **peritubular capillaries.** These capillaries surround the tubules of the nephron, where they provide them with oxygen and nutrients and also take substances reabsorbed by the tubules back into the blood. In some nephrons, a second set of capillaries called the **vasa recta** is found surrounding a portion of the nephron called the nephron loop. The peritubular capillaries then drain out through the small **interlobular veins,** which drain into **arcuate veins,** then into **interlobar veins,** and finally into the large **renal vein.** This pattern of blood flow allows the kidneys both to filter blood and to reclaim most of the fluid and solutes filtered.

Microscopically, each kidney is composed of more than a million tiny units called **nephrons** (NEF-rahnz; Figure 21.7). The nephron can be divided into two parts: the *renal corpuscle* and the *renal tubule.* The **renal corpuscle** itself consists of two parts: the glomerulus and the glomerular capsule. As you've seen, the glomerulus is a ball of looping capillaries. The capillaries themselves are *fenestrated,* meaning that they have large slits or pores, which allows large volumes of fluid to exit them in short period of time. The second portion of the renal corpuscle is the **glomerular capsule.** Note in Figure 21.7A that the glomerular capsule has two layers: (a) the outer **parietal layer,** which is simple squamous epithelium, and (b) the inner **visceral layer,** which consists of cells called **podocytes** (POH-doh-syt′z) that surround the capillaries of the glomerulus. The space between the parietal and visceral layers is known as the **capsular space.** Fluid forced out of the glomerular capillaries enters this space; once in the capsular space, the fluid is called *filtrate*.

The podocytes of the visceral layer have extensions called **foot processes** that interlock to form narrow **filtration slits.** As you can see in Figures 21.7B, the glomerular endothelial cells, the podocytes, and their shared basal lamina together form a structure called the **filtration membrane.** The filtration membrane prevents large substances in the blood, such as blood cells and most proteins, from exiting the glomerular capillaries, while allowing water and small solutes such as electrolytes, glucose, amino acids, and wastes such as urea to enter the filtrate.

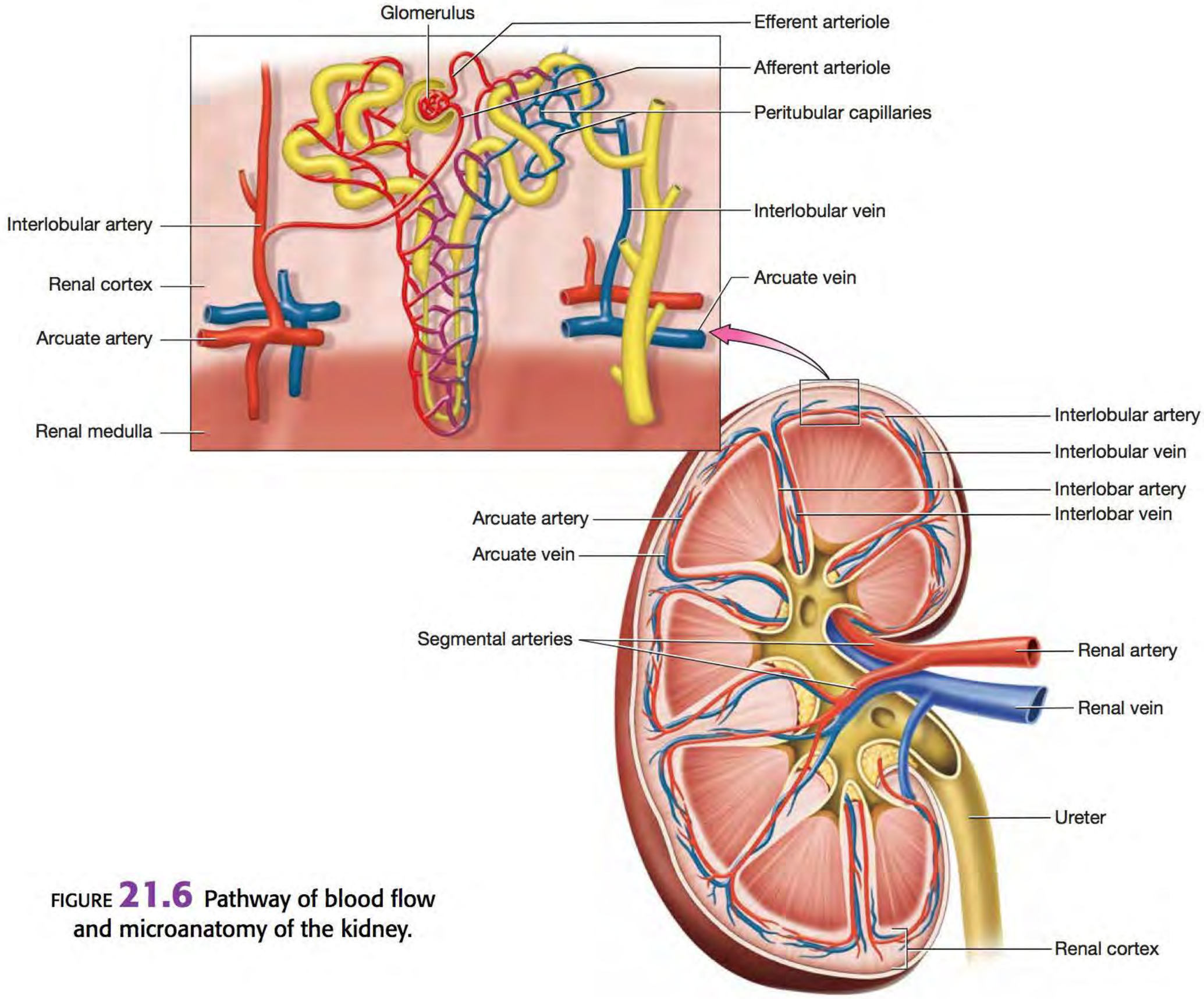


FIGURE **21.6** Pathway of blood flow and microanatomy of the kidney.

From the capsular space, the filtrate next enters the **renal tubule,** which can be likened to the "plumbing" of the kidney. The renal tubule consists of three parts, shown in Figure 21.7:

1. the **proximal tubule** (sometimes called the *proximal convoluted tubule*),
2. the ascending and descending limbs of the **nephron loop,** and
3. the **distal tubule** (sometimes called the *distal convoluted tubule*).

Note that the majority of the renal tubule is confined to the renal cortex; only the nephron loops of certain nephrons dip down into the renal medulla. Several distal tubules drain into one **collecting duct,** which is part of a larger collecting system that is not part of the nephron. Collecting ducts in the renal cortex are **cortical collecting ducts;** those in the renal medulla are **medullary collecting ducts.**

At the junction between the ascending limb of the nephron loop and the distal tubule we find a group of tall, closely packed cells known as the **macula densa** (MAK-yoo-lah DEN-sah; Figure 21.8). The macula densa comes into contact with a portion of the afferent arteriole that contains specialized cells called **juxtaglomerular** (jux-tah-gloh-MEHR-yoo-lur; **JG**) **cells.** The JG cells and macula densa together are called the **juxtaglomerular apparatus (JGA).** The JGA plays a role in controlling the flow of filtrate through the nephron and the blood pressure within the glomerulus.

Filtrate in the renal tubule and collecting duct is modified, and most of the water and solutes are reclaimed. From the medullary collecting ducts, filtrate drains into larger tubules called **papillary ducts,** where more water is reclaimed.

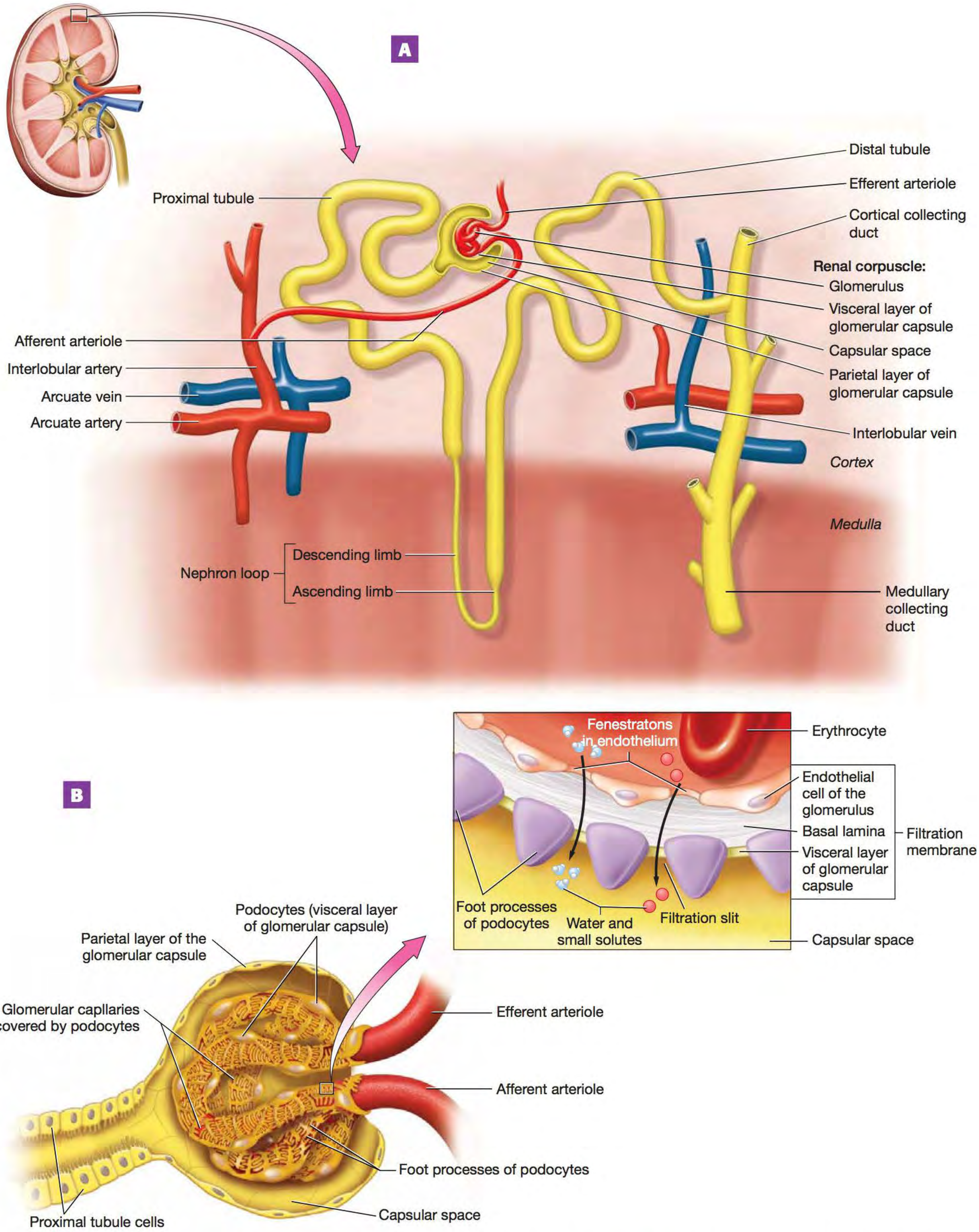


FIGURE **21.7** Microanatomy of the kidney: (**A**) nephron and collecting system; (**B**) renal corpuscle and filtration membrane.

After the fluid leaves the papillary ducts, it is known as **urine** and drains into the minor calyces, major calyces, and finally the renal pelvis. From the renal pelvis, urine enters the next organs of the urinary system—the tubes called the **ureters** (YOOR-eh-terz; Figures 21.9 and 21.10). Ureters are lined by a type of epithelium called **transitional epithelium,** and their walls contain smooth muscle that massages the urine inferiorly via peristalsis.

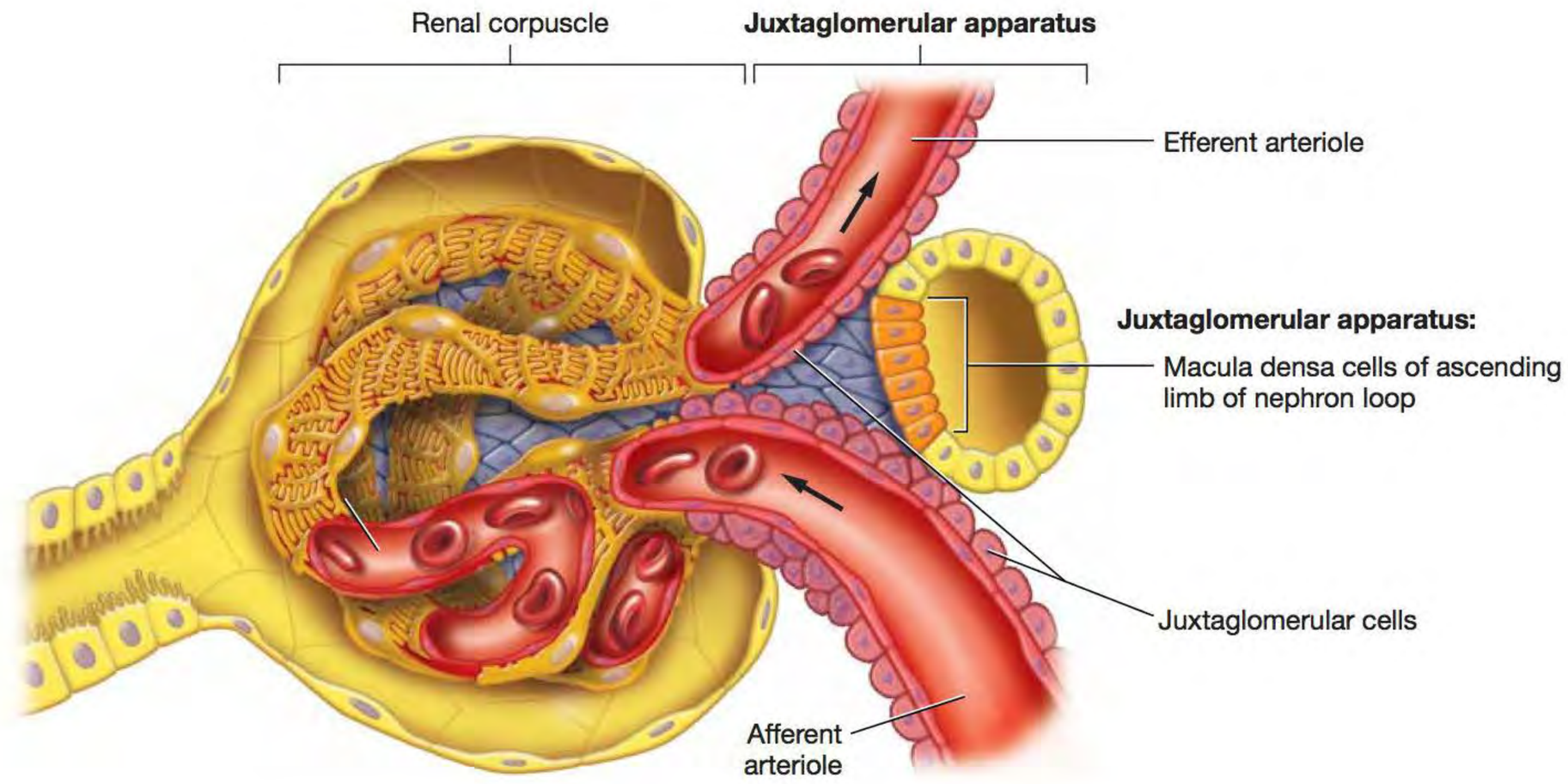


FIGURE **21.8** Juxtaglomerular apparatus.

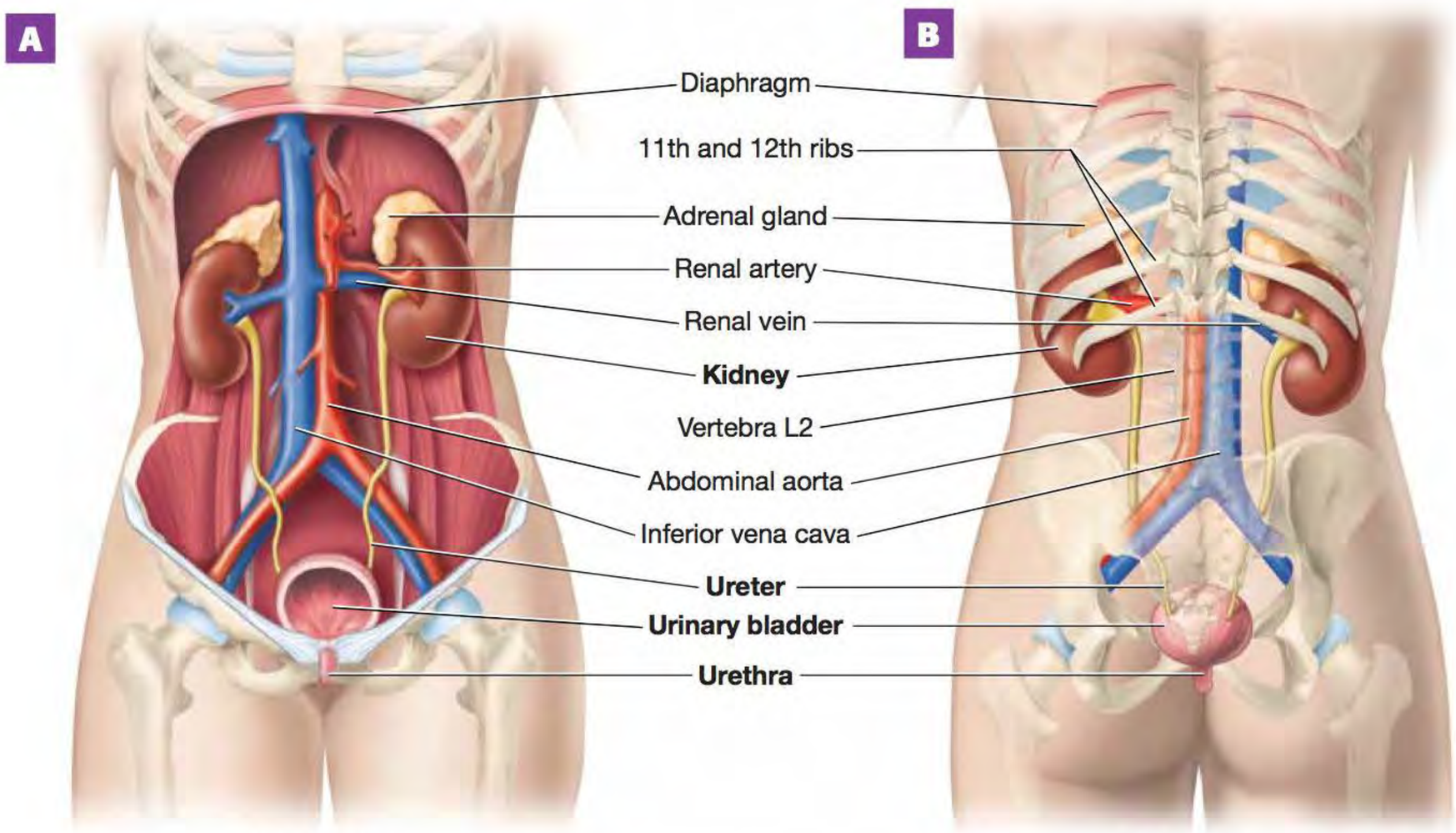


FIGURE **21.9** Organs of the female urinary system: (A) anterior view; (B) posterior view.

The ureters drain urine into the posterioinferior wall of the organ known as the **urinary bladder** at the **ureteral orifices** (yoo-REE-ter-ul; Figure 21.10). Like the ureters, the urinary bladder is lined with transitional epithelium and contains smooth muscle, sometimes called the **detrusor muscle** (dee-TROO-sohr), in its wall. The majority of the urinary bladder contains folds called **rugae** (ROO-ghee) that allow it to expand when it is filled with urine. The smooth inferior portion of the urinary bladder wall features a triangular-shaped area known as the **trigone** (TRY-gohn). This opens into the final organ of the urinary system—the **urethra** (yoo-REETH-rah). The urethra contains two rings of smooth muscle—the involuntary **internal urethral sphincter** and the voluntary **external urethral sphincter.** When both of these sphincters relax, urine is expelled from the body via a process called **micturition** (mik-chur-ISH-un).

Notice in Figure 21.11 that the male and female urethras are quite different. In females, the urethra is short, measuring only about 4 cm. In males, the urethra is much longer, about 20 cm, and has three divisions: the **prostatic urethra,** which passes through the *prostate gland*; the short **membranous urethra,** which passes through the levator ani muscle; and the **spongy urethra,** which passes through the penis. Another difference you may notice is the positon of the urinary bladder. The urinary bladder of the male is anterior to the rectum. The urinary bladder of the female sits posterior to the vagina and inferior to the uterus. This position is one of the reasons why pregnant women have to urinate so frequently—the enlarged uterus sits right on top of the urinary bladder.

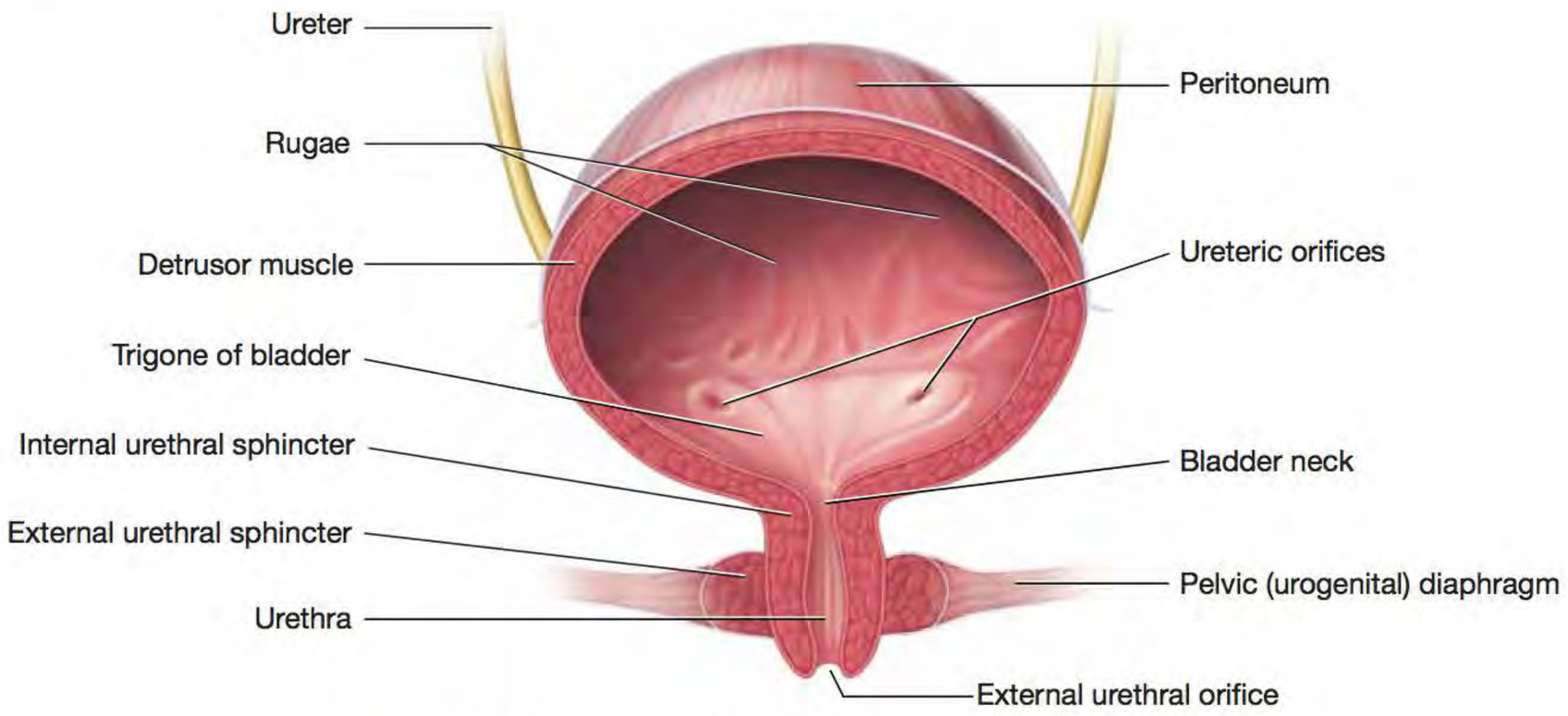


FIGURE **21.10** Female urinary bladder, frontal section.

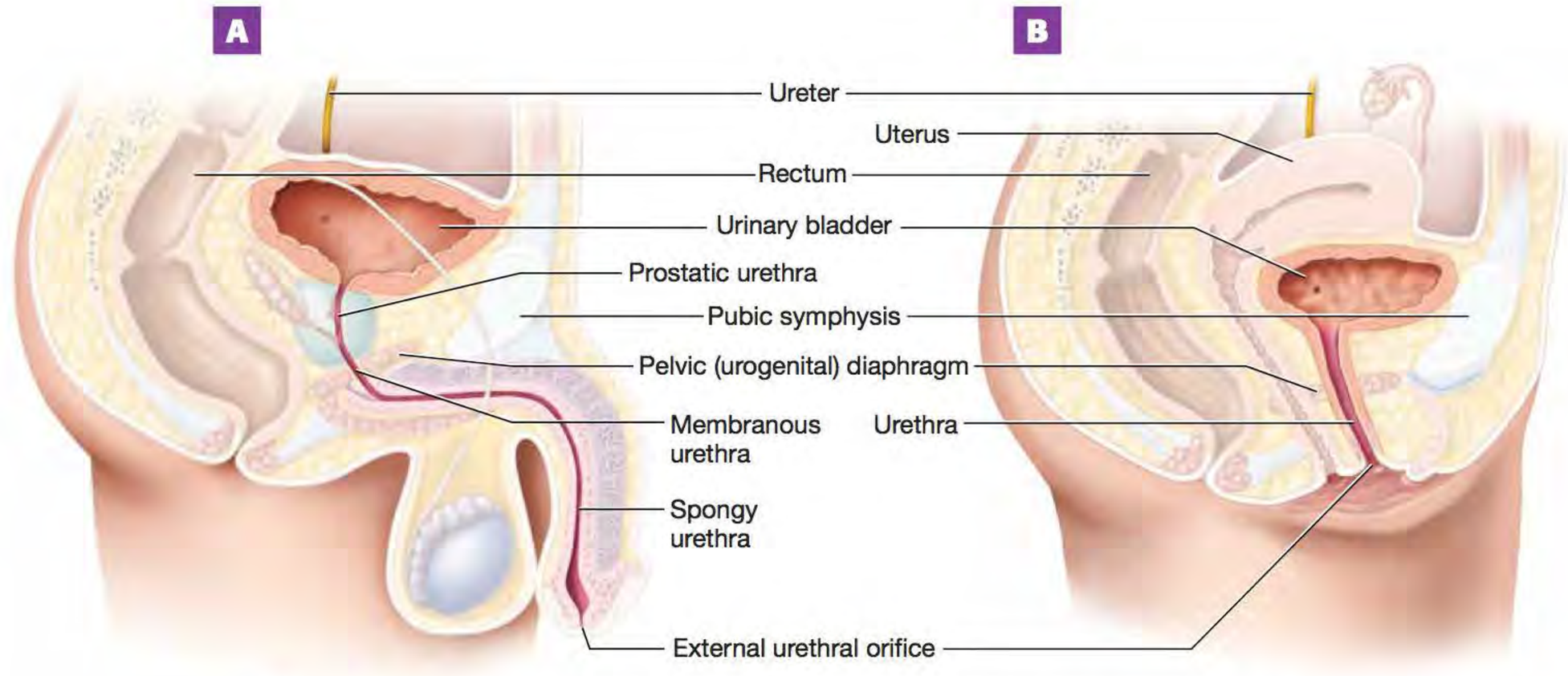


FIGURE **21.11** Organs of the urinary systems, sagittal sections: (**A**) male; (**B**) female.

Procedure 1 Model Inventory for the Urinary System

Identify the following structures of the urinary system on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 21.1. When you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 547).

Kidney Anatomy

1. Surrounding connective tissue:
   a. Renal fascia
   b. Adipose capsule
   c. Renal capsule
2. Hilum
3. Regions
   a. Renal cortex
   b. Renal medulla
      (1) Renal pyramids
      (2) Renal columns
      (3) Renal papilla
   c. Minor calyces
   d. Major calyces
   e. Renal pelvis
4. Blood supply
   a. Renal artery
      (1) Segmental artery
      (2) Interlobar artery
      (3) Arcuate artery
      (4) Interlobular artery
   b. Renal vein
      (1) Interlobular vein
      (2) Arcuate vein
      (3) Interlobar vein

Structures of the Nephron and Collecting System

1. Renal corpuscle
   a. Glomerulus
      (1) Afferent arteriole
      (2) Efferent arteriole
      (3) Peritubular capillaries
      (4) Vasa recta
   b. Glomerular capsule
      (1) Parietal layer
      (2) Visceral layer
      (3) Podocytes
      (4) Capsular space
2. Renal tubule
   a. Proximal tubule
   b. Nephron loop
      (1) Descending limb
      (2) Ascending limb
   c. Distal tubule
3. Collecting duct
   a. Cortical collecting duct
   b. Medullary collecting duct
4. Juxtaglomerular apparatus
   a. JG cells
   b. Macula densa
5. Papillary duct

Other Urinary Structures

1. Ureter
2. Urinary bladder
   a. Ureteral orifices
   b. Rugae
   c. Trigone
3. Urethra
   a. Internal urethral sphincter
   b. External urethral sphincter
   c. External urethral orifice
   d. Prostatic urethra
   e. Membranous urethra
   f. Spongy urethra

TABLE 21.1 Model Inventory for Urinary Anatomy

Model/Diagram	Structures Identified

Procedure 2 Time to Draw the Urinary System

In the space below, draw, color, and label one of the overview of the urinary system models that you examined. In addition, write the function of each structure that you label.

Procedure 3 Time to Draw a Nephron

In the space below, draw, color, and label a nephron. In addition, write the function of each structure that you label.

Procedure 4 Kidney Dissection

In this exercise you will identify several of the structures you just identified on models and diagrams by dissecting a preserved kidney.

Safety Note

Safety glasses and gloves are required!

1. Obtain a fresh or preserved kidney specimen and dissection supplies.
2. If the thick surrounding connective tissue coverings are intact, note their thickness and amount of adipose tissue.
3. Use scissors to cut through the connective tissue coverings, and remove the kidney.
4. List surface structures you are able to identify (see Figure 21.12A for reference):

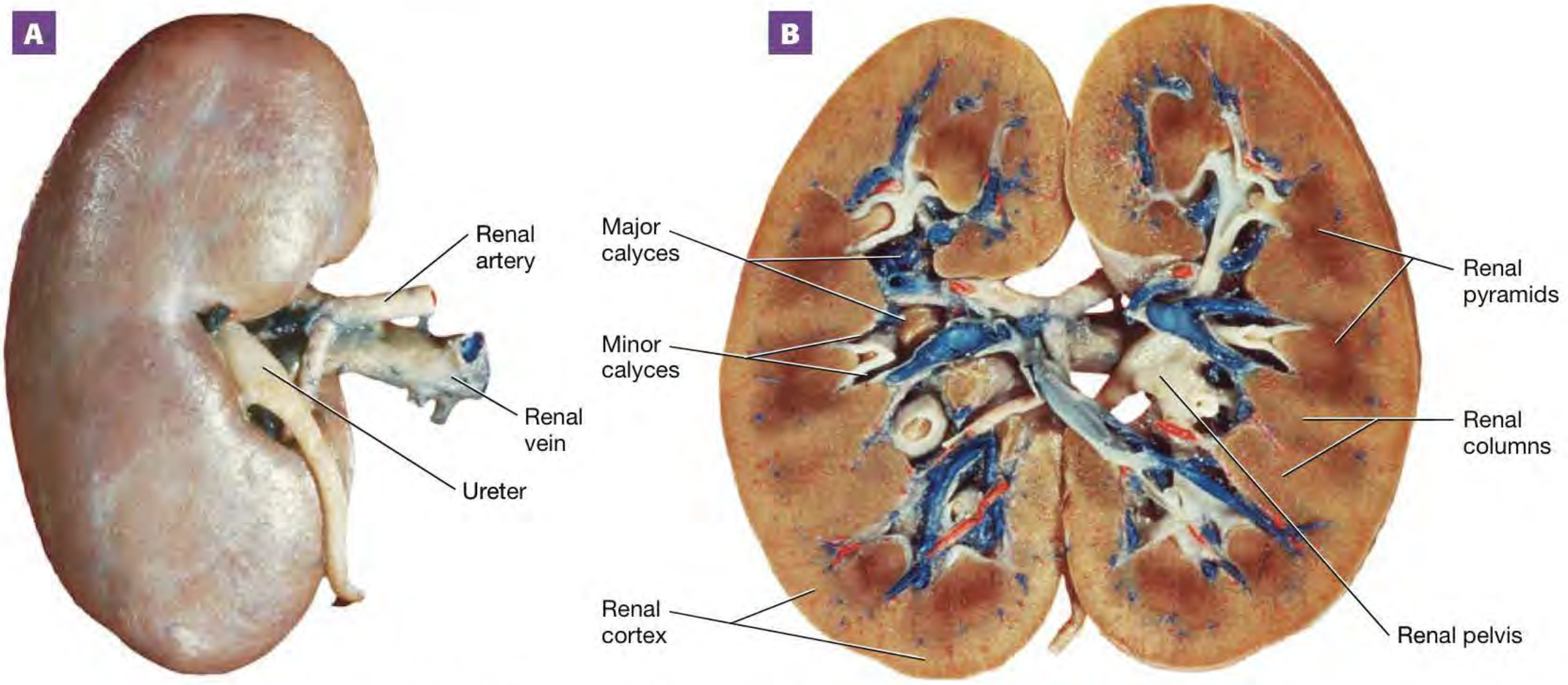


FIGURE 21.12 Preserved kidney: (A) anterior view; (B) frontal section.

5. Distinguishing between the ureter, the renal artery, and the renal vein is often difficult. Following are some hints:
   - **a** The renal artery typically has the thickest and most muscular wall, and it branches into several segmental arteries prior to entering the kidney.
   - **b** The renal vein is thinner, flimsier, and often larger in diameter than the renal artery.
   - **c** The ureter has a thick, muscular wall, too, but it does not branch after it leaves the kidney. Also, its diameter is usually smaller than either the renal artery or the renal vein.

   Keeping these points in mind, determine the location of the renal artery, the renal vein, and the ureter on your specimen. Sketch the arrangement of the three structures in the space provided:

6 Use a scalpel to make a frontal section of the kidney. Draw the kidney in the space provided and label the structures you are able to identify (Figure 21.12B):

Exercise 21-2

Urinary Organ Histology

MATERIALS

- ❑ Ureter slide
- ❑ Urinary bladder slide
- ❑ Renal cortex slide
- ❑ Renal medulla slide
- ❑ Light microscope
- ❑ Colored pencils
- ❑ Ureter slide

Like all hollow organs, the ureters and urinary bladder consist of several tissue layers (Figures 21.13 and 21.14). The innermost layer is the **mucosa,** which is composed of transitional epithelium and a thin layer of loose connective tissue. Recall from Unit 4 that transitional epithelium is stratified epithelium with cells that differ in appearance on the apical and basal sides. The cells at the apical edge are dome-shaped (or sometimes squamous) in appearance, and those nearer the basal edge are typically cuboidal. The apical cells can change shape to accommodate stretching of the urinary bladder.

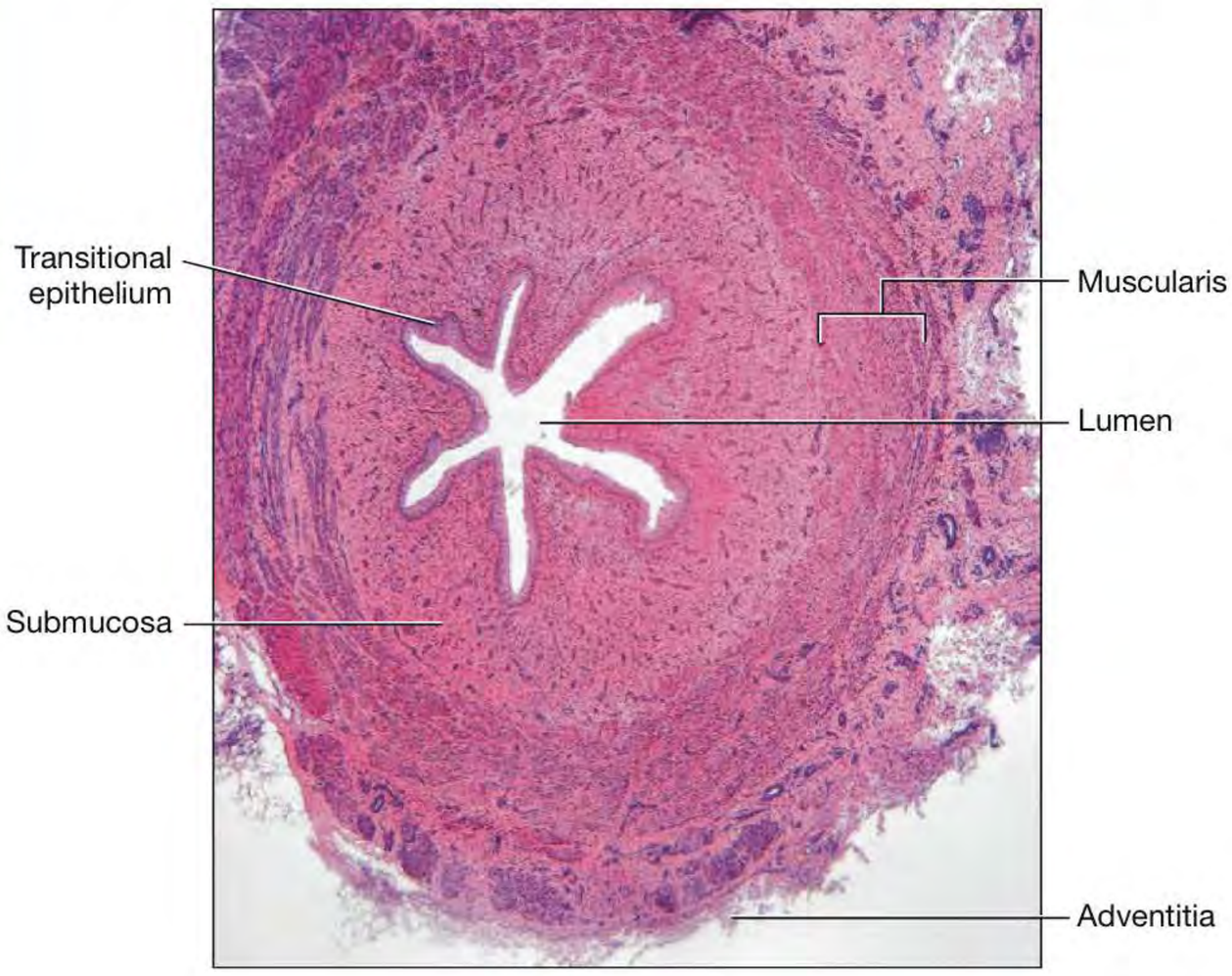


FIGURE **21.13** Tissues of the ureter.

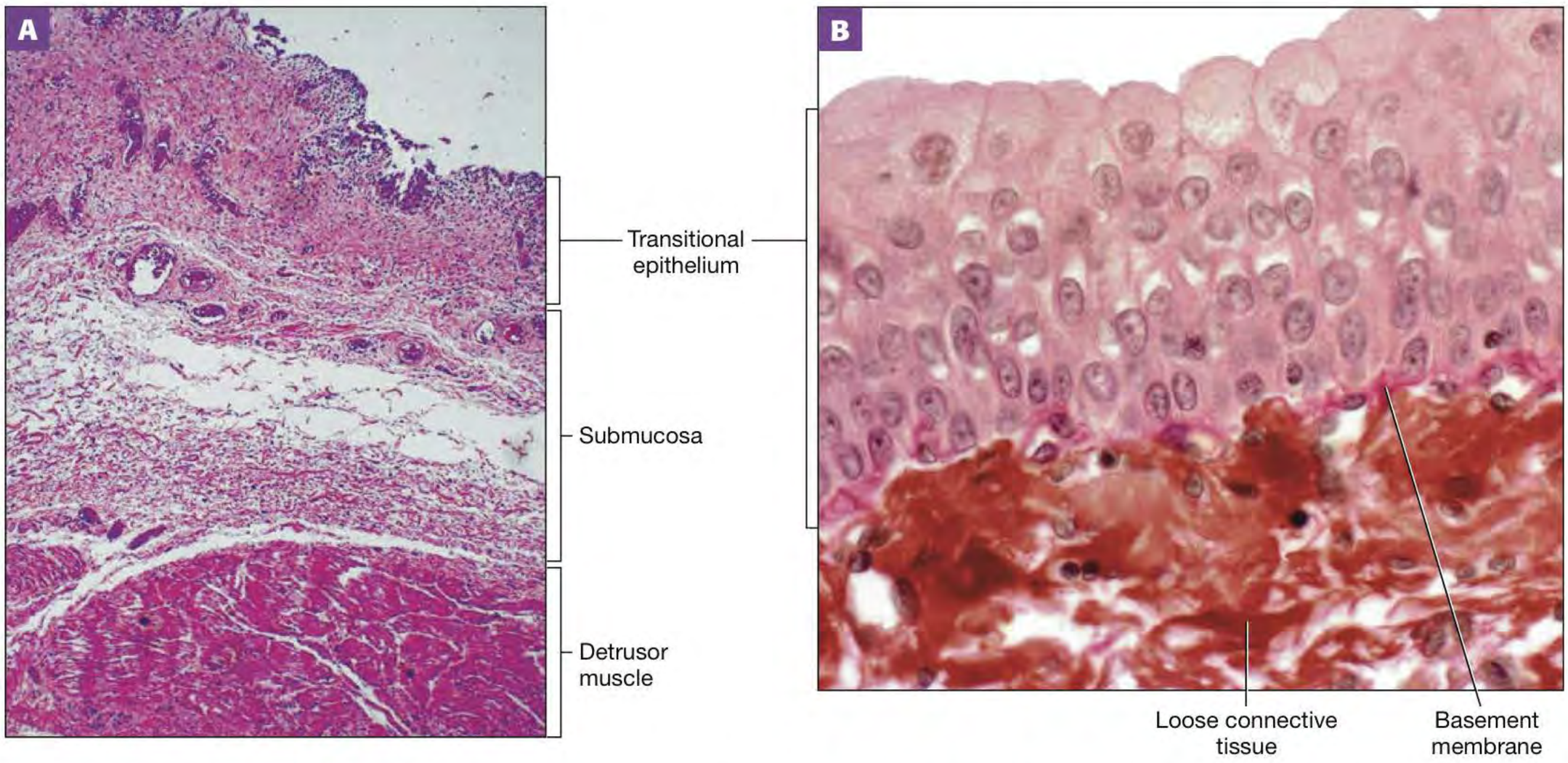


FIGURE **21.14** Urinary bladder: (**A**) bladder wall; (**B**) close-up of transitional epithelium.

The middle layer of the ureters and urinary bladder is the **submucosa**, composed of loose connective tissue and numerous glands that secrete a watery mucus. This mucus plays a critical protective role, because it prevents the chemicals in the urine from damaging and ulcerating the epithelium. The third layer is the muscularis, composed of smooth muscle that contracts to propel urine through the urinary tract. The outermost layer is the **adventitia**, composed of dense irregular collagenous connective tissue.

In this exercise you will also examine the tissues in two different regions of the kidney—the renal cortex and the renal medulla. Both regions are composed primarily of blood vessels and tubules made of simple epithelia. The simple epithelia of the renal tubules provide an example of structure following function: A main function of these tubules is to reabsorb the water and solutes in the filtrate, and they could not perform this function efficiently with thick stratified epithelium. Another structural feature that aids in reabsorption is the presence of microvilli on the proximal tubule cells (and to a much lesser extent, the distal tubule). Microvilli dramatically increase the surface area available for reabsorption, which ensures that solutes and large volumes of water are reabsorbed rapidly from the filtrate.

Note in Figure 21.15A the abundance of small, ball-shaped glomeruli in the renal cortex. The glomeruli are surrounded by a space (the capsular space) lined by the ring of simple squamous epithelial cells that make up the parietal layer of the glomerular capsule (Fig. 21.15B). Between the glomeruli, note the presence of nephron tubules (the proximal and distal tubules and sections of nephron loops).

Note in Figure 21.15C that the renal medulla is composed mostly of collecting ducts and the nephron loops. You will not see any glomeruli in the medulla, because they are confined to the cortex. This makes the renal cortex and renal medulla easily distinguishable.

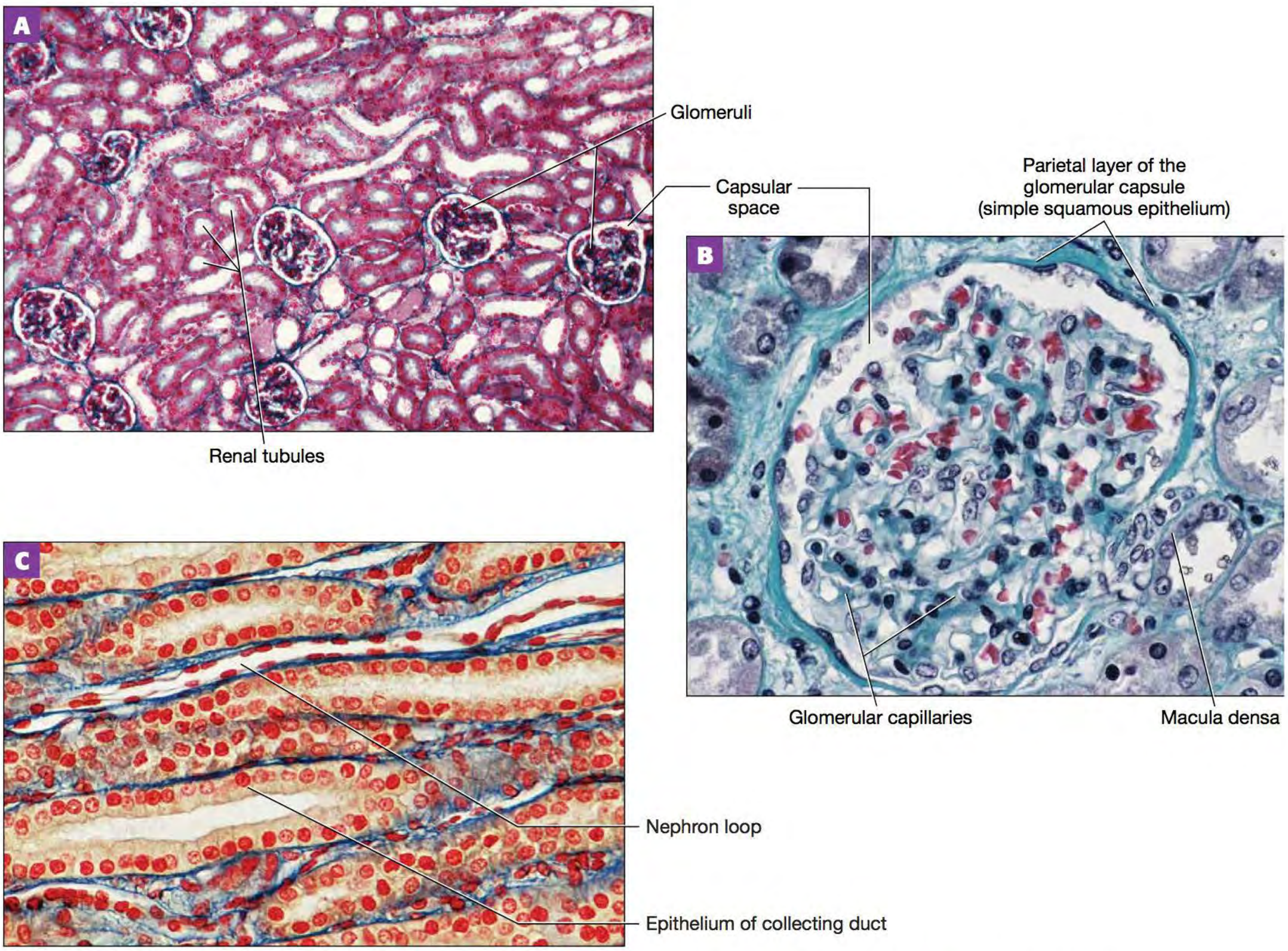


FIGURE **21.15** Tissues of the kidney: (**A**) renal cortex; (**B**) glomerulus; (**C**) renal medulla.

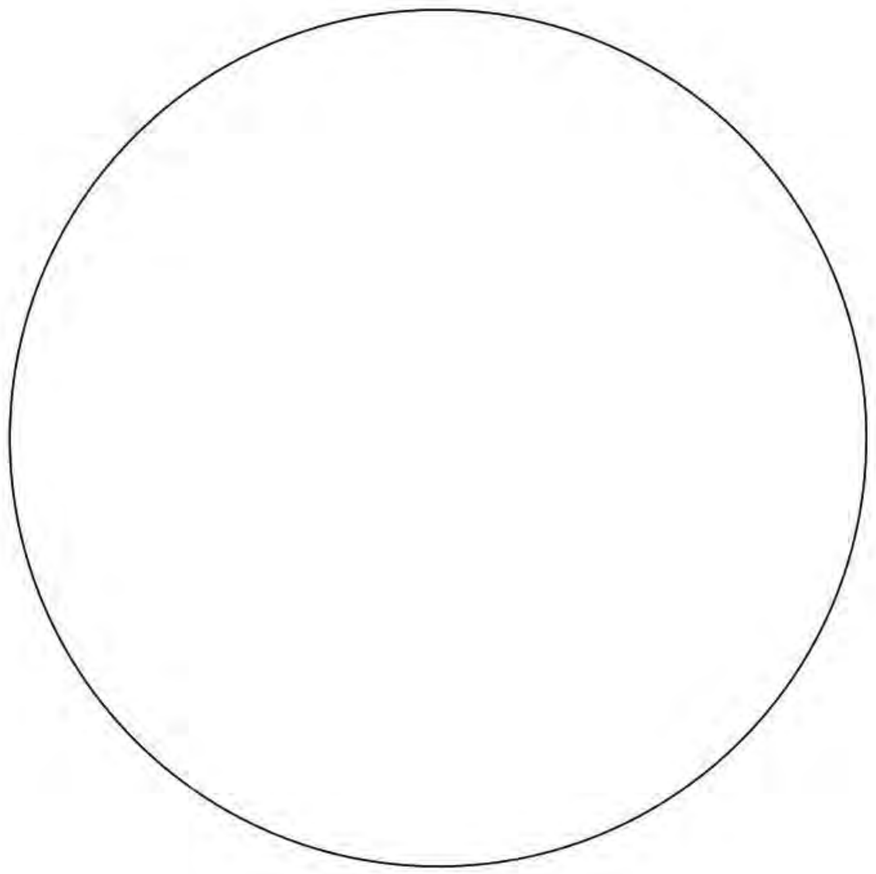
Procedure 1 Microscopy

Now you will view prepared slides of sections of the ureter, the urinary bladder, the renal cortex, and the renal medulla. Begin your examination of the slides on low power, and advance to medium and high power to observe details. Use colored pencils to draw what you see under the microscope, and label your drawing with the terms indicated. When you have completed the activity, answer Check Your Understanding questions 4 through 7 (p. 548).

Ureter

Label the following on your drawing:

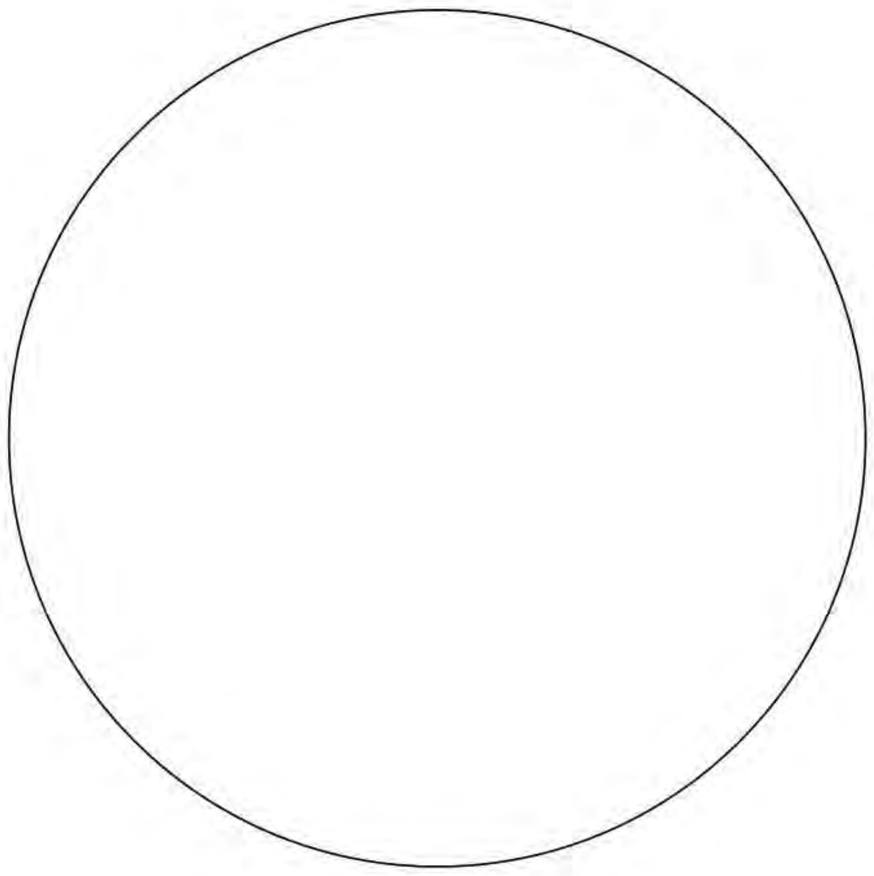
1. Transitional epithelium
2. Submucosa
3. Muscularis (smooth muscle)
4. Adventitia



Transitional Epithelium (Urinary Bladder)

Label the following on your drawing:

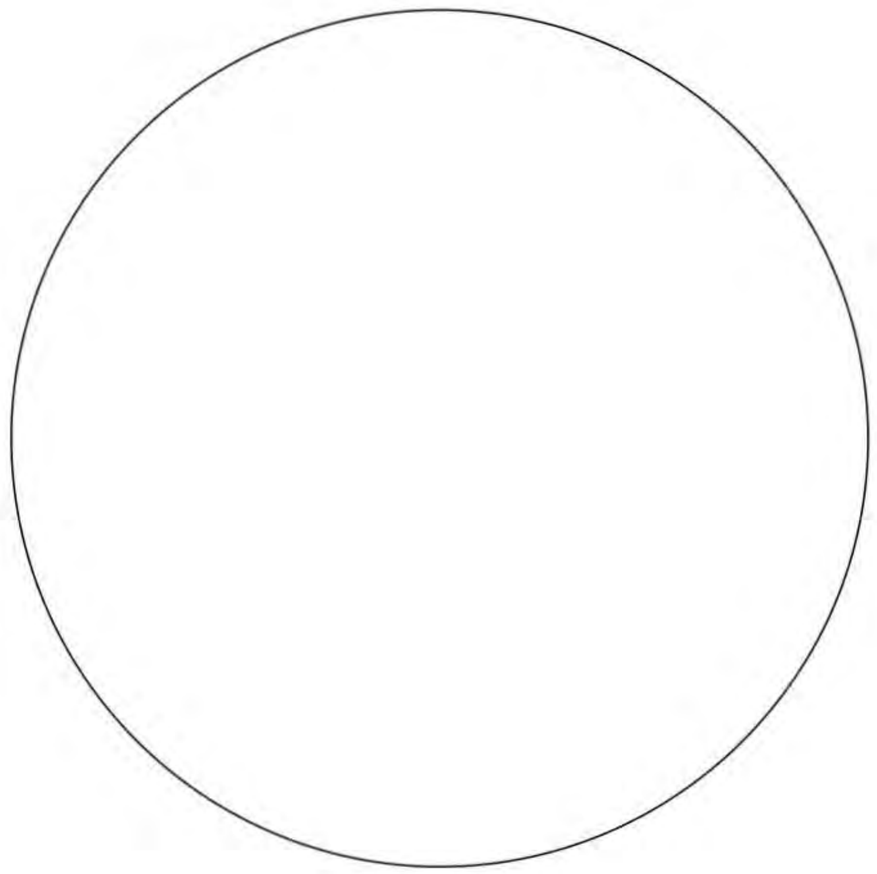
1. Transitional epithelium
2. Submucosa
3. Muscularis (detrusor muscle)



Renal Cortex

Label the following on your drawing:

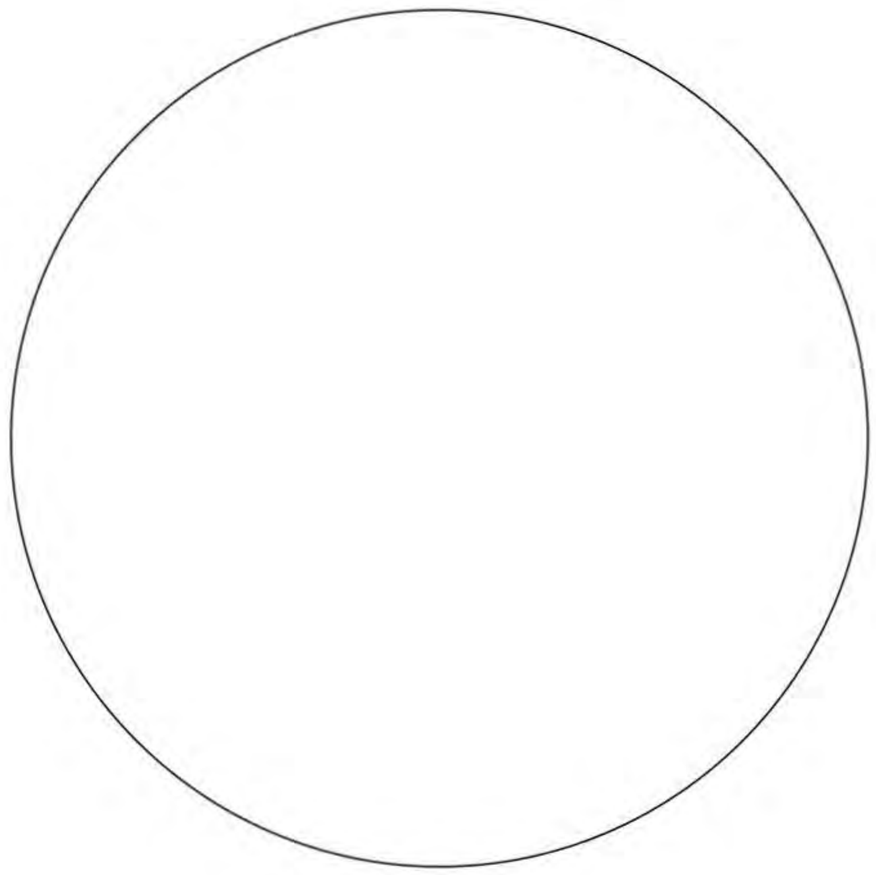
1. Glomerulus
2. Glomerular capsule with simple squamous epithelium
3. Capsular space
4. Renal tubules



Renal Medulla

Label the following on your drawing:

1. Nephron loop
2. Collecting ducts



Exercise 21-3

Time to Trace!

MATERIALS

- ❑ Anatomical models of the kidney and nephron

It's time to trace again! In this exercise you will trace the pathway of an erythrocyte and a molecule of urea through the vasculature of the kidney and the microanatomy of the kidney. Note that urea is sometimes recycled, being reabsorbed in the medullary collecting duct and secreted back into the filtrate at the proximal tubule. Your instructor may want you to take this into account in your tracing of the urea molecule, so ask before you begin your tracing.

Part 1: Erythrocyte

Trace an erythrocyte from the renal *artery* to the renal *vein*.

_____ → _____ →

_____ → _____ →

_____ → _____ →

_____ → _____ →

_____ → _____ →

_____ .

Part 2: Urea

Trace a molecule of urea from the renal artery to its final destination outside the body.

_____ → _____ →

_____ → _____ →

_____ → _____ →

_____ → _____ →

_____ → _____ →

_____ → _____ .

Name _____

Section _____ Date _____

UNIT 21 REVIEW

Check Your Recall

1 Label the following parts of the kidney on Figure 21.16.

- ❑ Major calyx
- ❑ Minor calyx
- ❑ Renal artery
- ❑ Renal capsule
- ❑ Renal column
- ❑ Renal cortex
- ❑ Renal medulla
- ❑ Renal pelvis
- ❑ Renal pyramid
- ❑ Renal vein
- ❑ Ureter

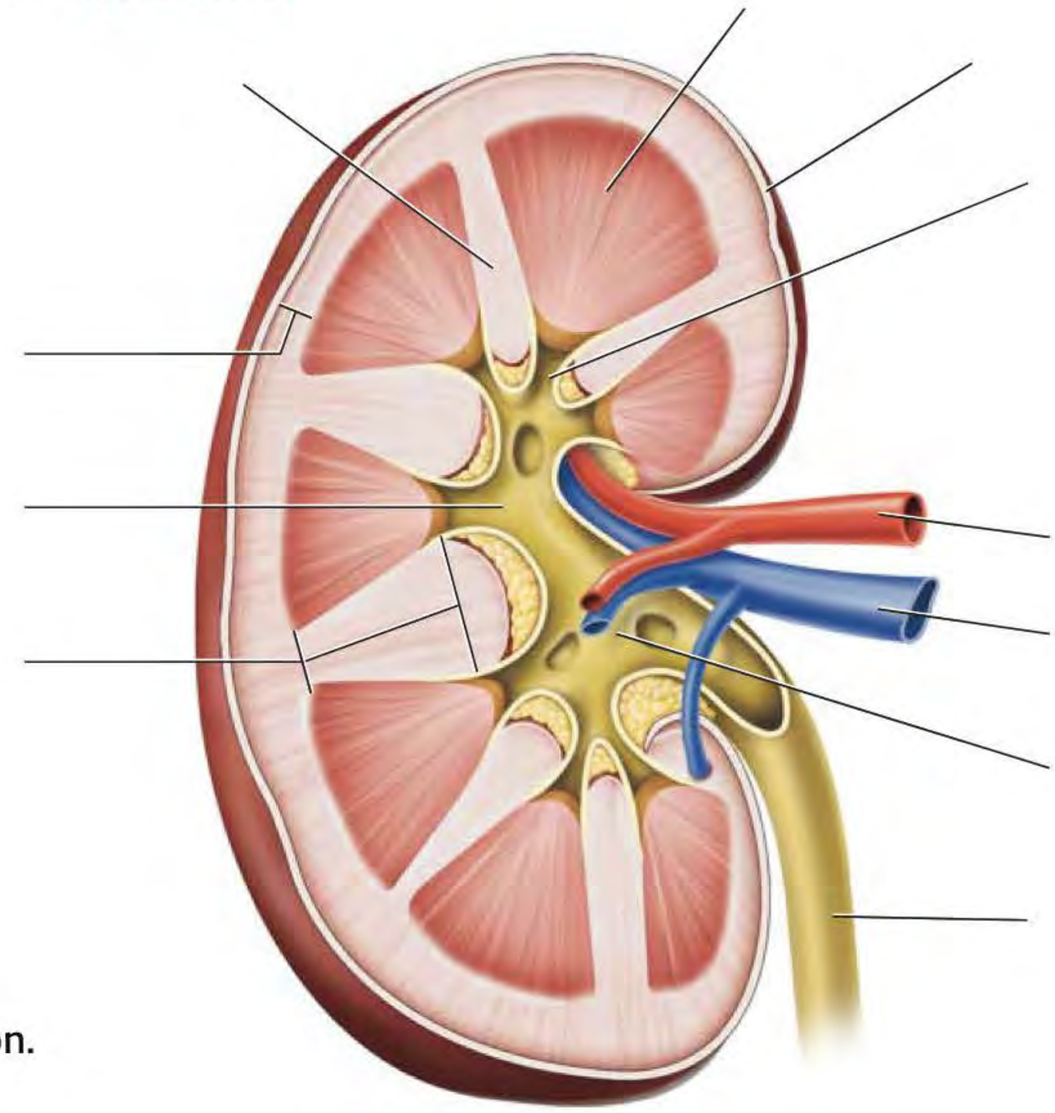


FIGURE **21.16** Right kidney, frontal section.

2 Label the following parts of the nephron on Figure 21.17.

- ❑ Afferent arteriole
- ❑ Cortical collecting duct
- ❑ Distal tubule
- ❑ Efferent arteriole
- ❑ Glomerular capsule
- ❑ Glomerulus
- ❑ Nephron loop
- ❑ Proximal tubule

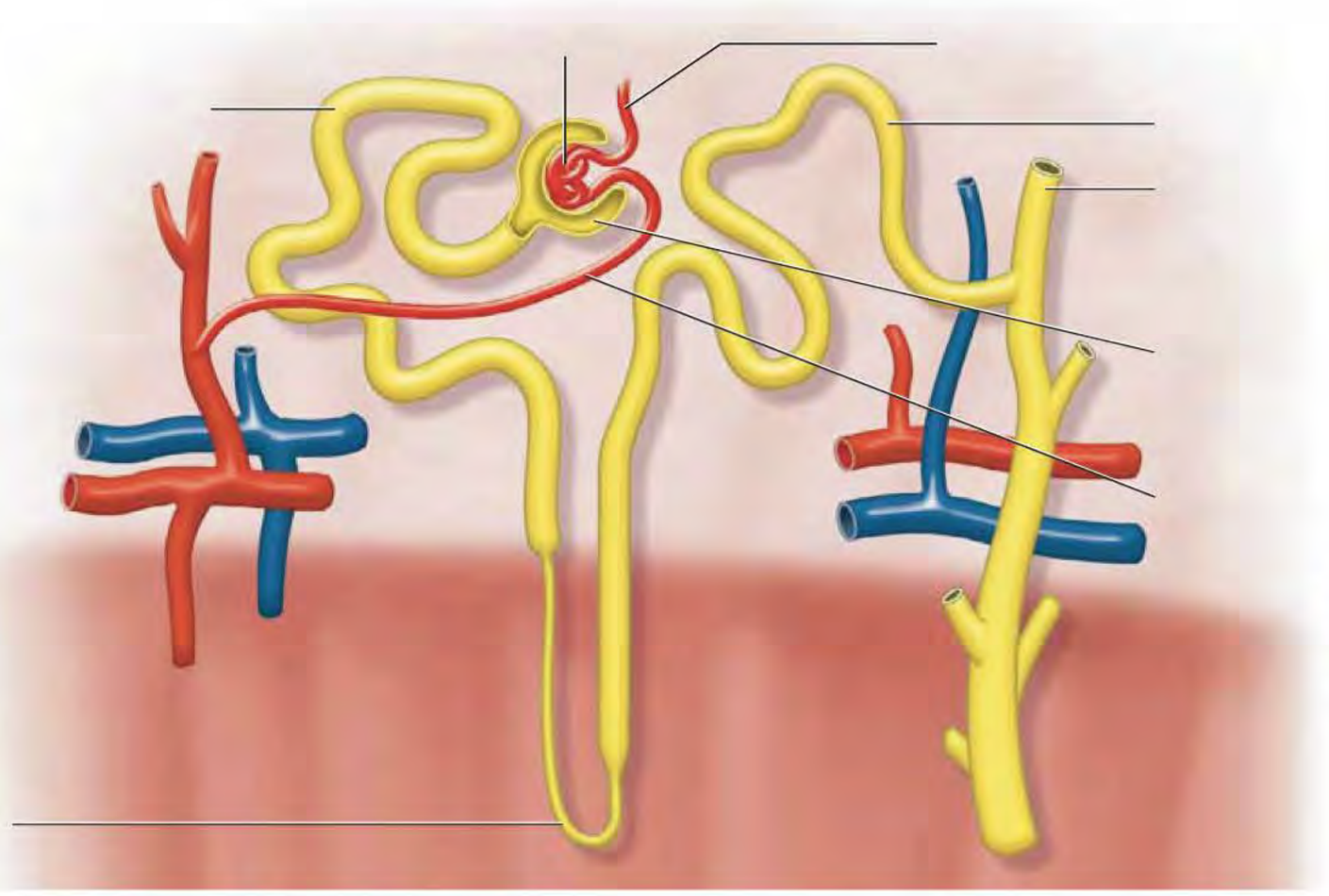


FIGURE **21.17** The nephron.

3 **Which of the following is *not* one of the urinary system's functions?**

a. Regulating fluid, electrolyte, and acid-base balance
b. Regulating blood cell formation
c. Regulating production of insulin and glucagon
d. Removing waste products from the blood

4 **The blood flow through the kidney is special because**

a. its first capillary beds drain into arterioles.
b. its second capillary beds drain into arterioles.
c. it is supplied by three renal arteries.
d. it contains no capillary beds.

5 **Number the following from the point the filtrate is first formed (with a number 1) to the point it drains into the renal pelvis (with a number 7).**

_____ Minor calyx
_____ Proximal tubule
_____ Collecting duct
_____ Capsular space
_____ Nephron loop
_____ Papillary duct
_____ Distal tubule

6 ***Fill in the blanks:*** **At the junction between the ascending limb of the nephron loop and the distal tubule, we find a group of densely packed cells called the _____. These cells come into contact with a portion of the afferent arteriole that contains cells called the _____. Together, the two are called the _____.**

7 **Urine drains from the kidneys via the**

a. urinary bladder.
b. urethra.
c. ureters.
d. papillary calyces.

8 **Urine is expelled from the body by a process called**

a. micturition.
b. parturition.
c. defecation.
d. procrastination.

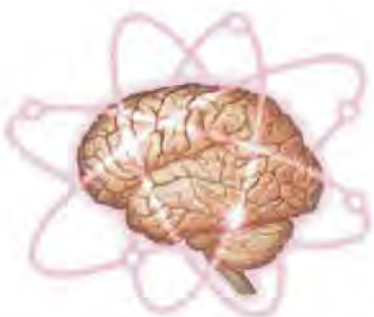
9 **The urinary bladder and ureters are lined by**

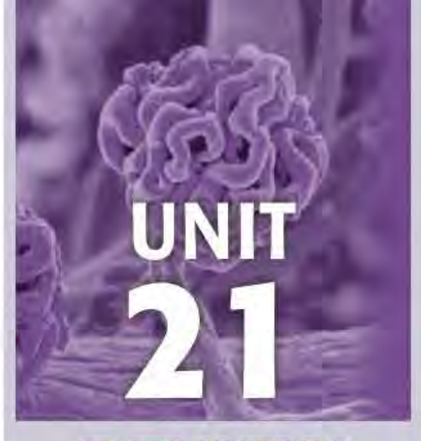
a. simple squamous epithelium.
b. transitional epithelium.
c. pseudostratified columnar epithelium.
d. stratified cuboidal epithelium.

10 **How can one easily discern the renal cortex from the renal medulla on a microscope slide?**

Name _____

Section _____ Date _____





REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 Predict the effects renal failure might have on the body's overall homeostasis.

2 Why do the medullary pyramids appear different from the renal cortex and renal columns? Why do the renal columns and renal cortex appear similar in color and texture?

3 How is the pattern of blood flow unique in the kidney? How does this pattern of blood flow allow the kidney's structure to follow its function?

4 Why do you think the epithelium of the urinary bladder is stratified? What might happen if the epithelial tissue were simple rather than stratified? (*Hint*: Remember that structure follows function.)

5 The condition *interstitial cystitis* is characterized by insufficient mucus production by the mucosa and submucosa of the urinary bladder. What signs and symptoms would you expect to see with interstitial cystitis? Why?

6 How does the structure of the simple epithelial tissues that make up the renal tubules follow its function?

7 Predict how the functioning of the kidney might be affected if the microvilli in the proximal tubules were destroyed. Explain your reasoning.

22 Reproductive System

OBJECTIVES

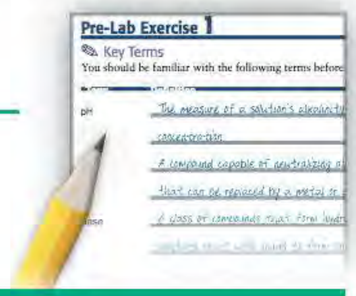
Once you have completed this unit, you should be able to:

1. Identify structures of the male and female reproductive systems.
2. Describe the histology of the ovary, seminiferous tubules, and spermatozoa.
3. Describe the basic processes of meiosis, oogenesis, and spermatogenesis.

Name _____ Section _____ Date _____

PRE-LAB EXERCISES

Complete the following exercises prior to coming to lab, using your textbook and lab manual for reference.



Pre-Lab Exercise 22-1

Key Terms

You should be familiar with the following terms before coming to lab.

Term	Definition

Structures of the Male Reproductive System

Testes _____

Seminiferous tubules _____

Epididymis _____

Ductus deferens _____

Spermatic cord _____

Seminal vesicle _____

Prostate gland _____

Corpus spongiosum _____

Corpora cavernosa _____

Structures of the Female Reproductive System

Ovaries _____

Ovarian follicles _____

Uterine tube _____

Name _____ Section _____ Date _____

Uterus _____

_____

Cervix _____

_____

Vagina _____

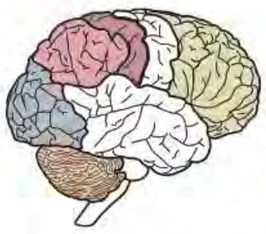
_____

Vulva _____

_____

Mammary glands _____

_____



Pre-Lab Exercise 22-2

Male Reproductive Anatomy

Label and color the structures of the male reproductive system in Figure 22.1 with the terms from Exercise 22-1 (p. 553). Use your text and Exercise 22-1 in this unit for reference.

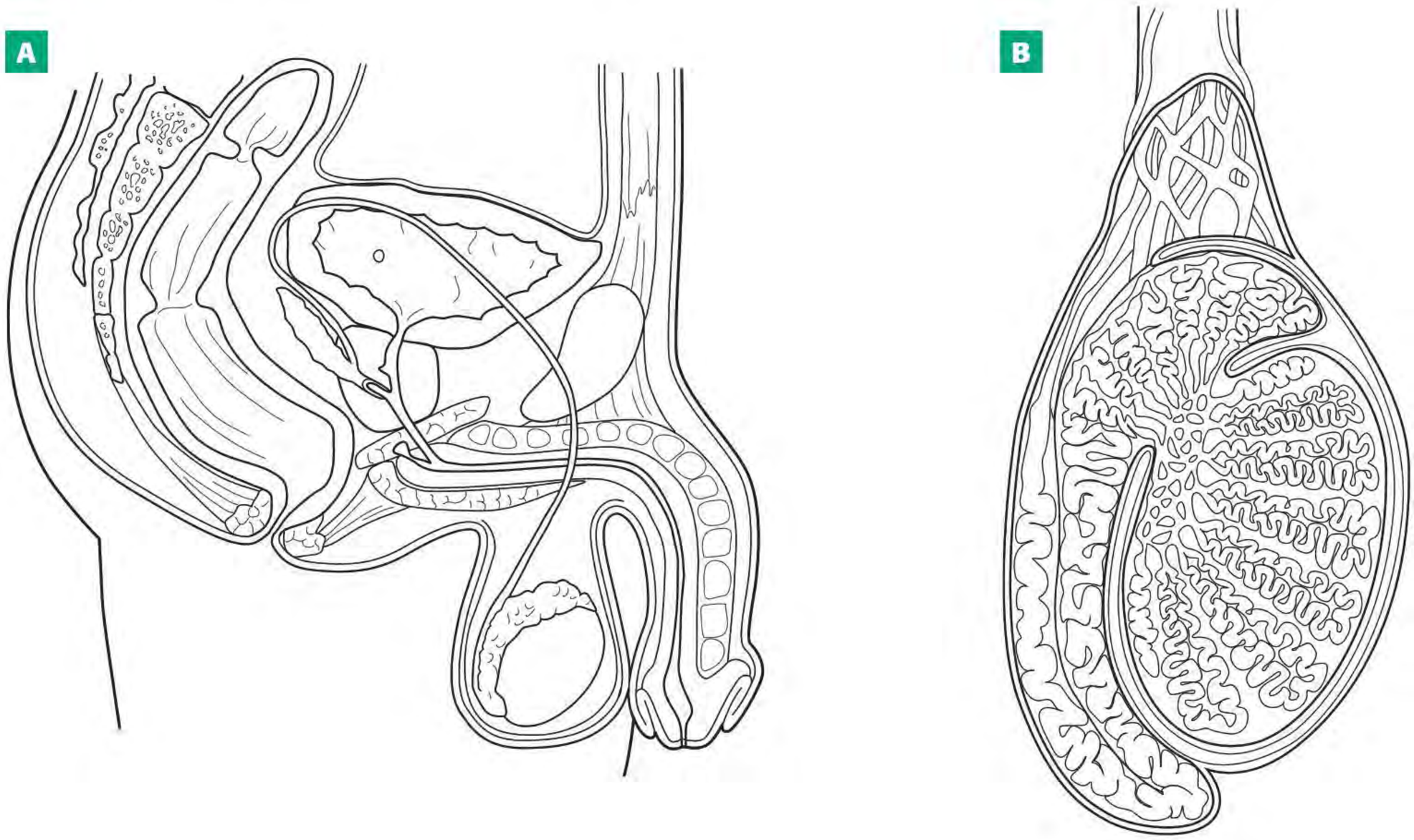


FIGURE **22.1** Male reproductive organs, midsagittal sections: (**A**) male pelvis; (**B**) through the testis.

Pre-Lab Exercise 22-3

Female Reproductive Anatomy

Label and color the structures of the female reproductive system in Figure 22.2 with the terms from Exercise 22-2 (p. 556). Use your text and Exercise 22-2 in this unit for reference.

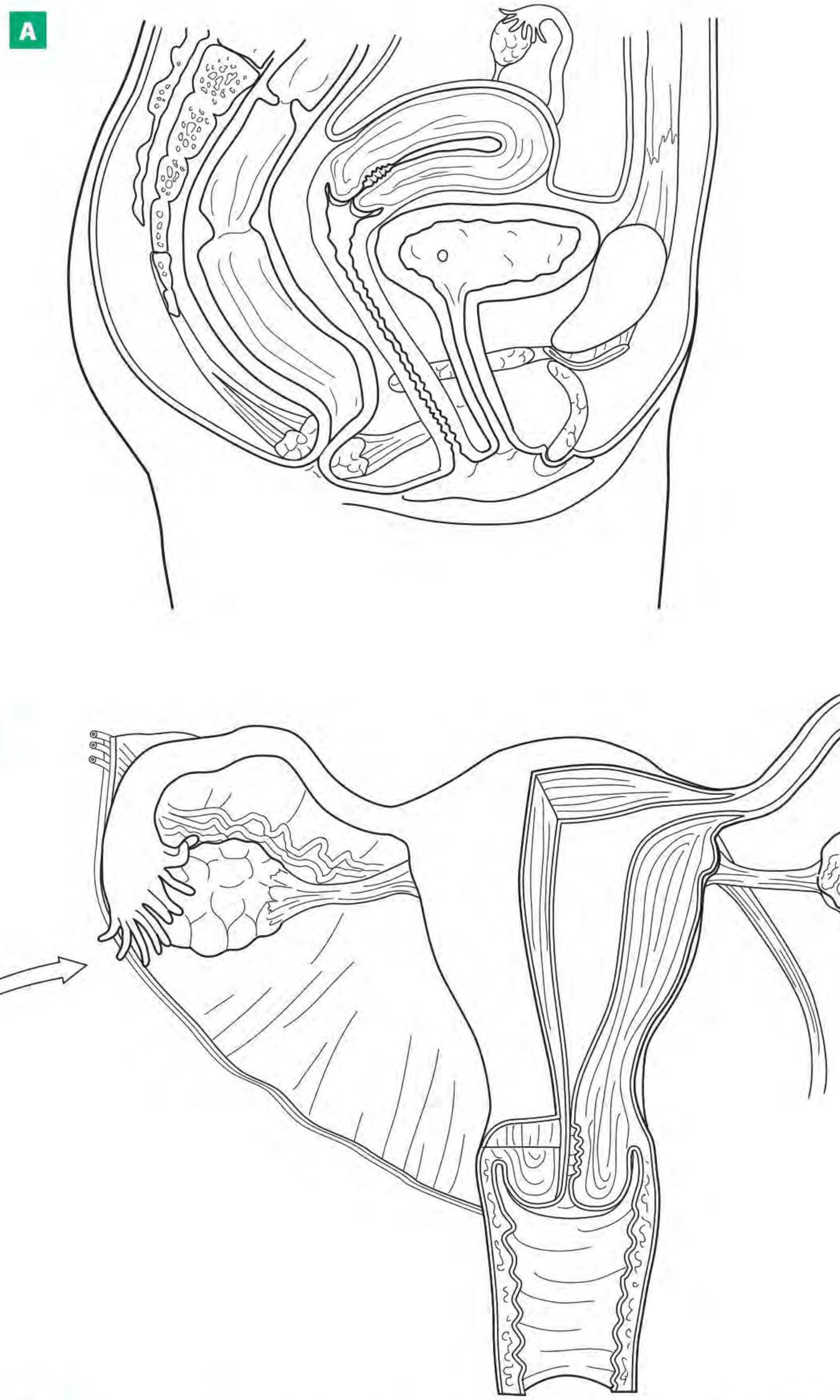


FIGURE **22.2** Female reproductive tract: (**A**) midsagittal section of the female pelvis; (**B**) posterior view of the female reproductive organs.

EXERCISES

The other organ systems in the human body we have discussed all function in some manner to help maintain homeostasis of the body. The reproductive system, however, plays little role in maintaining homeostasis and instead functions to perpetuate the species. The main organs of the reproductive system are the **gonads**—the testes and the ovaries—which produce **gametes**, or sex cells, for reproduction.

We begin this unit with the anatomy of the male (Exercise 22-1) and female (Exercise 22-2) reproductive systems. Then we turn to the main functions of these organs: **gametogenesis**, the formation of new gametes.

Exercise 22-1

Male Reproductive Anatomy

MATERIALS

- ❑ Male reproductive models
- ❑ Human torso models

The **testes**, the gamete-producing organs of the male, are situated outside the body in a sac known as the **scrotum**, which is composed of skin, connective tissue, and a layer of smooth muscle called the **dartos muscle** (Figure 22.3). Along the midline, the scrotum has a connective tissue septum that divides it into two chambers, one for each testis. They are located externally because sperm production requires a temperature lower than body temperature of about 34°C (about 94°F). Smooth muscle tissue called the **cremaster muscle** (kreh-MASS-ter) surrounds each testis in the scrotum, which helps to control their height and therefore their temperature.

The layer of connective tissue deep to the scrotum extends up into the pelvic cavity to form a structure known as the **spermatic cord**. Notice in Figure 22.3 that the spermatic cord surrounds the cremaster muscle, the **testicular artery**, a group of veins draining the testis called the **pampiniform venous plexus**, a duct that transports sperm known as the *ductus deferens*, and nerves that supply the testes. The spermatic cord passes into the pelvic cavity through the *external inguinal ring*, which is the opening to a small passageway called the **inguinal canal** (IN-gwih-nul).

Deep to the cremaster muscle we find two more connective tissue sheaths: the superficial **tunica vaginalis** and the deep **tunica albuginea** (al-byoo-JIN-ee-uh), which divides the interior of each testis into **lobules** (Figure 22.4). Each lobule contains a tightly coiled **seminiferous tubule** (sem-ih-NIF-er-us) where **spermatogenesis** (sper-mat-oh-JEN-ih-sis), or the formation of sperm cells, takes place.

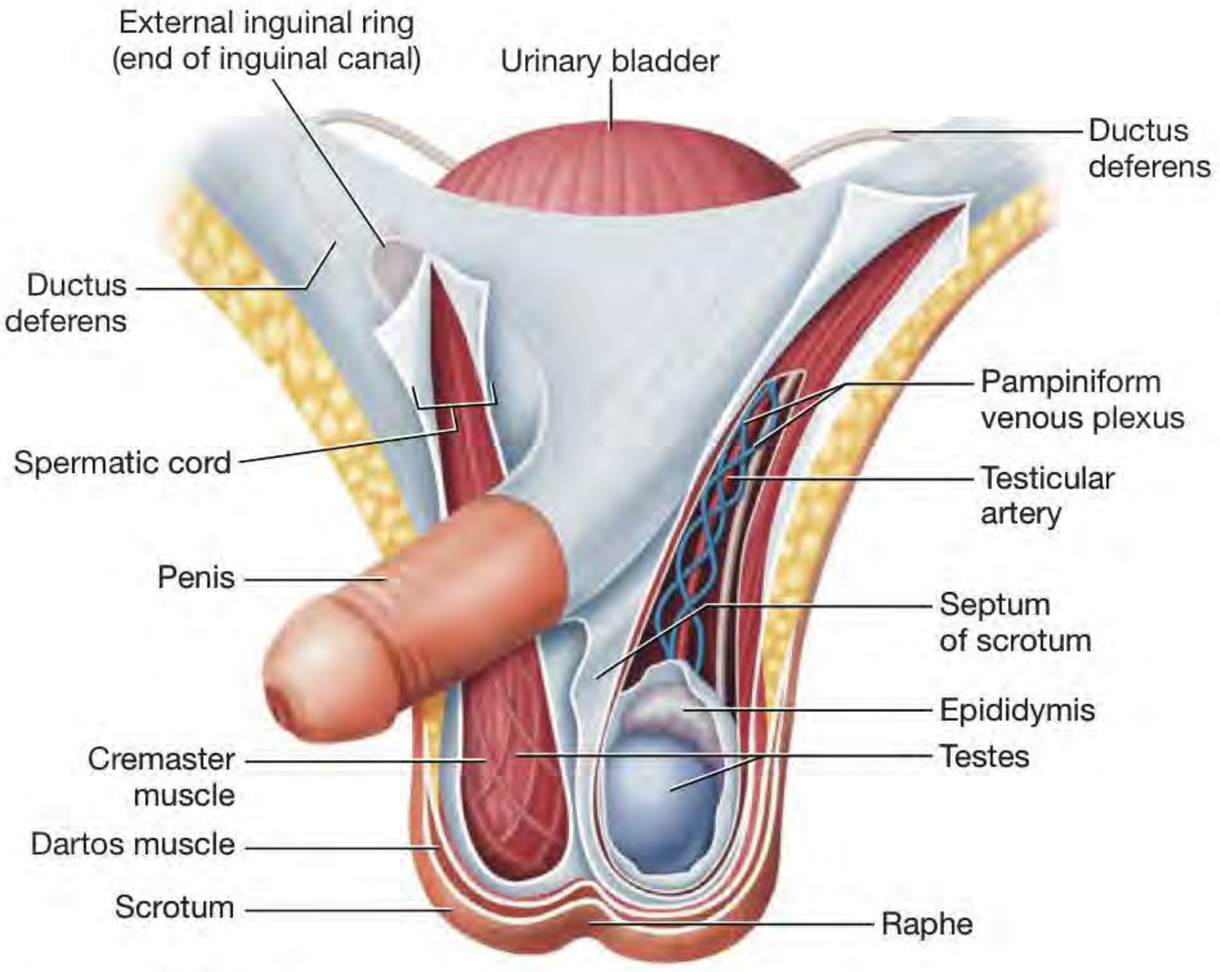


FIGURE **22.3** The scrotum and spermatic cord.

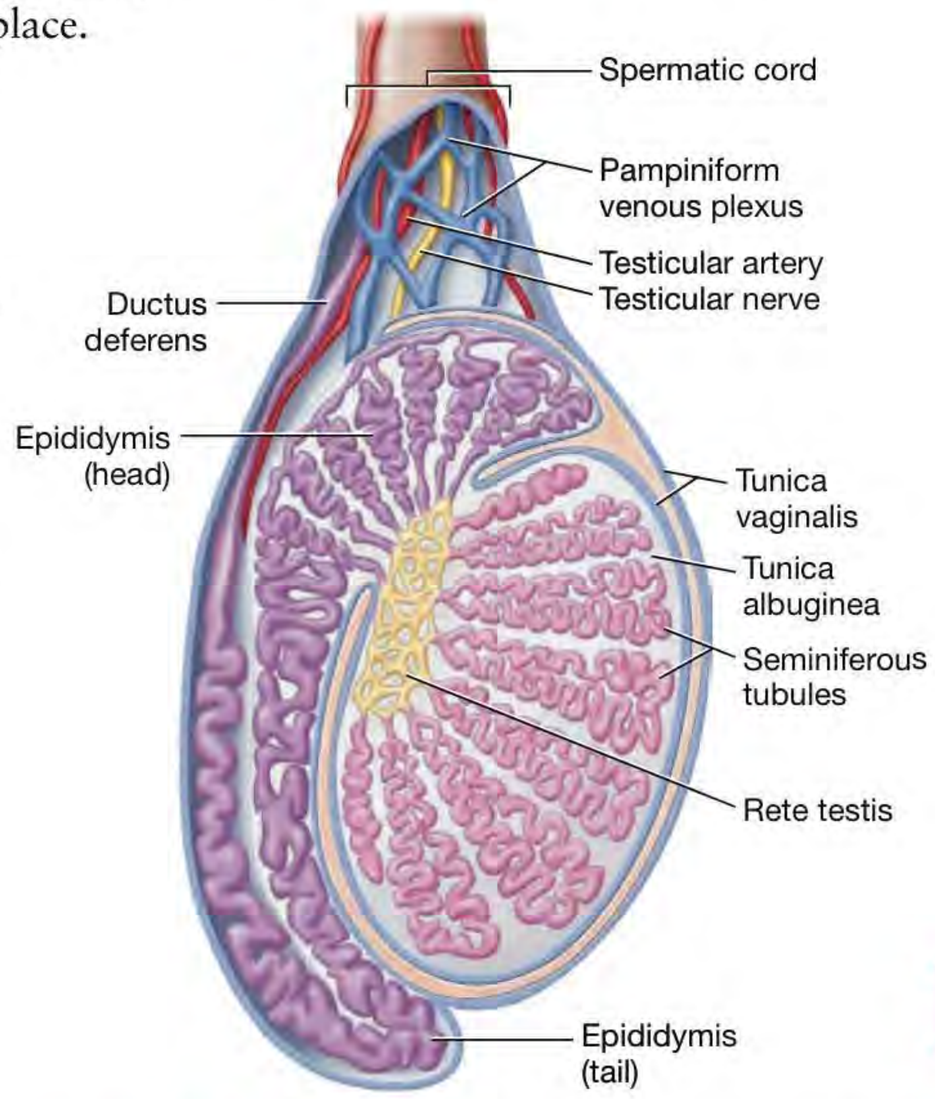


FIGURE **22.4** Midsagittal section through the testis.

The seminiferous tubules converge near the superior part of the testis to form a structure called the **rete testis** (REE-tee TES-tis). The rete testis exits the testis to join the first segment of the duct system of the male reproductive tract, the **epididymis** (ep-ih-DID-ih-miss; Figures 22.4 and 22.5). There are three portions of the epididymis: the initial *head*, the middle *body*, and the final *tail*. Immature sperm produced by the seminiferous tubules migrate through each of these regions of the epididymis to finish their maturation, after which they exit via a long tube called the **ductus** (or vas) **deferens** (DUK-tuss DEF-er-ahnz). The ductus deferens travels superiorly through the **spermatic cord** to enter the pelvis cavity.

Note in Figure 22.5 that once the ductus deferens enters the pelvic cavity, it crosses superiorly and posteriorly over the urinary bladder to join a gland called the **seminal vesicle**. At this point, the ductus deferens merges with the duct from the seminal vesicle to form the **ejaculatory duct**. This duct passes through the **prostate gland** (PRAH-stayt—be sure not to call it the "prostrate"), where it joins with the **prostatic urethra**. The prostatic urethra becomes the **membranous urethra** as it exits the prostate, and then becomes the **spongy urethra** as it enters the corpus spongiosum of the penis.

The male reproductive tract consists of three exocrine glands: the prostate gland, seminal vesicles, and **bulbourethral glands** (bul-boh-yoo-REETH-ruhl; Figures 22.5 and 22.6). The seminal vesicles and the prostate gland together produce about 90% of the volume of **semen**, a fluid that contains chemicals to nourish and activate sperm. The smaller bulbourethral glands produce an alkaline secretion released prior to the release of sperm during ejaculation.

The **penis** is composed of three erectile bodies: the single **corpus spongiosum** (KOHR-pus spon-jee-OH-sum) and the paired, dorsal **corpora cavernosa** (kohr-POHR-ah kah-ver-NOH-sah). The corpus spongiosum, which surrounds the spongy urethra, enlarges distally to form the **glans penis**. All three bodies consist of vascular spaces that fill with blood during an erection.

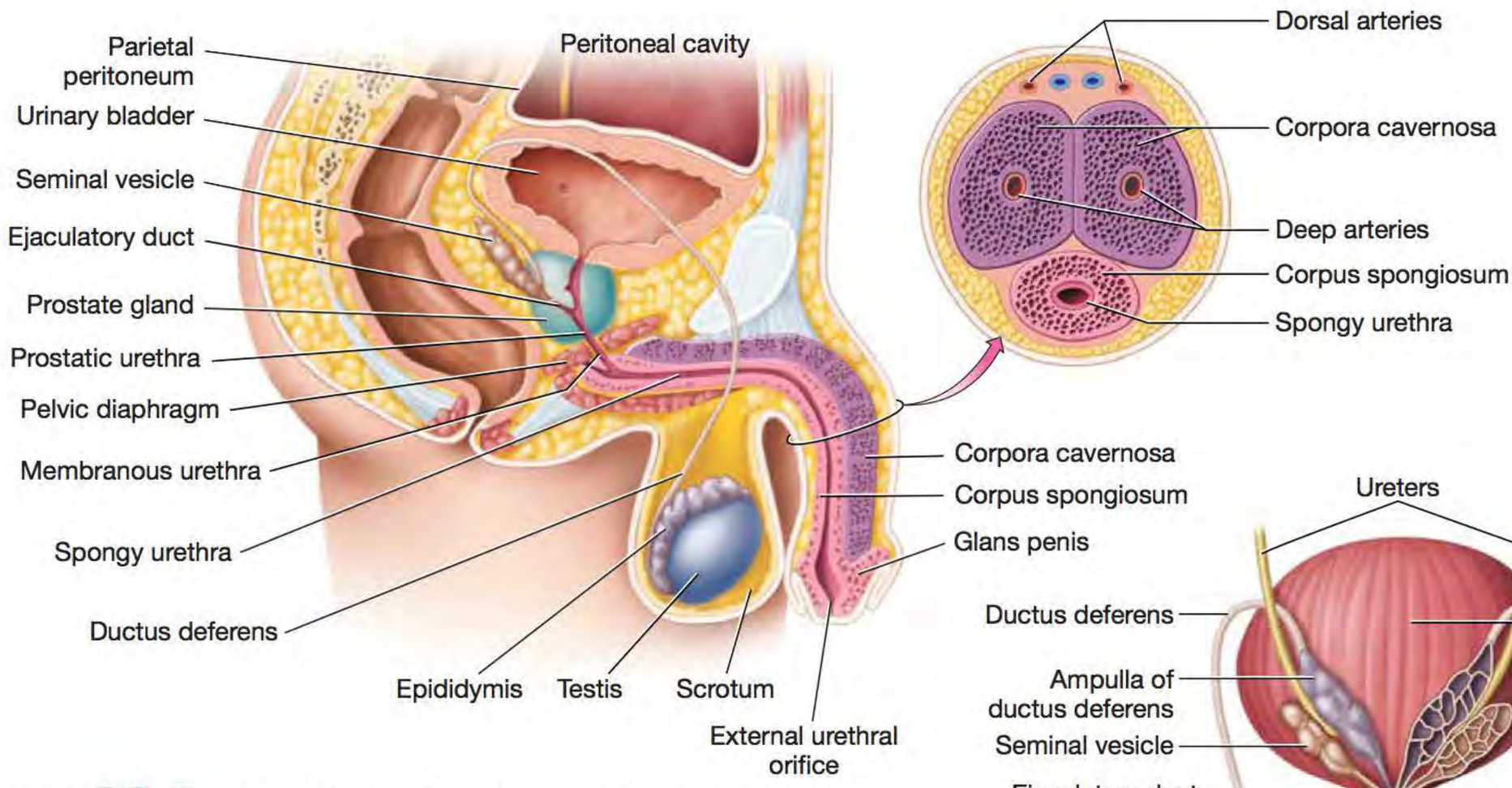


FIGURE **22.5** Midsagittal section through the male pelvis.

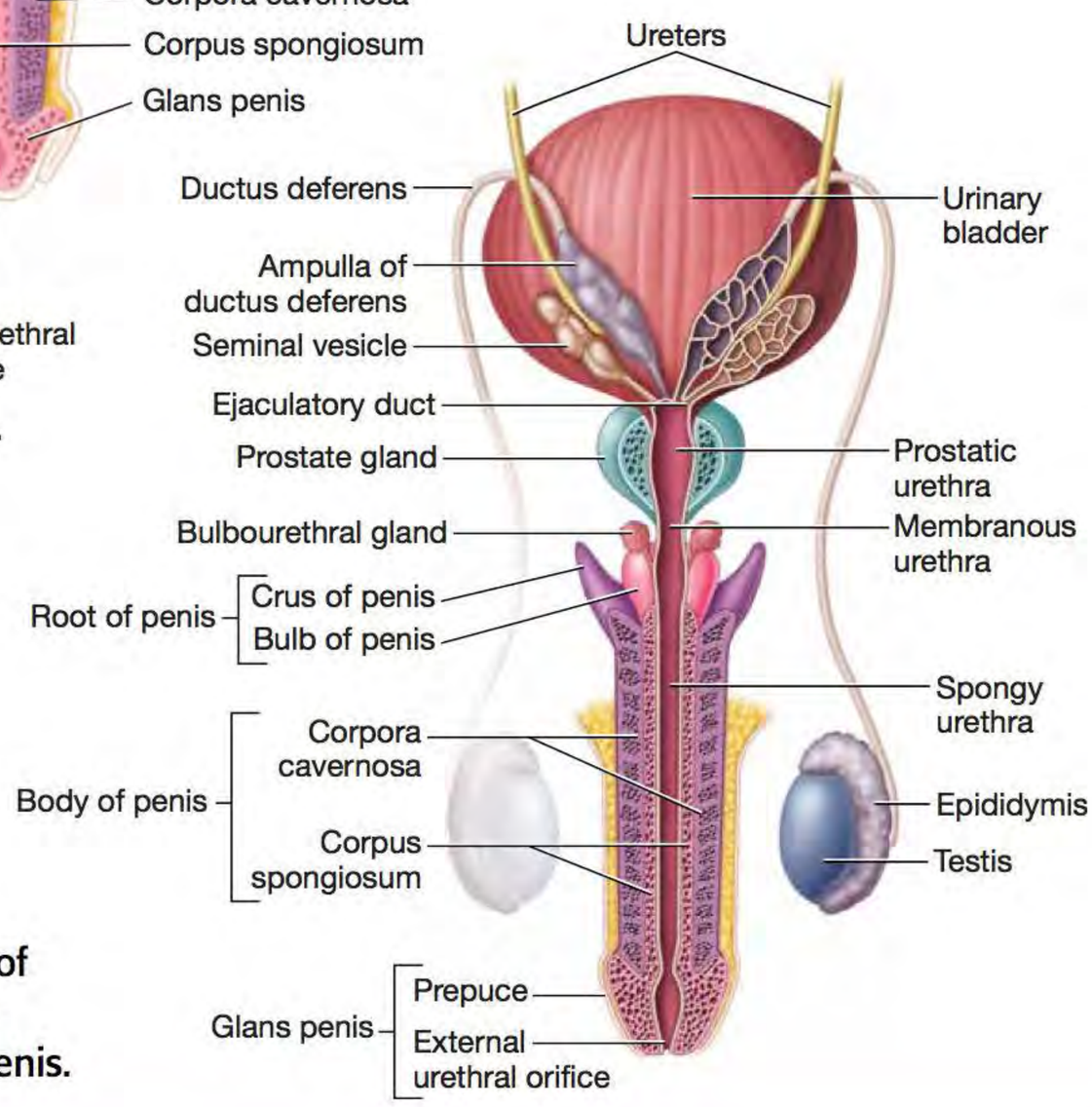


FIGURE **22.6** Posterior view of the male reproductive system with a frontal section of the penis.

Procedure 1 Model Inventory of the Male Reproductive System

Identify the following structures of the male reproductive system on models and diagrams using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 22.1. When you have completed the activity, answer Check Your Understanding questions 1 through 3 (p. 567).

1. Scrotum
2. Cremaster muscle
3. Spermatic cord
   a. Testicular arteries
   b. Pampiniform venous plexus
4. Testes
   a. Tunica albuginea
   b. Tunica vaginalis
   c. Seminiferous tubules
   d. Rete testis
5. Epididymis (head, body, tail)
6. Ductus deferens
7. Seminal vesicle
8. Ejaculatory duct
9. Prostate gland
10. Urethra
    a. Prostatic urethra
    b. Membranous urethra
    c. Spongy urethra
    d. External urethral orifice
11. Bulbourethral gland
12. Penis
    a. Corpora cavernosa
    b. Corpus spongiosum
       (1) Glans penis

TABLE 22.1 Model Inventory for the Male Reproductive System

Model/Diagram	Structures Identified

Exercise 22-2

Female Reproductive Anatomy

MATERIALS

- ❑ Female reproductive models
- ❑ Human torso models

The female reproductive organs are located in the pelvic cavity, with the exception of the almond-shaped **ovaries**, which are found in the peritoneal cavity (Figures 22.7 and 22.8). The **ovaries** are the female gonads, which produce **oocytes** (OH-oh-syt′z) that travel through the reproductive tract to be fertilized. Oocytes are located within small sacs in the ovary called **follicles** that sit in the outer region of the ovary, the **ovarian cortex**. The inner region of the ovary, where we find primarily blood vessels, is the **ovarian medulla**.

The ovaries are held in place by several ligaments, including the **ovarian ligament**, which attaches the ovary to the uterus; a sheet of connective tissue called the **broad ligament**, which anchors it to the lateral pelvic wall; and the **suspensory ligament**, which attaches the ovary to the posterolateral pelvic wall. Notice in Figure 22.7 that the suspensory ligaments also carry with them the ovaries' blood supply.

The duct system of the female reproductive system begins with the **uterine tube**. The uterine tube is not directly connected to the ovary. For this reason, when an oocyte is released from the ovary, it is actually released into the pelvic cavity and the uterine tube must "catch" it and bring it into the tube. This is accomplished by fingerlike extensions of the tube called **fimbriae** (FIM-bree-ay). The next region of the uterine tube is the wide **infundibulum**, followed by the **ampulla**, and finally the **isthmus**, where it joins the uterus. Like the ovaries, the uterine tubes are anchored by the broad ligament.

The uterine tubes join the superolateral portion of the **uterus** (YOOT-er-us), which is the organ in which a fertilized ovum implants, and in which an embryo and fetus develop. As you can see in Figure 22.8, the uterus is situated posterior to the urinary bladder and anterior to the rectum. It is held in place by several ligaments: the broad ligament anchors it to the anterior and lateral pelvis; the **round ligaments** anchor it to the anterior abdominal wall (visible in Figure 22.8); and the **uterosacral ligaments** (yoo-ter-oh-SAY-krul) anchor it posteriorly to the sacrum.

The uterus has three regions: the dome-shaped **fundus**, the central **body**, and the narrow **cervix**. The opening of the cervix is known as the **cervical os**. The uterine wall is quite thick, and its thickness changes as it progresses through the 28-day uterine cycle. There are three layers to the uterine wall: the inner epithelial and connective tissue lining called the **endometrium** (en-doh-MEE-tree-um), in which a fertilized ovum implants; the middle, muscular **myometrium** (MY-oh-mee-tree-um), composed of smooth muscle tissue; and the outermost **perimetrium** (pehr-ee-MEE-tree-um), which is an extension of the peritoneum.

The **vagina** is a tube about 8–10 cm (3.1–3.9 in) long that extends inferiorly from the cervical os and terminates at the vaginal orifice. The superior end of the vagina forms a recess around the cervical os called the **fornix**. Note that the

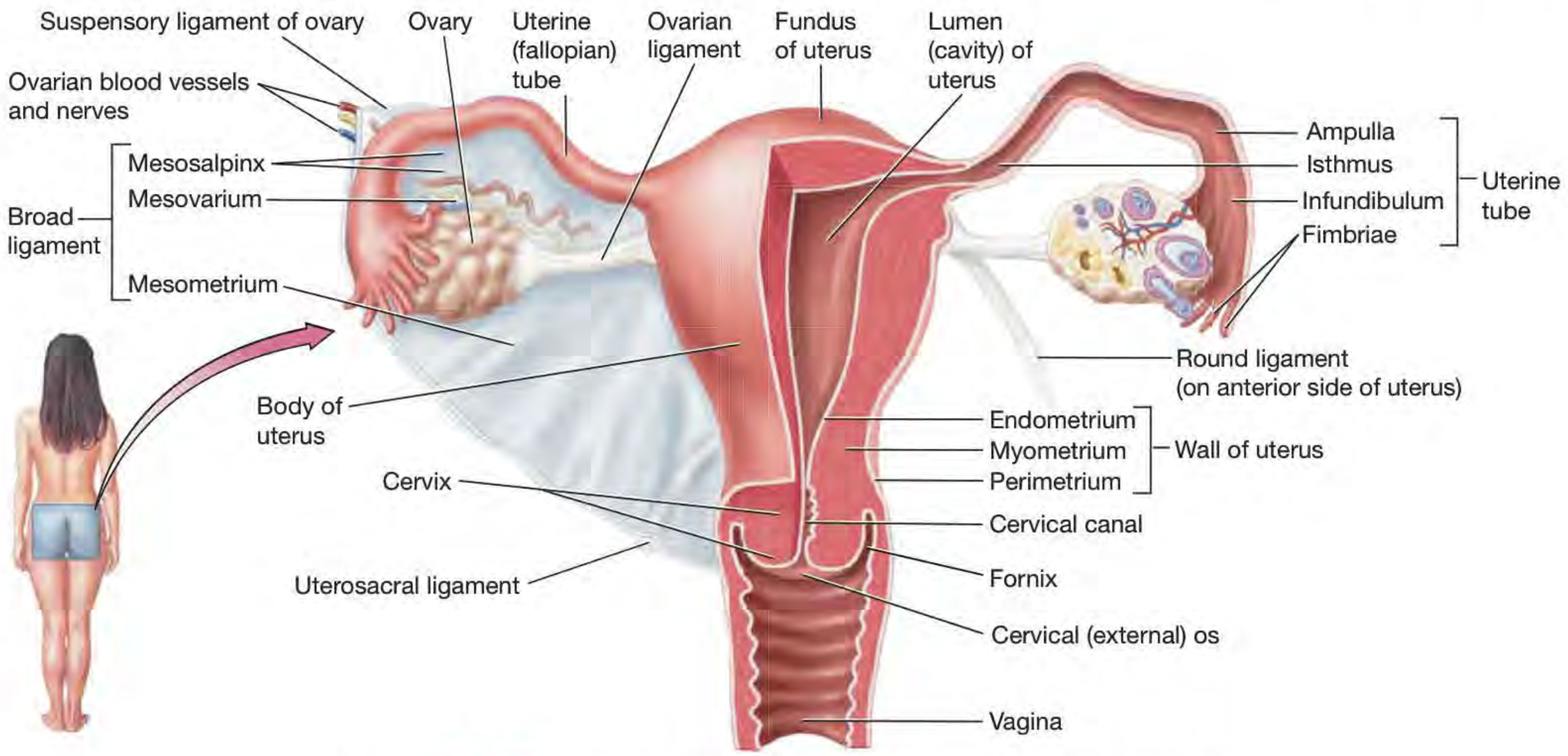


FIGURE **22.7** Posterior view of the female reproductive organs.

vagina is entirely *internal*, although it is frequently and incorrectly referred to as the female's external genitalia. Flanking the vaginal orifice are the **greater vestibular glands**, which secrete mucus to lubricate the vaginal canal during coitus (Figure 22.9).

The external genitalia of the female is collectively called the **vulva** (Figure 22.9), although it is quite often incorrectly called the vagina, even by women. It begins with the **mons pubis** (MAHNS PYOO-biss), the rounded area over the pubic symphysis that is covered in pubic hair after puberty. Posterior to the mons pubis are the **labia majora** and **labia minora** (LAY-bee-ah; singular: labium major and minus, respectively), fatty skin folds that enclose an area called the **vestibule.** Within the vestibule we find the *urethral* and *vaginal orifices* and the *paraurethral glands*. Anterior to the urethral orifice is the **clitoris** (KLIT-uhr-is), which is composed of erectile tissue.

The **mammary glands** are not true reproductive organs—indeed, they are modified sweat glands and part of the integumentary system—but do have an associated reproductive function in milk production (Figure 22.10; note that this figure shows a lactating mammary gland). Mammary glands are present in both males and females (males can produce milk, too), but their anatomy is most appropriately discussed with female anatomy. Internally, mammary glands consist of 15–25 **lobes,** each of which has smaller **lobules** that contain milk-producing **alveoli.** Milk leaves the alveoli through **lactiferous ducts,** which join to form storage areas called **lactiferous sinuses.** Milk leaves through the **nipple,** which is surrounded by a darkly pigmented area called the **areola** (aehr-ee-OH-lah).

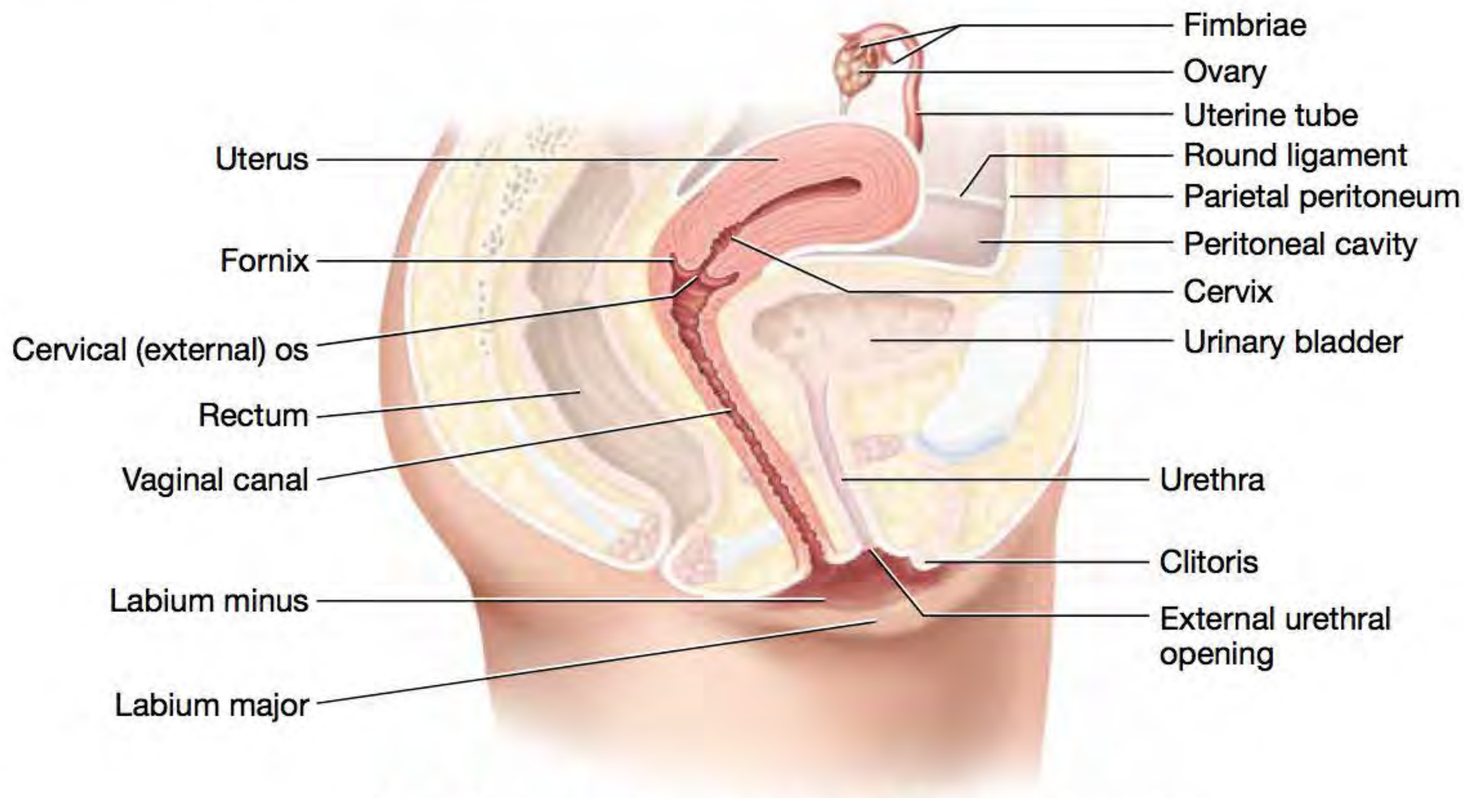


FIGURE **22.8** Midsagittal section of the female pelvis.

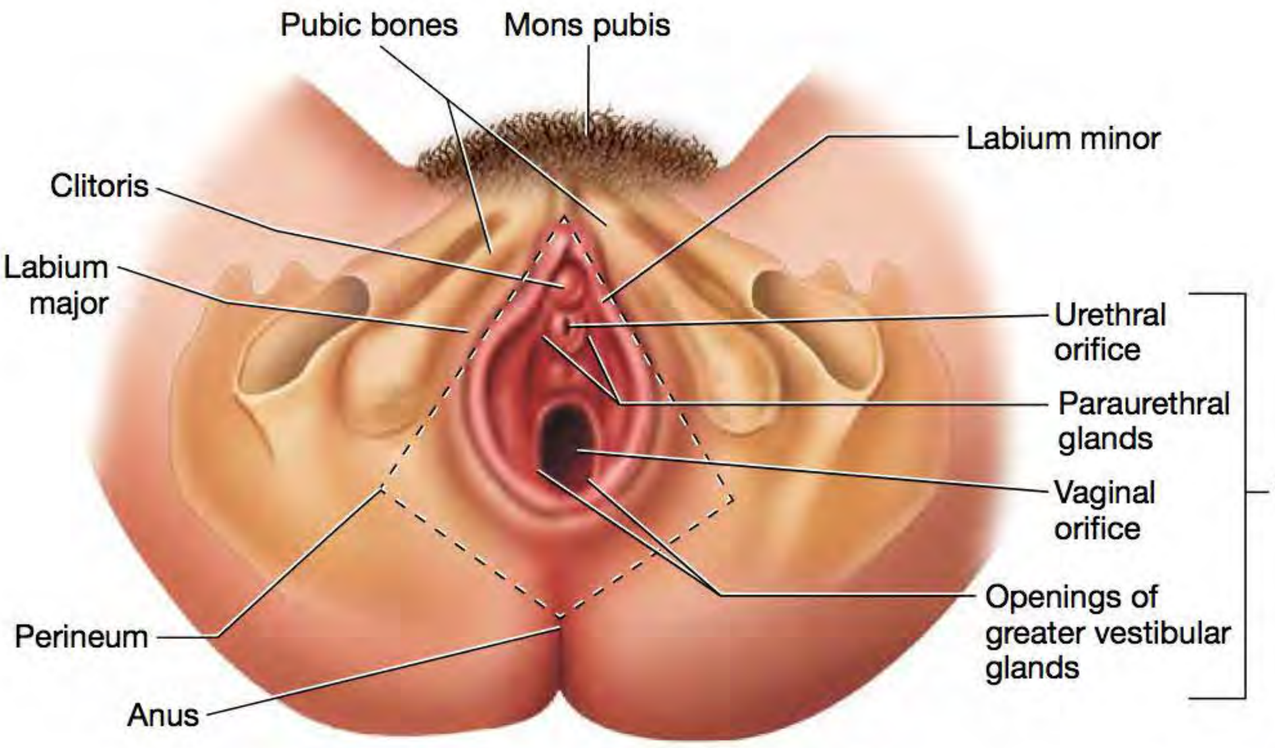


FIGURE **22.9** External female genitalia.

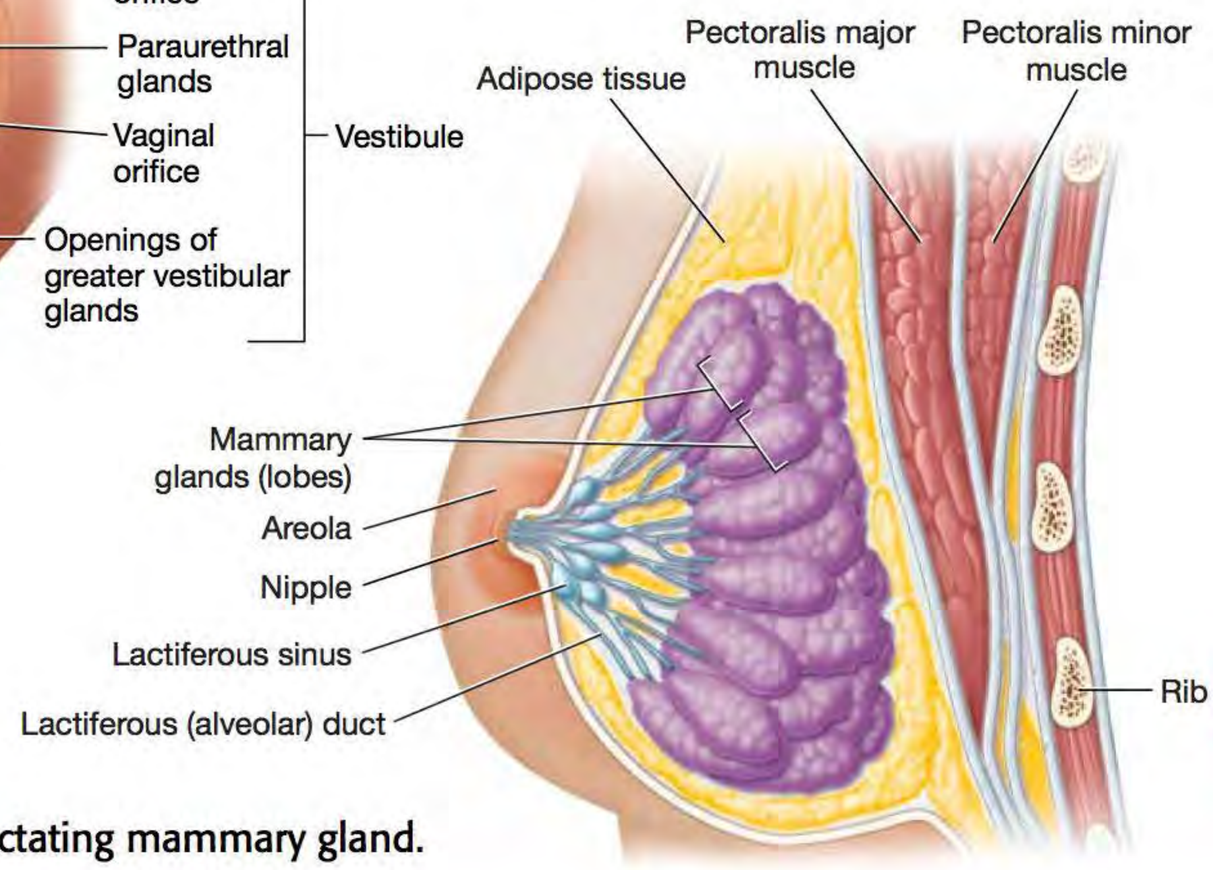


FIGURE **22.10** A lactating mammary gland.

Procedure 1 Model Inventory of the Female Reproductive System

Identify the following structures of the female reproductive system on models and diagrams, using your textbook and this unit for reference. As you examine the anatomical models and diagrams, record the name of the model and the structures you were able to identify on the model inventory in Table 22.2. After you have completed the activity, answer Check Your Understanding questions 4 and 5 (p. 568).

1. Ovary
   a. Ovarian follicles
   b. Ovarian cortex
   c. Ovarian medulla
   d. Ovarian ligament
   e. Broad ligament
   f. Suspensory ligament
2. Uterine (fallopian) tube
   a. Fimbriae
   b. Infundibulum
   c. Ampulla
   d. Isthmus
3. Uterus
   a. Round ligaments
   b. Uterosacral ligaments
   c. Fundus
   d. Body
   e. Cervix
      (1) Cervical os
   f. Layers
      (1) Endometrium
      (2) Myometrium
      (3) Perimetrium
4. Vagina
   a. Fornix
   b. Greater vestibular glands
5. Vulva
   a. Mons pubis
   b. Labia majora
   c. Labia minora
      (1) Vestibule
      (2) Urethral orifice
      (3) Vaginal orifice
   d. Clitoris
8. Mammary glands
   a. Lobe
   b. Lactiferous duct
   c. Lactiferous sinus
   d. Nipple
   e. Areola
   f. Adipose tissue

TABLE **22.2** Model Inventory for the Female Reproductive System

Model/Diagram	Structures Identified

Exercise 22-3

Histology of the Reproductive System

MATERIALS

- ❑ Testis slide
- ❑ Sperm slide
- ❑ Epididymis slide
- ❑ Ovary slide
- ❑ Light microscope
- ❑ Colored pencils

Gametogenesis is the process of producing sperm cells by the testes (*spermatogenesis*) and oocytes by the ovaries (*oogenesis*). Spermatogenesis, shown in Figure 22.11, begins with stem cells located at the outer edge of the seminiferous tubules called **spermatogonia** (sper-mat-oh-GOH-nee-ah). Before puberty, these cells undergo repeated rounds of mitosis to increase their numbers. As puberty begins, each spermatogonium divides into two different cells—one cell that stays a spermatogonium and another cell that becomes a **primary spermatocyte**.

The primary spermatocyte then undergoes a special kind of cellular division called **meiosis** (my-OH-sis) in which the amount of genetic material in the cell is divided by half. The result of this division is two **secondary spermatocytes** that migrate closer to the lumen of the tubule. The two secondary spermatocytes undergo a second round of meiosis and give rise to four haploid **spermatids**. The spermatids move to the lumen of the seminiferous tubule, at which point they are called spermatozoa, or sperm cells.

Note in Figure 22.12 that most of the stages of spermatogenesis are identifiable on a microscope slide of the seminiferous tubules. On the inner edge of the tubule near the lumen are small, round cells with little cytoplasm. These are the spermatozoa and spermatids. As we move to deeper layers of the tubule wall, we can see primary spermatocytes, and on the outer edge we can see the cuboidal spermatogonia. In between the tubules are small clusters of cells called **interstitial cells**. These cells make testosterone, required for spermatogenesis to take place. Note that secondary spermatocytes are not visible in Figure 22.12.

Spermatids then move to the epididymis to mature into functional gametes (Figure 22.13). Notice that the mucosal lining of the epididymis is pseudostratified columnar epithelium with long projections called **stereocilia**. These projections are nonmotile microvilli that help the sperm cells to complete the maturation process, absorb excess fluid,

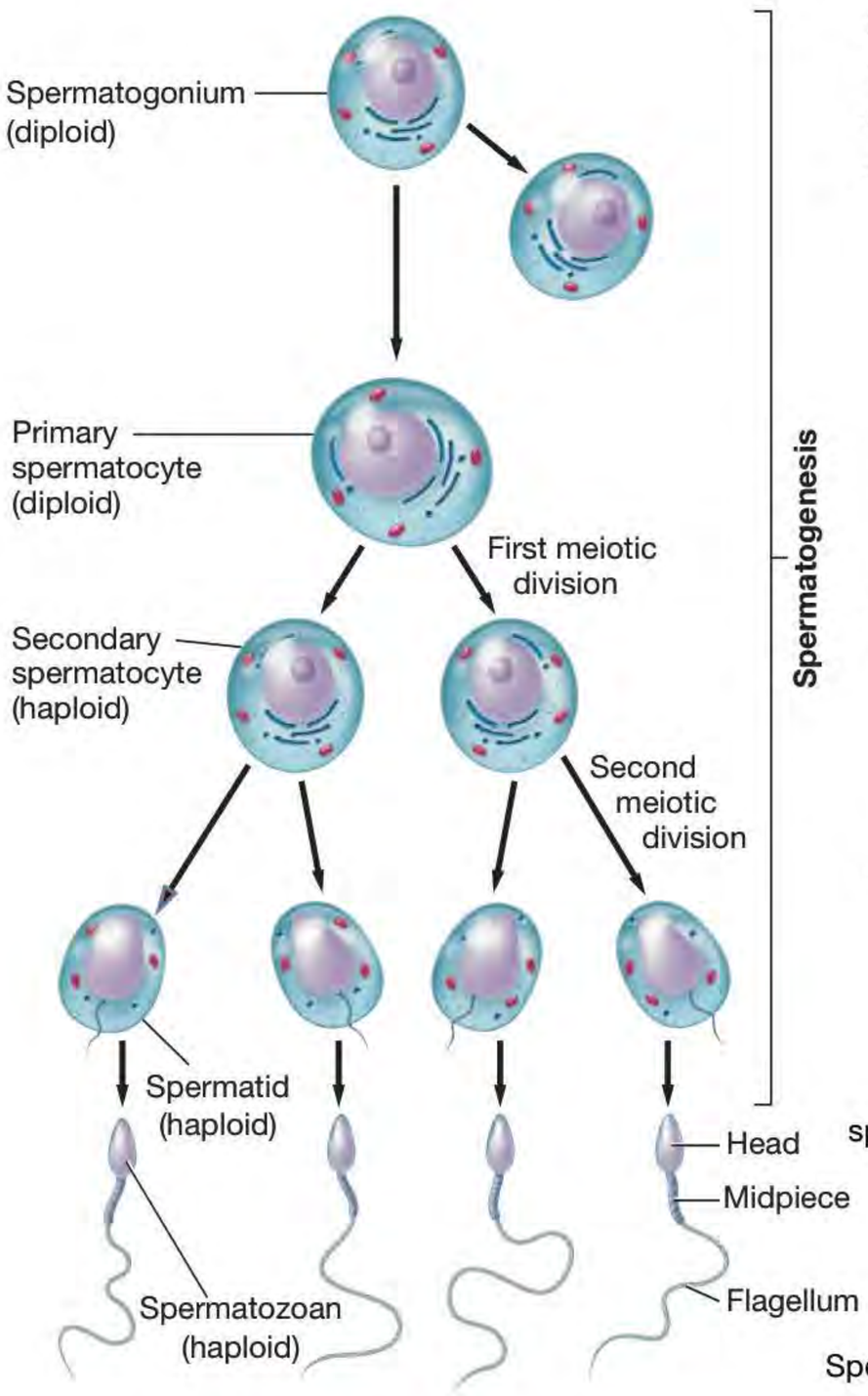


FIGURE 22.11 Spermatogenesis.

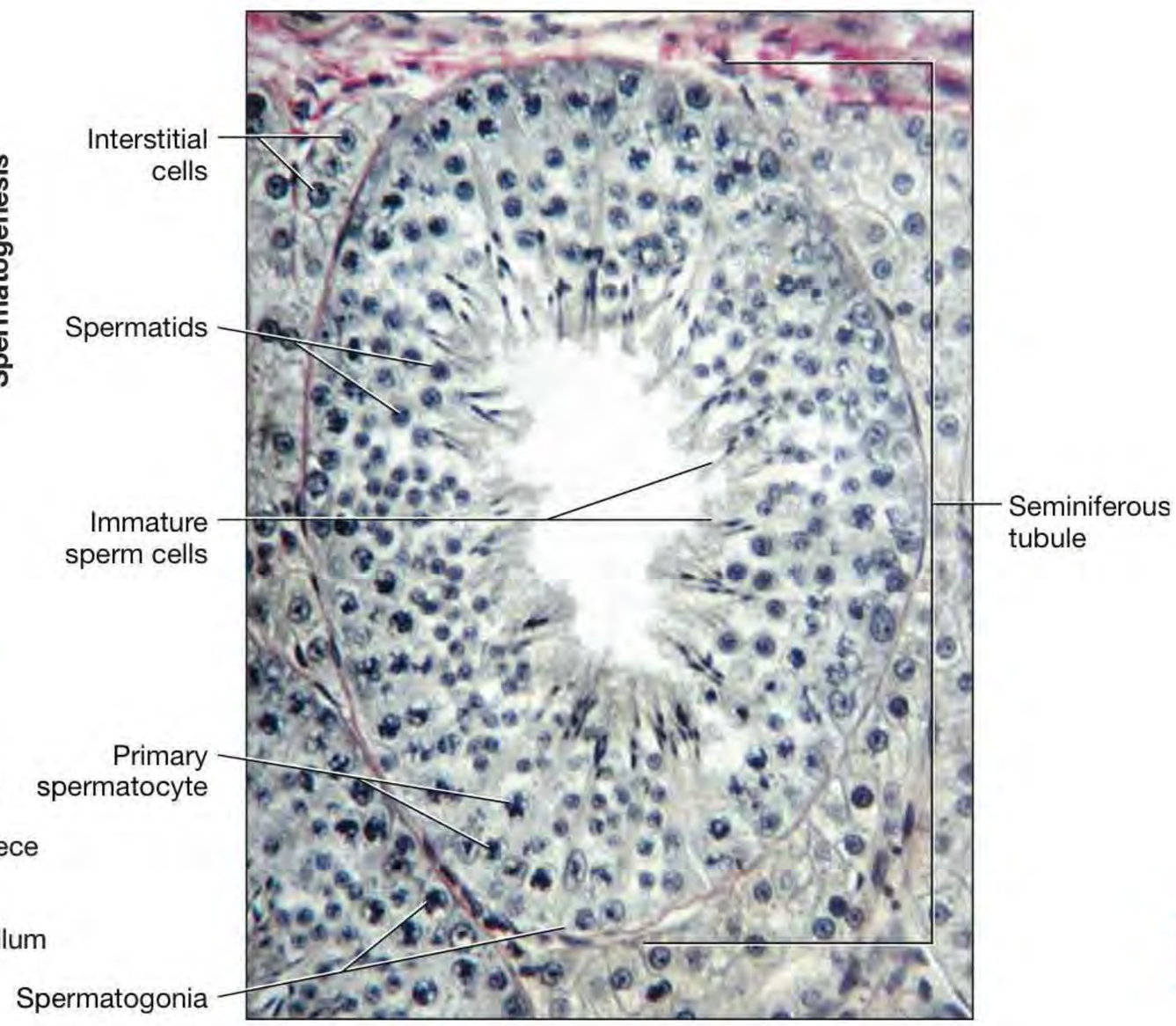


FIGURE 22.12 Seminiferous tubules, photomicrograph.

and pass nutrients to the developing cells. Notice also the smooth muscle cells lining the outside of the epididymis tubule, which function to propel the sperm cells along as they mature. By the time the cells reach the end of the epididymis, they are mature sperm cells that contain three parts: the **head,** in which the DNA resides, the **midpiece,** which contains an axomere and mitochondria, and the **flagellum** (Figure 22.14).

Like spermatogenesis, **oogenesis** (OH-oh-gen-eh-sis) proceeds through meiosis to yield a gamete, the **ovum** (Figure 22.15). But the two processes differ in some notable ways:

- *The number of oocytes is determined before birth.* During the fetal period, stem cells called **oogonia** (oh-oh-GOH-nee-ah) undergo mitosis, increasing their numbers to about 500,000 to 700,000. This is the total number of oocytes a woman will ever produce. This is in sharp contrast to spermatogenesis, which begins at puberty and continues throughout a male's lifetime.
- *Meiosis begins during the fetal period but is arrested.* Still during the fetal period, the oogonia become encased in a **primordial follicle,** enlarge, and become **primary oocytes** (see the ovary in Figure 22.16). The primary oocytes begin meiosis but are arrested. Meiosis does not resume until puberty.

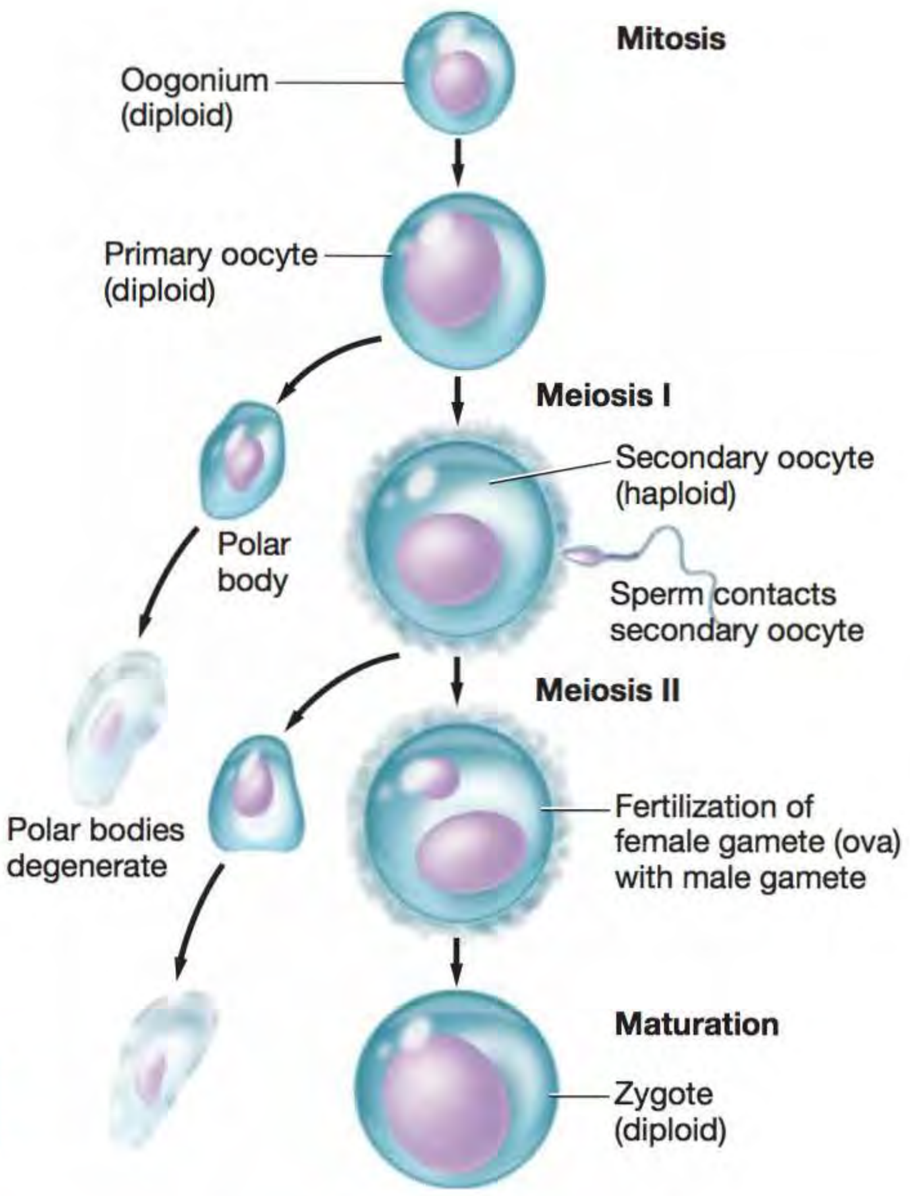


FIGURE **22.15** Oogenesis.

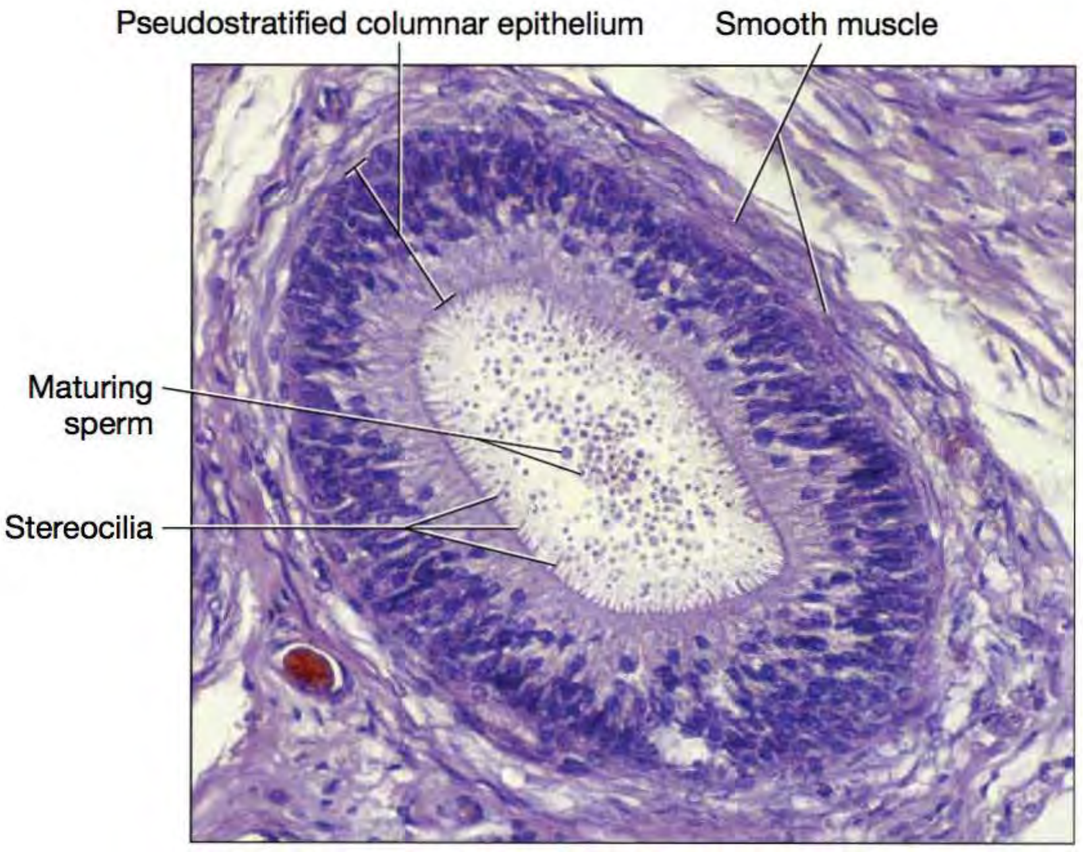


FIGURE **22.13** Epididymis, photomicrograph.

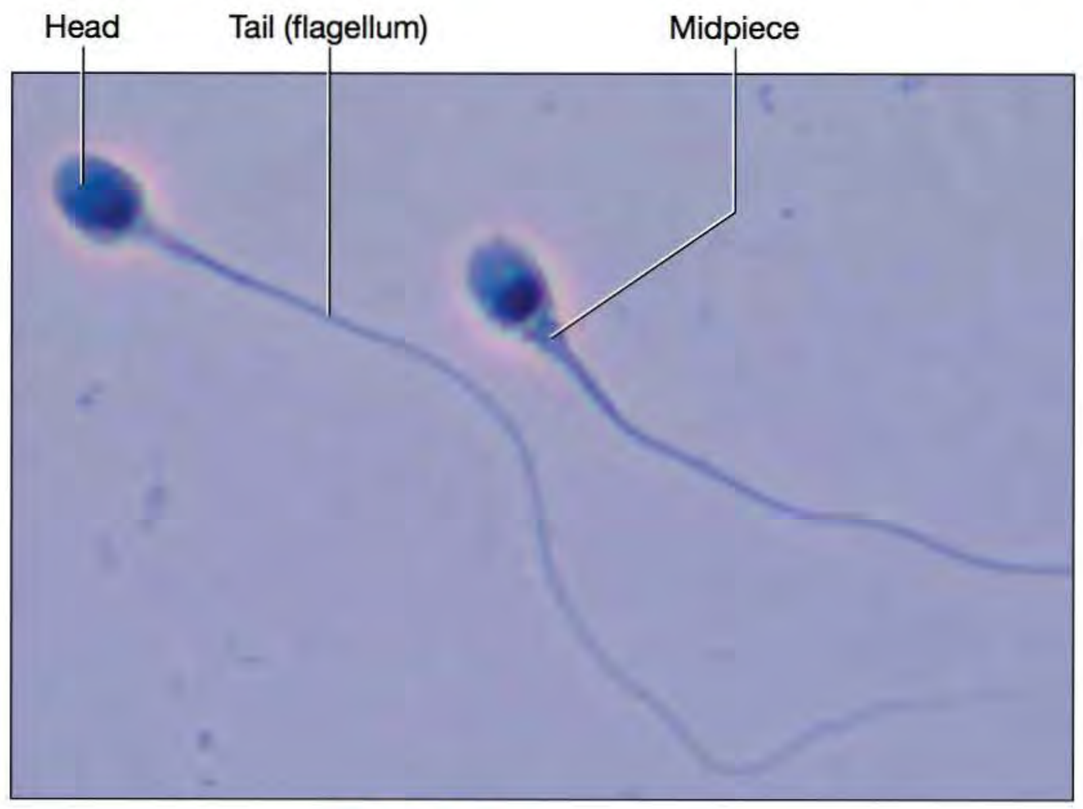


FIGURE **22.14** Mature sperm cells.

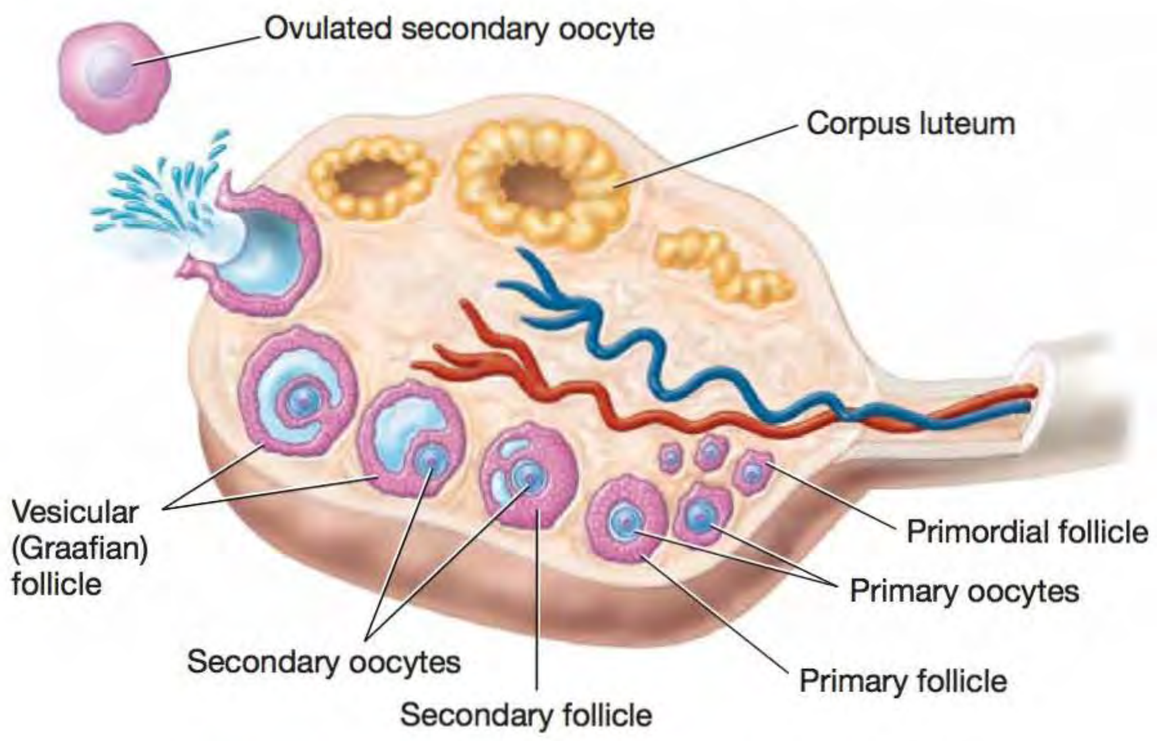


FIGURE **22.16** The ovary and ovarian follicles.

- *The first meiotic division results in one secondary oocyte and one polar body.* At puberty, hormones stimulate one primary oocyte to enlarge and become encased in a **primary follicle**. This primary oocyte then completes meiosis to produce a **secondary oocyte** and a small bundle of nuclear material called a **polar body**. The formation of a polar body allows the oocyte to conserve cytoplasm, which will have to sustain the cell if fertilization occurs. The secondary oocyte, initially encased in a **secondary follicle**, enlarges to form a **vesicular follicle**, which contains a large, fluid-filled space called the **antrum**.
- *The second round of meiosis completes only if fertilization takes place.* The secondary oocyte begins the second round of meiosis and is released when the vesicular follicle ruptures during ovulation. Note that the ruptured follicle then becomes an endocrine organ called a **corpus luteum** (KORH-pus LOO-tee-um). But the secondary oocyte only completes meiosis to form an ovum and a second polar body if fertilization occurs. If fertilization does not occur, the secondary oocyte degenerates.

You can easily see many of the different follicles on a slide of the ovary (Figure 22.17). In addition, you can determine the stage of the oocyte by looking at the surrounding follicle: Primary oocytes are encased in primordial and primary follicles, and secondary oocytes in secondary and vesicular follicles. Note that we cannot see oogonia in the ovary because these cells begin meiosis I and become primary oocytes during the fetal period.

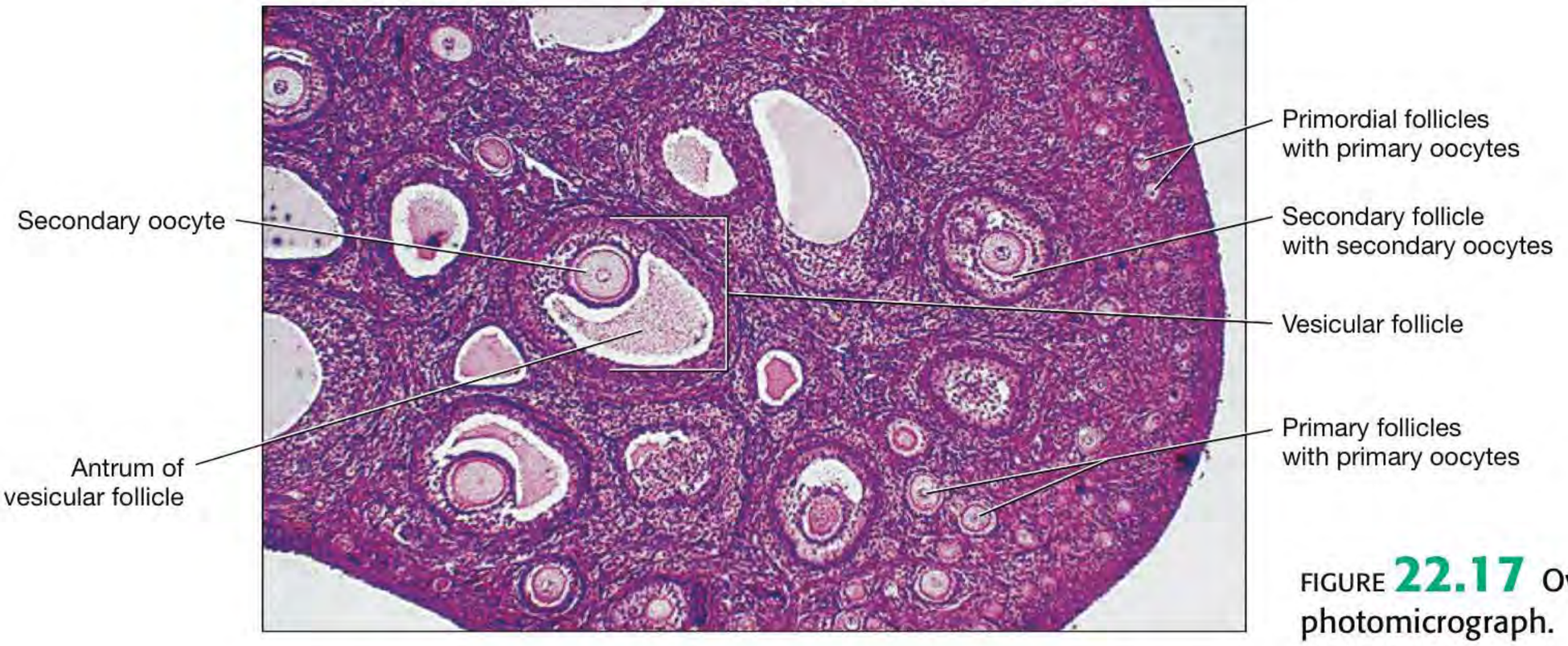


FIGURE **22.17** Ovary, photomicrograph.

Procedure 1 Microscopy of Male Reproductive Structures

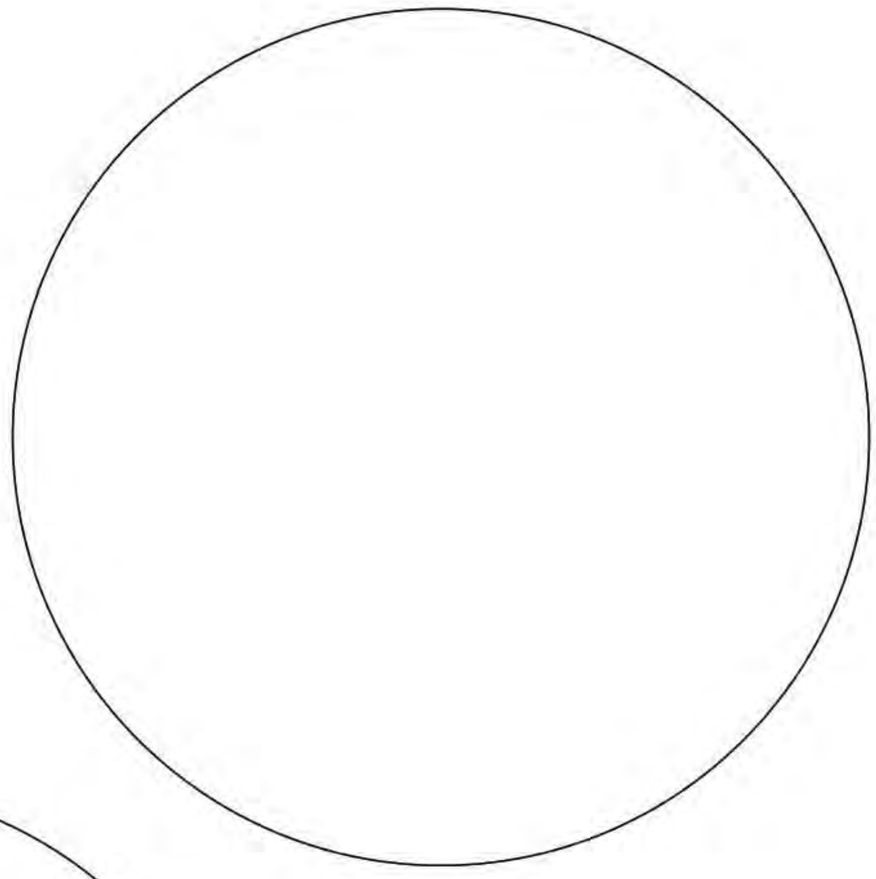
In this exercise you will examine prepared slides of the testes, epididymis, and a sperm smear. You will want to examine all three slides on high power, and you may wish to examine the sperm smear with an oil-immersion lens. Because sperm cells are so small, the slide will likely have a thread or some other marker to help you find them. As you examine the slides, use colored pencils to draw what you see, and label your drawings with the terms indicated.

Testes

1. Seminiferous tubule
2. Spermatogonia
3. Primary spermatocytes
4. Spermatids
5. Interstitial cells

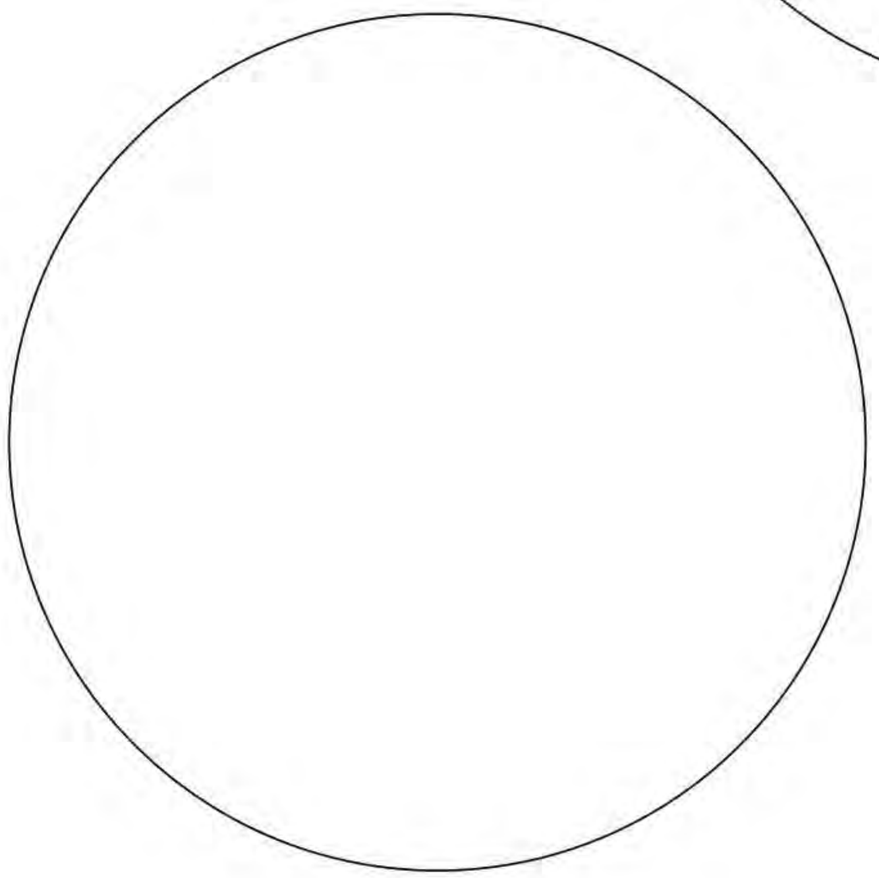
Epididymis

1. Maturing sperm
2. Stereocilia
3. Pseudostratified columnar epithelium
4. Smooth muscle



Mature Sperm

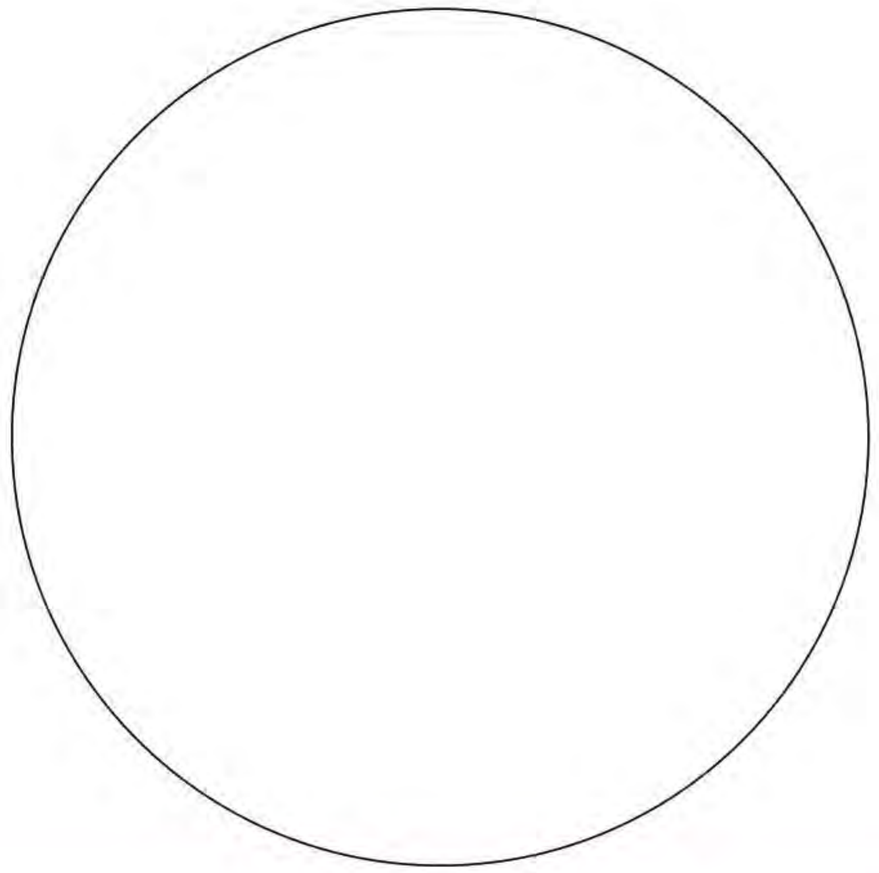
1. Head
2. Midpiece
3. Flagellum



Procedure 2 Microscopy of the Ovary

Obtain a prepared slide of an ovary. Use your colored pencils to draw what you see, and label your drawing with the following terms. You will have the best results if you examine the slide on low power. Please keep in mind that you may have to examine multiple slides to see all the follicular stages.

1. Primordial follicle
2. Primary follicle
   a. Primary oocyte
3. Secondary follicle
4. Vesicular follicle
   a. Secondary oocyte
   b. Antrum



Name _____

Section _____ Date _____

UNIT 22 REVIEW

Check Your Recall

1 Label the following structures on Figure 22.18.

- ❑ Cremaster muscle
- ❑ Pampiniform venous plexus
- ❑ Spermatic cord
- ❑ Testicular artery
- ❑ Scrotum
- ❑ External inguinal ring
- ❑ Ductus deferens

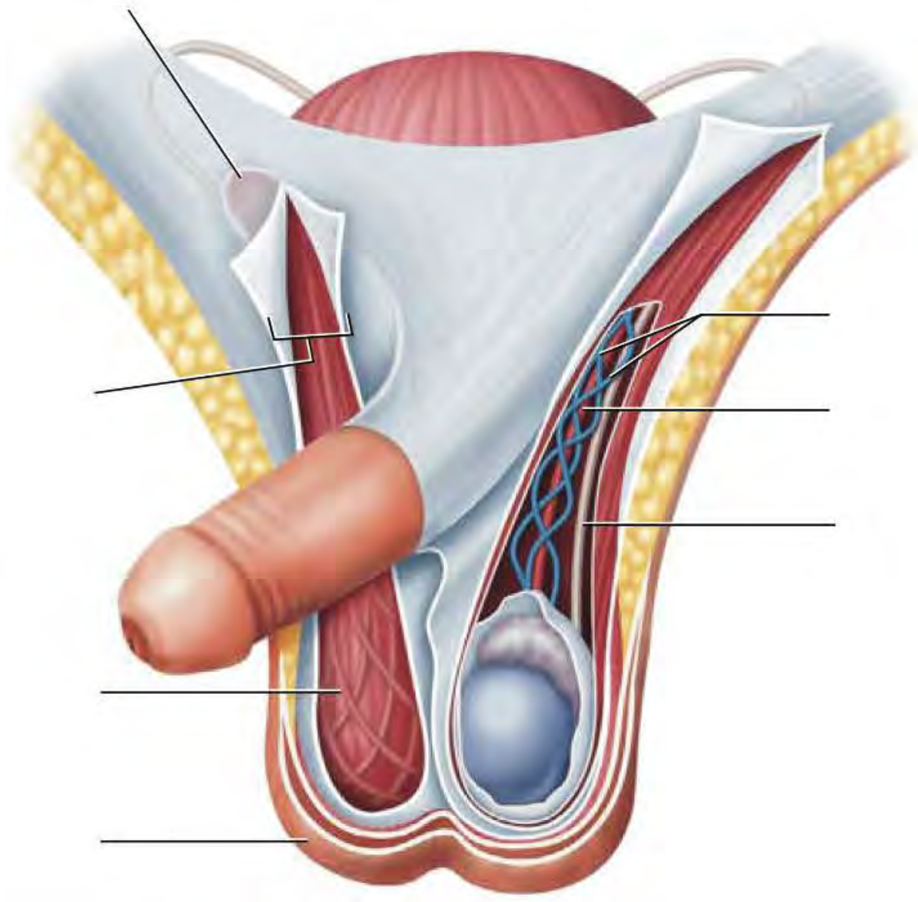


FIGURE **22.18** The scrotum and spermatic cord.

2 Label the following structures on Figure 22.19.

- ❑ Epididymis (head)
- ❑ Epididymis (tail)
- ❑ Seminiferous tubules
- ❑ Rete testis
- ❑ Tunica albuginea
- ❑ Tunica vaginalis

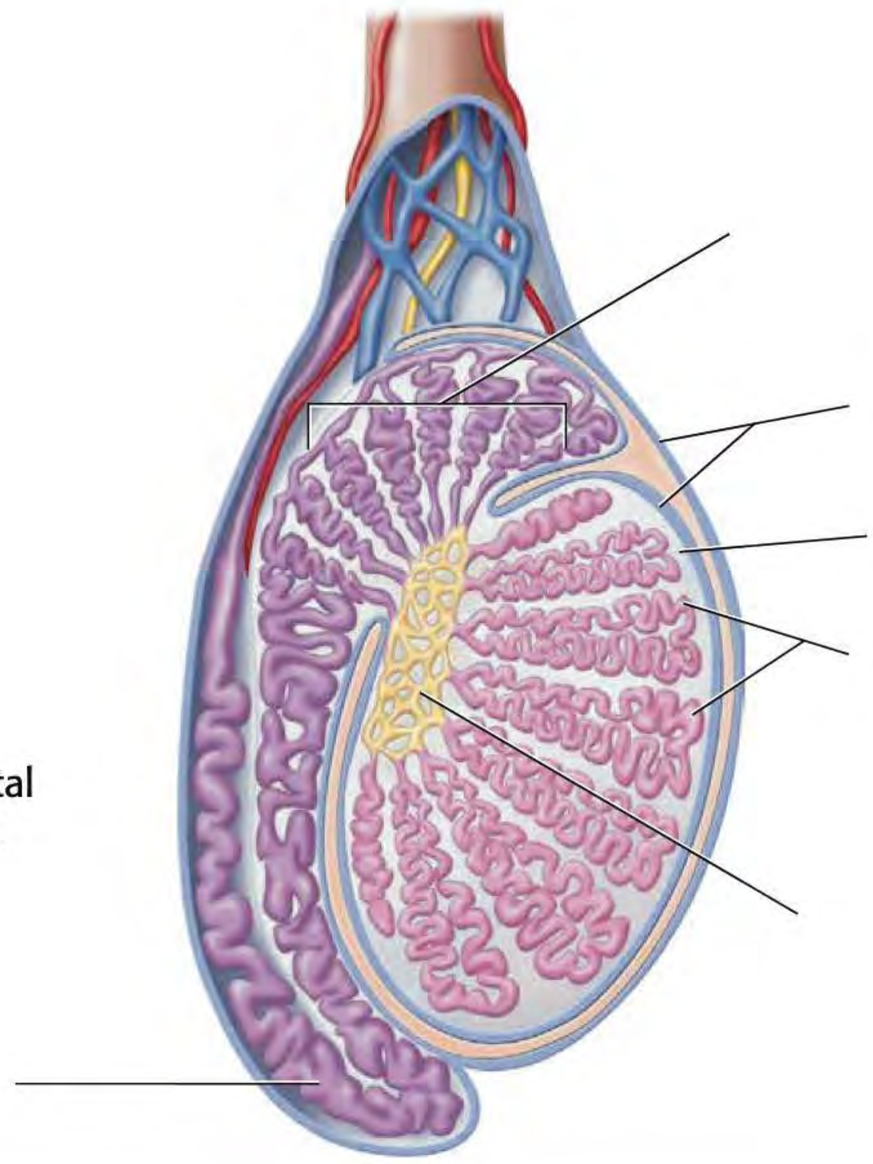


FIGURE **22.19** Midsagittal section through the testis.

3 Label the following structures on Figure 22.20.

- ❑ Corpora cavernosa
- ❑ Corpus spongiosum
- ❑ Ejaculatory duct
- ❑ Seminal vesicle
- ❑ Glans penis
- ❑ Prostate gland

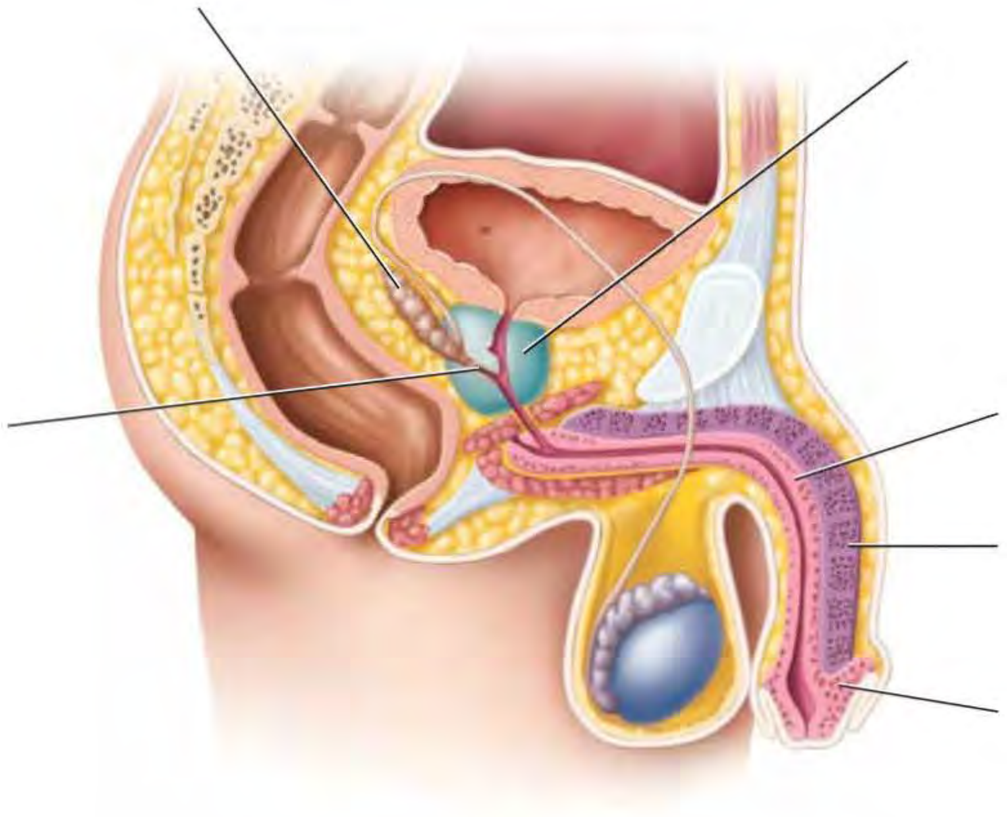


FIGURE **22.20** Midsagittal section through the male pelvis.

4 Label the following structures on Figure 22.21.

- ❑ Prostatic urethra
- ❑ Spongy urethra
- ❑ Membranous urethra
- ❑ External urethral orifice
- ❑ Bulbourethral gland

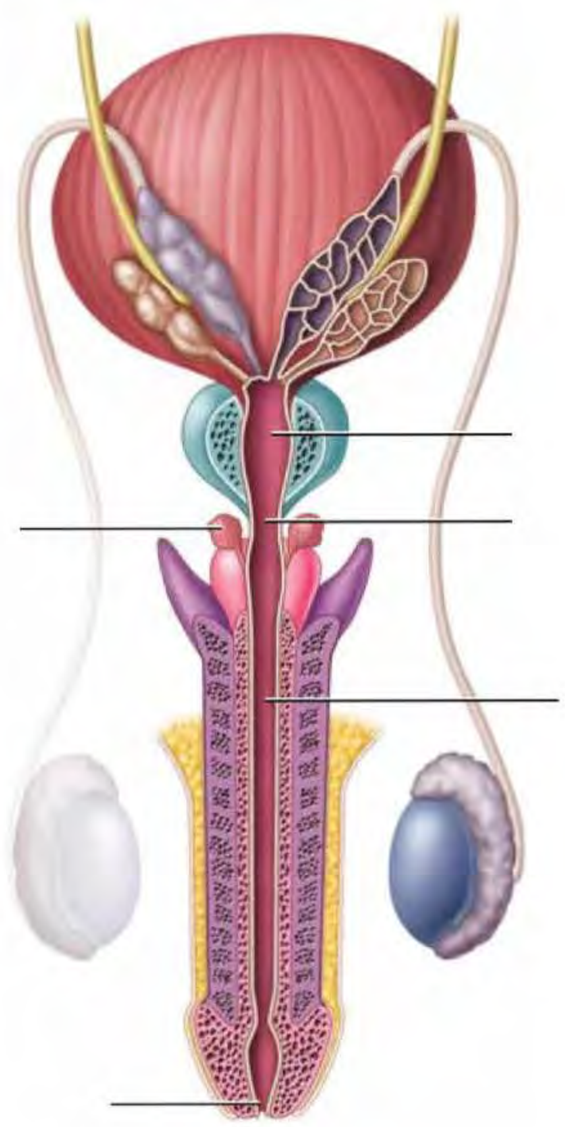


FIGURE **22.21** Posterior view of the male reproductive system with a frontal section of the penis.

Name _____

Section _____ Date _____

UNIT 22

5 Label the following structures on Figure 22.22.

- ❑ Cervical os
- ❑ Labium major
- ❑ Labium minus
- ❑ Round ligament
- ❑ Fornix
- ❑ Uterus
- ❑ Vaginal canal

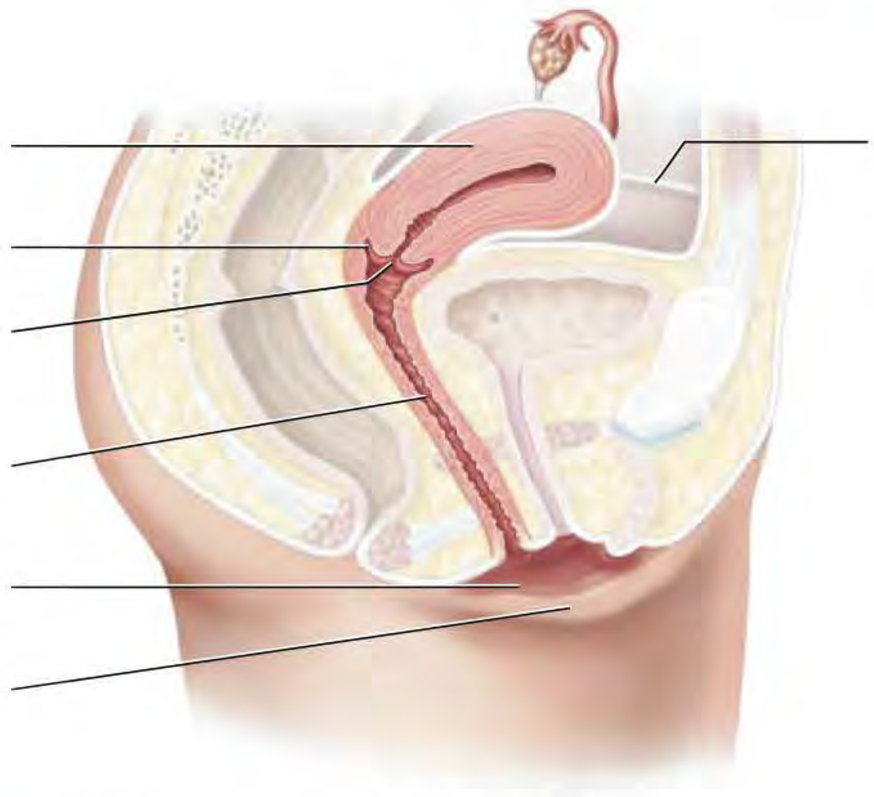


FIGURE **22.22** Midsagittal section of the female pelvis.

6 Label the following structures on Figure 22.23.

- ❑ Body of uterus
- ❑ Broad ligament
- ❑ Cervical canal
- ❑ Endometrium
- ❑ Fimbriae
- ❑ Fundus of uterus
- ❑ Myometrium
- ❑ Ovarian ligament
- ❑ Perimetrium
- ❑ Uterine tube

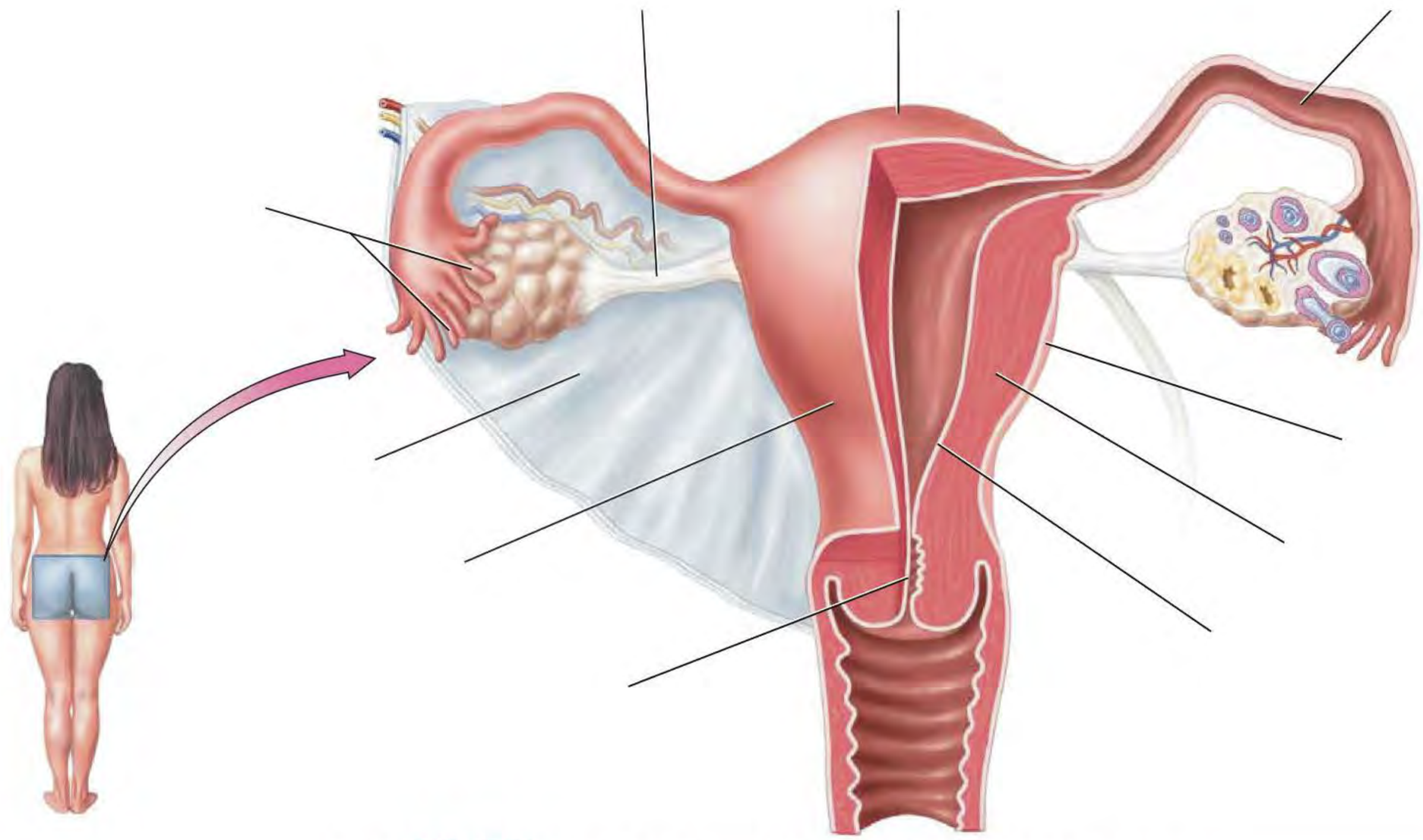


FIGURE **22.23** Posterior view of the female reproductive organs.

22

7 Label the following structures on Figure 22.24.

- ❑ Lactiferous sinus
- ❑ Lactiferous duct
- ❑ Areola
- ❑ Nipple
- ❑ Lobes
- ❑ Adipose tissue

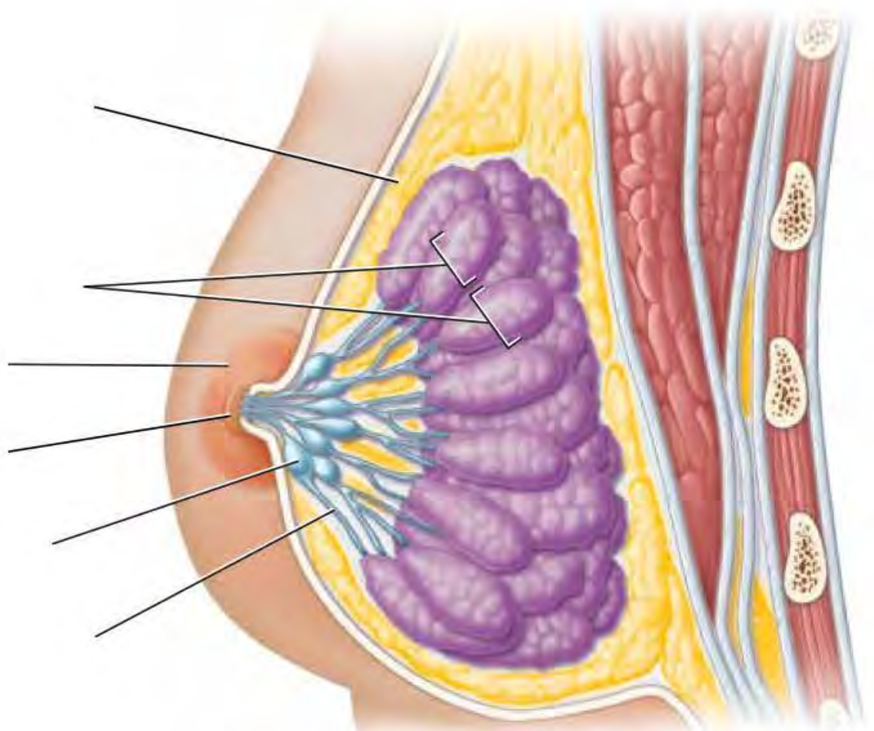


FIGURE **22.24** Lactating mammary gland.

8 **Which of the following statements about spermatogenesis and oogenesis is *false*?**

a. Meiosis does not complete in oogenesis unless fertilization takes place.
b. Meiosis begins during the fetal period but is arrested in oogenesis.
c. Spermatogenesis begins at puberty and continues throughout the male's lifetime, whereas the total number of oocytes a woman will produce is determined before birth.
d. Spermatogenesis results in one spermatid and two polar bodies, whereas oogenesis results in four ova.

9 **Spermatids migrate to the _____ to mature.**

a. ductus (ductus) deferens
b. epididymis
c. seminal vesicle
d. prostate gland

10 **Label the following structures on Figure 22.25.**

- ❑ Corpus luteum
- ❑ Primary follicle
- ❑ Primary oocyte
- ❑ Secondary follicle
- ❑ Secondary oocyte
- ❑ Vesicular follicle

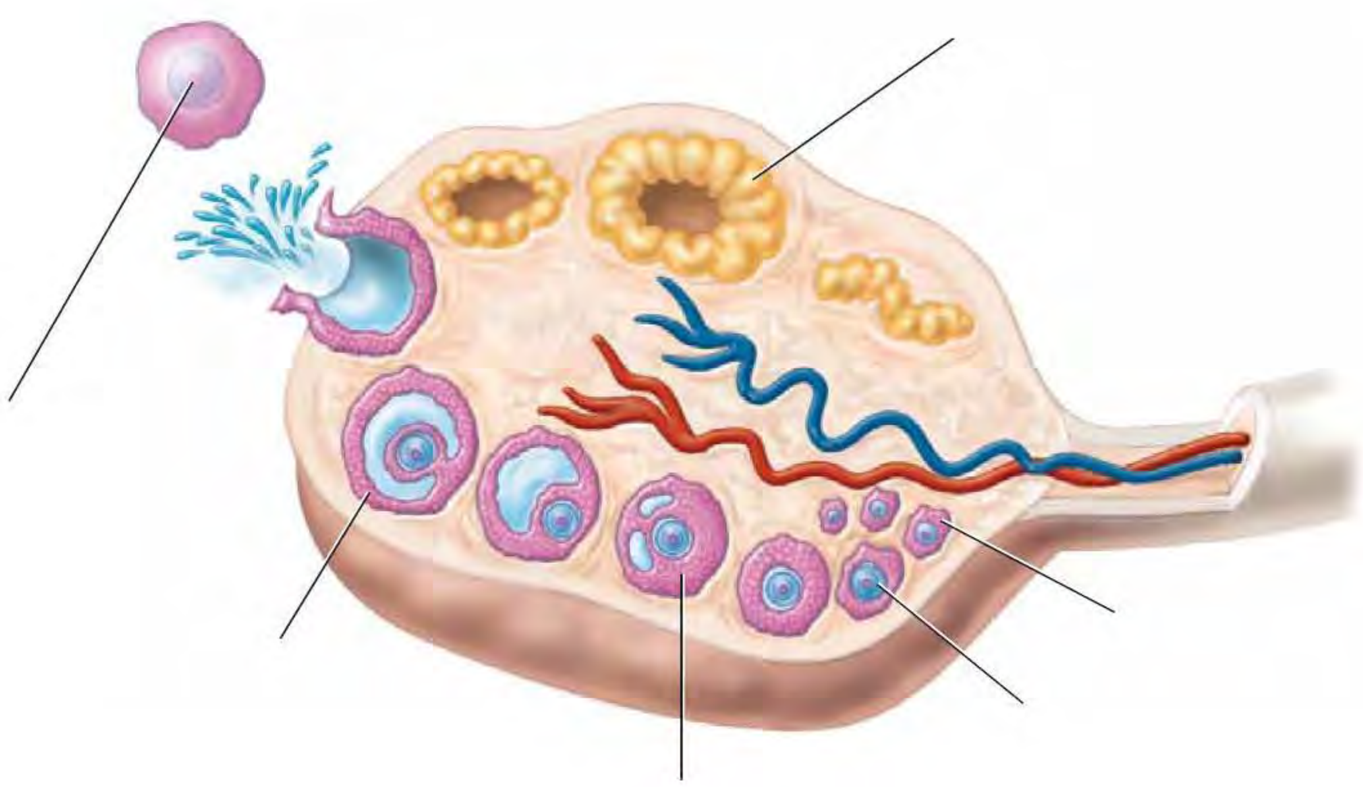


FIGURE **22.25** Ovary.

Name _____

Section _____ Date _____

UNIT 22 REVIEW

Check Your Understanding

Critical Thinking and Application Questions

1 A condition called *testicular torsion* results when the spermatic cord becomes twisted. Why would this condition be a surgical emergency?

2 What structure is sectioned in a vasectomy? What are the effects of this procedure? Will it affect the number of sperm or the volume of semen produced?

3 The condition *benign prostatic hypertrophy*, in which the prostate is enlarged, often results in urinary retention—the inability to completely empty the bladder. Considering the anatomy of the male genitourinary tract, explain this symptom.

4 A tubal (or ectopic) pregnancy results from implantation of a fertilized ovum in the uterine tube instead of the uterus. Why do you think that this is dangerous?

5 One of the most common complaints of pregnant women is the need to urinate often. Explain this, considering the arrangement of the pelvic organs.

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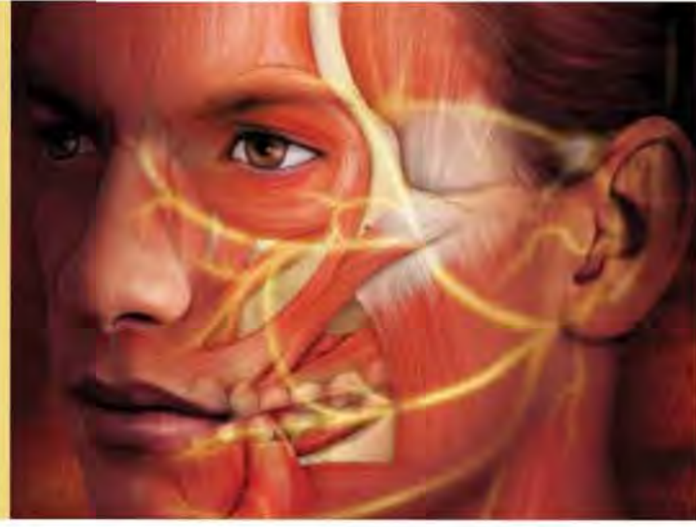

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Fig. 1.11 A–B: Neil Borden/Photo Researchers

Fig. 1.11C: SPL/Photo Researchers

Unit 2

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Fig. 2.1: Courtesy of Olympus America

Unit 3

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Fig. 3.4B: SPL/Photo Researchers

Fig. 3.6: SPL/Photo Researchers

Fig. 3.8: Michael Abbey/Photo Researchers

Fig. 3.9: Stem Jems/Photo Researchers

Unit 4

Opener: SPL/Photo Researchers

Fig. 4.2A: Biophoto Assoc./Photo Researchers

Fig. 4.2B: Biology Pics/Photo Researchers

Fig. 4.2C: Spike Walker/Photo Researchers

Fig. 4.2D: Biophoto Assoc./Photo Researchers and Meckes/Ottawa/Photo Researchers

Fig. 4.3A: David Phillips/Photo Researchers

Fig. 4.3B: Biophoto Assoc./Photo Researchers

Fig. 4.3C–D: SPL/Photo Researchers

Fig. 4.4A: Biophoto Assoc./Photo Researchers

Fig. 4.4B: Visuals Unlimited

Fig. 4.4C: Spike Walker/Photo Researchers and SPL/Photo Researchers

Fig. 4.5A: Biophoto Assoc./Photo Researchers and SPL/Photo Researchers

Fig. 4.5B: Biophoto Assoc./Photo Researchers and David Phillips/Photo Researchers

Fig. 4.5C: Biophoto Assoc./Photo Researchers

Fig. 4.6A: Erin Amerman

Fig. 4.6B: Spike Walker/Photo Researchers

Fig. 4.6C: Chuck Brown/Photo Researchers

Fig. 4.7: SPL/Photo Researchers

Fig. 4.8: Biophoto Assoc./Photo Researchers

Fig. 4.9A: Eric Grave/Photo Researchers

Fig. 4.9B: SPL/Photo Researchers

Fig. 4.9C: Getty Images

Fig. 4.9D: Biophoto Assoc./Photo Researchers

Fig. 4.10: Spike Walker/Photo Researchers

Unit 5

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Fig. 5.4: Biophoto Assoc./Photo Researchers

Fig. 5.6A: SPL/Photo Researchers

Fig. 5.6B: Gary Delong/Photo Researchers

Fig. 5.7: Biophoto Assoc./Photo Researchers

Fig. 5.8: Fabrication Enterprises

Unit 6

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Fig. 6.3: SPL/Photo Researchers

Fig. 6.6: Justin Moore

Fig. 6.9: Biophoto Assoc./Photo Researchers

Unit 7

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Fig. 7.3: VideoSurgery/Photo Researchers

Fig. 7.4: David Bassett/Photo Researchers

Fig. 7.5: Getty Images

Fig. 7.6: SPL/Photo Researchers

Fig. 7.7: VideoSurgery/Photo Researchers

Fig. 7.12A–B: Martin Shields/Photo Researchers

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Fig. 7.29B: VideoSurgery/Photo Researchers

Fig. 7.41: SPL/Photo Researchers

Unit 8

Opener: SPL/Photo Researchers

Fig. 8.6B: VideoSurgery/Photo Researchers

Unit 9

Opener: SPL/Photo Researchers

Fig. 9.4B: Video Surgery/Photo Researchers

Fig. 9.6B: Mike J. Leboffe

Fig. 9.7B: Biophoto Assoc./Photo Researchers

Unit 10

Opener: Hybrid/Photo Researchers

Fig. 10.3: Spike Walker/Photo Researchers

Fig. 10.8: Biophoto Assoc./Photo Researchers

Unit 11

Opener, Fig. 11.7: SPL/Photo Researchers

Fig. 11.2, Fig. 11.11, Fig 11.10: Kent M. Van De Graaff, David A. Morton, and John L. Crawley, *A Photographic Atlas for the Anatomy and Physiology Laboratory*, 6E ©Morton Publishing

Unit 12

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Fig. 12.3C: Martin Rotker/Photo Researchers

Fig. 12.9: SPL/Photo Researchers

Unit 13

Opener: Video Surgery/Photo Researchers

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Unit 14

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Fig. 14.7: Michael Ross/Photo Researchers

Fig. 14.8, Fig. 14.9: Biophoto Assoc./Photo Researchers

Unit 15

Opener: SPL/Photo Researchers

Fig. 15.3: Video Surgery/Photo Researchers

Fig. 15.8, Fig. 15.9, Fig. 15.10: Justin Moore

Fig. 15.12: SPL/Photo Researchers

Unit 16

Opener, Fig. 16.20: SPL/Photo Researchers

Unit 17

Opener: SPL/Photo Researchers

Fig. 17.1: Biophoto Assoc./Photo Researchers and Michael Ross/ Photo Researchers

Fig. 17.3: Justin Moore

Fig. 17.4: BSIP/Photo Researchers

Unit 18

Opener: SPL/Photo Researchers

Fig. 18.5A: Michael Abbey/Photo Researchers

Fig. 18.5B-C: Biophoto Assoc./Photo Researchers

Fig. 18.5D: SPL/Photo Researchers

Unit 19

Opener: SPL/Photo Researchers

Fig. 19.3B, Fig. 19.4B: Video Surgery/Photo Researchers

Fig. 19.7A: Erin Amerman

Fig. 19.7B-D: Biophoto Assoc./Photo Researchers

Fig. 19.8A-B: Justin Moore

Fig. 19.10: SPL/Photo Researchers

Unit 20

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Fig. 20.5B: Visuals Unlimited

Fig. 20.7B: Visuals Unlimited

Fig. 20.11: Video Surgery/Photo Researchers

Fig. 20.17, Fig. 20.18B, Fig. 20.19B, Fig. 20.20: Biophoto Assoc./ Photo Researchers

Fig. 20.21: Spike Walker/Photo Researchers

Fig. 20.22: Getty Images

Unit 21

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Fig. 21.12: Video Surgery/Photo Researchers

Fig. 21.13: Garry Delong/Photo Researchers

Fig. 21.14A: SPL/Photo Researchers

Fig. 21.14B: Biophoto Assoc./Photo Researchers

Fig. 21.15A: Erin Amerman

Fig. 21.15B: SPL/Photo Researchers

Fig. 21.15C: Biophoto Assoc./Photo Researchers

Unit 22

Opener: SPL/Photo Researchers

Fig. 22.12: Biophoto Assoc./Photo Researchers

Fig. 22.13: Biophoto Assoc./Photo Researchers

Fig. 22.14: Michael Abbey/ Photo Researchers

Fig. 22.17: Erin Amerman

Index