Laboratory Manual for Anatomy & Physiology

SEVENTH EDITION

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Preface

Students in two-semester allied health–related programs typically encounter a fast-paced anatomy and physiology course that leaves little time for leisurely learning. These students are intently focused on achieving their goals, which requires a course that includes a brief, hands-on laboratory experience to flesh-out and clarify the lecture sessions. This challenge is what provided the impetus for developing this concise laboratory manual.

Basic Pedagogical Approach

The Seventh Edition offers a variety of experiments to give the instructor the flexibility to choose which will best supplement what is being taught in lecture. This manual is a stand-alone resource that can complement any textbook. Because each experiment is preceded by pertinent background information, students will not find it necessary to carry their textbooks to the lab.

Although length and content have been rigorously controlled, the 27 exercises in this manual still provide fairly complete coverage of the routine topics of human anatomy and physiology.

For instructors who wish their students to have experience using a microscope, this manual also includes a complete exercise on its use and care (see Appendix A).

Pedagogy and Special Features

1. The art and photo program includes tissue tables with photomicrographs, realistic muscle art, and large illustrations that highlight and differentiate important structures and help students recognize important relationships between structure and function. Photographs supplement the art to show isolated organ specimens for dissection and observation.

2. Each exercise is preceded by a list of materials needed for conducting the laboratory, followed by learning outcomes, summaries of key concepts, step-by-step instructions, and efficient tear-out review sheets that can be used for pre-lab or post-lab review.

3. Body structures are studied from simple to complex. Histology lessons will be expedited by slides set up by the instructor at demonstration areas for student viewing, so students do not have to spend time trying to find the "right" section. These, along with physiology experiments (written to be conducted in limited time periods and with inexpensive, widely available equipment and supplies) allow ample opportunity for student observation, manipulation, and experimentation.

4. All exercises involving body fluids (blood, saliva, etc.) incorporate current Centers for Disease Control and Prevention guidelines for handling body fluids. A safety icon alerts students to observe special precautions.

5. An *Instructor's Guide* is available to instructors upon request (0-13-520203-5). This Guide contains answers to activity and review sheet questions, and information on laboratory supply houses.

For information on creating a custom version of this manual, visit www.pearsonhighered.com/collections/, or contact your Pearson representative for details.

New to the Seventh Edition: Highlights

- **Dozens of new, full-color illustrations, and photos** replace many black and white line drawings to help students differentiate among structures and more easily interpret diagrams.
- **New Clinical Application Questions** have been added to the Exercise Review Sheets to challenge students to apply lab concepts and critical thinking skills to real-world clinical scenarios.
- **Improved Interior design** incorporates more saturated colors in headings and exercise tabs to improve readability.
- **Content and illustration updates** have been made throughout the Seventh Edition. Please contact your Pearson representative for more details.

Also Available

- *The Anatomy & Physiology Coloring Workbook, Twelfth Edition* by Elaine Marieb and Simone Brito. (0-13-445936-9)
- *The Anatomy Coloring Book, Fourth Edition* by Wynn Kapit and Lawrence Elson. (0-321-83201-9)
- *The Physiology Coloring Book, Second Edition* by Wynn Kapit, Robert Macey, and Esmail Meisami. (0-321-03663-8)
- *MasteringA&P™ for Anatomy & Physiology, Seventh Edition* is highly recommended. Mastering is the most effective and widely used online homework, tutorial, and assessment system for the sciences. To learn more, ask your Pearson representative for details or a demo.

Acknowledgments

Many thanks to the Pearson Education product team: Lauren Harp, Senior Acquisitions Editor and Wendy Mears, Marketing Manager. Kudos as usual to Mangelli Productions and to David Novak, our production supervisor for this project.

As always, we invite users of this edition to send us their comments and suggestions for subsequent editions.

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EXERCISE 1

The Language of Anatomy

Materials

- Human torso model (dissectible)
- Human skeleton
- Scalpel
- Demonstration area:
  Station 1: Sectioned and labeled kidneys (three separate kidneys uncut or cut so that (a) entire, (b) transverse, and (c) median sectional views are visible)
  Station 2: Gelatin-spaghetti molds

Learning Outcomes

- ☐ Describe the anatomical position verbally or by demonstrating it.
- ☐ Demonstrate proficiency in using terms describing body landmarks, directions, planes, and surfaces.
- ☐ Name the body cavities, and indicate important organs in each cavity.

Most of us are naturally curious about our bodies. This curiosity is apparent even in infants, who are fascinated with their own waving hands or their mother's nose. Unlike the infant, however, an anatomy student must learn to identify body structures formally.

This exercise presents some of the most important anatomical terms you will be using to describe the body and introduces you to **gross anatomy,** the study of body structures you can see with your naked eye.

Anatomical Position

When anatomists or doctors refer to specific areas of the human body, they do so relative to a standard position called the **anatomical position.** In the anatomical position, the human body is erect, with head and toes pointed forward and arms hanging at the sides with palms facing forward (**Figure 1.1a**).

☐ Assume the anatomical position. Notice that it is not particularly comfortable because you must hold your hands unnaturally forward.

Surface Anatomy

The body is divided into two main regions, the axial and appendicular regions. The **axial region** includes the head, neck, and trunk; it runs along the vertical axis of the body. The **appendicular region** includes the limbs, which are also called the appendages or extremities. The body is also divided up into smaller regions within those two main divisions. Several of these are described on the following pages.

Activity 1

Locating Body Landmarks

Anterior Body Landmarks

Identify and use anatomical terms to correctly label the following regions in Figure 1.1a:

Abdominal: Anterior body trunk region inferior to the ribs

Acromial: Point of the shoulder

Antebrachial: Forearm

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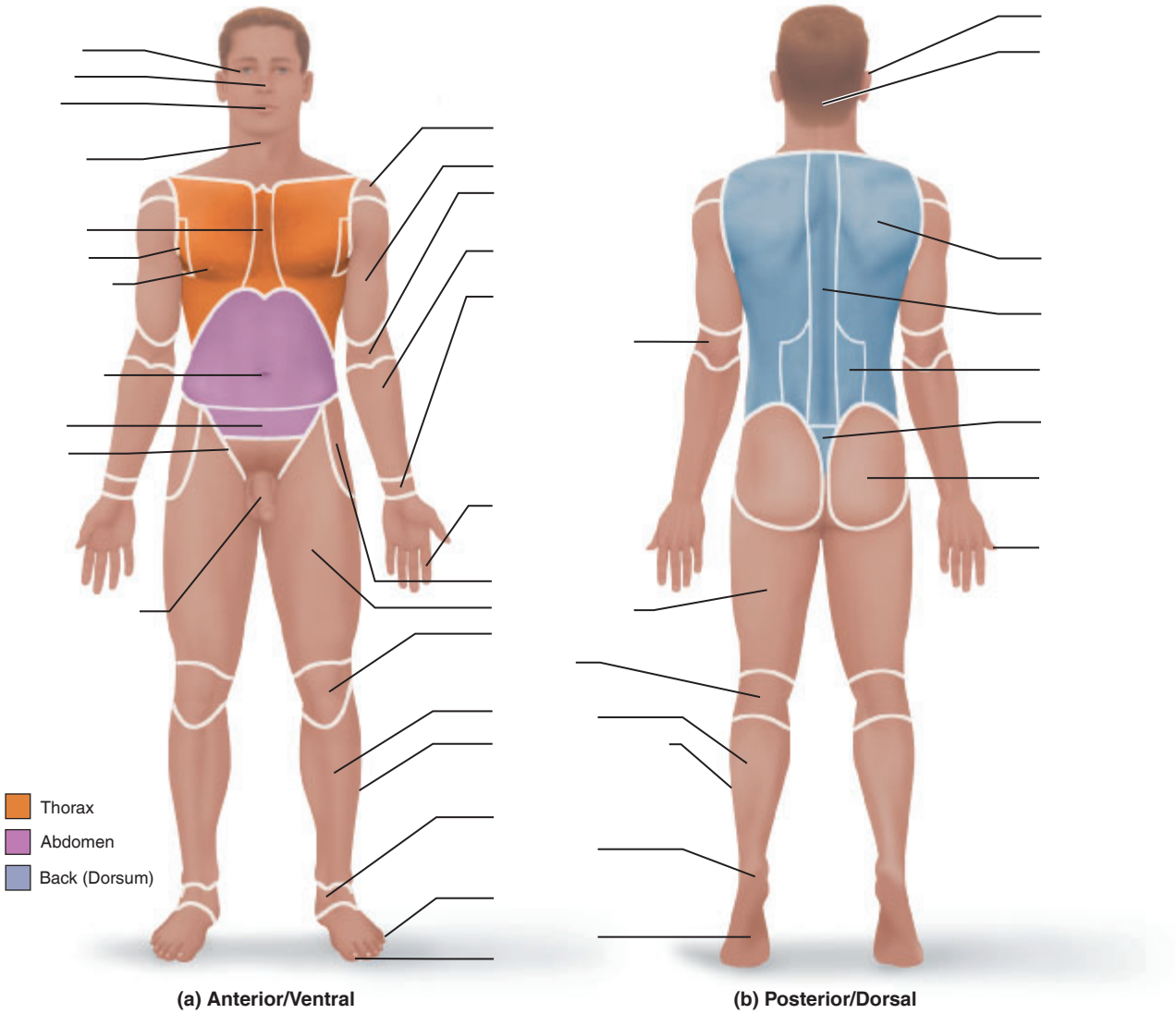


Figure 1.1 **Surface anatomy.**

Antecubital: Anterior surface of the elbow
Axillary: Armpit
Brachial: Arm
Buccal: Cheek
Carpal: Wrist
Cervical: Neck
Coxal: Hip
Crural: Leg (lower portion of the lower limb)
Digital: Fingers or toes
Femoral: Thigh
Fibular: Side of the leg
Hallux: Great toe
Inguinal: Groin
Mammary: Breast
Manus: Hand
Nasal: Nose
Oral: Mouth
Orbital: Bony eye socket (orbit)
Patellar: Kneecap
Pelvic: Pelvis
Pollex: Thumb
Pubic: Genital
Sternal: Breastbone
Tarsal: Ankle
Thoracic: Chest
Umbilical: Navel

Posterior Body Landmarks

Identify and appropriately label the following body surface regions in Figure 1.1b:

Brachial: Arm (upper portion of the upper limb)
Calcaneal: Heel of the foot
Cephalic: Head
Cervical: Neck
Femoral: Thigh
Fibular: Side of the leg
Gluteal: Buttocks
Lumbar: Lower back
Occipital: Back of the head
Olecranal: Back of the elbow
Otic: Ear
Popliteal: Back of the knee
Sacral: Posterior region between the hip bones
Scapular: Shoulder blade
Sural: Calf
Vertebral: Spine

Body Orientation and Direction

Study the terms below, referring to **Figure 1.2** as a visual aid.

Superior/inferior *(above/below):* These terms refer to the location of a structure along the long axis of the body. For example, the nose is superior to the mouth.

Anterior/posterior *(front/back):* In humans, the most anterior structures are those that are most forward—the face, chest, and abdomen. Posterior structures are those toward the backside of the body.

Medial/lateral *(toward the midline/away from the midline or median plane):* Medial structures are closer to the body midline (which is the spine in humans). Lateral structures are farther away from the midline.

The terms described above assume the person is in the anatomical position. The next four pairs of terms are more absolute. They do not relate to a particular body position, and they have the same meaning in humans and four-legged animals.

Cephalad/caudal *(toward the head/toward the tail):* In humans, these terms are used interchangeably with *superior* and *inferior.* But in four-legged animals, they are synonyms of *anterior* and *posterior*, respectively.

Ventral/dorsal *(belly side/backside):* In humans, the terms *ventral* and *dorsal* are used interchangeably with the terms *anterior* and *posterior,* but in four-legged animals, *ventral* and *dorsal* are synonymous with *inferior* and *superior,* respectively.

Proximal/distal *(nearer the trunk or attached end/farther from the trunk or point of attachment):* These terms locate various areas along the body limbs or an elongated organ, such as the intestine. For example, the fingers are distal to the elbow; the knee is proximal to the toes. *Note:* The terms *proximal* and *distal* would not be used to describe the relationship of two structures in the torso.

Superficial/deep *(toward or at the body surface/away from the body surface or more internal):* For example, the skin is superficial to the skeletal muscles.

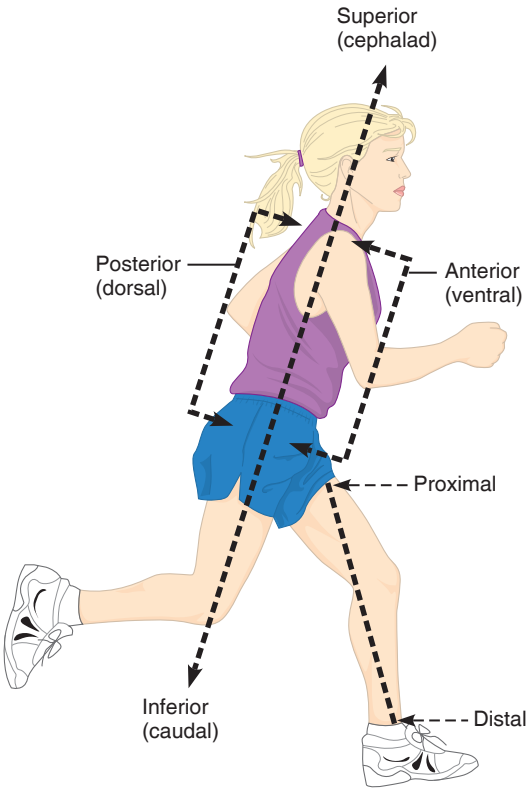


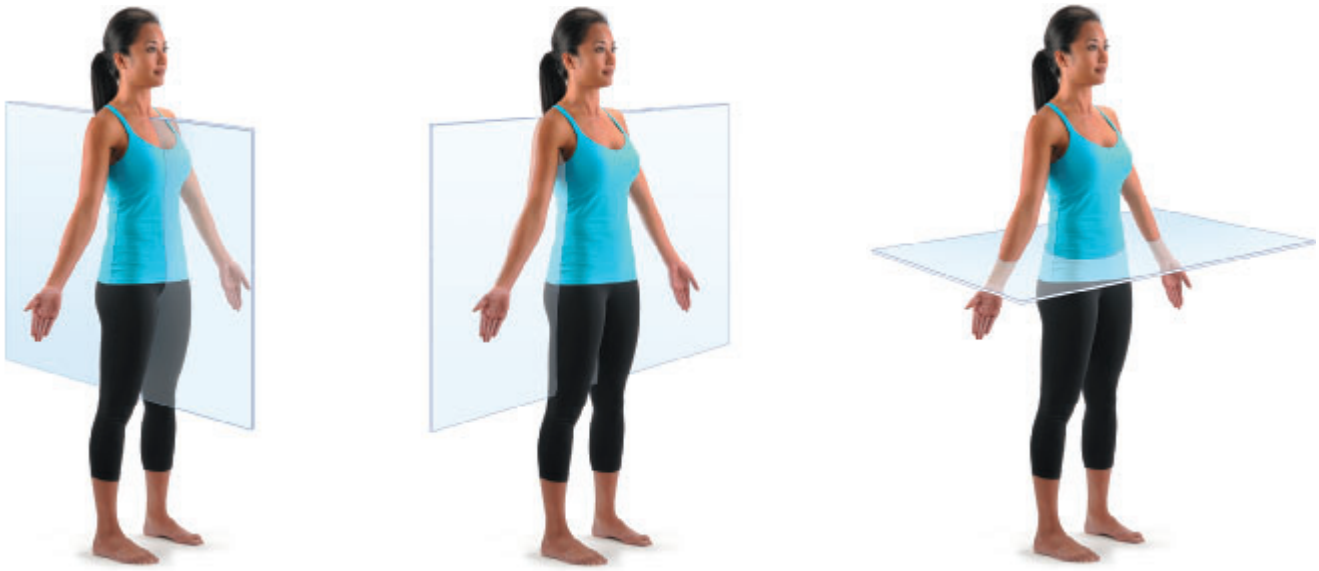
Figure 1.2 Anatomical terminology describing body orientation and direction in a human.

Activity 2

Practicing Using Correct Anatomical Terminology

Use a human torso model, a skeleton, or your own body to specify the relationship between the following structures.

1. The wrist is _____ to the hand.
2. The trachea (windpipe) is _____ to the spine.
3. The brain is _____ to the spinal cord.
4. The kidneys are _____ to the liver.
5. The nose is _____ to the cheekbones.
6. The chest is _____ to the abdomen.



(a) Median (midsagittal) plane (b) Frontal (coronal) plane (c) Transverse plane

Figure 1.3 **Planes of the body.**

Body Planes and Sections

The body is three-dimensional. So, in order to observe its internal parts, it helps to make use of a **section,** or cut made along an imaginary surface or line called a **plane.** A section is named for the plane along which it is cut. There are three planes of space (**Figure 1.3**), or sections, that lie at right angles to one another.

Sagittal plane: A plane that runs lengthwise or longitudinally down the length of the body, dividing it into right and left parts, is a sagittal plane. If it divides the body into equal parts, right down the median plane of the body, it is called a **median,** or **midsagittal, plane.**

Frontal (coronal) plane: A longitudinal plane that divides the body (or an organ) into anterior and posterior parts.

Transverse plane: A plane that runs horizontally, dividing the body into superior and inferior parts. These sections are also commonly called **cross sections.**

A sagittal or frontal section of any nonspherical object, be it a banana or a body organ, provides quite a different view from a transverse section (**Figure 1.4**).

Activity 3

Observing Sectioned Specimens

1. Go to the demonstration area, and observe the entire (uncut) and transversely and longitudinally cut kidneys at station 1.

2. After completing step 1, obtain a gelatin-spaghetti mold and a scalpel and bring them to your laboratory bench.

3. Cut through the gelatin-spaghetti mold along any plane, and examine the cut surfaces. You should see spaghetti strands that have been cut transversely (XS) and longitudinally (a median section).

4. Draw the appearance of each of these spaghetti sections below, and verify the accuracy of your section identifications with your instructor.

Transverse section	Median section

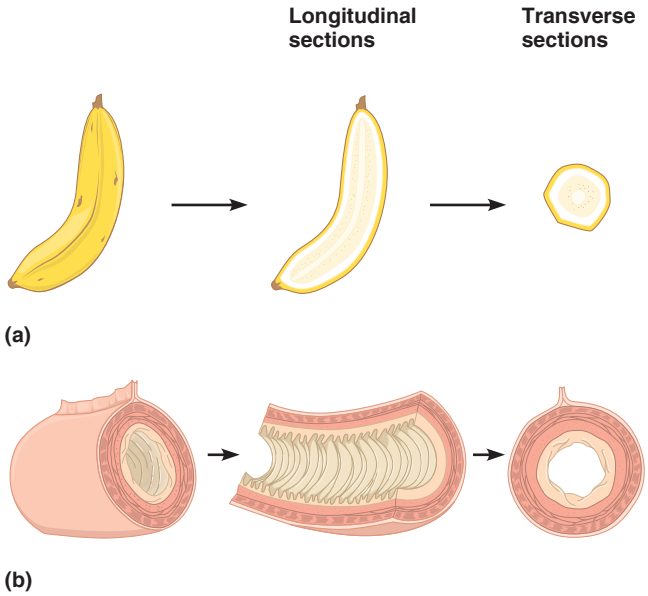


Figure 1.4 **Comparison of longitudinal and transverse sections.** Sections of **(a)** a banana and **(b)** the small intestine.

Body Cavities

The axial region of the body has two main cavities (**Figure 1.5**).

Dorsal Body Cavity

The dorsal body cavity consists of the cranial and spinal cavities. The **cranial cavity,** within the rigid skull, contains the brain. The **spinal cavity,** which runs within the bony vertebral column, protects the spinal cord.

Ventral Body Cavity

Like the dorsal cavity, the ventral body cavity is subdivided. The superior **thoracic cavity** is separated from the rest of the ventral cavity by the muscular diaphragm. The heart and lungs, which are located in the thoracic cavity, are protected by the bony rib cage. The thoracic cavity is further subdivided into the lateral **pleural cavities,** each of which surrounds a lung, and the medial **mediastinum.** The mediastinum contains the **pericardial cavity,** which encloses the heart, and it also surrounds the remaining thoracic organs (esophagus, trachea, and others).

The cavity inferior to the diaphragm is the **abdominopelvic cavity.** Although there is no further physical separation of this part of the ventral cavity, some describe the abdominopelvic cavity in terms of a superior **abdominal cavity,** the area that houses the stomach, intestines, liver, and other organs, and an inferior **pelvic cavity,** which is partially enclosed by the bony pelvis and contains the reproductive organs, bladder, and rectum.

Abdominopelvic Quadrants and Regions

The abdominopelvic cavity is quite large and contains many organs, so it is helpful to divide it up into smaller areas for study. The medical scheme divides the abdominal surface (and the abdominopelvic cavity deep to it) into four approximately equal regions called **quadrants,** named according to their relative position—that is, *right upper quadrant, right lower quadrant, left upper quadrant,* and *left lower quadrant* (**Figure 1.6**). *Note:* These directions refer to the patient's left and right—not yours!

Another scheme, commonly used by anatomists, divides the abdominal surface and abdominopelvic cavity into nine separate regions by four planes (**Figure 1.7a**). Read through the descriptions of these nine regions below and locate them in the figure. Notice the organs they contain (refer to **Figure 1.7b**).

Umbilical region: The centermost region, which includes the umbilicus (navel, or "belly button").

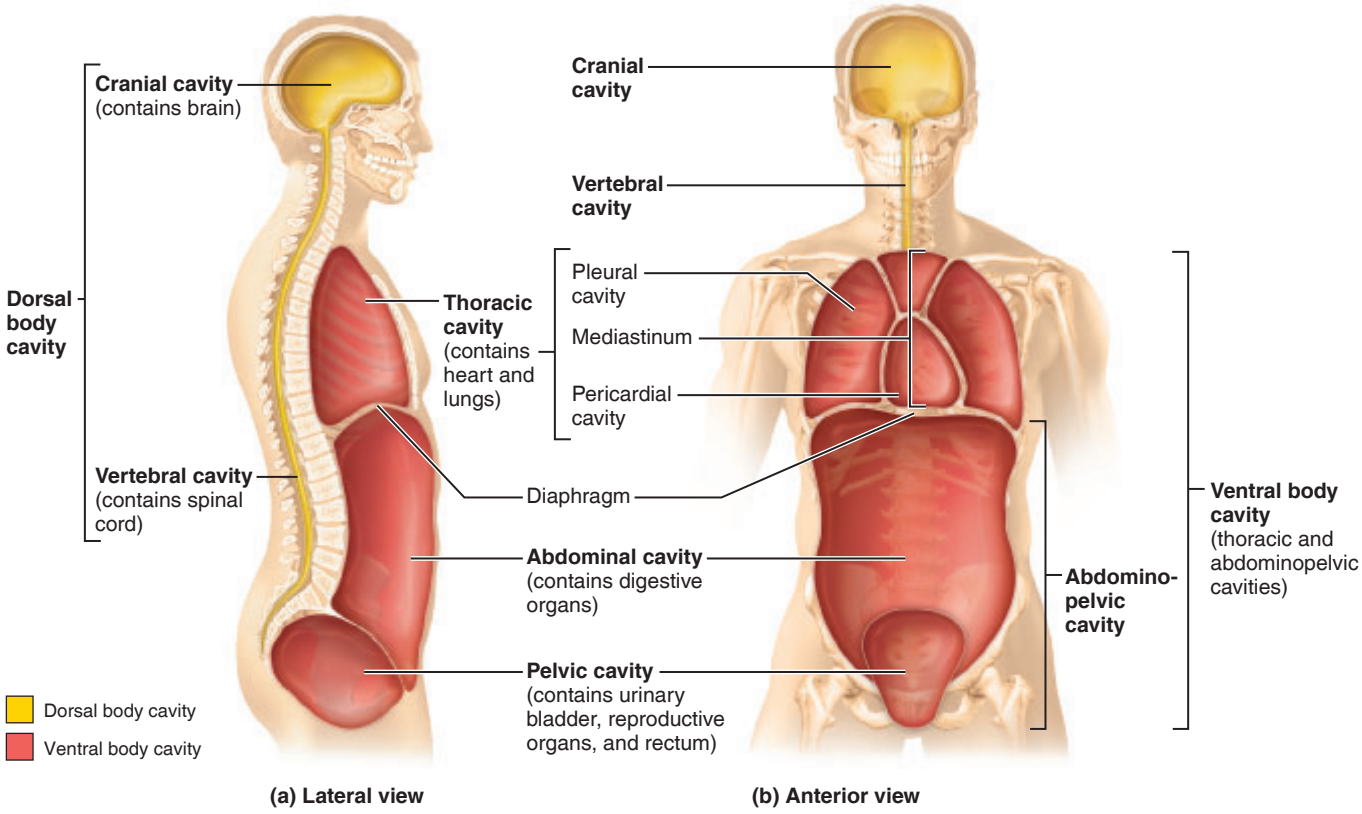


Figure 1.5 **Body cavities.**

Epigastric region: Immediately superior to the umbilical region; overlies most of the stomach.

Pubic (hypogastric) region: Immediately inferior to the umbilical region; encompasses the pubic area.

Inguinal, or iliac, regions: Lateral to the hypogastric region and overlying the superior parts of the hip bones.

Lateral (lumbar) regions: Between the ribs and the flaring portions of the hip bones; lateral to the umbilical region.

Hypochondriac regions: Flanking the epigastric region laterally and overlying the lower ribs.

Activity 4

Locating Abdominopelvic Surface Regions

Locate the regions of the abdominopelvic surface on a torso model and on yourself before continuing.

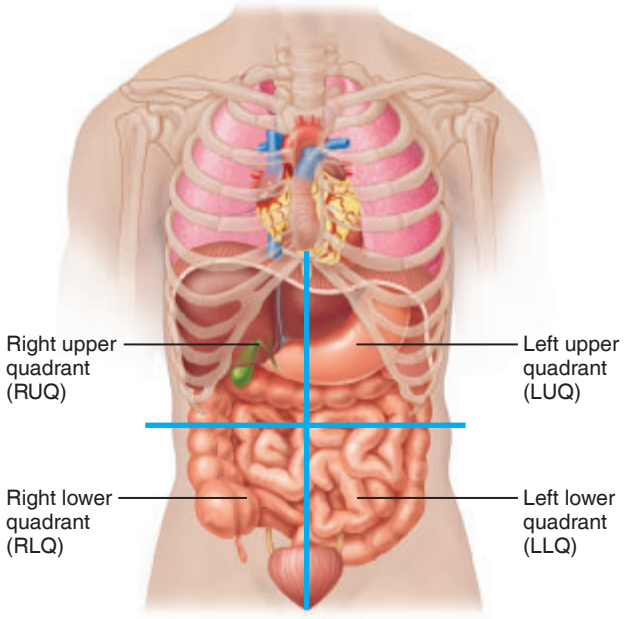
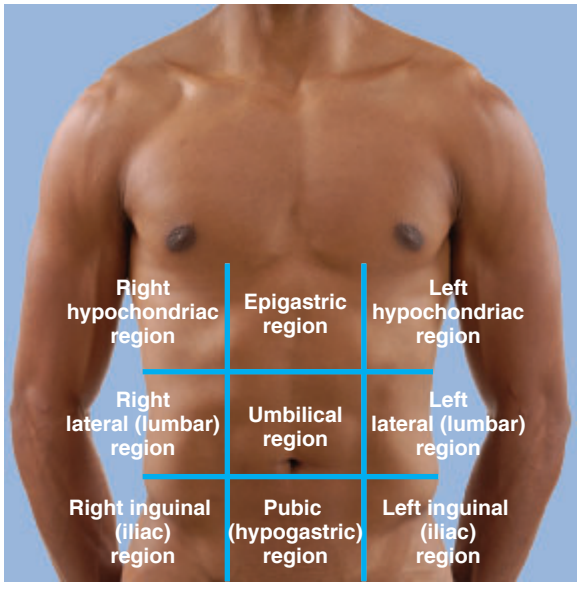
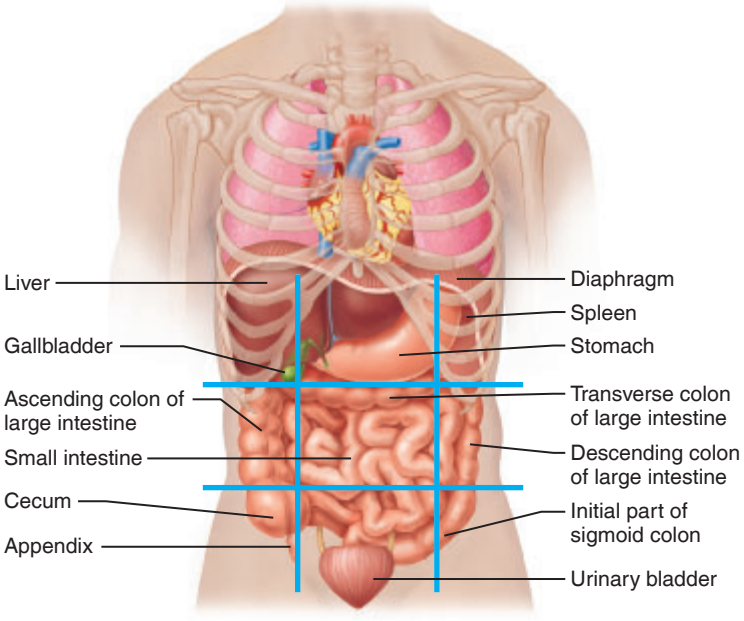


Figure 1.6 Abdominopelvic quadrants. Superficial organs shown in each quadrant.



(a)



(b)

Figure 1.7 Abdominopelvic regions. Nine regions defined by four planes. **(a)** The superior horizontal plane is just inferior to the ribs; the inferior horizontal plane is at the superior aspect of the hip bones. The vertical planes are just medial to the nipples. **(b)** Superficial organs are shown in each region.

EXERCISE 1

REVIEW SHEET

The Language of Anatomy

Name _____ Lab Time/Date _____

Surface Anatomy

1. Match each of the following descriptions with a key term, and write the term in front of the description.

Key:			
acromial	cervical	patellar	scapular
brachial	crural	popliteal	vertebral
carpal	digital		

_____ **1.** lower portion of the lower limb

_____ **2.** referring to the fingers

_____ **3.** posterior aspect of the knee

_____ **4.** shoulder blade

_____ **5.** wrist area

_____ **6.** anterior aspect of knee

_____ **7.** referring to the arm

_____ **8.** your backbone, or spine

_____ **9.** point of the shoulder

_____ **10.** referring to the neck

Body Orientation, Direction, Planes, and Sections

2. Several incomplete statements are listed below. Correctly complete each statement by choosing the appropriate anatomical term from the key. Write the key terms on the correspondingly numbered blanks below. Some terms may be used more than once.

Key:			
anterior	inferior	posterior	superior
distal	lateral	proximal	transverse
frontal	medial	sagittal	

In the anatomical position, the umbilicus and knees are on the _1_ body surface; the calves and shoulder blades are on the _2_ body surface; and the soles of the feet are the most _3_ part of the body. The ears are _4_ and _4_ to the shoulders and _5_ to the nose. The breastbone is _6_ to the vertebral column (spine) and _7_ to the shoulders. The elbow is _8_ to the shoulder but _9_ to the fingers. The thoracic cavity is _10_ to the abdominopelvic cavity and _11_ to the spinal cavity. In humans, the ventral surface can also be called the _12_ surface; however, in quadruped animals, the ventral surface is the _13_ surface.

If an incision cuts the brain into superior and inferior parts, the section is a _14_ section; but if the brain is cut so that anterior and posterior portions result, the section is a _15_ section. You are told to cut a dissection animal along two planes so that the lungs are observable in both sections. The body plane that would *not* meet these criteria is _16_.

1. _____

2. _____

3. _____

4. _____

_____

5. _____

6. _____

7. _____

8. _____

9. _____

10. _____

11. _____

12. _____

13. _____

14. _____

15. _____

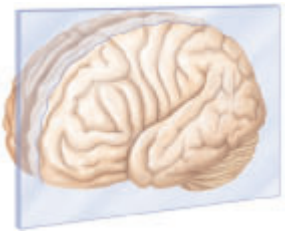
16. _____

3. A nurse informs you that she is about to give you a shot in the lateral femoral region. What portion of your body should you uncover?

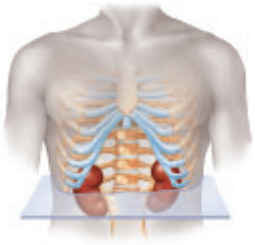
_____

4. Correctly identify each of the body planes by inserting the appropriate term for each on the answer line below the drawing.

(a) _____



(b) _____



(c) _____

Body Cavities

5. Which body cavity would have to be opened for the following types of surgery? (Insert the key term in the same-numbered blank.)

Key: abdominopelvic cranial spinal thoracic

1. surgery to remove a cancerous lung lobe — 1. _____
2. gastric bypass surgery to reduce the size of the stomach — 2. _____
3. surgery to remove a ruptured spinal disk — 3. _____
4. removal of a brain tumor — 4. _____

6. Name the body region that blood is usually drawn from. _____

7. A patient has been diagnosed with appendicitis. Use anatomical terminology to describe the location of the person's pain. Assume that the pain is referred to the surface of the body above the organ.

_____

8. Which body cavity would be opened to perform a hysterectomy? _____

_____

EXERCISE 2

Organ Systems Overview

Materials

- Freshly killed or predissected rat (if available)
- Probes
- Forceps
- Scissors
- Dissecting pins or twine
- Dissecting trays
- Disposable gloves
- Human torso model (dissectible)

Learning Outcomes

- ☐ Identify several organs of the various organ systems on a dissected rat.
- ☐ Identify several organs on a dissectible human torso model, and, given a list of organs, assign each to the correct organ system.

The building block of life is the **cell.** Cells fall into four different groups according to their structures and functions. These categories correspond to the four primary **tissue** types: epithelial, muscular, nervous, and connective. An **organ** is a structure composed of two or more tissue types that performs a specific function for the body.

An **organ system** is a group of organs that act together to perform a particular body function. For example, digestive system organs work together to break down foods moving through the digestive system and absorb the end products into the bloodstream to provide nutrients for all the body's cells.

An important concept in your study of anatomy and physiology is **homeostasis,** which can be defined as a state of body equilibrium or a stable internal environment of the body. Keep this concept in mind as you study the organ systems listed in **Table 2.1** and begin to think about how each of these important systems works to maintain homeostasis in the human body.

Activity 1

Studying the Organ Systems of the Body and Their Functions

In all, there are 11 organ systems (Table 2.1). Read through this summary before beginning the rat dissection.

DISSECTION

Rat Dissection and/or Observation

Many of the external and internal structures of the rat are quite similar in structure and function to those of the human, so a study of the gross anatomy of the rat should help you understand your own anatomy.

The following instructions complement and direct your dissection and observation of a rat. In addition, you can easily adapt the general instructions for observing external structures to observing a human cadaver, if cadavers are available.

Note that four organ systems—integumentary, skeletal, muscular, and nervous—will not be studied at this time, because they require microscopic study or more detailed dissection.

Table 2.1 Overview of Organ Systems of the Body

Organ system	Major component organs	Function
Integumentary	Skin, nails, and hair; cutaneous sense organs and glands	• Protects deeper organs from injury due to bumps, chemicals, bacteria, and dehydration (drying out) • Excretes salts and urea • Helps regulate body temperature
Skeletal	Bones, cartilages, tendons, ligaments, and joints	• Supports and protects internal organs • Provides levers for muscular action • Stores minerals (calcium and others) • Cavities provide a site for blood cell formation
Muscular	Muscles attached to the skeleton	• Skeletal muscles contract, or shorten; in doing so, they move bones to allow motion (running, walking, etc.), grasping and manipulating the environment, and facial expression • Generates heat
Nervous	Brain, spinal cord, nerves, and sensory receptors	• Allows body to detect changes in its internal and external environment and to respond to such information by activating appropriate muscles or glands • Helps maintain short-term homeostasis of the body by rapidly transmitting electrical signals
Endocrine	Pituitary, thyroid, parathyroid, adrenal, and pineal glands; ovaries, testes, and pancreas	• Promotes growth and development; produces chemical "messengers" (hormones) that travel in the blood to exert their effect(s) on various target organs of the body • Plays a role in regulating long-term homeostasis
Cardiovascular	Heart and blood vessels	• Carries blood containing oxygen, carbon dioxide, nutrients, wastes, ions, hormones, and other substances to and from the cells where exchanges are made; pumping action of the heart propels blood through the blood vessels • Protects body with blood clots, antibodies, and other protein molecules in the blood
Lymphatic	Lymphatic vessels, lymph nodes, spleen, and thymus	• Picks up fluid leaked from the blood vessels and returns it to the blood • Cleanses blood of pathogens and other debris • Houses cells (lymphocytes and others) that act in the immune response to protect the body from foreign substances (antigens)
Respiratory	Nasal cavity, pharynx, larynx, trachea, bronchi, and lungs	• Keeps the blood continuously supplied with oxygen while removing carbon dioxide • Contributes to the acid-base balance of the blood via its carbonic acid/bicarbonate buffer system
Digestive	Oral cavity, pharynx, esophagus, stomach, small and large intestines, and accessory structures (teeth, salivary glands, liver, gallbladder, and pancreas)	• Breaks down ingested foods to tiny particles, which can be absorbed into the blood for delivery to the body's cells • Undigested residue leaves the body as feces
Urinary	Kidneys, ureters, urinary bladder, and urethra	• Filters the blood and then rids the body of nitrogen-containing wastes (urea, uric acid, and ammonia) that result from the breakdown of proteins and nucleic acids by the body's cells. • Maintains water, electrolyte, and acid-base balance of blood
Reproductive	Male: testes, scrotum, penis, and duct system, which carries sperm to the body exterior	• Produces gametes called sperm for producing offspring
	Female: ovaries, uterine tubes, uterus, and vagina	• Produces gametes called eggs; the female uterus houses a developing fetus until birth

Activity 2

Observing External Structures

1. If your instructor has provided a predissected rat, go to the demonstration area to make your observations. Alternatively, if you and/or members of your group will be dissecting the specimen, obtain a preserved or freshly killed rat (one for every two to four students), a dissecting tray, dissecting pins, scissors, forceps, and disposable gloves. Bring these items to your laboratory bench.

2. Don the gloves before beginning your observations. This precaution is particularly important when you are handling freshly killed animals, which may harbor internal parasites.

3. Observe the major divisions of the animal's body—head, trunk, and extremities. Compare these divisions to those of humans.

Activity 3

Examining the Mouth (Oral Cavity)

Examine the structures of the mouth or oral cavity, the most superior part of the digestive system. Identify the teeth and tongue. Observe the hard palate (the part supported by bone) and the soft palate (immediately posterior to the hard palate and with no bony support). Notice that the posterior end of the oral cavity leads into the throat, or pharynx, a passageway used by both the digestive and respiratory systems.

Activity 4

Opening the Ventral Body Cavity

1. Pin the animal to the wax of the dissecting tray by placing its dorsal side down and securing its extremities to wax (**Figure 2.1a**).

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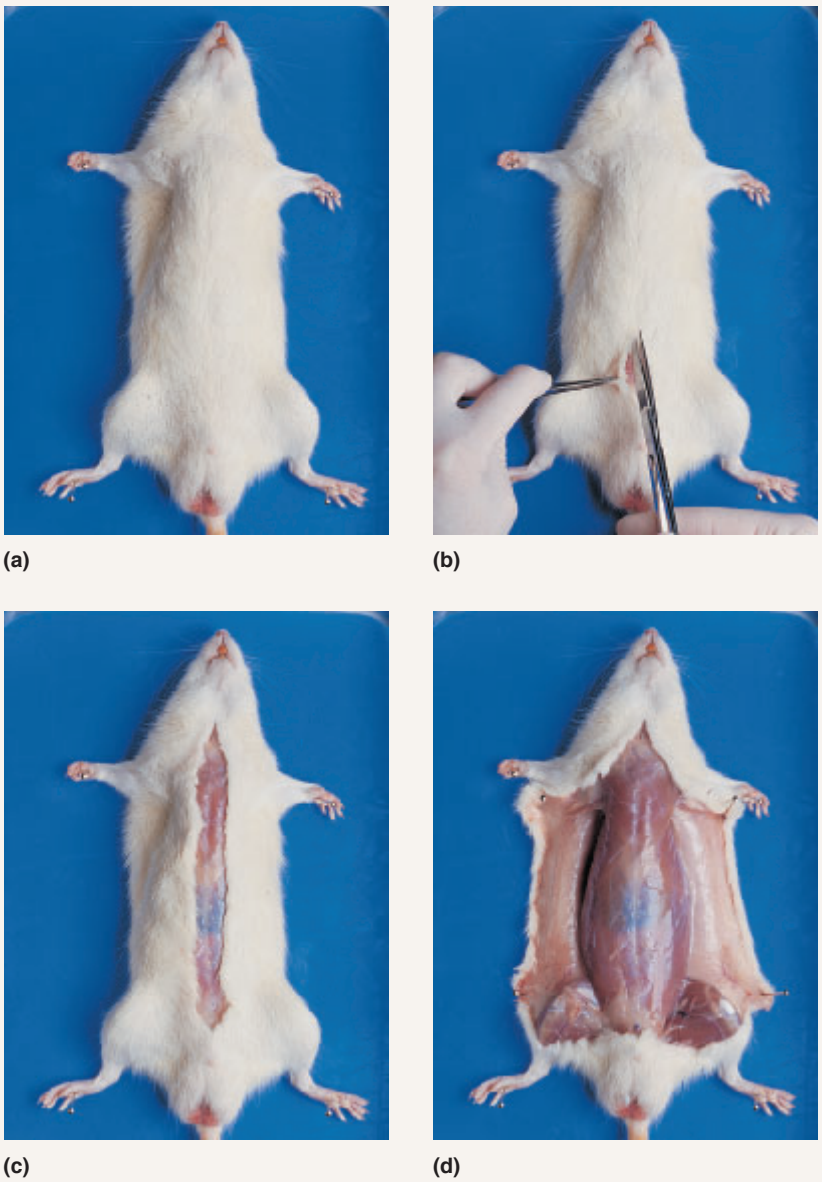


(a) (b) (c) (d)

Figure 2.1 Rat dissection: Securing for dissection and the initial incision. **(a)** Securing the rat to the dissection tray with dissecting pins. **(b)** Using scissors to make the incision on the median line of the abdominal region. **(c)** Completed incision from the pelvic region to the lower jaw. **(d)** Reflecting (folding back) the skin to expose the underlying muscles.

2. Lift the abdominal skin with a forceps, and cut through it with the scissors (Figure 2.1b). Close the scissor blades and insert them under the cut skin. Moving in a cephalad direction, open and close the blades to loosen the skin from the underlying connective tissue and muscle. Once you have completed this skin-freeing procedure, cut the skin along the body midline, from the pubic region to the lower jaw (Figure 2.1c). Make a lateral cut about halfway down the ventral surface of each limb. Complete the job of freeing the skin with the scissor tips, and pin the flaps to the tray (Figure 2.1d). The underlying tissue that is now exposed is the skeletal musculature of the body wall and limbs. It allows voluntary body movement. Notice that the muscles are packaged in sheets of pearly white connective tissue (fascia), which protect the muscles and bind them together.

3. Carefully cut through the muscles of the abdominal wall in the pubic region, avoiding the underlying organs. Remember, *to dissect* means "to separate." Now, hold and lift the muscle layer with a forceps and cut through the muscle layer from the pubic region to the bottom of the rib cage. Make two lateral cuts through the rib cage (**Figure 2.2**). You should easily see a thin membrane attached to the inferior boundary of the rib cage: this is the **diaphragm,** which separates the thoracic and abdominal cavities. Cut the diaphragm away to loosen the rib cage. You can now carefully cut through the rib cage to view the contents of the thoracic cavity.

Figure 2.2 Rat dissection: Opening the ventral body cavity. Making lateral cuts at the base of the rib cage.

Activity 5

Examining the Ventral Body Cavity

1. Examine the structures of the thoracic cavity, starting with the most superficial structures and working deeper. As you work, refer to the figure that shows the superficial thoracic organs (**Figure 2.3**).

Thymus: An irregular mass of glandular tissue overlying the heart.

With a probe, push the thymus to the side to view the heart.

Heart: Medial oval structure that lies between the lungs.

Lungs: Lateral to the heart on either side.

Now observe the throat region to identify the trachea.

Trachea: Tubelike "windpipe" running medially down the throat; part of the respiratory system.

Follow the trachea into the thoracic cavity. Notice where it divides into two branches—these are the bronchi.

Bronchi: Two passageways that plunge laterally into the tissue of the two lungs.

To expose the esophagus, push the trachea to one side.

Esophagus: A food chute; the part of the digestive system that transports food from the pharynx (throat) to the stomach.

Diaphragm: A thin muscular membrane attached to the inferior boundary of the rib cage.

Follow the esophagus through the diaphragm to its junction with the stomach.

Stomach: A curved organ important in food digestion and temporary food storage.

2. Examine the superficial structures of the abdominopelvic cavity. Lift the *greater omentum*, an apronlike membrane fold that covers the abdominal organs. Continuing from the stomach, trace the rest of the digestive tract (Figure 2.3b).

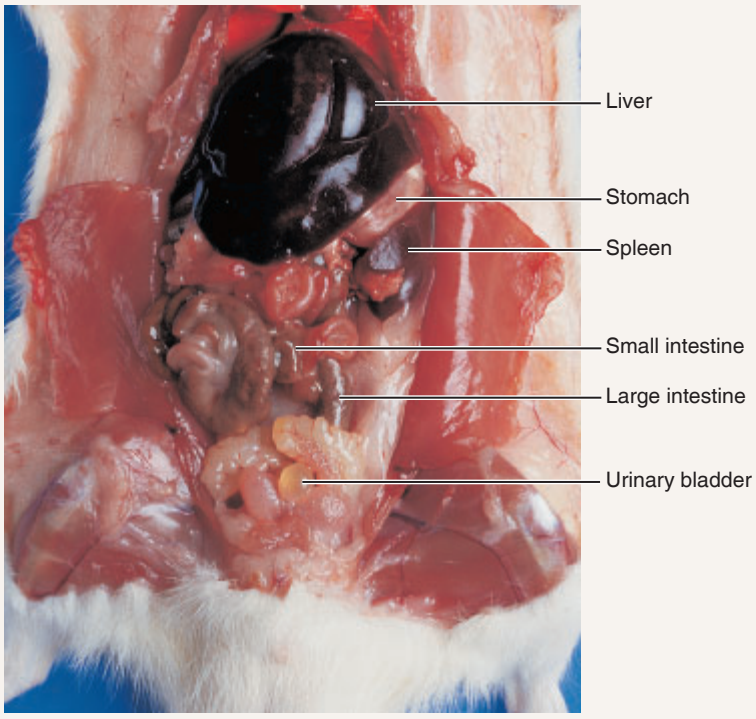
Small intestine: A long coiled tube connected to the stomach and ending just before the saclike cecum.

Large intestine: A large muscular tube coiled within the abdomen.

Follow the course of the large intestine, which begins at the saclike cecum, frames the small intestine, and ends at the rectum. Notice that it is partially covered by the urinary bladder.

Rectum: Terminal part of the large intestine; continuous with the anal canal.

(a) Thoracic cavity



(b) Abdominal cavity

Figure 2.3 **Rat dissection: Superficial organs of the thoracic and abdominal cavities.**

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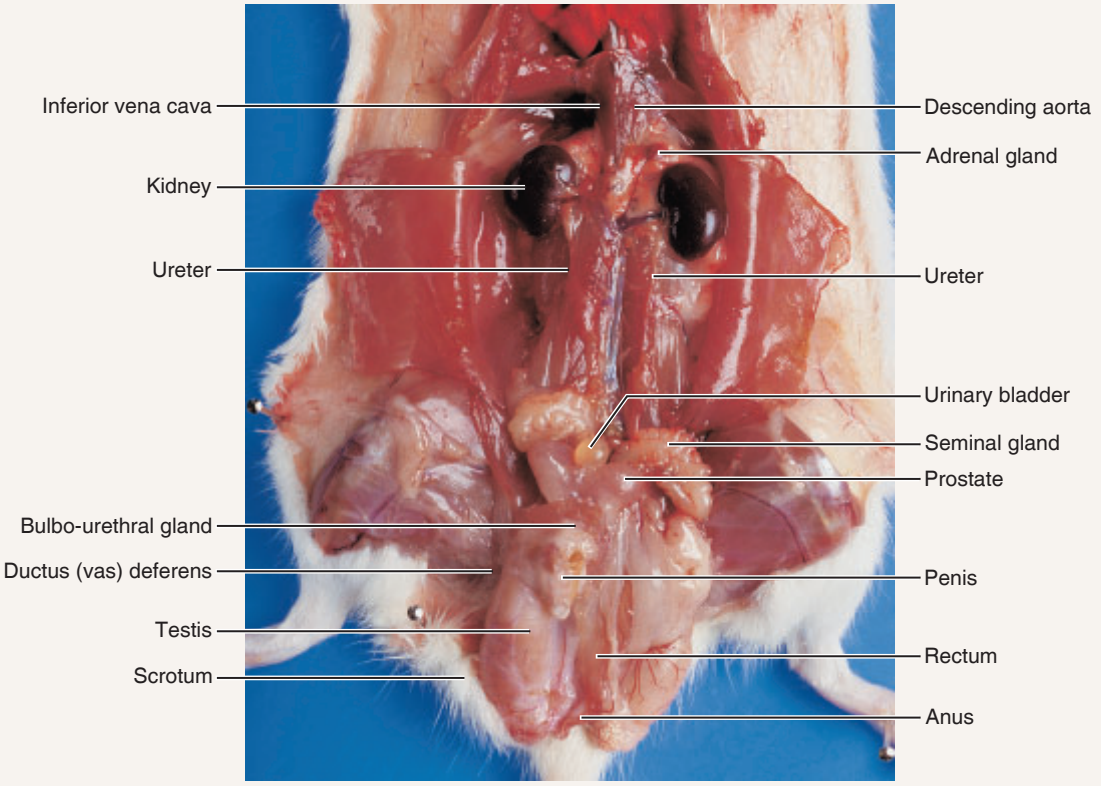
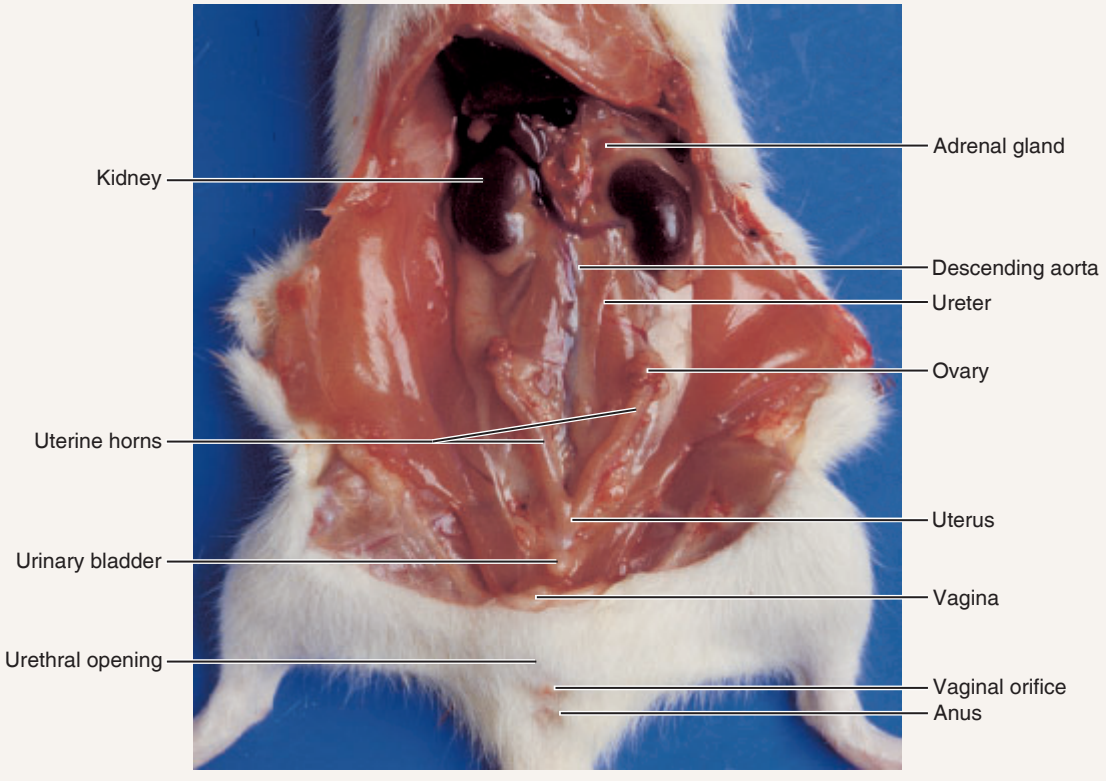


(a) Male



(b) Female

Figure 2.4 **Rat dissection: Deeper organs of the abdominopelvic cavity.**

Anus: The opening of the digestive tract (anal canal) to the exterior.

Now lift the small intestine with the forceps to view the mesentery.

Mesentery: A delicate membrane; suspends the small intestine in the abdominal cavity. Notice that it is heavily invested with blood vessels.

Locate the remaining abdominal structures.

Pancreas: A diffuse gland; rests posterior to and between the first portion of the small intestine and the stomach. You will need to lift the stomach to view the pancreas.

Spleen: A dark red organ curving around the left lateral side of the stomach; an organ of the lymphatic system.

Liver: Large and brownish red; the most superior organ in the abdominal cavity, directly inferior to the diaphragm.

3. To locate the deeper structures of the abdominopelvic cavity, move the stomach and the intestines to one side with the probe. Refer to **Figure 2.4** as you work.

Examine the posterior wall of the abdominal cavity to locate the two kidneys.

Kidneys: Bean-shaped organs; secured to the posterior wall of the body trunk.

Adrenal glands: Small glands that sit on the top of each kidney; considered part of the endocrine system.

Carefully strip away part of the membrane covering a kidney with forceps. Attempt to follow the course of one of the ureters to the bladder.

Ureter: Tube running from the indented region of a kidney to the urinary bladder (see also Figure 2.4b).

Urinary bladder: The sac in the pelvis that serves as a reservoir for urine.

4. In the midline of the body cavity lying between the kidneys are the two principal abdominal blood vessels.

Inferior vena cava: The large vein that returns blood to the heart from the lower regions of the body.

Descending aorta: Deep to the inferior vena cava; the largest artery of the body; carries blood away from the heart.

5. You will perform only a cursory examination of reproductive organs. First determine whether the animal is a male or female. Observe the ventral body surface beneath the tail. If a saclike scrotum and a single body opening are visible, the animal is a male. If three body openings are present, it is a female. (See Figure 2.4.)

Male Rat

Make a shallow incision into the **scrotum.** Loosen and lift out the oval **testis.** Pull very gently on the testis to identify the slender **ductus deferens,** or sperm duct, which carries sperm from the testis superiorly into the abdominal cavity and joins with the urethra. The urethra runs through the penis of the male and carries both urine and sperm out of the body. Identify the **penis,** extending from the bladder to the ventral body wall. You may see other glands of the male reproductive system (Figure 2.4a), but you don't need to identify them at this time.

Female Rat

Inspect the pelvic cavity to identify the Y-shaped **uterus** lying against the dorsal body wall and beneath the bladder (Figure 2.4b). Follow one of the uterine horns superiorly to identify an **ovary,** a small oval structure at the end of the uterine horn. (The rat uterus is quite different from the uterus of a human female, which is a single-chambered organ about the size and shape of a pear.) The inferior undivided part of the rat uterus is continuous with the vagina, which leads to the body exterior. Identify the **vaginal orifice** (external vaginal opening).

Activity 6

Examining the Human Torso Model

1. Examine a human torso model to identify the organs listed below. If a torso model is not available, refer to **Figure 2.5** for part of this exercise. You'll need to remove some organs on the model to see deeper organs.

Dorsal body cavity: Brain, spinal cord

Thoracic cavity: Heart, lungs, bronchi, trachea, esophagus, diaphragm, thyroid gland

Abdominopelvic cavity: Liver, gall bladder, stomach, pancreas, spleen, small intestine, large intestine, rectum, kidneys, ureters, bladder, adrenal gland, uterus, descending aorta, inferior vena cava

2. Before continuing, identify each organ with a leader line in Figure 2.5.

3. Assign all of the structures listed above to one of the following organ system categories.

Digestive: _____

_____

_____

Urinary: _____

_____

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Cardiovascular: _____

_____

Endocrine: _____

_____

Reproductive: _____

Respiratory: _____

_____

Lymphatic: _____

Nervous: _____

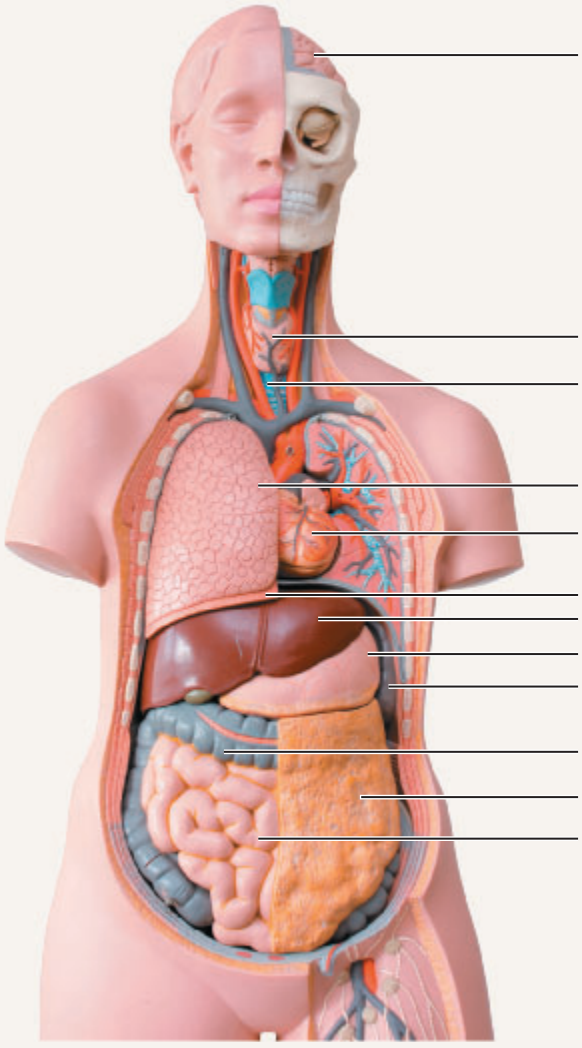


Figure 2.5 **Human torso model.**

EXERCISE 2

REVIEW SHEET

Organ Systems Overview

Name _____ Lab Time/Date _____

1. Using the key, indicate which body system matches each of the following descriptions.

Key: cardiovascular, digestive, endocrine, integumentary, lymphatic, muscular, nervous, reproductive, respiratory, skeletal, urinary

_____ **1.** rids the body of nitrogen-containing wastes

_____ **2.** is affected by removal of the adrenal gland

_____ **3.** protects and supports body organs; provides a framework for muscular action

_____ **4.** includes arteries and veins

_____ **5.** composed of glands that secrete hormones

_____ **6.** external body covering

_____ **7.** houses cells involved in the body's immune response

_____ **8.** breaks down ingested food into its absorbable units

_____ **9.** loads oxygen into the blood

_____ **10.** uses blood as a transport vehicle

_____ **11.** generates body heat and provides for movement of the body as a whole

_____ **12.** key organs include the brain and spinal cord

_____ and _____ **13.** necessary for conception and childbearing

_____ **14.** is damaged when you fall and scrape your knee

2. Using the above key, choose the *organ system* to which each of the following sets of organs or body structures belongs:

_____ **1.** lymph nodes, spleen, lymphatic vessels

_____ **2.** bones, cartilages, ligaments

_____ **3.** thyroid, pancreas, pituitary gland

_____ **4.** trachea, bronchi, lungs

_____ **5.** uterus, ovaries, vagina

_____ 6. arteries, veins, heart

3. Name the cells that are produced by the testes and ovaries. _____

4. List the four primary tissue types. _____

5. Explain why an artery is an organ. _____

6. Name the two main organ systems that communicate within the body to maintain homeostasis. Briefly explain their different control mechanisms. _____

7. Explain the role that the skeletal system plays in facilitating cardiovascular system function. _____

8. Untreated diabetes mellitus can lead to a condition in which the blood is more acidic than normal. Name two organ systems that play the largest role in compensating for acid-base imbalances. _____

9. The mother of a child scheduled to receive a thymectomy (removal of the thymus gland) asks you whether there will be any side effects from the removal of the gland. Which two organ systems would you mention in your explanation? _____

10. Individuals with asplenia are missing their spleen or have a spleen that doesn't function well. It is recommended that these patients talk to their doctor about vaccines that are indicated for their health condition. Explain how this recommendation correlates to their chronic health condition. _____

EXERCISE

3 The Cell—Anatomy and Division

Materials

- Three-dimensional model of the "composite" animal cell or chart of cell anatomy
- Chenille sticks (pipe cleaners) and chalk
- Three-dimensional models of mitotic stages
- Demonstration area:

  Station 1: Compound microscopes set up and focused on slides of four tissue samples for student observation (simple squamous epithelium [$AgNO_3$ stain], teased smooth muscle, human blood cell smear, and sperm)

  Station 2: Compound microscopes set up and focused with pointers on whitefish blastula cells exhibiting the major phases of mitosis (prophase, metaphase, anaphase, and telophase)

Learning Outcomes

- ☐ Name, identify, and list the major function(s) of the various cell structures.
- ☐ Compare and contrast specialized cells to the generalized cells.
- ☐ Define interphase, mitosis, and cytokinesis, and identify and describe the stages of mitosis.

The **cell** is the structural and functional unit of all living things. Differences in size, shape, and internal makeup of the cells of the human body reflect their specific roles in the body. Still, cells do have many common features and functions. For example, all cells maintain their boundaries, metabolize and digest nutrients, dispose of wastes, grow and reproduce, move, and respond to a stimulus. Most of these functions are considered in detail in later exercises. This exercise begins by describing the structural similarities typical of the "composite," or "generalized," cell and then considers the function of cell reproduction (cell division).

Anatomy of the Composite Cell

All cells have three major regions: **nucleus, plasma membrane,** and **cytoplasm.** The nucleus is typically a round or oval structure near the center of the cell. It is surrounded by cytoplasm, which in turn is enclosed by the plasma membrane. Within the cytoplasm, even smaller cell structures—organelles—have been identified. **Figure 3.1** is a diagram of the internal structure of the composite cell.

Nucleus

The nucleus is often described as the control center of the cell and is necessary for cell reproduction. The nucleus is the site of the genes, or genetic material—DNA—and when the cell is not dividing, that genetic material is in a threadlike form called **chromatin.** When a cell is dividing to form daughter cells, the chromatin coils and condenses to form rodlike bodies called **chromosomes**—much in the way a stretched spring becomes shorter and thicker when it is released.

The nucleus also contains one or more small round bodies, called **nucleoli.** The nucleoli are assembly sites for ribosomes that are particularly abundant in the cytoplasm.

The nucleus is bound by a double-layered porous membrane, the **nuclear envelope.** The nuclear envelope is similar to other cellular membranes, but is distinguished by its large *nuclear pores,* which permit large molecules like protein and RNA molecules to pass easily.

Activity 1

Identifying Parts of a Cell

Locate the nuclear envelope, chromatin, nucleoli, and nuclear pores in Figure 3.1.

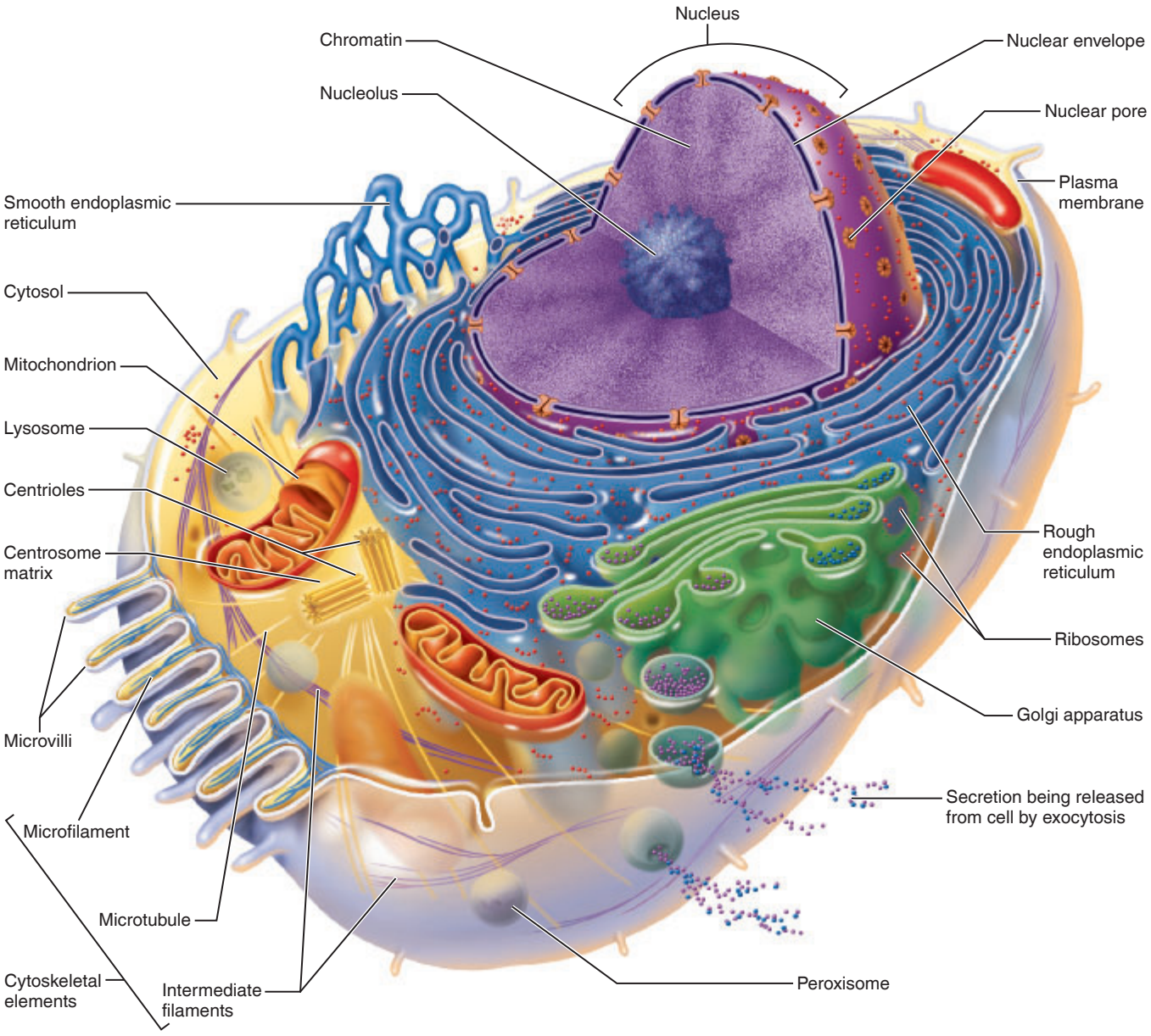


Figure 3.1 **Structure of the generalized cell.**

Plasma Membrane

The **plasma membrane** separates cell contents from the surrounding environment. Essentially, the membrane has a double-layered lipid structure that the protein molecules (some with attached carbohydrate groups) float in (**Figure 3.2**). Occasional cholesterol molecules dispersed in the fluid phospholipid bilayer help to stabilize it.

Besides protecting the cell, the plasma membrane determines which substances may enter or leave the cell and in what quantity. In some cells the membrane has **microvilli,** tiny fingerlike projections that greatly increase the surface area of the cell.

Activity 2

Identifying Components of a Plasma Membrane

Identify the phospholipid and protein portions of the plasma membrane in Figure 3.2. Also locate the carbohydrate side chains and cholesterol molecules. Identify the microvilli in the figure of the generalized cell (Figure 3.1).

Cytoplasm and Organelles

The cytoplasm is the cell contents outside the nucleus and is the major site of most activities carried out by the cell. Suspended

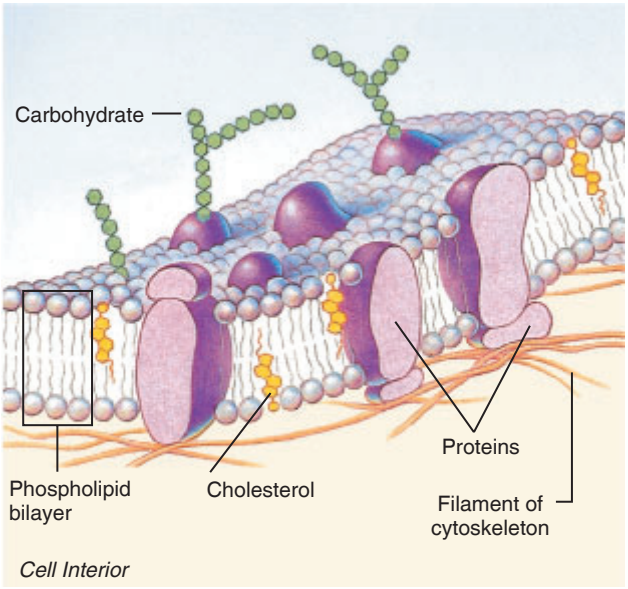


Figure 3.2 Structure of the plasma membrane.

in the **cytosol,** the fluid part of the cytoplasm, are tiny structures called **organelles** (literally, "small organs"). The organelles (**Table 3.1**) are the metabolic machinery of the cell, organized to carry out specific activities for the cell as a whole.

The cell cytoplasm contains various other substances and structures, including stored foods (glycogen granules and lipid droplets), pigment granules, crystals of various types, water vacuoles, and ingested foreign materials. But these are not part of the active metabolic machinery of the cell and are therefore called **inclusions.**

Activity 3

Locating Organelles

Read about the organelles and their structure and function in Table 3.1, and then be sure you can locate the organelles in the figure depicting the generalized cell (Figure 3.1).

Activity 4

Examining the Cell Model

Once you have located all of the structures in the figure of the generalized cell (Figure 3.1), examine the cell model (or cell chart) to repeat and reinforce your identifications. Try not to look at the figure as you make your identifications.

Table 3.1 Cytoplasmic Organelles

Organelle	Location and function
Ribosomes	Tiny spherical bodies consisting of RNA and protein; actual sites of protein synthesis; seen floating free or attached to a membranous structure (the rough ER) in the cytoplasm
Endoplasmic reticulum (ER)	Membranous system of tubules that extends throughout the cytoplasm; two varieties: (1) rough ER—studded with ribosomes (tubules of the rough ER provide an area for proteins made on the ribosomes to be transported to other cell areas) and (2) smooth ER—a site of steroid and lipid synthesis, lipid metabolism, and drug detoxification (no protein synthesis–related function)
Golgi apparatus	Stack of flattened sacs with swollen ends and associated small vesicles; found close to the nucleus; plays a role in packaging proteins or other substances that will be exported from the cell or incorporated into the plasma membrane and in packaging lysosomal enzymes
Lysosomes	Various-sized membranous sacs containing digestive enzymes including acid hydrolases; digest worn-out cell organelles and foreign substances that enter the cell; if ruptured, they have the capacity to totally destroy the cell and are for this reason referred to as "suicide sacs"
Peroxisomes	Small lysosome-like membranous sacs containing oxidase enzymes that detoxify alcohol, free radicals, and other harmful chemicals
Mitochondria	Generally rod-shaped bodies with a double-membrane wall; inner membrane is shaped into folds, or cristae; contain enzymes that oxidize foodstuffs to produce cellular energy (ATP); often referred to as "powerhouses of the cell"
Centrioles	Paired, cylindrical bodies that lie at right angles to each other close to the nucleus; direct the formation of the mitotic spindle during cell division; form the bases of cilia and flagella
Cytoskeletal elements: microtubules, intermediate filaments, and microfilaments	Form an internal scaffolding called the *cytoskeleton;* provide cellular support; function in intracellular transport; microtubules form the internal structure of the centrioles and help determine cell shape; intermediate filaments, which are stable elements made up of a variety of proteins, resist mechanical forces acting on cells; microfilaments are formed largely of actin, a contractile protein, and are thus important in cell mobility, particularly in muscle cells

Activity 5

Observing Differences and Similarities in Cell Structure

1. Go to station 1 of the demonstration area, and examine the slides of simple squamous epithelium, sperm, human blood, and teased smooth muscle cells.

2. Observe each slide under the microscope carefully, noting similarities and differences in the four kinds of cells. Notice the cell shape and position of the nucleus in each case. When you look at the human blood smear, direct your attention to the red blood cells, the pink-stained cells that are most numerous. Sketch your observations in the circles below.

3. How do these four cell types differ in shape?

How might cell shape affect cell function?

Which cells have visible projections?

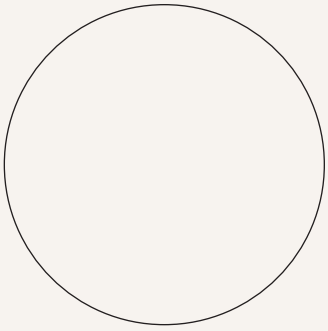
How do these projections relate to the function of these cells?

Do any of these cells lack a plasma membrane? _____

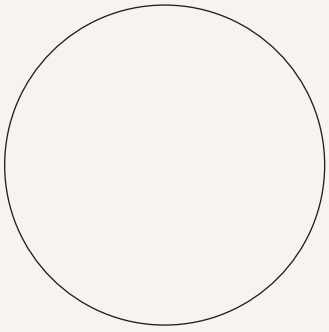
A nucleus? _____

Were you able to observe any of the organelles in these cells?

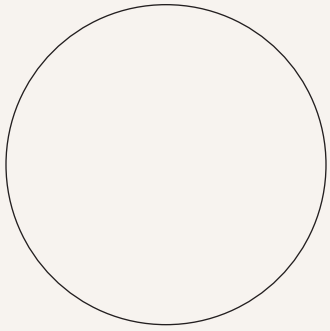
_____ Why or why not? _____



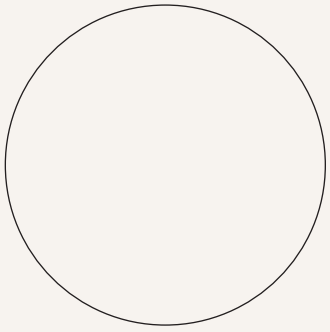
Simple squamous epithelium



Sperm cells



Human red blood cells



Teased smooth muscle cells

Cell Division: Mitosis and Cytokinesis

The cell cycle is the series of changes that a cell goes through from the time it is formed until it reproduces. It includes two stages—**interphase,** the longer period when the DNA and centrioles duplicate and the cell grows and carries out its usual activities (**Figure 3.3a**), and **cell division,** when the cell reproduces itself by dividing (Figure 3.3b–f).

Cell division in human cells consists of a series of events collectively called mitosis and cytokinesis. **Mitosis** is nuclear division; **cytokinesis** is the division of the cytoplasm, which begins after mitosis is nearly complete. Although mitosis is usually accompanied by cytokinesis, sometimes the cytoplasm does not divide. This results in cells that are binucleate or multinucleate. This is relatively common in the human liver and during embryonic development of skeletal muscle cells.

The products of **mitosis** are two daughter nuclei that are genetically identical to the mother nucleus. The function of *mitotic* cell division in the body is to increase the number of cells for growth and repair.

Prophase (Figure 3.3b and c): As nuclear division begins, the chromatin threads coil and shorten to form densely staining, short, barlike **chromosomes.** By the middle of prophase, the chromosomes are obviously double-stranded structures (each strand is a **sister chromatid**) connected by a buttonlike body called a **centromere.** The centrioles separate from one another and direct the assembly of a system of microtubules called the **mitotic spindle.** The spindle acts as a scaffolding the chromosomes attach to and are moved along during later mitotic stages. Meanwhile, the nuclear envelope and the nucleolus break down and disappear.

Metaphase (Figure 3.3d): In this brief stage, the chromosomes align along the metaphase plate, or the equator of the spindle.

Anaphase (Figure 3.3e): During anaphase, the centromeres split, and the chromatids now become chromosomes in their own right. The chromosomes separate from one another and move slowly toward opposite ends of the cell with their "arms" dangling behind them. Anaphase is complete when poleward movement ceases.

Telophase (Figure 3.3f): Similar to prophase in reverse. The chromosomes uncoil and resume the chromatin form, the spindle breaks down and disappears, a nuclear envelope forms around each chromatin mass, and nucleoli appear in the daughter nuclei. Mitosis is now ended.

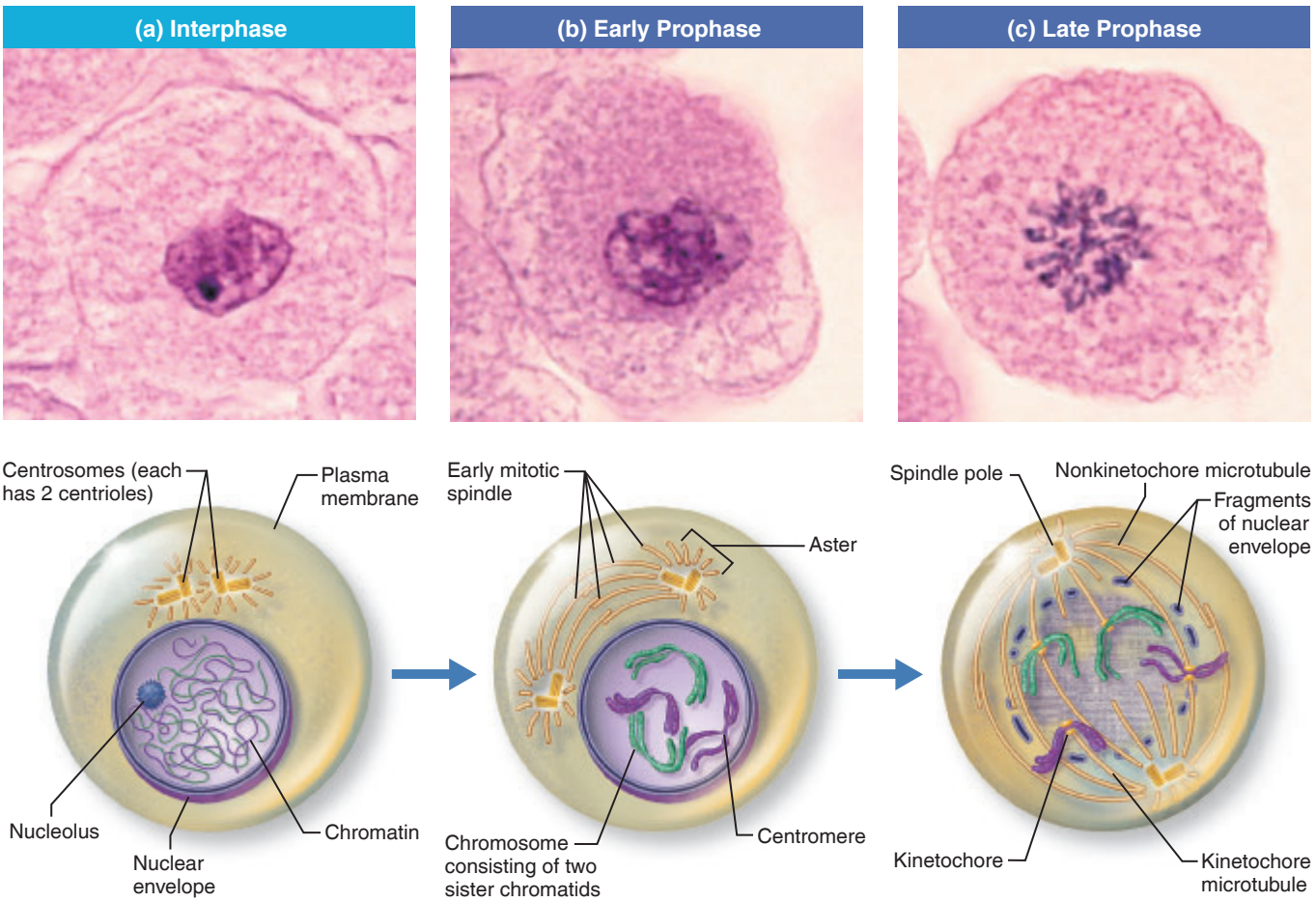


Figure 3.3 The interphase cell and the events of cell division. The cells shown are from an early embryo of a whitefish. Photomicrographs are above; corresponding diagrams are below. *(Figure continues on page 24.)*

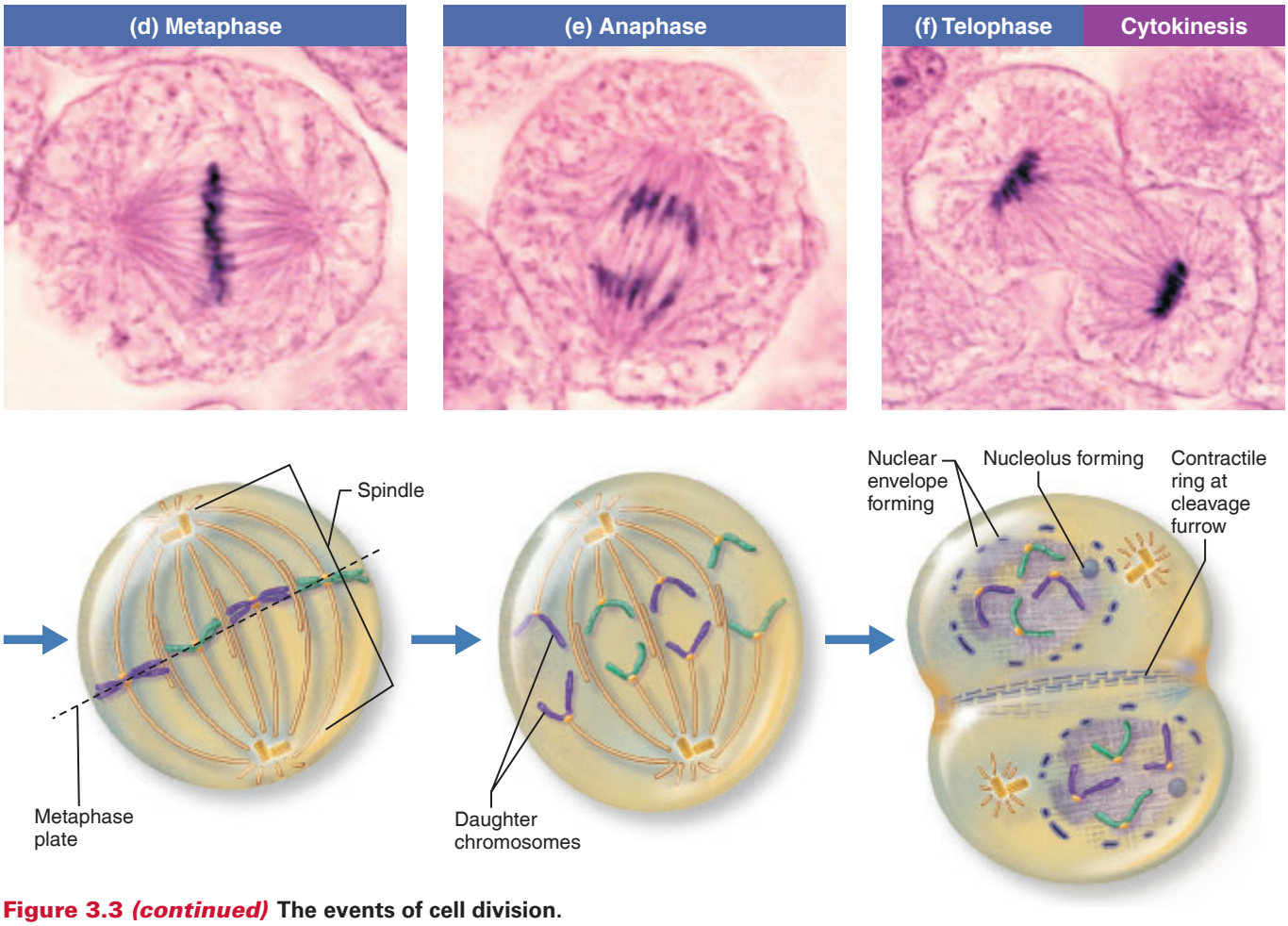


Figure 3.3 *(continued)* **The events of cell division.**

Cytokinesis typically begins during late anaphase and continues through and beyond telophase (Figure 3.3f). In animal cells, a *cleavage furrow* begins to form and eventually pinches the cells apart. Once formed, the daughter cells grow and carry out the normal spectrum of metabolic processes until it is their turn to divide.

Examine the slides carefully, identifying the four mitotic phases and the process of cytokinesis. Compare your observations with the figure that illustrates these processes (Figure 3.3).

Activity 6

Identifying the Mitotic Stages

1. Use the three-dimensional models of dividing cells to identify each of the mitotic phases illustrated in Figure 3.3.

2. Go to station 2 of the demonstration area, where slides of whitefish blastulas are set up for your microscopic study of mitosis. The cells of each blastula (a stage of embryonic development consisting of a hollow ball of cells) are at approximately the same mitotic stage, so it is necessary to observe more than one blastula to view all the mitotic stages. You can think of a blastula as a soccer ball in which each of the multisided leather pieces making up the ball's surface represents an embryonic cell.

Activity 7

Creating Mitotic Figures

1. Obtain a packet of chenille sticks and a piece of chalk from the supply area, and bring them to your bench.

2. Using the chalk, draw three representations of mitotic spindles on the bench top.Then bend the chenille sticks as necessary to create the typical appearance and location of chromosomes in (1) prophase, (2) metaphase, (3) anaphase, and (4) telophase by placing them on your spindle drawings.

3. Have your instructor check your mitotic figures before cleaning up your bench top.

EXERCISE 3

REVIEW SHEET

The Cell—Anatomy and Division

Name _____ Lab Time/Date _____

Anatomy of the Composite Cell

1. Define the following:

organelle: _____

_____

cell: _____

_____

2. Identify the following cell structures:

_____ **1.** external boundary of cell; regulates flow of materials into and out of the cell

_____ **2.** contains digestive enzymes of many varieties; "suicide sac" of the cell

_____ **3.** scattered throughout the cell; major site of ATP synthesis

_____ **4.** slender extensions of the plasma membrane that increase its surface area

_____ **5.** stored glycogen granules, crystals, pigments; present in some cell types

_____ **6.** membranous system consisting of flattened sacs and vesicles; packages proteins for export

_____ **7.** control center of the cell; necessary for cell division and cell life

_____ **8.** rod-shaped bodies that direct the formation of the mitotic spindle

_____ **9.** dense, darkly staining nuclear body; packaging site for ribosomes

_____ **10.** contractile elements of the cytoskeleton

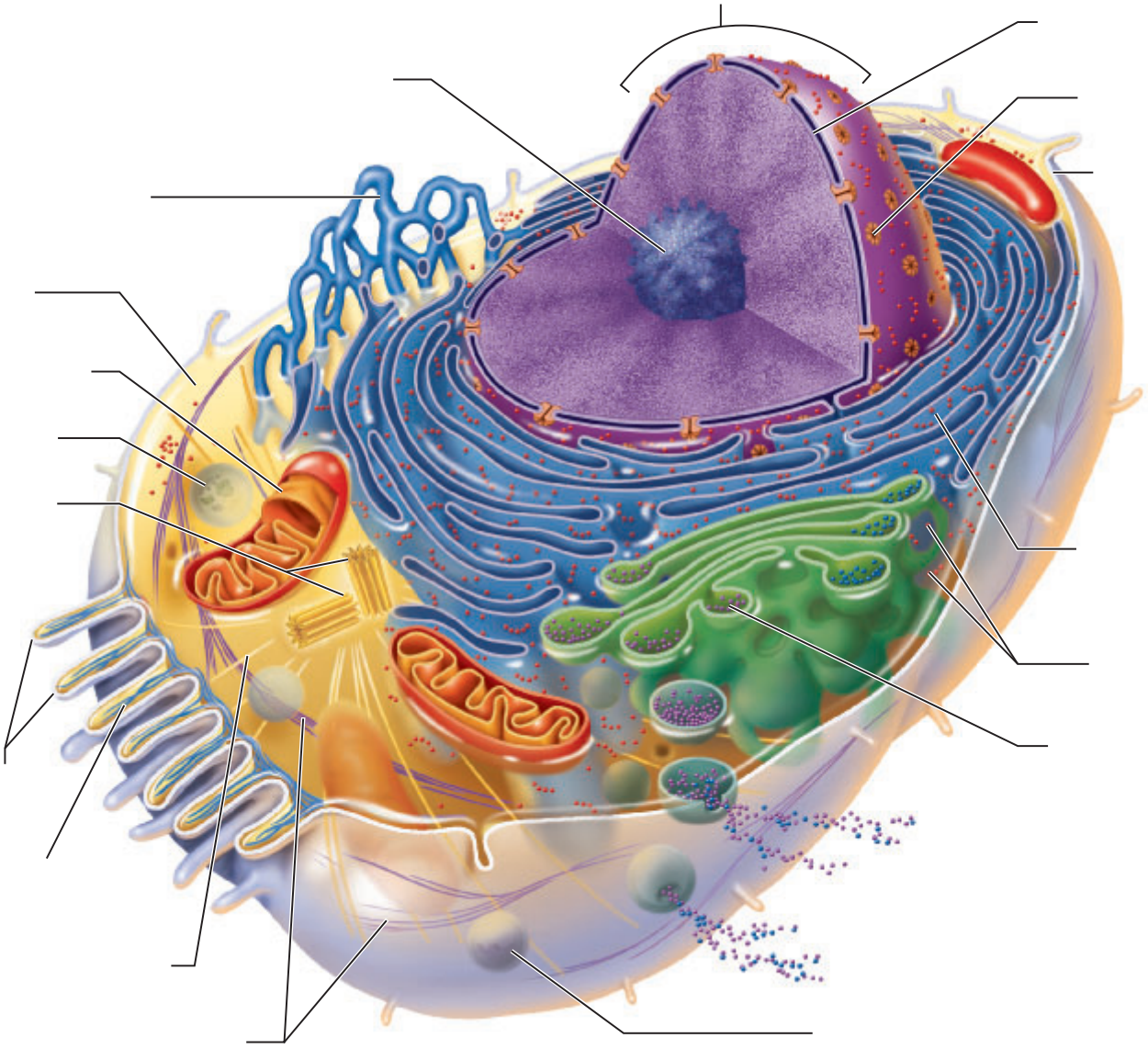
_____ **11.** membranous system that has "rough" and "smooth" varieties

_____ **12.** attached to membrane systems or scattered in the cytoplasm; synthesize proteins

_____ **13.** threadlike structures in the nucleus; contain genetic material (DNA)

_____ **14.** site of free radical detoxification

3. Label the cell structures using the leader lines provided.



Differences and Similarities in Cell Structure

4. For each of the following cell types, list (a) *one* important *structural* characteristic you observed in the laboratory and (b) the *function* that the structure complements or ensures.

squamous epithelium
a. _____
b. _____

sperm
a. _____
b. _____

smooth muscle
a. _____
b. _____

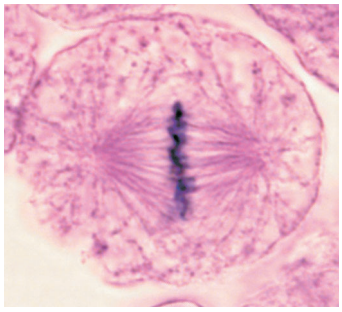
red blood cells
a. _____
b. _____

Cell Division: Mitosis and Cytokinesis

5. Identify the four phases of mitosis shown in the following photomicrographs, and select the events from the key that correctly identify each phase. On the appropriate answer line, write the letters that correspond to these events.

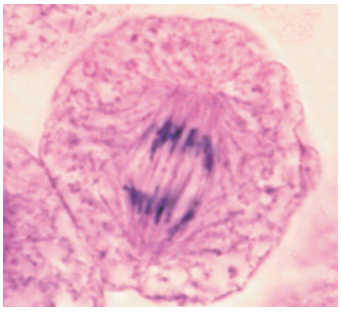
Key:

a. Chromatin coils and condenses, forming chromosomes.
b. The chromosomes (chromatids) are V-shaped.
c. The nuclear envelope re-forms.
d. Chromosomes stop moving toward the poles.
e. Chromosomes line up in the center of the cell.
f. The nuclear envelope fragments.
g. The mitotic spindle begins to form.



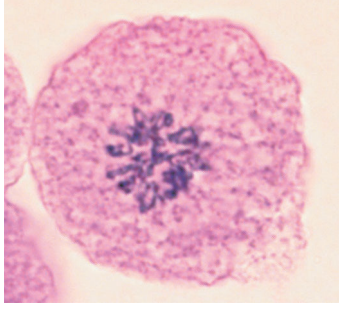
1. Phase: _____

Events: _____



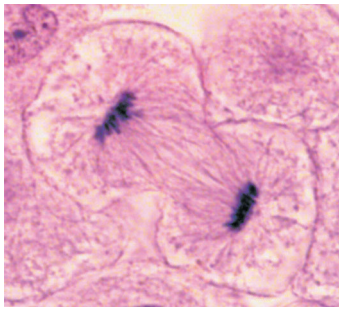
2. Phase: _____

Events: _____



3. Phase: _____

Events: _____



4. Phase: _____

Events: _____

6. What is the function of mitotic cell division? _____

_____

7. Describe the events that occur during interphase.

_____

_____

8. Complete or respond to the following statements:

Division of the __1__ is referred to as mitosis. Cytokinesis is division of the __2__. The major structural difference between chromatin and chromosomes is that the latter are __3__. Chromosomes attach to the spindle fibers by undivided structures called __4__. If a cell undergoes mitosis but not cytokinesis, the product is __5__. The structure that acts as a scaffolding for chromosomal attachment and movement is called the __6__. __7__ is the period of cell life when the cell is not involved in division. Three cell populations in the body that do not routinely undergo cell division are __8__, __9__, and __10__.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

9. Plasma cells are key to the immune response because they secrete antibodies. Given that antibodies are made of protein, which membrane-enclosed cell organelle would you expect the plasma cells to have in abundance?

Why?_____

_____

10. Name which organelle you would expect to play the largest role in decomposition of the human body. Why?

_____

_____

11. Some antifungal medications work by blocking DNA synthesis in the fungal cell. Describe where in the cell cycle such a medication would halt the fungal cell and the consequences of this early termination of the cycle.

_____

_____

EXERCISE

4 Cell Membrane Transport Mechanisms

Materials

Diffusion Experiment 1:

- Forceps
- Petri dishes (2) containing 12 ml of 1.5% agar-agar
- 3.5% methylene blue solution (approximately 0.1 M)
- 1.6% potassium permanganate solution (approximately 0.1 M)
- Millimeter-ruled graph paper
- Medicine dropper

Diffusion Experiment 2:

- Four dialysis sacs
- 15-ml graduated cylinders
- Four beakers (250 ml)
- Distilled water
- 40% glucose solution
- Fine twine or dialysis tubing clamps
- 10% NaCl solution
- 40% sucrose solution
- Laboratory balance
- Hot plate and large beaker for water bath
- Benedict's solution in dropper bottle
- Four test tubes in racks, test tube holder
- Wax marker
- Small syringes (without needles)
- Silver nitrate ($AgNO_3$) in dropper bottle
- Lugol's iodine solution in dropper bottle
- Demonstration area: Three microscopes with blood cells suspended in:
  1. Physiological saline
  2. 1.5% saline
  3. Distilled water

Filtration:

- Flask
- Filter paper, funnel
- Solution containing a mixture of uncooked starch, powdered charcoal, and copper sulfate ($CuSO_4$)
- Lugol's iodine solution in dropper bottle

Learning Outcomes

- ☐ Describe processes that move substances across the plasma membrane and indicate the driving force for each.
- ☐ Determine which way substances will move passively through a selectively permeable membrane (given appropriate information on concentration differences).

The plasma membrane is selective about what passes through it. It allows nutrients to enter the cell but keeps out undesirable substances. At the same time, the plasma membrane keeps valuable cell proteins and other substances within the cell, and allows excreta, or wastes, to pass to the exterior. This property is known as **selective,** or **differential, permeability.** Transport through the plasma membrane occurs in two basic ways. In **active processes,** the cell provides energy (ATP) to power the transport process. In the other, **passive processes,** the transport process is driven by particle concentration or pressure differences. In this exercise, we will observe several examples of passive processes.

Passive Processes

The two important types of passive membrane transport are *diffusion* and *filtration.* Diffusion is an important means of transport for every cell in the body. By contrast, filtration usually occurs only across capillary walls. Here we will consider diffusion only.

Diffusion

Recall that all molecules possess *kinetic energy* and are in constant motion. As molecules move about randomly, they collide and ricochet off one another, changing direction with each collision. In general, the smaller the particle, the more kinetic energy it has and the faster it moves.

When a **concentration gradient** (difference in concentration) exists, the net effect of this random molecular movement is that the molecules eventually become evenly distributed throughout the environment, that is, the process called diffusion occurs. Hence, **diffusion** is the movement of molecules from a region of their higher concentration to a region of their lower concentration. Its driving force is the kinetic energy of the molecules themselves.

In general, molecules diffuse passively through the plasma membrane if they are small enough to pass through its pores or if they can dissolve in the lipid portion of the membrane as CO_2 and O_2 can. The unassisted diffusion of solutes (particles dissolved in water) through a semipermeable membrane is called **simple diffusion.** The diffusion of water through a semipermeable membrane is called **osmosis.**

In general, molecules in a warm environment diffuse more quickly than those that are cooler; light molecules move more quickly than heavy ones; and diffusion through a nondense medium (such as water) occurs faster than diffusion through a denser or more viscous substance (such as agar gel). The next activity examines these relationships in the diffusion of two dyes.

(Text continues on page 33.)

Activity 1

Observing Diffusion of Dye Through Agar Gel

1. Obtain a Petri dish containing agar gel, millimeter-ruled graph paper, dropper bottles of methylene blue (molecular weight = 320 g/mole) and potassium permanganate (molecular weight = 158 g/mole) stain, and a medicine dropper. Bring these items to your bench.

2. Place the Petri dish on the graph paper.

3. Create a well in the center of each section using the medicine dropper (**Figure 4.1a**). To do this, squeeze the bulb of the medicine dropper, and push the tip of the dropper down into the agar. Release the bulb as you slowly pull the dropper out of the agar. This should remove an agar plug, leaving a well in the agar that extends all the way down to the bottom of the Petri dish.

4. Carefully fill one well with the methylene blue solution and the other with potassium permanganate solution (Figure 4.1b).

Record the time: _____.

5. At 15-minute intervals, measure the distance the dye has diffused from *each* solution source by measuring the diameter of the dye using the graph paper. Continue these observations for 1 hour, and record the results in the **Activity 1 chart**.

Calculate the rate of diffusion of the potassium permanganate molecules in millimeters per minute (mm/min), and record.

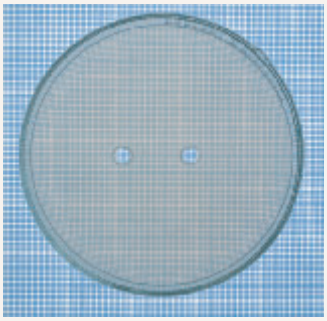
_____ mm/min

Calculate the rate of diffusion of the methylene blue molecules in mm/min, and record.

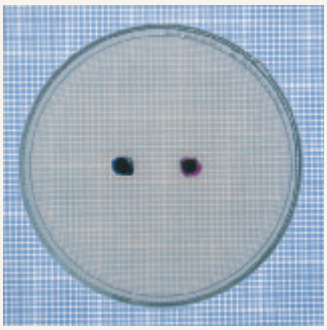
_____ mm/min

Activity 1: Diffusion of Dye Through Agar Gel

Time (min)	Diameter of methylene blue (mm) at room temperature	Diameter of potassium permanganate (mm) at room temperature
15		
30		
45		
60		



(a)



(b)

Figure 4.1 Setup for comparing the diffusion rates of molecules of methylene blue and potassium permanganate through an agar gel.

Which dye diffused more rapidly? _____

What is the relationship between molecular weight and rate of molecular movement (diffusion)?

_____

Why did the dye molecules move?

_____

What would be the effect of heating on the rate of diffusion of the dyes? _____

In molecular terms, what is the basis of this effect?

_____

_____

Activity 2

Observing Diffusion Through Nonliving Membranes

This experiment provides information on the diffusion of water and solutes through semipermeable membranes, which may be applied to the study of membrane transport in living cells.

Dialysis sacs are selectively permeable membranes with pores of a particular size. The selectivity of living membranes depends on more than just pore size, but using the dialysis sacs will allow you to examine selectivity due to this factor.

1. Obtain four dialysis sacs, a small syringe, a graduated cylinder, a wax marker, fine twine or dialysis tubing clamps, and four beakers (250 ml). Number the beakers 1 to 4 with the wax marker, and fill beakers 1, 3, and 4 halfway with distilled water. To beaker 2, add 40% glucose solution (**Figure 4.2**).

2. Prepare the dialysis sacs one at a time. Using the syringe, half fill each with 10 ml of the specified liquid: 40% glucose solution for sacs 1 and 2; 10% NaCl for sac 3; and sucrose solution for sac 4 (see Figure 4.2). Press out the air, fold over the open end of the sac, and tie it securely with fine twine or clamp it (Figure 4.2). Before proceeding to the next sac, rinse it under the tap and quickly and carefully blot the sac dry by rolling it on a paper towel. Weigh it with a laboratory balance. Record the weight, and then drop the sac into the corresponding beaker. Be sure the sac is completely covered by the beaker solution, adding more solution if necessary.

- Sac 1: 40% glucose solution. Weight: _____ g
- Sac 2: 40% glucose solution. Weight: _____ g
- Sac 3: 10% NaCl solution. Weight: _____ g
- Sac 4: 40% sucrose solution. Weight: _____ g

Allow sacs to remain undisturbed in the beakers for 1 hour. (Use this time to continue with other experiments.)

3. After an hour, boil a beaker of water on the hot plate. Obtain the supplies you will need to determine your experimental results: dropper bottles of Benedict's solution, silver nitrate solution, and Lugol's iodine, a test tube rack, four test tubes, and a test tube holder.

4. Quickly and gently blot sac 1 dry and weigh it. (*Note:* Do not squeeze the sac during the blotting process.)

Weight of sac 1: _____ g

Has there been any change in weight? _____

Conclusions: _____

_____

_____

Place 5 drops of Benedict's solution in each of two test tubes. Put 2 ml of the fluid from beaker 1 into one test tube and 2 ml of the sac fluid into the other. Mark the tubes for identification, and then place them in the beaker containing boiling water. Boil test tubes for 2 minutes then cool them slowly. (See **Table 4.1** to interpret test results.)

Text continues on next page. →

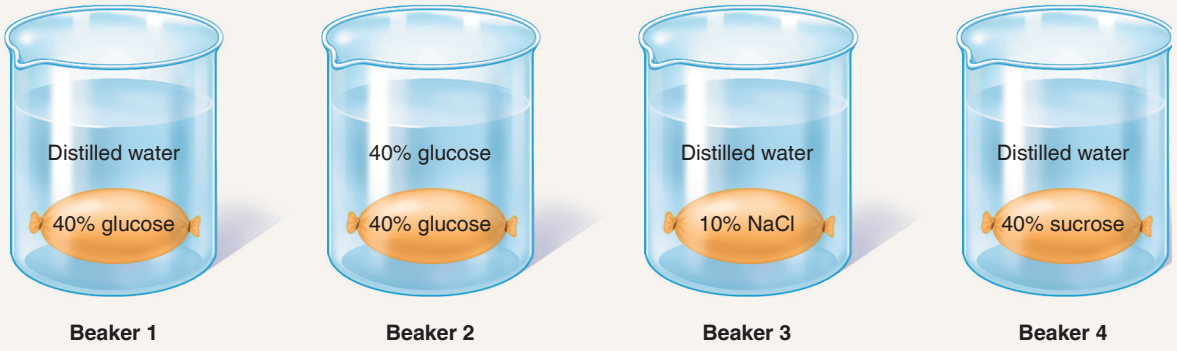


Figure 4.2 **Setup for observing diffusion through nonliving membranes.**

Table 4.1 Reagent Testing Solutions

Testing solution	Positive result
Benedict's solution	A green, yellow, or rusty red color indicates the presence of glucose
Silver nitrate	A white precipitate or cloudiness indicates the presence of salt
Lugol's iodine	A blue-black color indicates the presence of starch

Was glucose still present in the sac? _____

Was glucose present in the beaker? _____

Conclusions: _____

_____

_____

5. Blot gently and weigh sac 2: _____ g

Was there any change in weight? _____

With 40% glucose in the sac and 40% glucose in the beaker, would you expect to see any net movements of water (osmosis) or of glucose molecules (simple diffusion)?

_____ Why or why not? _____

_____

6. Blot gently and weigh sac 3: _____ g

Was there any change in weight? _____

Conclusions: _____

Take a 3-ml sample of beaker 3 solution, and put it in a clean test tube. Add a drop of silver nitrate. (See Table 4.1 to interpret test results.)

Results: _____

Conclusions: _____

7. Blot gently and weigh sac 4: _____ g

Was there any change in weight? _____

Take a 1-ml sample of beaker 4 solution, and put the test tube in boiling water in a hot water bath. Add 5 drops of Benedict's solution to the tube, and boil for 5 minutes. Benedict's solution detects the presence of glucose, a hydrolysis product of sucrose. (See Table 4.1 to interpret test results.)

Did sucrose diffuse from the sac into the bath water?

_____ Explain your conclusion. _____

_____

8. In which of the test situations did net osmosis occur?

_____

In which of the test situations did net simple diffusion occur?

_____

What conclusions can you make about the relative size of glucose, sucrose, NaCl, and water molecules?

_____

_____

_____

_____

With what cell structure can the dialysis sac be compared?

_____

Activity 3

Investigating Diffusion Through Living Membranes

To examine permeability properties of cell membranes, conduct the following microscopic study.

Isotonic solution (physiological saline)—the solution surrounding the red blood cell has the *same* concentration of solutes as the fluid inside the red blood cell.

Hypertonic solution—the solution surrounding the red blood cell has a *higher* concentration of solutes than the fluid inside the red blood cell.

Hypotonic solution—the solution surrounding the red blood cell has a *lower* concentration of solutes than the fluid inside the red blood cell.

1. Go to the demonstration area, where three red blood cell suspensions have been prepared for microscopic observation. In slide 1, the red blood cells are suspended in physiological saline; in slide 2, they are bathed in 1.5 percent saline (NaCl); and in slide 3, the cells are suspended in distilled water. The following definitions will help you to draw some conclusions about variations in the shape of the red blood cells.

Normal shape of a red blood cell—a biconcave *disc*.

Crenation—occurs when a red blood cell loses water and shrinks.

Lysis—occurs when a red blood cell takes in so much additional fluid that it bursts.

2. View slide 1 to see whether any changes in the normal disclike shape of the red blood cells have occurred.

Observation: _____

3. Observe slide 2. What has happened to the red blood cells in this preparation?

_____

A solution of 1.5 percent saline is *hypertonic* to red blood cells. On the basis of what you know about the effect of such solutions on living cells, explain your observation.

_____

_____

4. Observe slide 3. What has happened to the cells in this preparation?

_____

Explain. _____

Filtration

Filtration is a passive process by which water and solutes are forced through a membrane by hydrostatic (fluid) pressure. For example, fluids and solutes filter out of the capillaries in the kidneys and into the kidney tubules because the blood pressure in the capillaries is greater than the fluid pressure in the tubules. Filtration is not selective. The amount of filtrate (fluids and solutes) formed depends almost entirely on the pressure gradient (difference in pressure on the two sides of the membrane) and on the size of the membrane pores.

Activity 4

Observing the Process of Filtration

1. Obtain the following equipment: a funnel; a piece of filter paper; a flask; a solution containing uncooked starch, powdered charcoal, and copper sulfate; and a dropper bottle of Lugol's iodine.

2. Fold the filter paper in half twice, open it into a cone, and place it in a funnel (**Figure 4.3**). Set the funnel on the flask. Shake the starch solution, and fill the funnel with it to just below the top of the filter paper. When the steady stream of filtrate changes to countable filtrate drops, count the number of drops formed in 10 seconds, and record the count.

_____ drops

When the funnel is half empty, again count the number of drops formed in 10 seconds. Record the count.

_____ drops

3. After all the fluid has passed through the filter, check the filtrate and paper to see which materials were retained by the paper. *Note:* If the filtrate is blue, the copper sulfate passed. Check both the paper and filtrate for black particles to see whether the charcoal passed. Finally, add Lugol's iodine to a 2-ml filtrate sample in a test tube. (See Table 4.1 to interpret test results.)

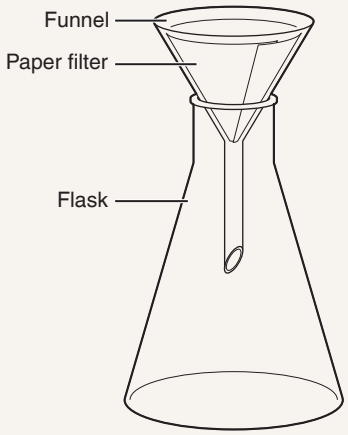


Figure 4.3 **Setup for observing the process of filtration.**

Text continues on next page. →

Passed: _____

Retained: _____

What does the filter paper represent? _____

During which counting interval was the filtration rate greatest?

_____

Explain: _____

_____

What characteristic of the three solutes determined whether or not they passed through the filter paper?

_____

_____

_____

EXERCISE 4

REVIEW SHEET

Cell Membrane Transport Mechanisms

Name _____ Lab Time/Date _____

Choose all answers that apply to items 1 and 2, and place their letters on the response blanks.

1. The movement of molecules _____.

a. reflects the kinetic energy of molecules
b. reflects the potential energy of molecules
c. is ordered and predictable
d. is random and erratic

2. Speed of molecular movement _____.

a. is higher in larger molecules
b. is lower in larger molecules
c. increases with increasing temperature
d. decreases with increasing temperature
e. reflects kinetic energy

3. Summarize below the results of Activity 2, Observing Diffusion Through Nonliving Membranes.

Sac 1: 40% glucose suspended in distilled water

Did glucose diffuse out of the sac? _____ Did the sac weight change? _____

Explanation: _____

_____

Sac 2: 40% glucose suspended in 40% glucose

Was there net movement of glucose into or out of the sac? _____

Explanation: _____

Did the sac weight change? _____

Explanation: _____

_____

Sac 3: 10% NaCl suspended in distilled water

Was there net movement of NaCl out of the sac? _____

Direction of net osmosis: _____

Sac 4: 40% sucrose suspended in distilled water

Was there net movement of sucrose out of the sac? _____

Explanation: _____

Direction of net osmosis: _____

4. What single characteristic of the semipermeable membranes used in the laboratory determines the substances that can pass through them? _____

   In addition to this characteristic, what other factors influence the passage of substances through living membranes?

   _____

5. A semipermeable sac filled with a solution containing 4% NaCl, 9% glucose, and 10% albumin is suspended in a solution with the following composition: 10% NaCl, 10% glucose, and 40% albumin. Assume that the sac is permeable to all substances except albumin. State whether each of the following will (a) move into the sac, (b) move out of the sac, or (c) not move.

   glucose _____ albumin _____

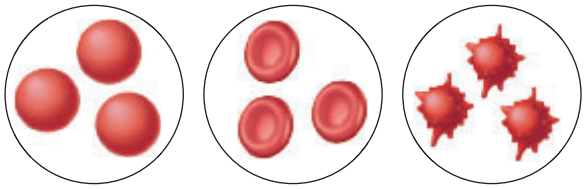
   water _____ NaCl _____

6. The diagrams below represent three microscope fields containing red blood cells.

   Which field contains a hypertonic solution? _____ The cells in this field are said to be _____.

   Which field contains an isotonic bathing solution? _____ Which field contains a hypotonic solution? _____

   What is happening to the cells in this field? _____



(a) (b) (c)

7. What is the driving force for filtration? _____

   How does knowing this help you to explain why the filtration process examined in the lab slowed down with time?

   _____

8. Define *diffusion:* _____

   _____

9. Drinking too much plain water in a short period of time can result in water intoxication. As a result, blood plasma will become hypotonic. What effect do you think this would have on cells, and why? _____

   _____

10. Receptor-mediated endocytosis is used to remove low-density lipoproteins (LDLs) from circulating in the blood. Explain the effect that defective LDL receptors would have on a patient's cholesterol levels and overall risk for heart disease. (Hint: LDLs are the "bad cholesterol.")

    _____

    _____

EXERCISE

5 Classification of Tissues

Materials

- Demonstration area with four microscope stations set up:

  Station 1: Prepared slides of simple squamous, simple cuboidal, simple columnar, stratified squamous (nonkeratinized), pseudostratified ciliated columnar, and transitional epithelia

  Station 2: Prepared slides of adipose, areolar, reticular, and dense regular (tendon) connective tissue; of hyaline cartilage; and of bone (cross section)

  Station 3: Prepared slides of skeletal, cardiac, and smooth muscle (longitudinal sections)

  Station 4: Prepared slide of nervous tissue (spinal cord smear)

Learning Outcomes

- ☐ Name the four primary tissue types in the human body, and state a general function of each.
- ☐ Name the major subcategories of the primary tissue types, and identify the tissues of each subcategory microscopically or in an appropriate image.
- ☐ State the locations of the various tissues in the body.
- ☐ List the general function and structural characteristics of each of the tissues studied.

Cells are the building blocks of life. In humans and other multicellular organisms, cells depend on one another and cooperate to maintain homeostasis in the body.

With a few exceptions, even the most complex animal starts out as a single cell, the fertilized egg, which divides almost endlessly. The resulting trillions of cells then specialize for a particular function. Some become supportive bone, others skin cells, and so on. Thus a division of labor exists, with certain groups of cells highly specialized to perform functions that benefit the organism as a whole.

Groups of cells that are similar in structure and function are called **tissues.** The four primary tissue types—epithelial, connective, muscle, and nervous—have distinct structures, patterns, and functions.

To perform specific body functions, the tissues are organized into **organs** such as the heart, kidneys, and lungs. Most organs contain several representatives of the primary tissues, and the arrangement of these tissues determines the organ's structure and function. The main objective of this exercise is to familiarize you with the major similarities and dissimilarities of the primary tissues. In this exercise, we will focus chiefly on epithelial tissues and some types of connective tissue. Muscle tissue, nervous tissue, and bone (a connective tissue), are covered in greater depth in other exercises.

Epithelial Tissue

Epithelial tissues, or **epithelia,** cover surfaces. For example, epithelia cover the external body surface (as the epidermis), line its cavities, and generally mark off our "insides" from our outsides. Because glands of the body almost always develop from epithelial membranes, glands too are classed as epithelia.

Epithelial functions include protection, absorption, filtration, excretion, secretion, and sometimes sensory reception. For example, the epithelium covering the body protects against bacterial invasion and chemical damage; that lining the respiratory tract is ciliated to sweep dust and other foreign particles away from the lungs. Secretion is a specialty of the glands, and taste receptors are epithelial cells.

Epithelia generally exhibit these characteristics:

- *Specialized contacts*. Cells fit closely together to form membranes, or sheets of cells, and are bound together by specialized junctions.
- *Polarity*. The membranes always have one exposed surface or free edge, called the *apical surface*. Typically, that surface is significantly different from the *basal surface*.

- *Supported by connective tissue.* The cells are attached to and supported by an adhesive **basement membrane,** a material secreted collectively by the epithelial cells and the connective tissue cells that lie next to each other.
- *Avascular but innervated.* Epithelial tissues have no blood supply of their own (are avascular), but depend on diffusion of nutrients from the underlying connective tissue. They are supplied by nerves.
- *Regeneration.* If well nourished, epithelial cells can easily regenerate themselves. This is an important characteristic because many epithelia are subjected to a good deal of abrasion and other types of trauma.

The covering and lining epithelia are classified according to two criteria—number of cell layers and cell shape (**Figure 5.1**).

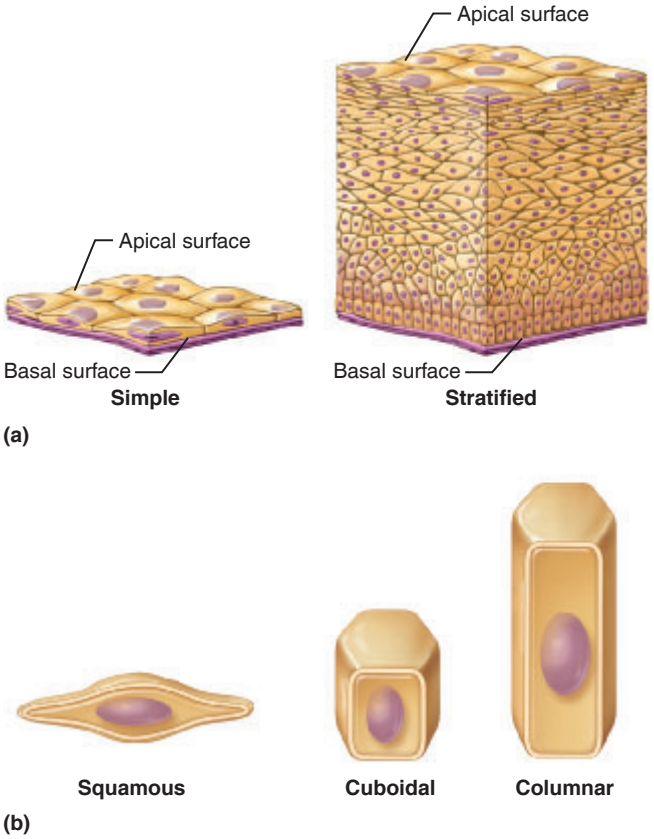


Figure 5.1 Classification of epithelia. (a) Classification based on number of cell layers. **(b)** Classification based on cell shape.

On the basis of layers, epithelia are classified as follows:

- **Simple** epithelia consist of one layer of cells attached to the basement membrane.
- **Stratified** epithelia consist of two or more layers of cells; only the deepest layer rests on the basement membrane.

Based on cell shape, epithelia are classified according to these categories:

- **Squamous** (scalelike)
- **Cuboidal** (cubelike)
- **Columnar** (column-shaped)

The terms denoting shape and arrangement of the epithelial cells are combined to describe the epithelium fully. *Stratified epithelia are named according to the cells at the apical surface of the epithelial sheet, not those resting on the basement membrane.*

There are also two less easily categorized types of epithelia:

- **Pseudostratified epithelium** is actually a simple columnar epithelium (one layer of cells with all cells attached to the basement membrane), but its cells extend varied distances from the basement membrane so it gives the false appearance of being stratified. This epithelium is often ciliated.
- **Transitional epithelium** is a rather peculiar stratified squamous epithelium formed of rounded, or "plump," cells with the ability to slide over one another to allow the organ to be stretched. Transitional epithelium is found only in urinary system organs. The superficial cells are flattened (like true squamous cells) when the organ is full and rounded when the organ is empty.

The most common types of epithelia, their characteristic locations in the body, and their functions are described in **Figure 5.2**.

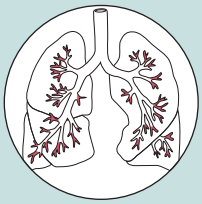
(Text continues on page 42.)

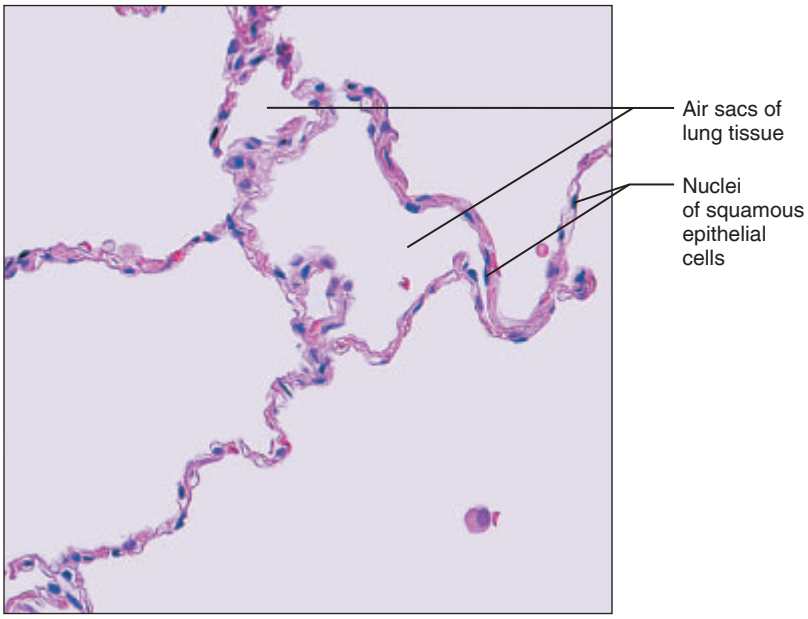
(a) Simple squamous epithelium

Description: Single layer of flattened cells with disc-shaped central nuclei and sparse cytoplasm; the simplest of the epithelia.

Function: Allows materials to pass by diffusion and filtration in sites where protection is not important; secretes lubricating substances in serosae.

Location: Kidney glomeruli; air sacs of lungs; lining of heart, blood vessels, and lymphatic vessels; lining of ventral body cavity (serosae).





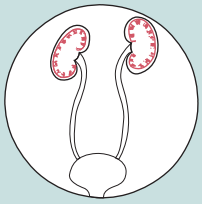
Photomicrograph: Simple squamous epithelium forming part of the alveolar (air sac) walls (140×).

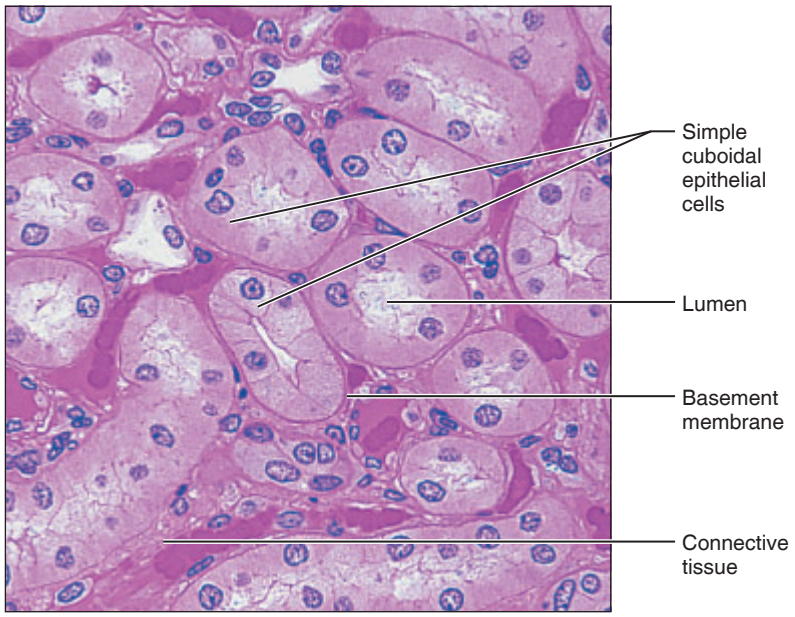
(b) Simple cuboidal epithelium

Description: Single layer of cubelike cells with large, spherical central nuclei.

Function: Secretion and absorption.

Location: Kidney tubules; ducts and secretory portions of small glands; ovary surface.



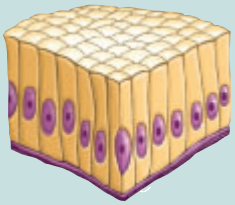


Photomicrograph: Simple cuboidal epithelium in kidney tubules (430×).

Figure 5.2 Epithelial tissues. Simple epithelia **(a** and **b)**.
(Figure continues on page 40.)

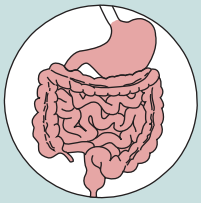
(c) Simple columnar epithelium

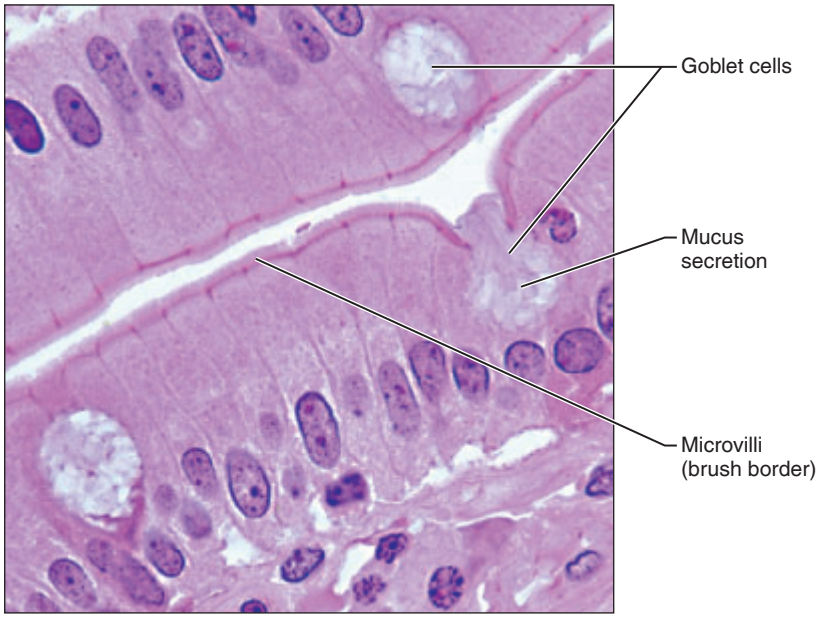
Description: Single layer of tall cells with *round* to *oval* nuclei; some cells bear cilia; layer may contain mucus-secreting unicellular glands (goblet cells).



Function: Absorption; secretion of mucus, enzymes, and other substances; ciliated type propels mucus (or reproductive cells) by ciliary action.

Location: Nonciliated type lines most of the digestive tract (stomach to rectum), gallbladder, and excretory ducts of some glands; ciliated variety lines small bronchi, uterine tubes, and some regions of the uterus.

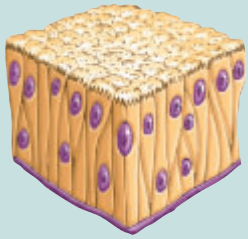




Photomicrograph: Simple columnar epithelium containing goblet cells from the small intestine (640×).

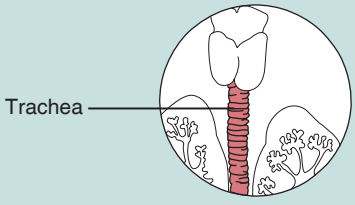
(d) Pseudostratified columnar epithelium

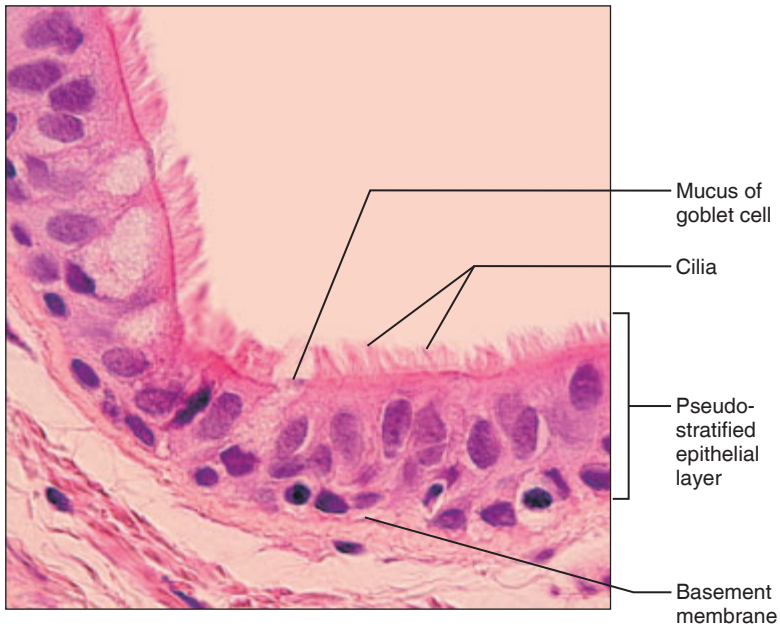
Description: Single layer of cells of differing heights, some not reaching the free surface, but all touching the basement membrane; nuclei seen at different levels; may contain mucus-secreting goblet cells and bear cilia.



Function: Secrete substances, particularly mucus; propulsion of mucus by ciliary action.

Location: Nonciliated type in male's sperm-carrying ducts and ducts of large glands; ciliated variety lines the trachea, most of the upper respiratory tract.



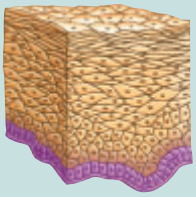


Photomicrograph: Pseudostratified ciliated columnar epithelium lining the human trachea (530×).

Figure 5.2 *(continued)* Epithelial tissues. Simple epithelia (**c** and **d**).
(See also Plate 1 of the Histology Atlas to view simple columnar epithelium.)

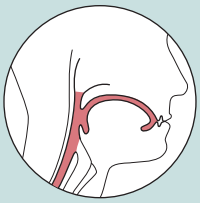
(e) Stratified squamous epithelium

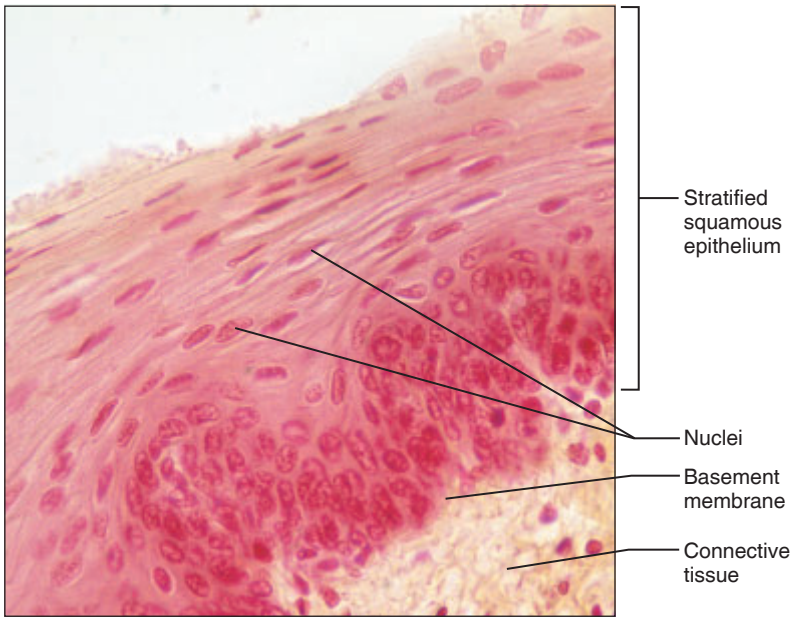
Description: Thick membrane composed of several cell layers; basal cells are cuboidal or columnar and metabolically active; cells at the apical surface are flattened (squamous); in the keratinized type, the surface cells are full of keratin and dead; basal cells are active in mitosis and produce the cells of the more superficial layers.



Function: Protects underlying tissues in areas subjected to abrasion.

Location: Nonkeratinized type forms the moist linings of the esophagus, mouth, and vagina; keratinized variety forms the epidermis of the skin, a dry membrane.

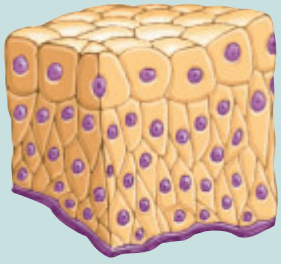




Photomicrograph: Stratified squamous epithelium lining the esophagus (285×).

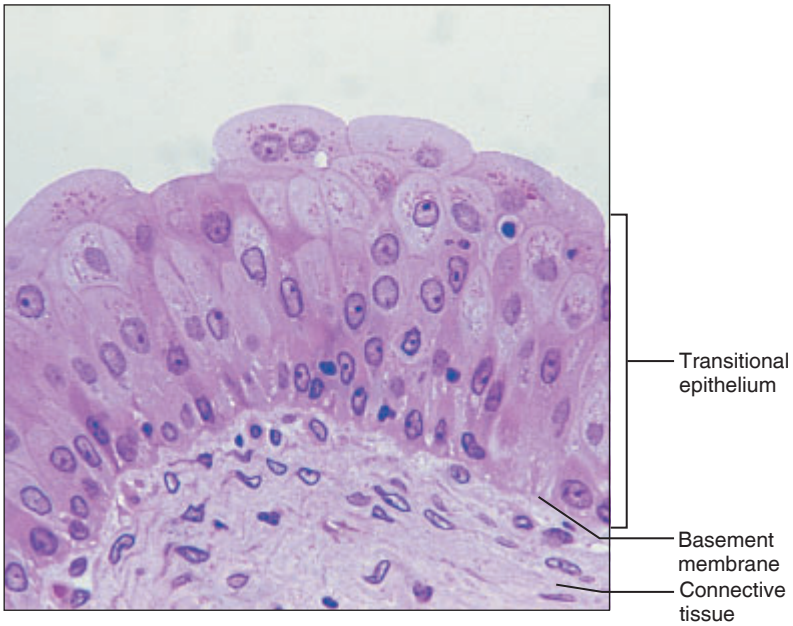
(f) Transitional epithelium

Description: Resembles both stratified squamous and stratified cuboidal; basal cells cuboidal or columnar; surface cells dome shaped or squamouslike, depending on degree of organ stretch.



Function: Stretches readily and permits stored urine to distend urinary organ.

Location: Lines the ureters, urinary bladder, and part of the urethra.



Photomicrograph: Transitional epithelium lining the urinary bladder, relaxed state (360×); note the bulbous, or rounded, appearance of the cells at the surface; these cells flatten and become elongated when the bladder is filled with urine.

Figure 5.2 *(continued)* **Epithelial tissues.** Stratified epithelia (**e** and **f**).

Activity 1

Examining Epithelial Tissue Under the Microscope

Go to station 1 of the demonstration area to examine slides of simple squamous, simple cuboidal, simple columnar, stratified squamous (nonkeratinized), pseudostratified ciliated columnar, and transitional epithelia. Observe each carefully, and notice how the epithelial cells fit closely together to form intact sheets of cells, a necessity for a tissue that forms linings or covering membranes. Scan each epithelial type for modifications for specific functions, such as cilia (motile cell projections that help to move substances along the cell surface), microvilli (which increase the surface area for absorption), and goblet cells (which secrete lubricating mucus). Compare your observations with the photomicrographs (Figure 5.2).

While working, check the questions in the laboratory Review Sheet section for this exercise (beginning on page 51). A number of the questions there refer to some of the observations you are asked to make during your microscopic study.

Connective Tissue

5

Connective tissue is found in all parts of the body. It is the most abundant and widely distributed of the tissue types. There are four main types of connective tissue: **connective tissue proper, cartilage, bone,** and **blood**. All of these derive from an embryonic tissue called *mesenchyme*. Connective tissue proper has two subclasses: **loose connective tissues** (areolar, adipose, and reticular) and **dense connective tissues** (dense regular, dense irregular, and elastic).

The connective tissues perform a variety of functions, but primarily they protect, support, and bind together other tissues of the body. For example, bones are composed of connective tissue (bone or osseous tissue), and they protect and support other body tissues and organs. Ligaments and tendons (dense regular connective tissue) bind the bones together or bind skeletal muscles to bones. Connective tissue also serves a vital function in the repair of all body tissues: many wounds are repaired by connective tissue in the form of scar tissue.

Connective tissues are composed of many types of cells, and there is a great deal of nonliving material between the cells. The nonliving material between the cells—the **extracellular matrix**—distinguishes connective tissue from all other tissues. The matrix, secreted by the cells, is primarily responsible for the strength associated with connective tissue, but its firmness and relative amount vary.

The matrix has two components—ground substance and fibers. The **ground substance** is chiefly glycoproteins and large polysaccharide molecules. Depending on its makeup, the ground substance may be liquid, gel-like, or very hard. When the matrix is firm, as in cartilage and bone, the connective tissue cells reside in cavities in the matrix called *lacunae.* The fibers, which provide support, include **collagen** (white) **fibers, elastic** (yellow) **fibers,** and **reticular** (fine collagen) **fibers.**

Figure 5.3 lists the general characteristics, location, and function of some of the connective tissues found in the body. Blood, considered in detail in Exercise 19, is not covered here.

(Text continues on page 47.)

Activity 2

Examining Connective Tissue Under the Microscope

Go to station 2 at the demonstration area to examine prepared slides of adipose, areolar, reticular, and dense regular connective tissue; of fibrocartilage, hyaline cartilage, and elastic cartilage; and of osseous connective tissue (bone). Compare your observations with Figure 5.3.

Distinguish the living cells from the matrix, and pay particular attention to the appearance of the matrix. For example, notice how the matrix of the dense regular connective tissues making up tendons is packed with collagen fibers, and notice that the fibers are all running in the same direction.

While examining the areolar connective tissue, a soft "packing tissue," notice how much empty space (*areol* = small empty space) there appears to be, and distinguish the collagen fibers from the thin, coiled elastic fibers.

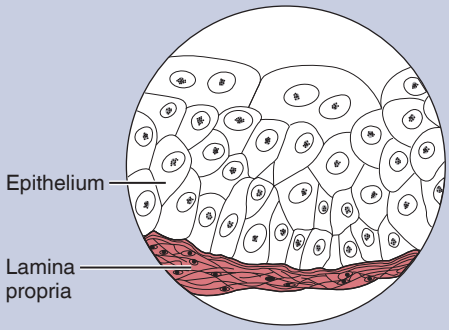
In adipose (fat) tissue, locate a hollow-appearing cell in which the nucleus is pushed to one side by the large, fat-filled vacuole that appears to be a large empty space. Also notice how little matrix there is in adipose tissue. Distinguish the living cells from the matrix in the dense connective tissues, bone, and hyaline cartilage preparations.

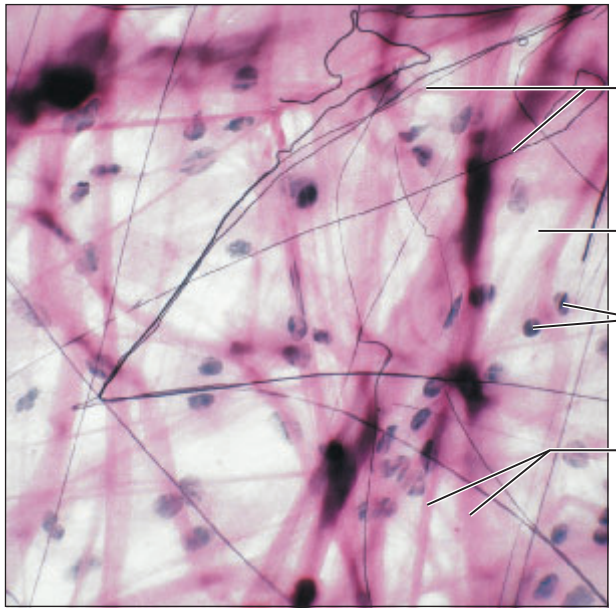
(a) Connective tissue proper: loose connective tissue, areolar

Description: Gel-like matrix with all three fiber types; cells: fibroblasts, macrophages, mast cells, and some white blood cells.

Function: Wraps and cushions organs; its macrophages phagocytize bacteria; plays important role in inflammation; holds and conveys tissue fluid.

Location: Widely distributed under epithelia of body, e.g., forms lamina propria of mucous membranes; packages organs; surrounds capillaries.





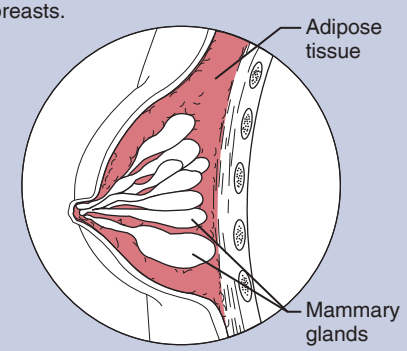
Photomicrograph: Areolar connective tissue from the lamina propria of a mucous membrane (340×).

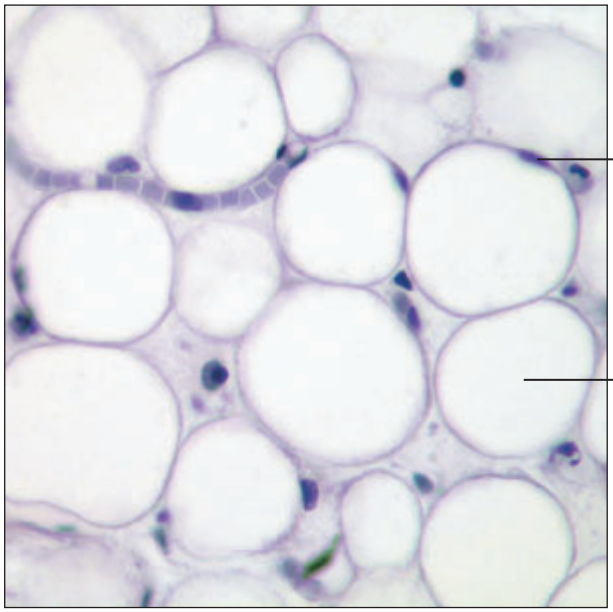
(b) Connective tissue proper: loose connective tissue, adipose

Description: Matrix as in areolar, but very sparse; closely packed adipocytes, or fat cells, have nucleus pushed to the side by large fat droplet.

Function: Provides reserve food fuel; insulates against heat loss; supports and protects organs.

Location: Under skin in subcutaneous tissue; around kidneys and eyeballs; within abdomen; in breasts.





Photomicrograph: Adipose tissue from the subcutaneous layer under the skin (350×).

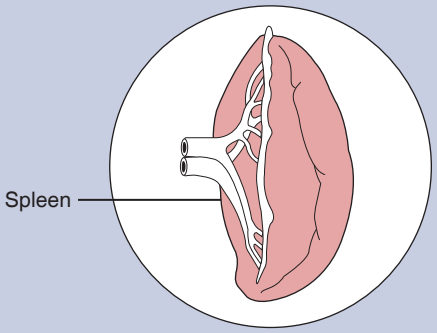
Figure 5.3 Connective tissues. Loose connective tissues: areolar **(a)** and adipose **(b)**.
(Figure continues on page 44.)

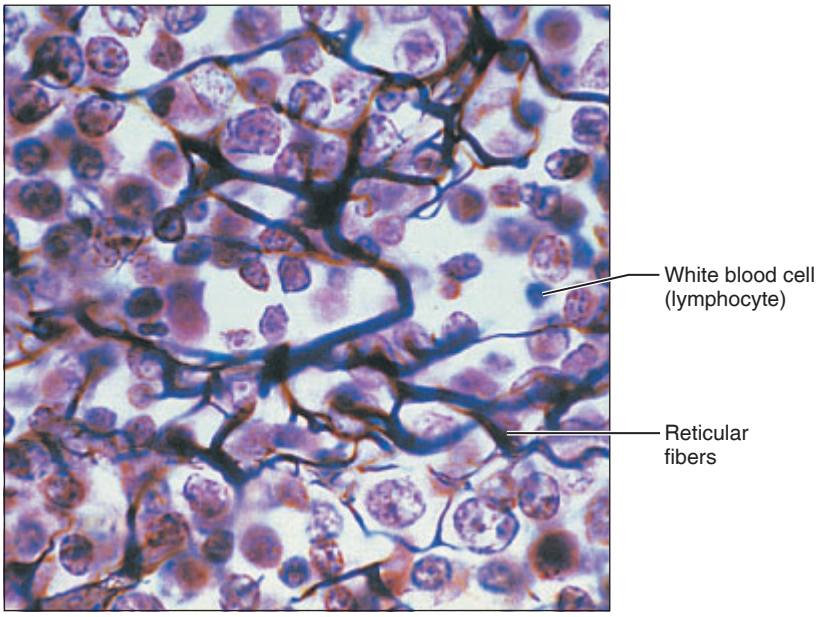
(c) Connective tissue proper: loose connective tissue, reticular

Description: Network of reticular fibers in a typical loose ground substance; reticular cells lie on the network.

Function: Fibers form a soft internal skeleton (stroma) that supports other cell types, including white blood cells, mast cells, and macrophages.

Location: Lymphoid organs (lymph nodes, bone marrow, and spleen).





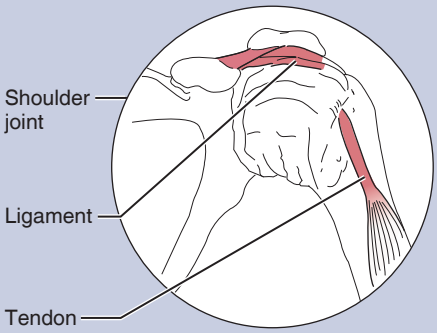
Photomicrograph: Dark-staining network of reticular connective tissue fibers forming the internal skeleton of the spleen (350×).

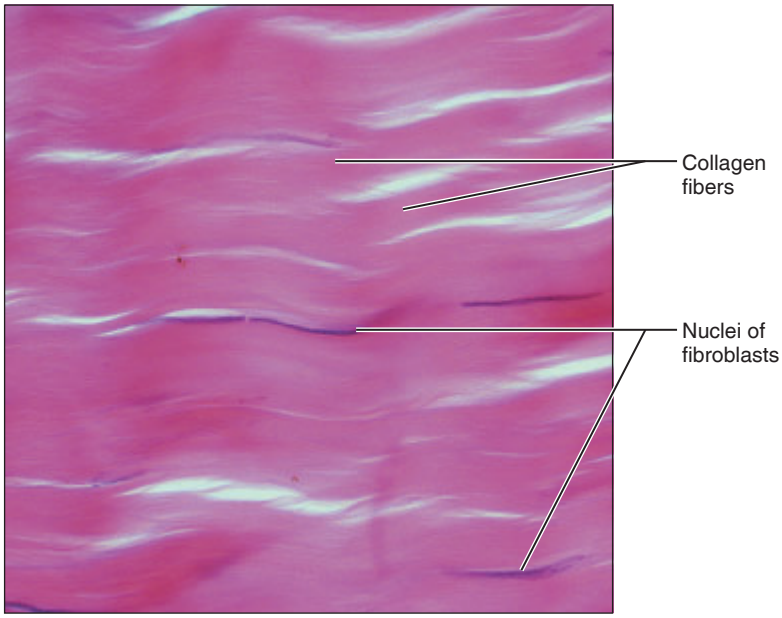
(d) Connective tissue proper: dense regular connective tissue

Description: Primarily parallel collagen fibers; a few elastic fibers; major cell type is the fibroblast.

Function: Attaches muscles to bones or to muscles; attaches bones to bones; withstands great tensile stress when pulling force is applied in one direction.

Location: Tendons, most ligaments, aponeuroses.





Photomicrograph: Dense regular connective tissue from a tendon (430×).

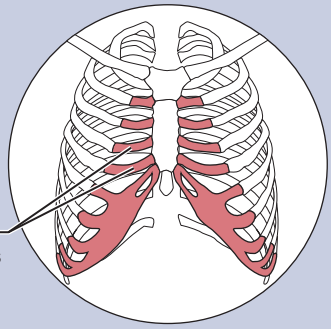
Figure 5.3 *(continued)* **Connective tissues.** Loose connective tissue: reticular **(c)**. Dense regular connective tissue **(d)**.

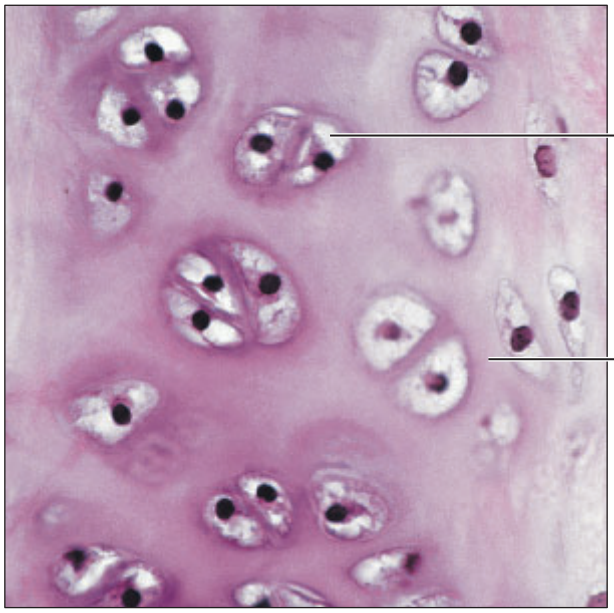
(e) Cartilage: hyaline

Description: Amorphous but firm matrix; collagen fibers form an imperceptible network; chondroblasts produce the matrix and when mature (chondrocytes) lie in lacunae.

Function: Supports and reinforces; serves as resilient cushion; resists compressive stress.

Location: Forms most of the embryonic skeleton; covers the ends of long bones in joint cavities; forms costal cartilages of the ribs; cartilages of the nose, trachea, and larynx.





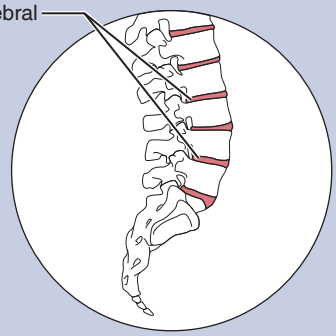
Photomicrograph: Hyaline cartilage from a costal cartilage of a rib (470×).

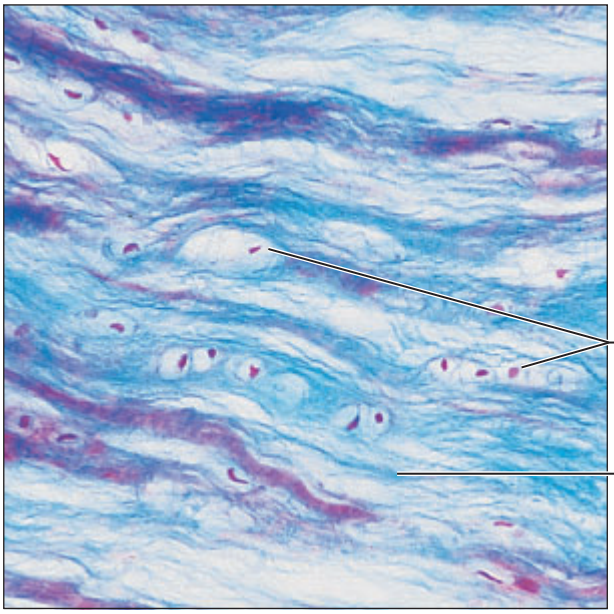
(f) Cartilage: fibrocartilage

Description: Matrix similar to but less firm than that in hyaline cartilage; thick collagen fibers predominate.

Function: Tensile strength with the ability to absorb compressive shock.

Location: Intervertebral discs; pubic symphysis; discs of knee joint.





Photomicrograph: Fibrocartilage of an intervertebral disc (125×). Special staining produced the blue color.

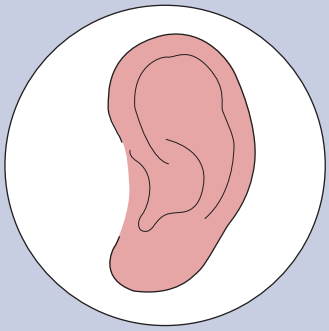
Figure 5.3 *(continued)* Hyaline cartilage **(e)** and fibrocartilage **(f)**. *(Figure continues on page 46.)*

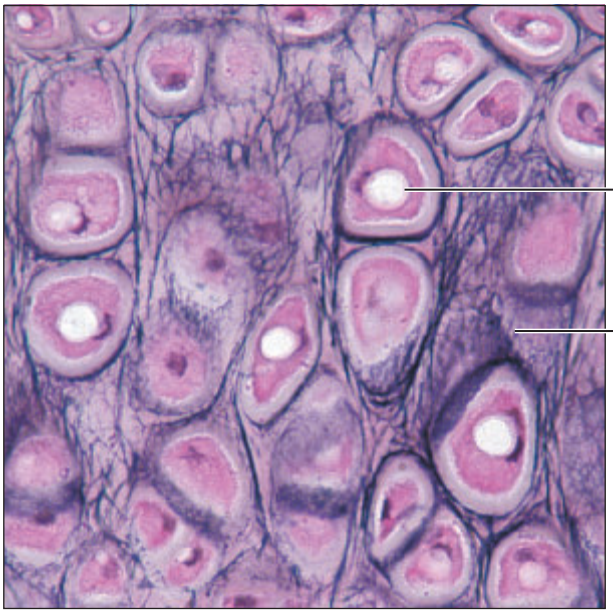
(g) Cartilage: elastic

Description: Similar to hyaline cartilage, but more elastic fibers in matrix.

Function: Maintains the shape of a structure while allowing great flexibility.

Location: Supports the external ear (auricle); epiglottis.





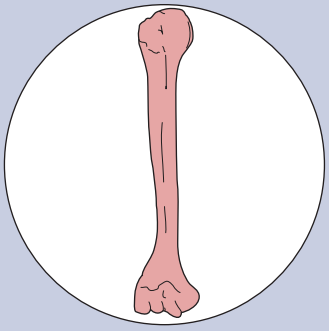
Photomicrograph: Elastic cartilage from the human ear auricle; forms the flexible skeleton of the ear (800×).

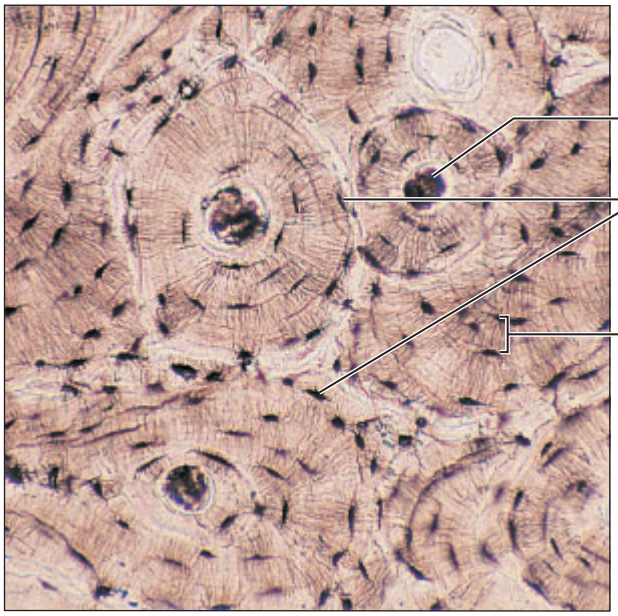
(h) Bone (osseous tissue)

Description: Hard, calcified matrix containing many collagen fibers; osteocytes lie in lacunae. Very well vascularized.

Function: Bone supports and protects (by enclosing); provides levers for the muscles to act on; stores calcium and other minerals and fat; marrow inside bones is the site for blood cell formation (hematopoiesis).

Location: Bones





Photomicrograph: Cross-sectional view of bone (125×).

Figure 5.3 *(continued)* **Connective tissues.** Elastic cartilage **(g)** and bone (osseous tissue) **(h)**.

Muscle Tissue

Muscle tissue is specialized to contract in order to produce movement of some body parts. As you might expect, muscle cells are elongated to provide a long axis for contraction. The three basic types of muscle tissue are described briefly here.

Skeletal muscle, the flesh of the body, is attached to the skeleton. It is under voluntary control (consciously controlled), and as it contracts it moves the limbs and other external body parts. The cells of skeletal muscles are long, cylindrical, nonbranching, and multinucleate (several nuclei per cell); they have obvious *striations* (stripes).

Cardiac muscle is found only in the heart. As it contracts, the heart acts as a pump, propelling the blood into the blood vessels. Like skeletal muscle, cardiac muscle has striations, but cardiac cells are branching cells with one nucleus (or occasionally two) that fit together at junctions called **intercalated discs,** which allow cardiac muscle to act as a unit. Cardiac muscle is under involuntary control, which means that we cannot voluntarily or consciously control the operation of the heart.

Smooth muscle is found mainly in the walls of hollow organs (digestive and urinary tract organs, uterus, blood vessels). Typically two layers run at right angles to each other, so the muscle can constrict or dilate the lumen (cavity) of an organ and also propel substances along existing pathways. No striations are visible, and the uninucleate smooth muscle cells are spindle-shaped.

Activity 3

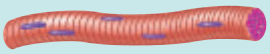
Examining Muscle Tissue Under the Microscope

Go to station 3 of the demonstration area to examine prepared slides of skeletal, cardiac, and smooth muscle. Notice their similarities and dissimilarities in your observations and in the illustrations (**Figure 5.4**). (See also Plates 2 and 3 in the Histology Atlas.)

5

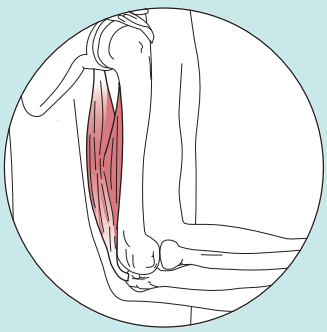
(a) Skeletal muscle

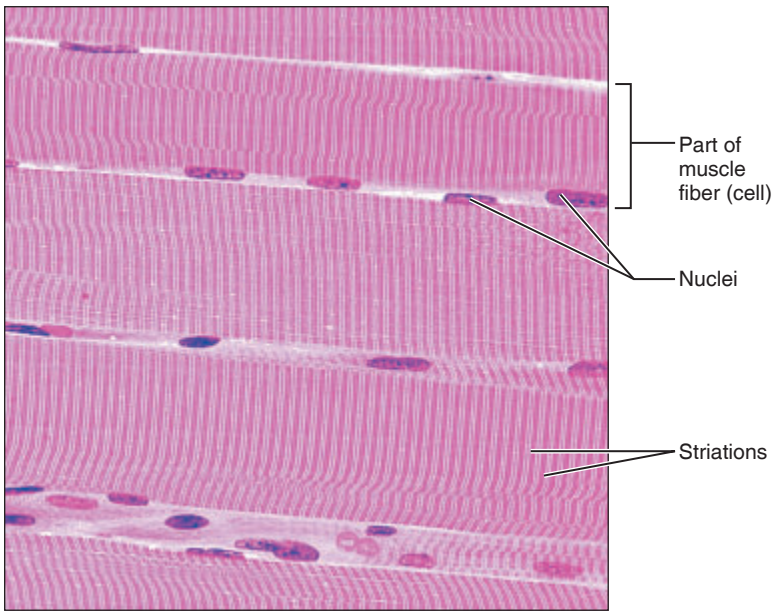
Description: Long, cylindrical, multinucleate cells; obvious striations.



Function: Voluntary movement; locomotion; manipulation of the environment; facial expression; voluntary control.

Location: In skeletal muscles attached to bones or occasionally to skin.



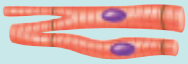


Photomicrograph: Skeletal muscle (approx. 440×). Notice the obvious banding pattern and the fact that these large cells are multinucleate.

Figure 5.4 Muscle tissues. Skeletal muscle **(a)** *(Figure continues on page 48.)*

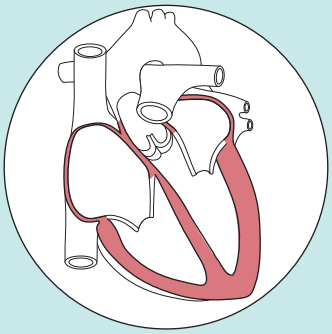
(b) Cardiac muscle

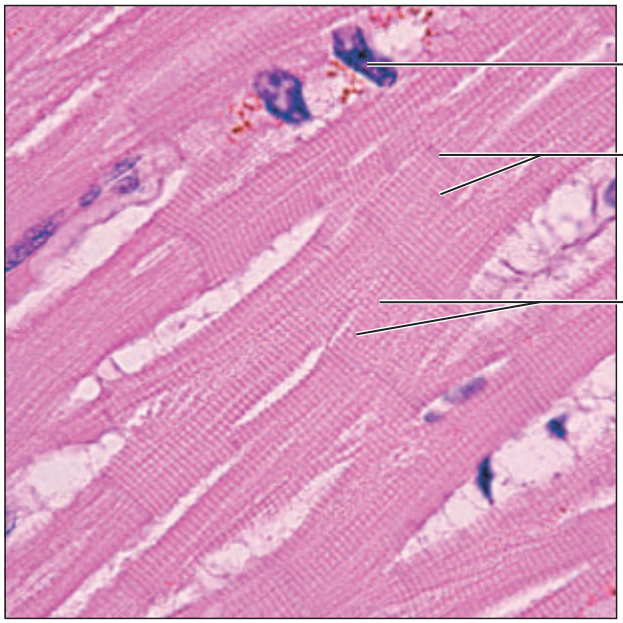
Description: Branching, striated, generally uninucleate cells that interdigitate at specialized junctions called intercalated discs.



Function: As it contracts, cardiac muscle propels blood into the circulation; involuntary control.

Location: The walls of the heart.

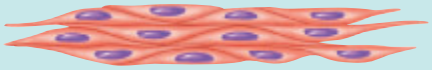




Photomicrograph: Cardiac muscle (775×); notice the striations, branching of cells, and the intercalated discs.

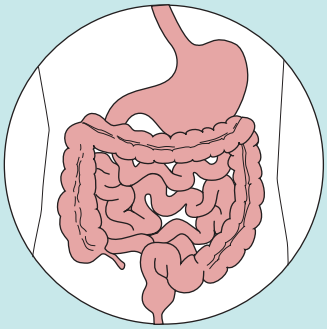
(c) Smooth muscle

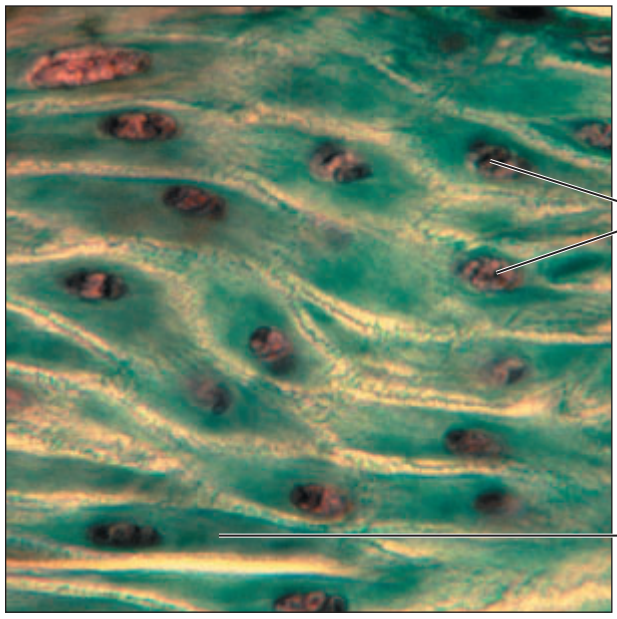
Description: Spindle-shaped cells with central nuclei; no striations; cells arranged closely to form sheets.



Function: Propels substances (foodstuffs, urine) or a baby along internal passageways; involuntary control.

Location: Mostly in the walls of hollow organs.





Photomicrograph: Sheet of smooth muscle (720×).

Figure 5.4 *(continued)* Muscle tissues. Cardiac muscle **(b)** and smooth muscle **(c)**.

Nervous Tissue

Nervous tissue is composed of two major cell populations. **Neuroglia** are special supporting cells that protect, support, and insulate the more delicate neurons. The **neurons** are highly specialized to receive stimuli and to conduct impulses to all parts of the body. They are the cells that are most often associated with nervous system functioning.

The structure of neurons is markedly different from that of all other body cells. They all have a nucleus-containing cell body, and their cytoplasm is drawn out into long extensions (cell processes)—sometimes as long as 3 feet (about 1 m). This allows a single neuron to conduct an impulse over relatively long distances. For more detail about the anatomy of the different classes of neurons and neuroglia, see Exercise 13.

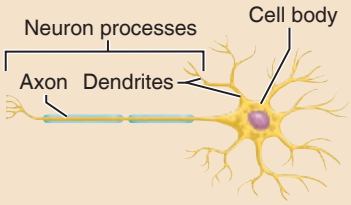
Activity 4

Examining Nervous Tissue Under the Microscope

Go to station 4 at the demonstration area, and examine a prepared slide of a spinal cord smear. Locate a neuron and compare it to **Figure 5.5** and Plate 5 of the Histology Atlas. Keep the light on the microscope dim—this will help you see the cellular extensions of the neurons.

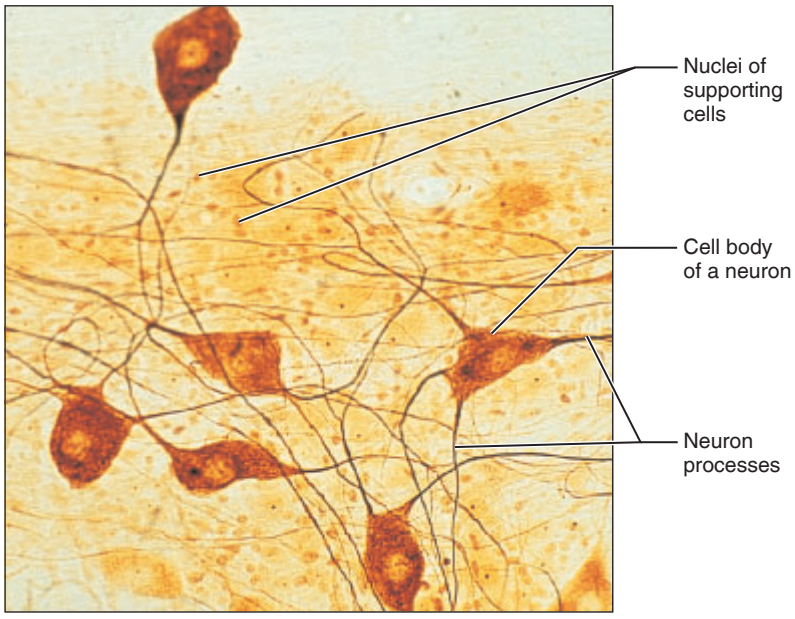
Nervous tissue

Description: Neurons are branching cells; cell processes that may be quite long extend from the nucleus-containing cell body; also contributing to nervous tissue are nonexcitable supporting cells.



Function: Neurons transmit electrical signals from sensory receptors and to effectors (muscles and glands). Supporting cells support and protect neurons.

Location: Brain, spinal cord, and nerves.



Photomicrograph: Neurons (350×).

Figure 5.5 **Nervous tissue.**