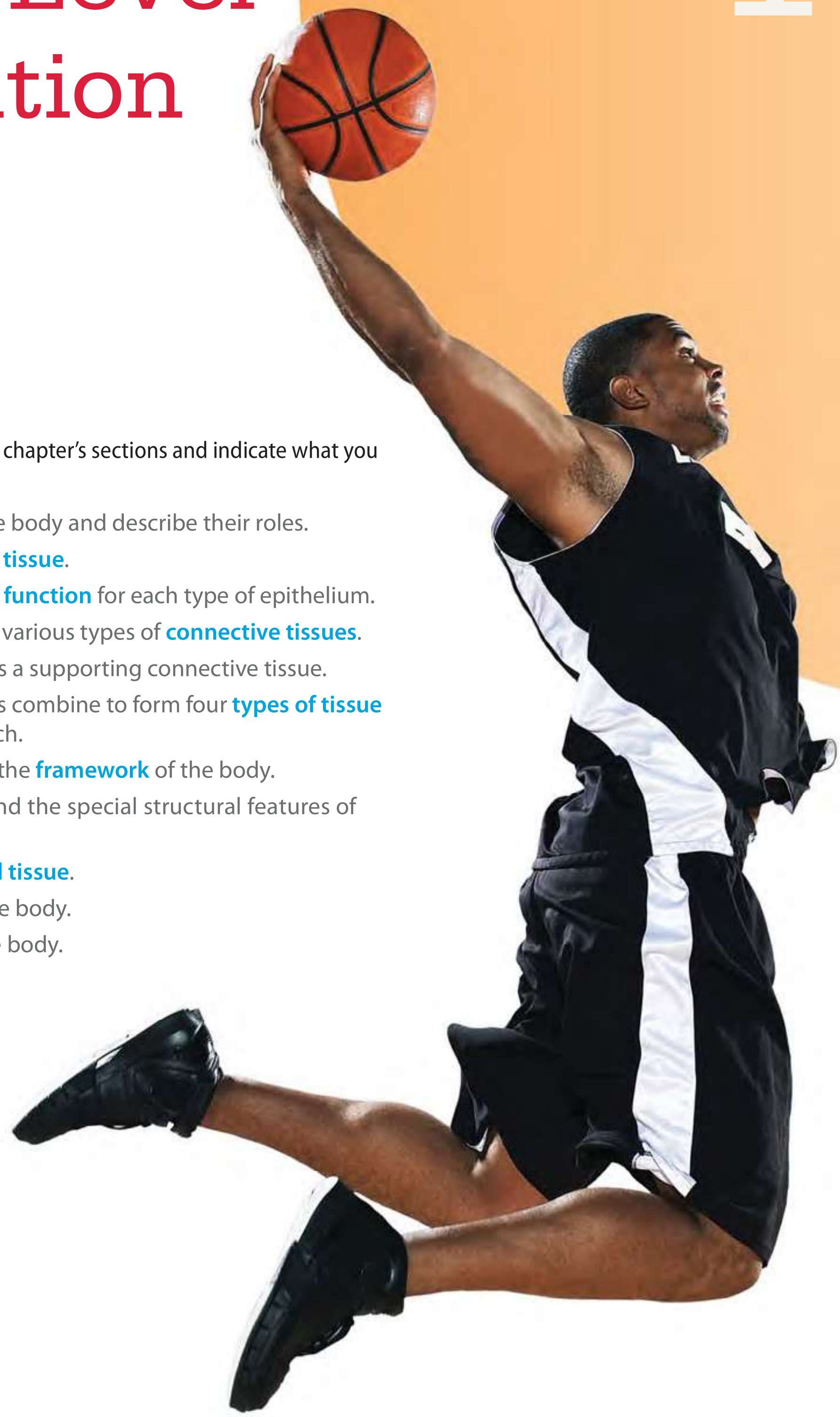
4

# The Tissue Level of Organization



## Learning Outcomes

These Learning Outcomes correspond by number to this chapter's sections and indicate what you should be able to do after completing the chapter.

- **4-1** Identify the four major **types of tissues** in the body and describe their roles.
- **4-2** Discuss the types and functions of **epithelial tissue**.
- **4-3** Describe the relationship between **form and function** for each type of epithelium.
- **4-4** Compare the structures and functions of the various types of **connective tissues**.
- **4-5** Describe how **cartilage and bone** function as a supporting connective tissue.
- **4-6** Explain how epithelial and connective tissues combine to form four **types of tissue membranes**, and specify the functions of each.
- **4-7** Describe how **connective tissue** establishes the **framework** of the body.
- **4-8** Describe the three types of **muscle tissue** and the special structural features of each type.
- **4-9** Discuss the basic structure and role of **neural tissue**.
- **4-10** Describe how **injuries** affect the tissues of the body.
- **4-11** Describe how **aging** affects the tissues of the body.

## Clinical Notes



## Spotlight

## An Introduction to the Tissue Level of Organization

This chapter discusses how a variety of cell types arranged in various combinations form *tissues*, structures with discrete structural and functional properties. Tissues in combination form *organs*, such as the heart or liver, and in turn organs can be grouped into 11 *organ systems*.

## 4-1 The four tissue types are epithelial, connective, muscle, and neural

Although the human body contains trillions of cells, differentiation produces only about 200 types of cells. To work efficiently, several different types of cells must coordinate their efforts. Cells working together form **tissues**—collections of specialized cells and cell products that perform a limited number of functions. The study of tissues is called **histology.** Histologists recognize four basic types of tissue:

1. *Epithelial tissue*, which covers exposed surfaces, lines internal passageways and chambers, and forms glands.
2. *Connective tissue*, which fills internal spaces, provides structural support for other tissues, transports materials within the body, and stores energy reserves.
3. *Muscle tissue*, which is specialized for contraction and includes the skeletal muscles of the body, the muscle of the heart, and the muscular walls of hollow organs.
4. *Neural tissue*, which carries information from one part of the body to another in the form of electrical impulses.

This chapter will introduce the basic characteristics of these tissues. You will need this information to understand the descriptions of organs and organ systems in later chapters. Additionally, a working knowledge of basic histology will help you make the connections between anatomical structures and their physiological functions. ATLAS: Embryology Summary 1: The Formation of Tissues

### Checkpoint

1. **Define histology.**
2. **Identify the four major types of tissues in the body.**

See the blue Answers tab at the back of the book.

## 4-2 Epithelial tissue covers body surfaces, lines cavities and tubular structures, and serves essential functions

It is convenient to begin our discussion with **epithelial tissue,** because it includes the surface of your skin, a very familiar feature. Epithelial tissue includes *epithelia* and *glands*. **Epithelia** (ep-i-THĒ-lē-a; singular, *epithelium*) are layers of cells that cover internal or external surfaces. **Glands** are structures that produce fluid secretions; they are either attached to or derived from epithelia.

Epithelia cover every exposed surface of the body. Epithelia form the surface of the skin and line the digestive, respiratory, reproductive, and urinary tracts—in fact, they line all passageways that communicate with the outside world. The more delicate epithelia line internal cavities and passageways, such as the chest cavity, fluid-filled spaces in the brain, the inner surfaces of blood vessels, and the chambers of the heart.

Epithelia have several important characteristics:

- *Cellularity.* Epithelia are composed almost entirely of cells bound closely together by interconnections known as *cell junctions*. In other tissue types, the cells are often widely separated by extracellular materials.
- *Polarity.* An epithelium has an exposed surface, which faces the exterior of the body or an internal space, and a base, which is attached to underlying tissues. The term **polarity** refers to the presence of structural and functional differences between the exposed and attached surfaces. In an epithelium consisting of a single layer of cells, the exposed *(apical)* and attached *(basal)* surfaces differ in membrane structure and function.
- *Attachment.* The base of an epithelium is bound to a thin **basement membrane** or **basal lamina.** The basement membrane is a complex structure produced by the basal surface of the epithelium and the underlying connective tissue.
- *Avascularity.* Epithelia are **avascular** (ā-VAS-kū-lar; *a-*, without + *vas*, vessel); that is, they lack blood vessels. Epithelial cells must obtain nutrients by diffusion or absorption across either the exposed or the attached epithelial surface.
- *Regeneration.* Epithelial cells that are damaged or lost at the exposed surface are continuously replaced through stem cell divisions in the epithelium. Although regeneration is a characteristic of other tissues as well, the rates of cell division and replacement are typically much higher in epithelia than in other tissues.

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## Functions of Epithelial Tissue

Epithelia perform four essential functions:

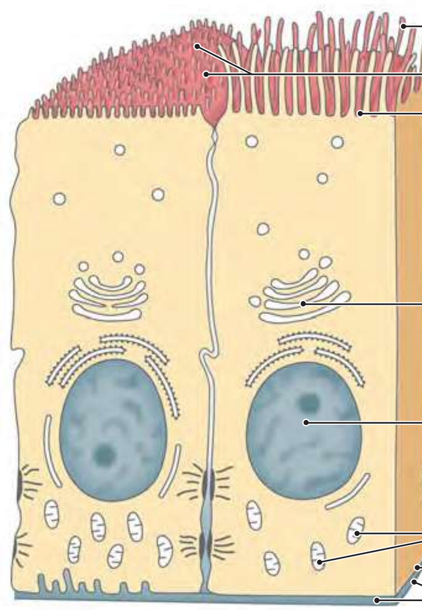
1. *Provide Physical Protection.* Epithelia protect exposed and internal surfaces from abrasion, dehydration, and destruction by chemical or biological agents.
2. *Control Permeability.* Any substance that enters or leaves your body must cross an epithelium. Some epithelia are relatively impermeable; others are easily crossed by compounds as large as proteins. Many epithelia contain the molecular "machinery" needed for selective absorption or secretion. The epithelial barrier can be regulated and modified in response to stimuli. For example, hormones can affect the transport of ions and nutrients through epithelial cells. Even physical stress can alter the structure and properties of epithelia; for example, calluses form on your hands when you do manual labor for some time.
3. *Provide Sensation.* Most epithelia are extremely sensitive to stimulation, because they have a large sensory nerve supply. These sensory nerves continually provide information about the external and internal environments. For example, the lightest touch of a mosquito will stimulate sensory neurons that tell you where to swat. A *neuroepithelium* is an epithelium that is specialized to perform a particular sensory function; neuroepithelia contain sensory cells that provide the sensations of smell, taste, sight, equilibrium, and hearing.
4. *Produce Specialized Secretions.* Epithelial cells that produce secretions are called *gland cells*. Individual gland cells are usually scattered among other cell types in an epithelium. In a **glandular epithelium,** most or all of the epithelial cells produce secretions, which are either discharged onto the surface of the epithelium (to provide physical protection or temperature regulation) or released into the surrounding interstitial fluid and blood (to act as chemical messengers).

## Specializations of Epithelial Cells

Epithelial cells have several structural specializations that distinguish them from other body cells. For the epithelium as a whole to perform the functions just listed, individual epithelial cells may be specialized for (1) the movement of fluids over the epithelial surface, providing protection and lubrication; (2) the movement of fluids through the epithelium, to control permeability; or (3) the production of secretions that provide physical protection or act as chemical messengers. Specialized epithelial cells generally possess a strong polarity; one common type of epithelial polarity is shown in **Figure 4–1**.

The cell is often divided into two functional regions: (1) the *apical surface*, where the cell is exposed to an internal or external environment; and (2) the *basolateral surfaces*, which include both the base, where the cell attaches to underlying epithelial cells or deeper tissues, and the sides, where the cell contacts its neighbors.

**Figure 4–1 The Polarity of Epithelial Cells.** Many epithelial cells have an uneven distribution of organelles between the free surface (here, the top) and the basement membrane. Often, the free surface has microvilli; sometimes it has cilia. In some epithelia, such as the lining of the kidney tubules, mitochondria are concentrated near the base of the cell, probably to provide energy for the cell's transport activities.




Many epithelial cells that line internal passageways have *microvilli* on their exposed surfaces. p. 70 Just a few may be present, or microvilli may carpet the entire surface. Microvilli are especially abundant on epithelial surfaces where absorption and secretion take place, such as along portions of the digestive and urinary tracts. The epithelial cells in these locations are transport specialists; each cell has at least 20 times more surface area to transport substances than it would have if it lacked microvilli.

*Cilia* are characteristic of surfaces covered by a **ciliated epithelium.** A typical ciliated cell contains about 250 cilia that beat in a coordinated manner. As though on an escalator, substances are moved over the epithelial surface by the synchronized beating of the cilia. The ciliated epithelium that lines the respiratory tract, for example, moves mucus up from the lungs and toward the throat. The sticky mucus traps inhaled particles, including dust, pollen, and pathogens; the ciliated epithelium carries the mucus and the trapped debris to the throat, where they can be swallowed or expelled by coughing. Injury to the cilia or to the epithelial cells, most commonly by abrasion or exposure to toxic compounds such as nicotine and carbon monoxide in cigarette smoke, can stop ciliary movement and block the protective flow of mucus, possibly leading to infection or disease.

## Maintaining the Integrity of Epithelia

To be effective as a barrier, an epithelium must form a complete cover or lining. Three factors help maintain the physical integrity of an epithelium: (1) intercellular connections, (2) attachment to the basement membrane, and (3) epithelial maintenance and repair.

### Intercellular Connections

Cells in an epithelium are firmly attached to one another, and the epithelium as a unit is attached to extracellular fibers of the clear layer of the basement membrane. Many cells in your body form permanent or temporary bonds with other cells or extracellular material. Epithelial cells, however, are specialists in intercellular connection (**Figure 4–2**).

Intercellular connections involve either extensive areas of opposing plasma membranes or specialized attachment sites, discussed shortly. Large areas of opposing plasma membranes are interconnected by transmembrane proteins called **cell adhesion molecules (CAMs),** which bind to each other and to extracellular materials. For example, CAMs on the basolateral surface of an epithelium help bind the cell to the underlying basement membrane. The membranes of adjacent cells may also be bonded by a thin layer of proteoglycans that contain polysaccharide derivatives known as *glycosaminoglycans*, most notably **hyaluronan** *(hyaluronic acid)*.

**Cell junctions** are specialized areas of the plasma membrane that attach a cell to another cell or to extracellular materials. The three most common types of cell junctions are (1) tight junctions, (2) gap junctions, and (3) desmosomes.

At a **tight junction,** the lipid portions of the two plasma membranes are tightly bound together by interlocking membrane proteins (**Figure 4–2b**). Inferior to the tight junctions, a continuous *adhesion belt* forms a band that encircles cells and binds them to their neighbors. The bands are attached to the microfilaments of the terminal web. ⮌ p. 69 This kind of attachment is so tight that these junctions largely prevent the passage of water and solutes between the cells. When the epithelium lines a tube, such as the intestinal tract, the apical surfaces of the epithelial cells are exposed to the space inside the tube, a passageway called the **lumen** (LOO-men). Tight junctions effectively isolate the contents of the lumen from the basolateral surfaces of the cell. For example, tight junctions near the apical surfaces of cells that line the digestive tract help keep enzymes, acids, and wastes in the lumen from reaching the basolateral surfaces and digesting or otherwise damaging the underlying tissues and organs.

Some epithelial functions require rapid intercellular communication. At a **gap junction** (**Figure 4–2c**), two cells are held together by two interlocking transmembrane proteins called *connexons*. Because these are channel proteins, they form a narrow passageway that lets small molecules and ions pass from cell to cell. Gap junctions are common among epithelial cells, where the movement of ions helps coordinate functions such as the beating of cilia. Gap junctions are also common in other tissues. For example, gap junctions in cardiac muscle tissue and smooth muscle tissue are essential to the coordination of muscle cell contractions.



Most epithelial cells are subject to mechanical stresses—stretching, bending, twisting, or compression—so they must have durable interconnections. At a **desmosome** (DEZ-mō-sōm; *desmos*, ligament + *soma*, body), CAMs and proteoglycans link the opposing plasma membranes. Desmosomes are very strong and can resist stretching and twisting.

A typical desmosome is formed by two cells. Within each cell is a complex known as a *dense area*, which is connected to the cytoskeleton (**Figure 4–2d**). It is this connection to the cytoskeleton that gives the desmosome—and the epithelium—its strength. For example, desmosomes are abundant between cells in the superficial layers of the skin. As a result, damaged skin cells are usually lost in sheets rather than as individual cells. (That is why your skin peels rather than comes off as a powder after a sunburn.)

There are two types of desmosomes:

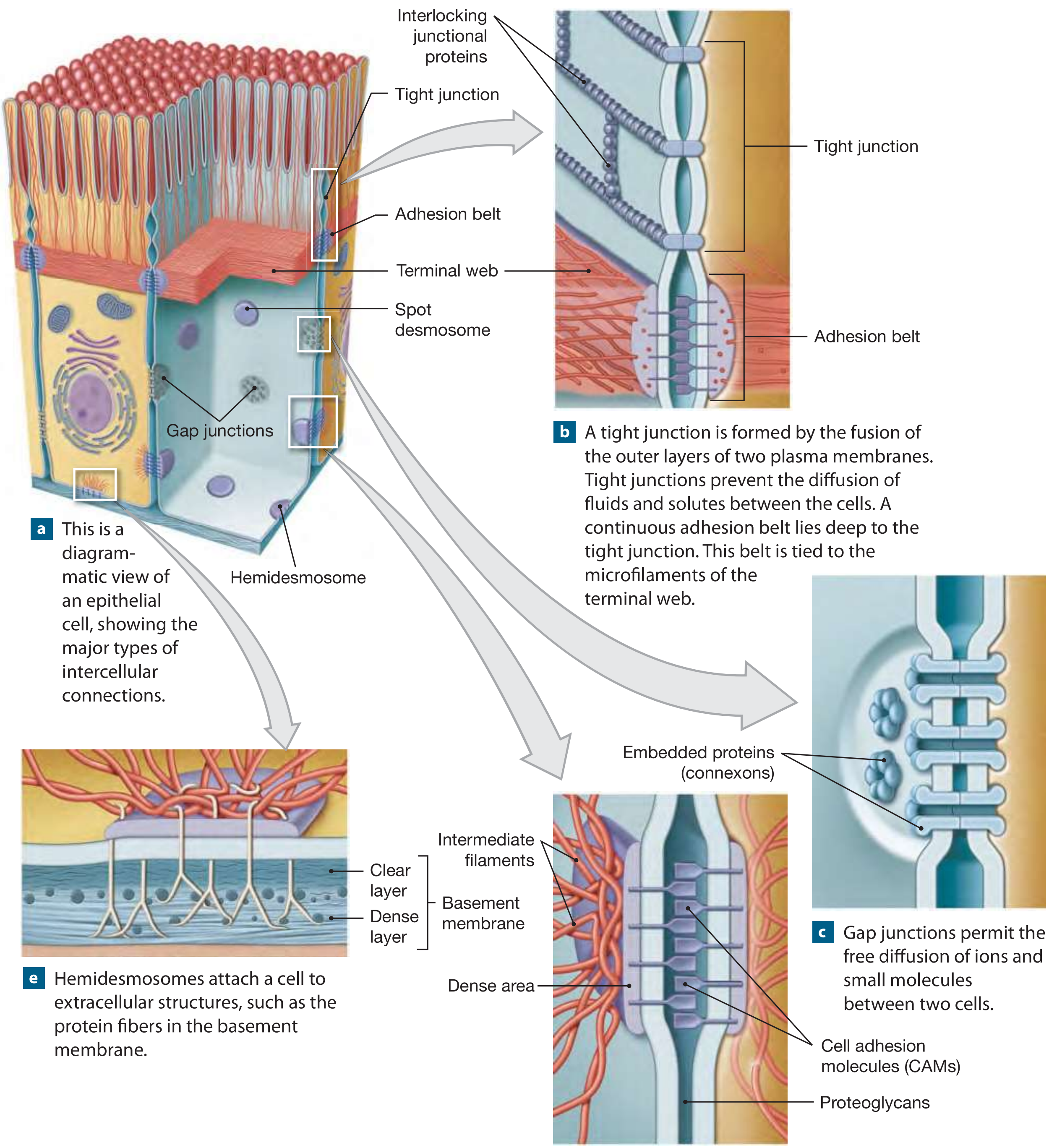
- *Spot desmosomes* are small discs connected to bands of intermediate filaments. The intermediate filaments function to stabilize the shape of the cell.
- *Hemidesmosomes* resemble half of a spot desmosome. Rather than attaching one cell to another, a hemidesmosome attaches a cell to extracellular filaments in the basement membrane (**Figure 4–2e**). This attachment helps stabilize the position of the epithelial cell and anchors it to underlying tissues.

### Attachment to the Basement Membrane

Not only do epithelial cells hold onto one another, but they also remain firmly connected to the rest of the body. The inner surface of each epithelium is attached to a two-part basement membrane. The layer closer to the epithelium, the *clear layer*, contains glycoproteins and a network of fine protein filaments (**Figure 4–2e**). Secreted by the adjacent layer of epithelial cells, the clear layer acts as a barrier that restricts the movement of proteins and other large molecules from the underlying connective tissue into the epithelium.

The deeper portion of the basement membrane, the *dense layer*, contains bundles of coarse protein fibers produced by connective tissue cells. The dense layer gives the basement membrane its strength. Attachments between the fibers of the clear layer and those of the dense layer hold the two layers together, and hemidesmosomes attach the epithelial cells to the composite basement membrane. The dense layer also acts as a

**Figure 4–2** **Cell Junctions.**




**a** This is a diagrammatic view of an epithelial cell, showing the major types of intercellular connections.

**b** A tight junction is formed by the fusion of the outer layers of two plasma membranes. Tight junctions prevent the diffusion of fluids and solutes between the cells. A continuous adhesion belt lies deep to the tight junction. This belt is tied to the microfilaments of the terminal web.

**c** Gap junctions permit the free diffusion of ions and small molecules between two cells.

**d** A spot desmosome ties adjacent cells together.

**e** Hemidesmosomes attach a cell to extracellular structures, such as the protein fibers in the basement membrane.

filter that determines what substances can diffuse between the adjacent tissues and the epithelium.

## Epithelial Maintenance and Repair

Epithelial cells lead hard lives, for they are exposed to disruptive enzymes, toxic chemicals, pathogenic bacteria, and mechanical abrasion. Consider the lining of the small intestine, where epithelial cells are exposed to a variety of enzymes and abraded by partially digested food. In this extreme environment, an epithelial cell may last just a day or two before it is shed or destroyed. The only way the epithelium can maintain its structure over time is by the continual division of *stem cells*. ⮌ p. 100 Most epithelial stem cells, also called **germinative cells,** are located near the basement membrane, in a relatively protected location. ATLAS: Embryology Summary 2: The Development of Epithelia

### Checkpoint

3. **List five important characteristics of epithelial tissue.**
4. **Identify four essential functions of epithelial tissue.**
5. **What is the probable function of an epithelial surface whose cells bear many microvilli?**
6. **Identify the various types of epithelial cell junctions.**
7. **What is the functional significance of gap junctions?**

See the blue Answers tab at the back of the book.

## 4-3 ◗ Cell shape and number of layers determine the classification of epithelia

There are many different specialized types of epithelia. You can easily sort these into categories based on (1) the cell shape, and (2) the number of cell layers between the basement membrane and the exposed surface of the epithelium. Using these two criteria, we can describe almost every epithelium in the body (**Table 4–1**).

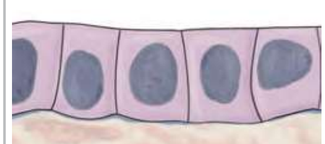
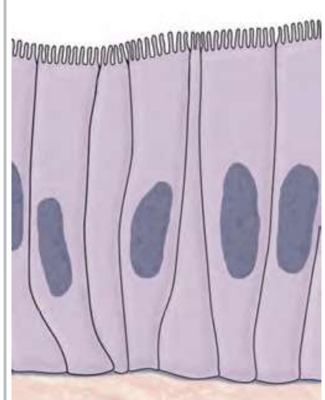
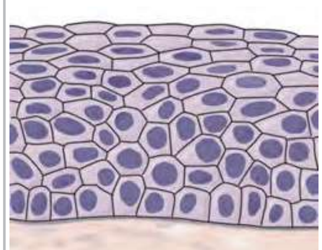
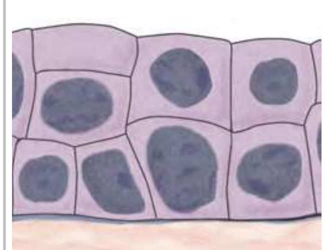
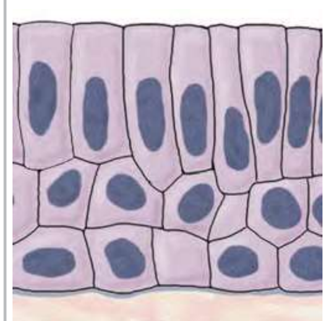
### Classification of Epithelia

Three epithelial cell shapes are identified: *squamous*, *cuboidal*, and *columnar*. For classification purposes, one looks at the superficial cells in a section perpendicular to both the exposed surface and the basement membrane. In sectional view, squamous cells appear thin and flat, cuboidal cells look like little boxes, and columnar cells are tall and relatively slender rectangles.

Once you have determined whether the superficial cells are squamous, cuboidal, or columnar, you then look at the number of cell layers. There are only two options: *simple* or *stratified*.

If only one layer of cells covers the basement membrane, that layer is a **simple epithelium.** Simple epithelia are necessarily thin. All the cells have the same polarity, so the distance from the nucleus to the basement membrane does not change from one cell to the next. Because they are so thin, simple epithelia are also fragile. A single layer of cells cannot provide much mechanical protection, so simple epithelia are located only in protected areas inside the body. They line internal

**Table 4–1** Classifying Epithelia

| | SQUAMOUS | CUBOIDAL | COLUMNAR |
|---|---|---|---|
| **Simple** |  Simple squamous epithelium |  Simple cuboidal epithelium |  Simple columnar epithelium |
| **Stratified** |  Stratified squamous epithelium |  Stratified cuboidal epithelium |  Stratified columnar epithelium |

compartments and passageways, including the ventral body cavities, the heart chambers, and blood vessels.

Simple epithelia are also characteristic of regions in which secretion or absorption occurs, such as the lining of the intestines and the gas-exchange surfaces of the lungs. In these places, thinness is an advantage, for it reduces the time required for materials to cross the epithelial barrier.

In a **stratified epithelium,** several layers of cells cover the basement membrane. Stratified epithelia are generally located in areas that are exposed to mechanical or chemical stresses, such as the surface of the skin and the lining of the mouth.

**Tips & Tricks**

To help you remember the meanings of the terms *squamous* and *stratified,* associate the word "**squa**mous" with "**sca**ly," and the word "**strat**ified" with "**strat**osphere," an upper *layer* of Earth's atmosphere.

### Squamous Epithelia

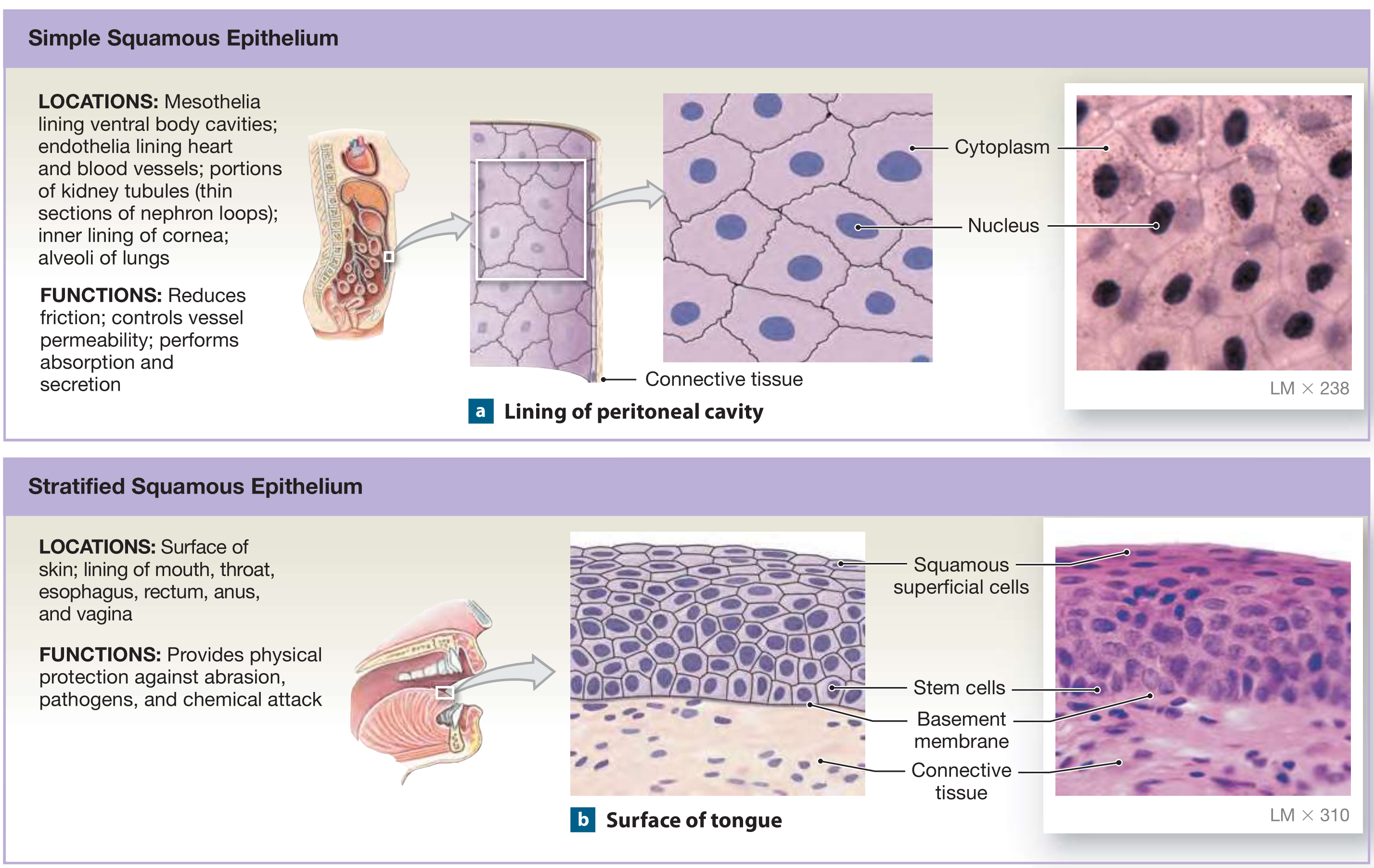
The cells in a **squamous epithelium** (SKWĀ-mus; *squama*, plate or scale) are thin, flat, and somewhat irregular in shape, like pieces of a jigsaw puzzle (**Figure 4–3**). From the surface, the cells resemble fried eggs laid side by side. In sectional view, the disc-shaped nucleus occupies the thickest portion of each cell.

A **simple squamous epithelium** is the body's most delicate type of epithelium. This type of epithelium is located in protected regions where absorption or diffusion takes place, or where a slick, slippery surface reduces friction. Examples are the respiratory exchange surfaces *(alveoli)* of the lungs, the lining of the ventral body cavities (**Figure 4–3a**), and the lining of the heart and blood vessels. Smooth linings are extremely important; for example, any irregularity in the lining of a blood vessel may result in the formation of a potentially dangerous blood clot.

Special names have been given to the simple squamous epithelia that line chambers and passageways that do not communicate with the outside world. The simple squamous epithelium that lines the ventral body cavities is a **mesothelium** (mez-ō-THĒ-lē-um; *mesos*, middle). The pleura, peritoneum, and pericardium each contain a superficial layer of mesothelium. The simple squamous epithelium lining the inner surface of the heart and all blood vessels is an **endothelium** (en-dō-THĒ-lē-um; *endo-*, inside).

A **stratified squamous epithelium** (**Figure 4–3b**) is generally located where mechanical stresses are severe. The cells form a series of layers, like the layers in a sheet of ply-

**Figure 4–3** Squamous Epithelia.



wood. The surface of the skin and the lining of the mouth, esophagus, and anus are areas where this type of epithelium protects against physical and chemical attacks. On exposed body surfaces, where mechanical stress and dehydration are potential problems, apical layers of epithelial cells are packed with filaments of the protein *keratin*. As a result, superficial layers are both tough and water resistant; the epithelium is said to be *keratinized*. A *nonkeratinized* stratified squamous epithelium resists abrasion, but will dry out and deteriorate unless kept moist. Nonkeratinized stratified squamous epithelia are situated in the oral cavity, pharynx, esophagus, anus, and vagina.

### Cuboidal Epithelia

The cells of a **cuboidal epithelium** resemble hexagonal boxes. (In typical sectional views they appear square.) The spherical nuclei are near the center of each cell, and the distance between adjacent nuclei is roughly equal to the height of the epithelium. A **simple cuboidal epithelium** provides limited protection and occurs where secretion or absorption takes place. Such an epithelium lines portions of the kidney tubules (**Figure 4–4a**).

**Stratified cuboidal epithelia** are relatively rare; they are located along the ducts of sweat glands (**Figure 4–4b**) and in the larger ducts of the mammary glands.

### Transitional Epithelia

A **transitional epithelium** (**Figure 4–4c**) is an unusual stratified epithelium because, unlike most epithelia, it tolerates repeated cycles of stretching and recoiling (returning to its previous shape) without damage. It is called transitional because the appearance of the epithelium changes as stretching occurs. A transitional epithelium is situated in regions of the urinary system, such as the urinary bladder, where large changes in volume occur. In an empty urinary bladder, the superficial cells of the epithelium are typically plump and cuboidal. In the full urinary bladder, when the volume of urine has stretched the lining to its limits, the epithelium appears flattened, and more like a stratified squamous epithelium.

### Columnar Epithelia

In a typical sectional view, **columnar epithelial cells** appear rectangular. In reality, the densely packed cells are hexagonal, but they are taller and more slender than cells in a cuboidal epithelium (**Figure 4–5**). The elongated nuclei are crowded into a narrow band close to the basement membrane. The height of the epithelium is several times the distance between adjacent nuclei. A **simple columnar epithelium** is typically found where absorption or secretion occurs, such as in the small intestine (**Figure 4–5a**). In the stomach and large intestine, the secretions of simple columnar epithelia protect against chemical stresses.

Portions of the respiratory tract contain a **pseudostratified columnar epithelium,** a columnar epithelium that includes several types of cells with varying shapes and functions. The distances between the cell nuclei and the exposed surface vary, so the epithelium appears to be layered, or stratified (**Figure 4–5b**). It is not truly stratified, though, because every epithelial cell contacts the basement membrane. Pseudostratified columnar epithelial cells typically possess cilia. Epithelia of this type line most of the nasal cavity, the trachea (windpipe), the bronchi (branches of the trachea leading to the lungs), and portions of the male reproductive tract.

**Stratified columnar epithelia** are relatively rare, providing protection along portions of the pharynx, epiglottis, anus, and urethra, as well as along a few large excretory ducts. The epithelium has either two layers (**Figure 4–5c**) or multiple layers. In the latter case, only the superficial cells are columnar.

Now that we have considered the classes of epithelia, we turn to a specialized type of epithelium: glandular epithelia.

#### Clinical Note

**Exfoliative Cytology** *Exfoliative cytology* (eks-FŌ-lē-a-tiv; *ex-* from + *folium*, leaf) is the study of cells shed or removed from epithelial surfaces. The cells are examined for a variety of reasons—for example, to check for cellular changes that indicate cancer, or for genetic screening of a fetus. Cells are collected by sampling the fluids that cover the epithelia lining the respiratory, digestive, urinary, or reproductive tract; by removing fluid from one of the ventral body cavities; or by removing cells from an epithelial surface.

One common sampling procedure is called a *Pap test*, named after Dr. George Papanicolaou, who pioneered its use. The most familiar Pap test is that for cervical cancer; it involves the scraping of cells from the tip of the *cervix*, the portion of the uterus that projects into the vagina.

*Amniocentesis* is another important test based on exfoliative cytology. In this procedure, shed epithelial cells are collected from a sample of *amniotic fluid*, which surrounds and protects a developing fetus. Examination of these cells can determine whether the fetus has a genetic abnormality, such as *Down's syndrome*, that affects the number or structure of chromosomes.

## Glandular Epithelia

Many epithelia contain gland cells that are specialized for secretion. Collections of epithelial cells (or structures derived from epithelial cells) that produce secretions are called *glands*. They range from scattered cells to complex glandular organs. Some of these glands, called **endocrine glands,** release their secretions into the interstitial fluid. Others, known as **exocrine glands,** release their secretions into passageways called **ducts** that open onto an epithelial surface.

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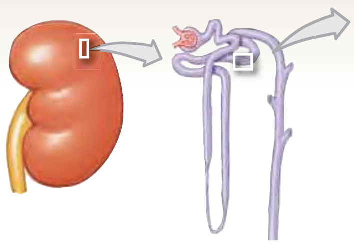
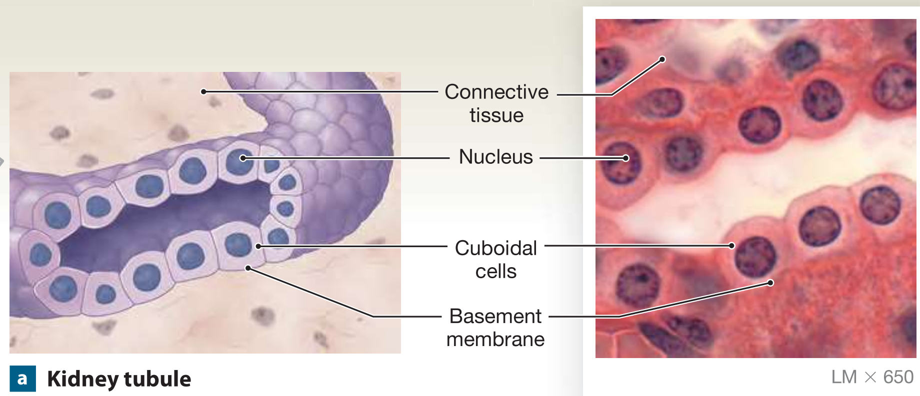
**Figure 4–4** **Cuboidal and Transitional Epithelia.**

## Simple Cuboidal Epithelium

**LOCATIONS:** Glands; ducts; portions of kidney tubules; thyroid gland

**FUNCTIONS:** Limited protection, secretion, absorption



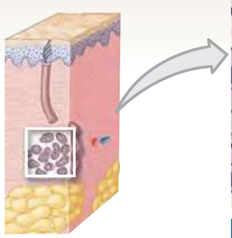


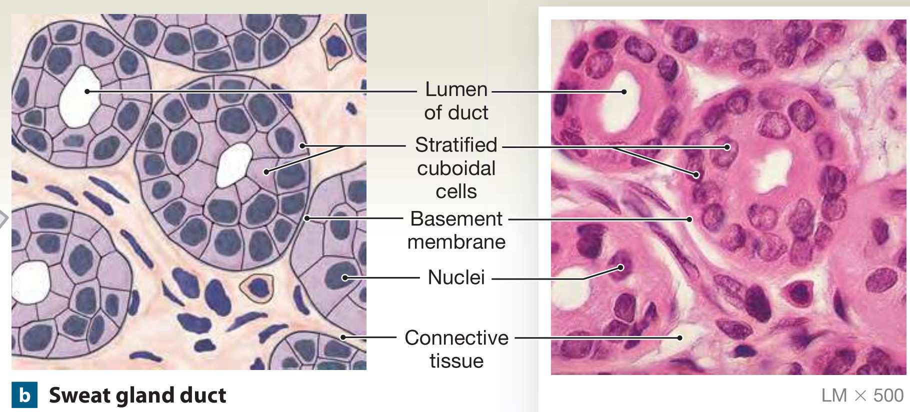

**a** **Kidney tubule**

## Stratified Cuboidal Epithelium

**LOCATIONS:** Lining of some ducts (rare)

**FUNCTIONS:** Protection, secretion, absorption



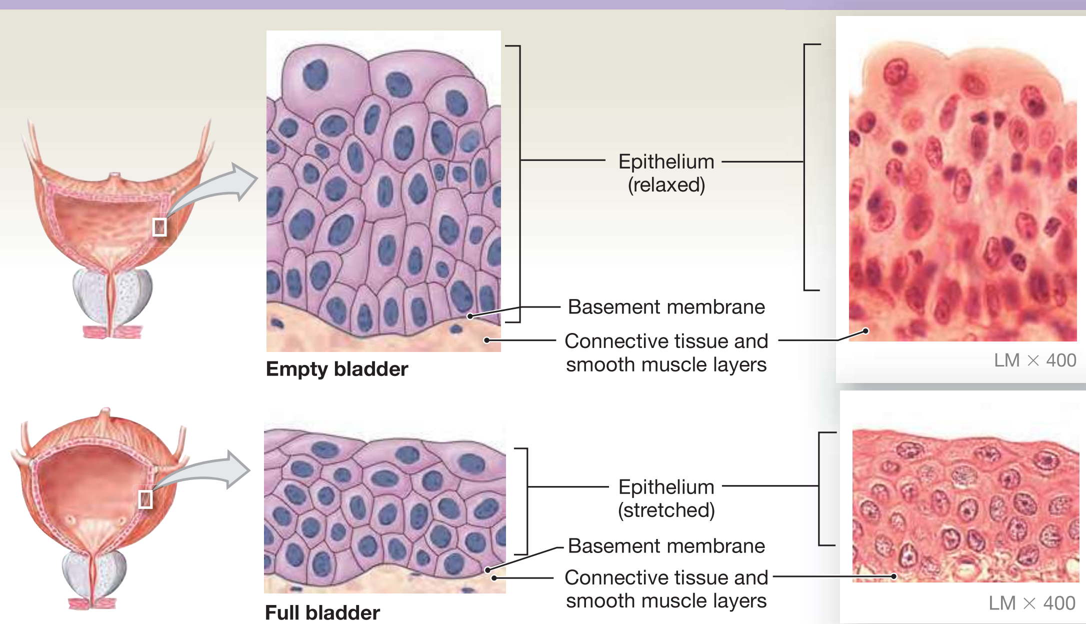



**b** **Sweat gland duct**

## Transitional Epithelium

**LOCATIONS:** Urinary bladder; renal pelvis; ureters

**FUNCTIONS:** Permits expansion and recoil after stretching



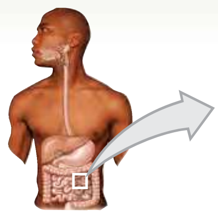

**c** **Urinary bladder**

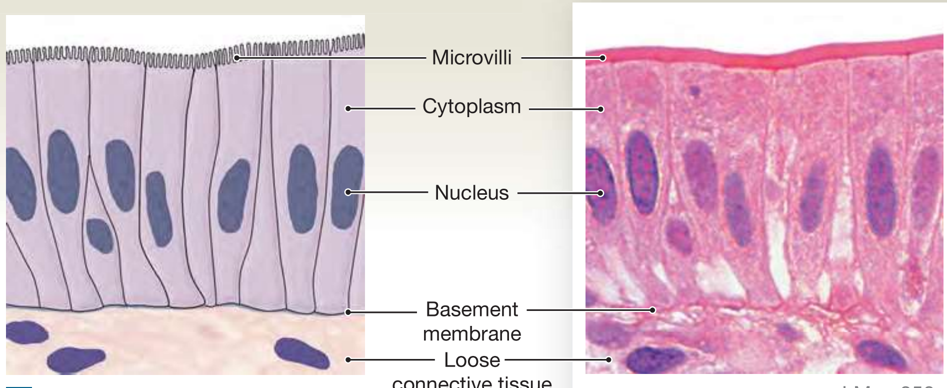
**Figure 4–5** Columnar Epithelia.

## Simple Columnar Epithelium

**LOCATIONS:** Lining of stomach, intestine, gallbladder, uterine tubes, and collecting ducts of kidneys

**FUNCTIONS:** Protection, secretion, absorption



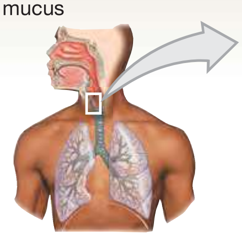


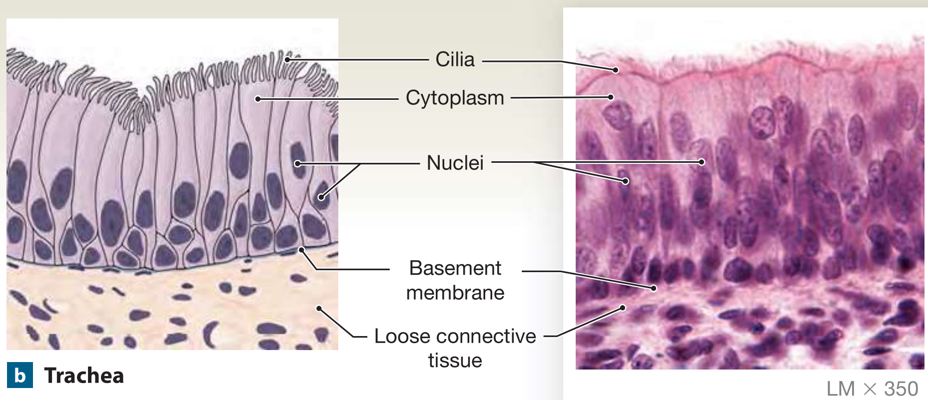

**a** **Intestinal lining**

## Pseudostratified Ciliated Columnar Epithelium

**LOCATIONS:** Lining of nasal cavity, trachea, and bronchi; portions of male reproductive tract

**FUNCTIONS:** Protection, secretion, move mucus with cilia



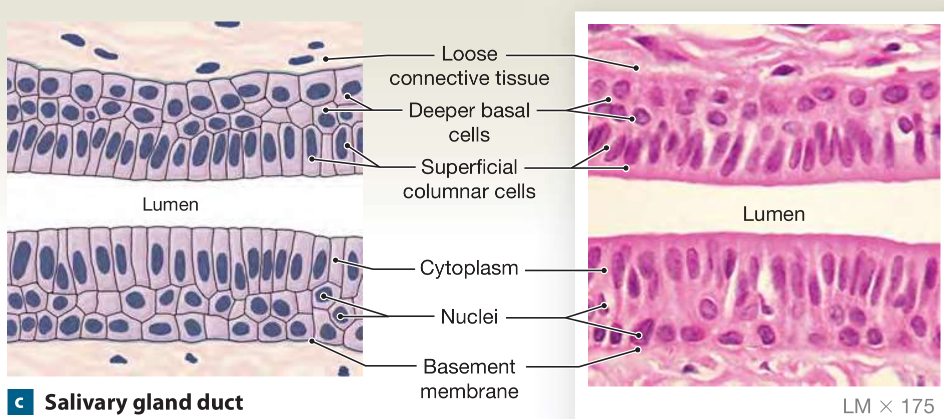



**b** **Trachea**

## Stratified Columnar Epithelium

**LOCATIONS:** Small areas of the pharynx, epiglottis, anus, mammary glands, salivary gland ducts, and urethra

**FUNCTION**: Protection




**c** **Salivary gland duct**

4

## Endocrine Glands

An endocrine gland produces *endocrine* (*endo-*, inside + *krinein*, to separate) *secretions*, which are released directly into the surrounding interstitial fluid. These secretions, also called *hormones*, enter the bloodstream for distribution throughout the body. Hormones regulate or coordinate the activities of various tissues, organs, and organ systems. Examples of endocrine glands include the thyroid gland and the pituitary gland. Because their secretions are not released into ducts, endocrine glands are often called *ductless glands*.

Endocrine cells may be part of an epithelial surface, such as the lining of the digestive tract, or they may be found in separate organs, such as the pancreas, thyroid gland, thymus, and pituitary gland. We will consider endocrine cells, organs, and hormones further in Chapter 18.

## Exocrine Glands

Exocrine glands produce *exocrine* (*exo-*, outside) *secretions*, which are discharged onto an epithelial surface. Most exocrine secretions reach the surface through tubular ducts, which empty onto the skin surface or onto an epithelium lining an internal passageway that communicates with the exterior. Examples of exocrine secretions delivered to epithelial surfaces by ducts are enzymes entering the digestive tract, perspiration on the skin, tears in the eyes, and milk produced by mammary glands.

Exocrine glands exhibit several different methods of secretion; therefore, they are classified by their mode and type of secretion, and by the structure of the gland cells and associated ducts.

**Modes of Secretion** A glandular epithelial cell releases its secretions by (1) merocrine secretion, (2) apocrine secretion, or (3) holocrine secretion.

In **merocrine secretion** (MER-u-krin; *meros*, part), the product is released from secretory vesicles by exocytosis (**Figure 4–6a**). This is the most common mode of secretion. *Mucin* is one type of merocrine secretion that mixes with water to form **mucus.** Mucus is an effective lubricant, a protective barrier, and a sticky trap for foreign particles and microorganisms. The mucous secretions of the salivary glands coat food and reduce friction during swallowing. In the skin, merocrine sweat glands produce the watery perspiration that helps cool you on a hot day.

**Apocrine secretion** (AP-ō-krin; *apo-*, off) involves the loss of cytoplasm as well as the secretory product (**Figure 4–6b**). The apical portion of the cytoplasm becomes packed with secretory vesicles and is then shed. Milk production in the mammary glands involves a combination of merocrine and apocrine secretions.

Merocrine and apocrine secretions leave a cell relatively intact and able to continue secreting. **Holocrine secretion** (HOL-ō-krin; *holos*, entire), by contrast, destroys the gland cell. During holocrine secretion, the entire cell becomes packed with secretory products and then bursts (**Figure 4–6c**), releasing the secretion, but killing the cell. Further secretion depends on the replacement of destroyed gland cells by the division of stem cells. Sebaceous glands, associated with hair follicles, produce an oily hair coating by means of holocrine secretion.

**Types of Secretions** Exocrine glands are also categorized by the types of secretion produced:

- *Serous glands* secrete a watery solution that contains enzymes. The parotid salivary glands are serous glands.
- *Mucous glands* secrete mucins that hydrate to form mucus. The sublingual salivary glands and the submucosal glands of the small intestine are mucous glands.
- *Mixed exocrine glands* contain more than one type of gland cell and may produce two different exocrine secretions, one serous and the other mucous. The submandibular salivary glands are mixed exocrine glands.

**Gland Structure** The final method of classifying exocrine glands is by structure. In epithelia that have independent, scattered gland cells, the individual secretory cells are called **unicellular glands. Multicellular glands** include glandular epithelia and aggregations of gland cells that produce exocrine or endocrine secretions.

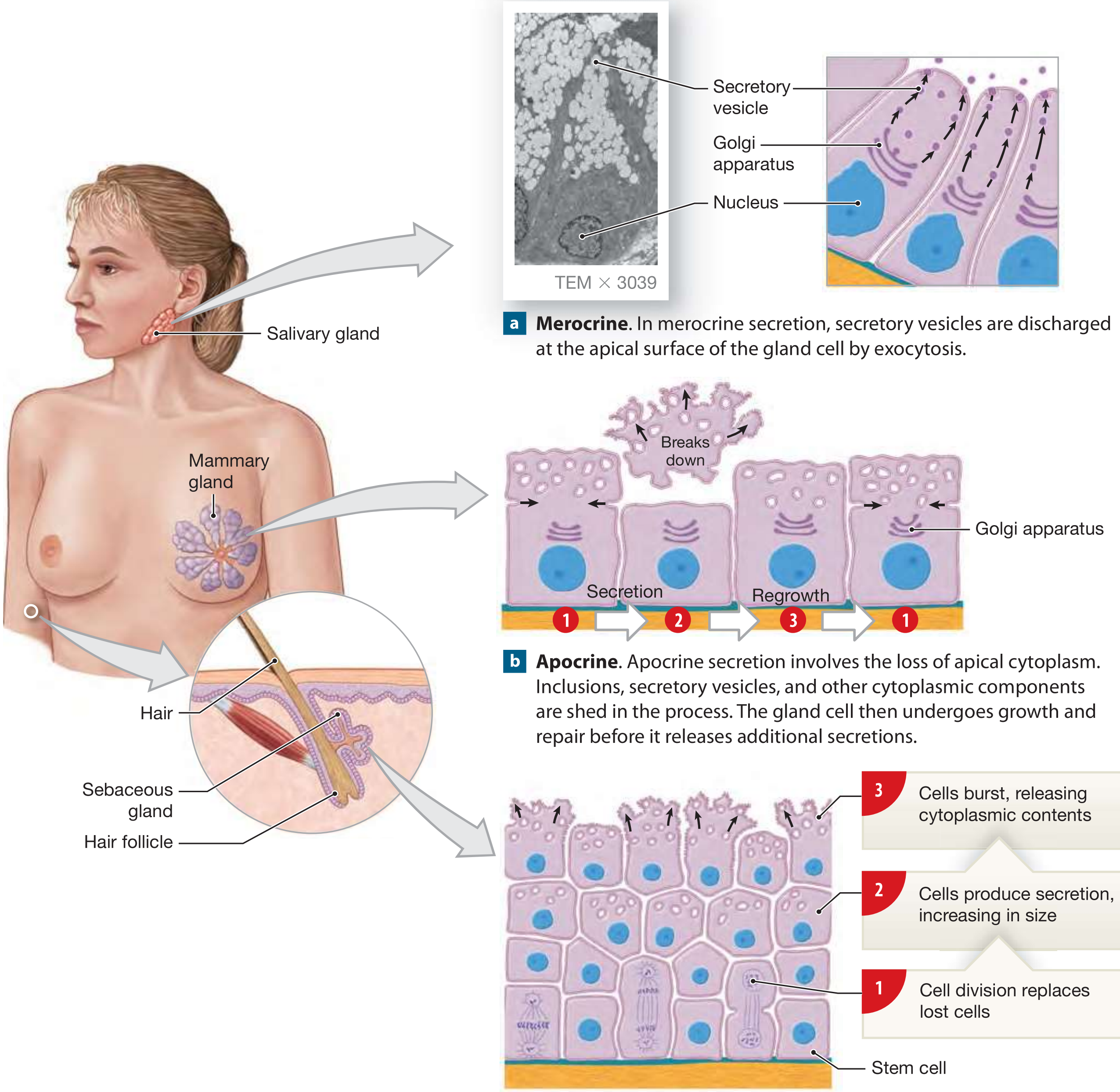
The only **unicellular exocrine glands** in the body are **mucous (goblet) cells,** which secrete mucins. Mucous cells are scattered among other epithelial cells. Both the pseudostratified ciliated columnar epithelium that lines the trachea and the columnar epithelium of the small and large intestines have an abundance of mucous cells.

The simplest **multicellular exocrine gland** is a *secretory sheet*, in which gland cells form an epithelium that releases secretions into an inner compartment. The continuous secretion of mucin-secreting cells that line the stomach, for instance, protects that organ from its own acids and enzymes. Most other multicellular exocrine glands are in pockets set back from the epithelial surface; their secretions travel through one or more ducts to the surface. Examples include the salivary glands, which produce mucins and digestive enzymes.

Three characteristics are used to describe the structure of multicellular exocrine glands (**Figure 4–7**):

1. *The Structure of the Duct.* A gland is *simple* if it has a single duct that does not divide on its way to the gland cells. The gland is *compound* if the duct divides one or more times on its way to the gland cells.
2. *The Shape of the Secretory Portion of the Gland.* Glands whose glandular cells form tubes are *tubular*; the tubes may be straight or coiled. Those that form blind pockets are *alveolar* (al-VĒ-ō-lar; *alveolus*, sac) or *acinar* (AS-i-nar;

**Figure 4–6 Modes of Glandular Secretion.**




**a Merocrine**. In merocrine secretion, secretory vesicles are discharged at the apical surface of the gland cell by exocytosis.

**b Apocrine**. Apocrine secretion involves the loss of apical cytoplasm. Inclusions, secretory vesicles, and other cytoplasmic components are shed in the process. The gland cell then undergoes growth and repair before it releases additional secretions.

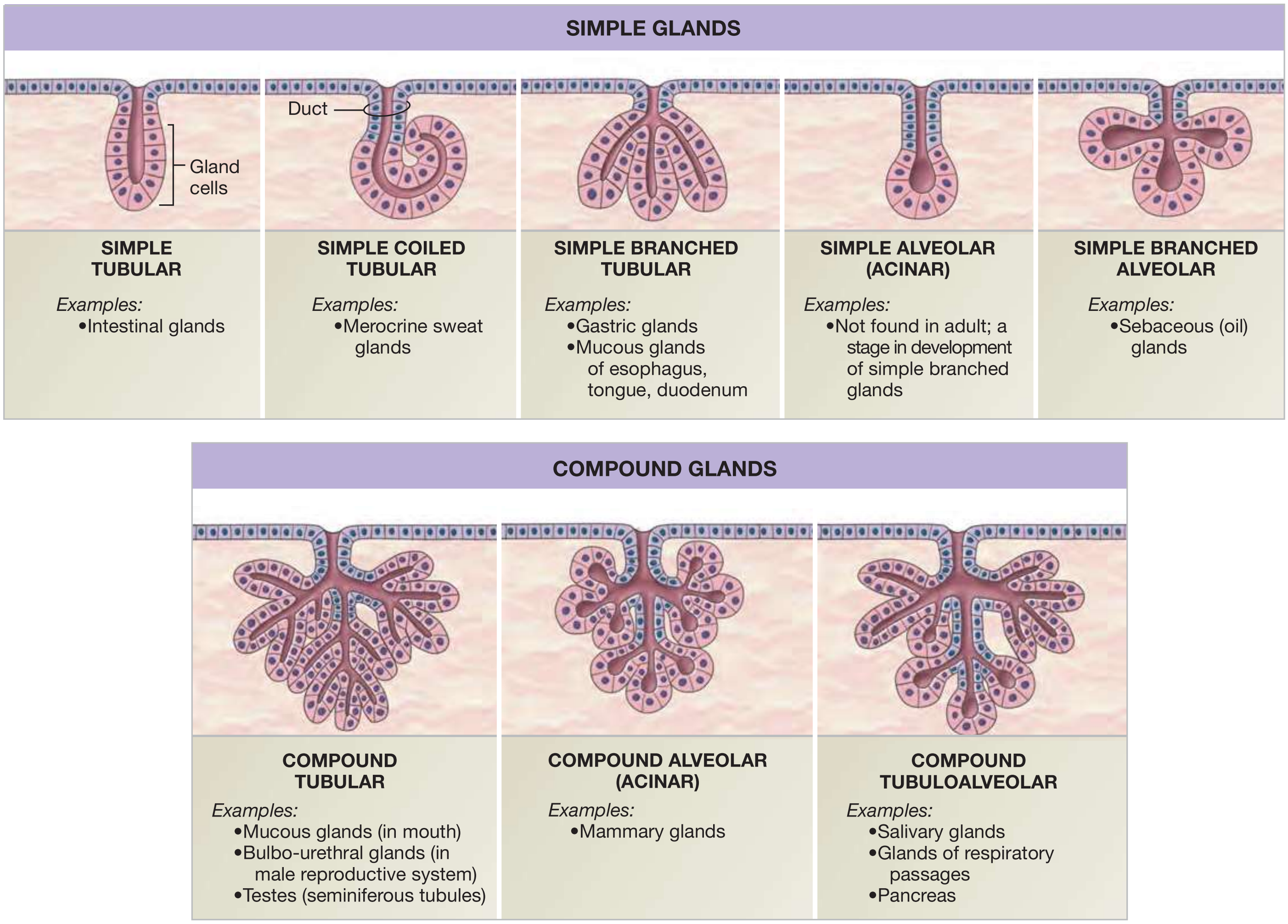
**c Holocrine**. Holocrine secretion occurs as superficial gland cells burst. Continued secretion involves the replacement of these cells through the mitotic division of underlying stem cells.

*acinus*, chamber). Glands whose secretory cells form both tubes and pockets are called *tubuloalveolar* and *tubuloacinar*.

3. *The Relationship between the Ducts and the Glandular Areas.* A gland is *branched* if several secretory areas (tubular or acinar) share a duct. ("Branched" refers to the glandular areas and not to the duct.)

The vast majority of glands in the body produce either exocrine or endocrine secretions. However, a few complex organs, including the digestive tract and the pancreas, produce both kinds of secretions. We will consider the organization of these glands in Chapters 18 and 24.

**Figure 4–7** A Structural Classification of Exocrine Glands.




## Checkpoint

8. Identify the three cell shapes characteristic of epithelial cells.
9. When classifying epithelial tissue, the number of layers of cells determines whether it is simple or stratified. A single layer of cells is termed ___________, whereas multiple layers of cells are known as ___________.
10. Using a light microscope, a tissue appears as a simple squamous epithelium. Can this be a sample of the skin surface? Why or why not?
11. Why do the pharynx, esophagus, anus, and vagina have a similar epithelial organization?
12. Name the two primary types of glandular epithelia.
13. The secretory cells of sebaceous glands fill with secretions and then rupture, releasing their contents. Which mode of secretion is this?
14. Which type of gland releases its secretions directly into the extracellular fluid?

See the blue Answers tab at the back of the book.

## 4-4 Connective tissue provides a protective structural framework for other tissue types

It is impossible to discuss epithelial tissue without mentioning an associated type of tissue: **connective tissue.** Recall that the dense layer of the basement membrane of all epithelial tissues is created by connective tissue; in essence, connective tissue connects the epithelium to the rest of the body. Other connective tissues include bone, fat, and blood, which provide structure, store energy reserves, and transport materials throughout the body, respectively. Connective tissues vary widely in appearance and function, but they all share three basic components: (1) specialized cells, (2) extracellular protein fibers, and (3) a fluid known as **ground substance.** The extracellular fibers and ground substance together constitute the **matrix,** which surrounds the cells. Whereas cells make up the bulk of epithelial tissue, the matrix typically accounts for most of the volume of connective tissues. ATLAS: Embryology Summary 3: The Origins of Connective Tissues

Connective tissues occur throughout the body, but are never exposed to the outside environment. Many connective tissues are highly vascular (that is, they have many blood vessels) and contain sensory receptors that detect pain, pressure, temperature, and other stimuli. Among the specific functions of connective tissues are the following:

- Establishing a structural framework for the body.
- Transporting fluids and dissolved materials.
- Protecting delicate organs.
- Supporting, surrounding, and interconnecting other types of tissue.
- Storing energy reserves, especially in the form of triglycerides.
- Defending the body from invading microorganisms.

## Classification of Connective Tissues

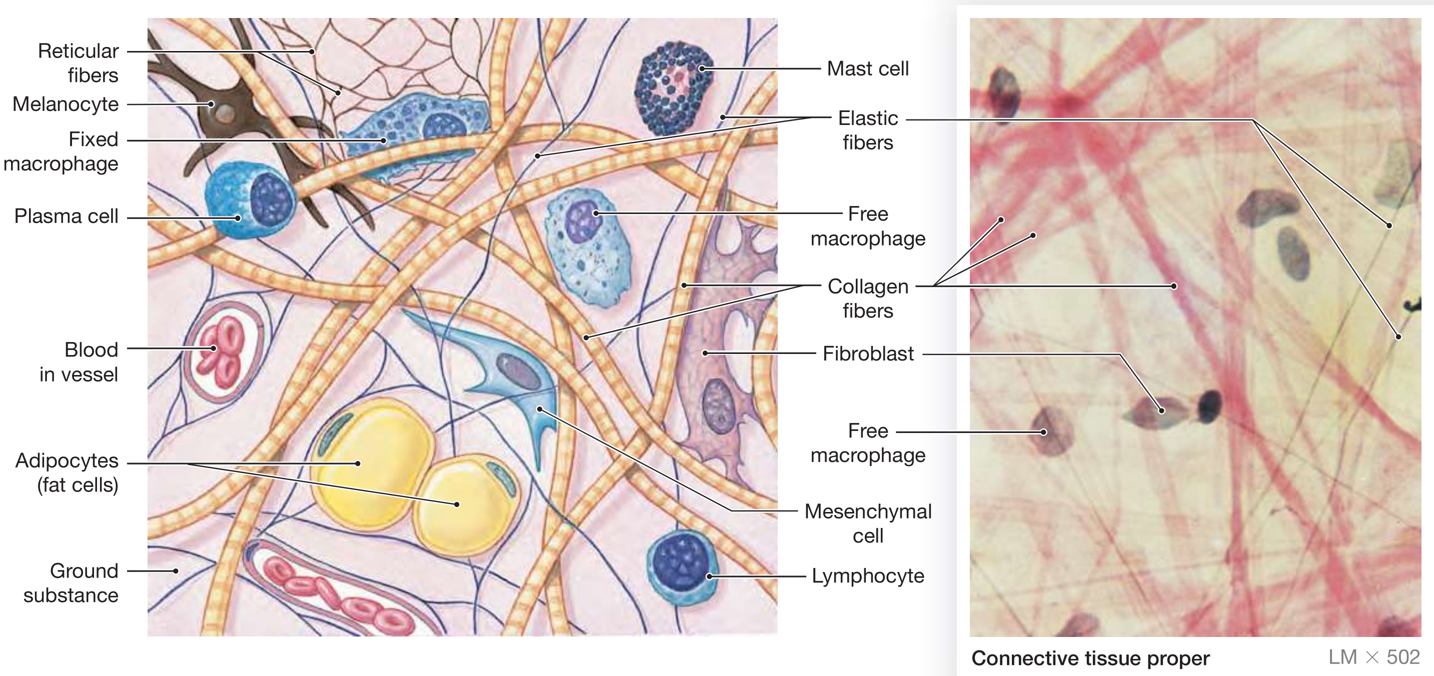
Connective tissues are classified on the basis of their physical properties. The three general categories of connective tissue are connective tissue proper, fluid connective tissues, and supporting connective tissues.

1. **Connective tissue proper** includes those connective tissues with many types of cells and extracellular fibers in a syrupy ground substance. This broad category contains a variety of connective tissues that are divided into (a) *loose connective tissues* and (b) *dense connective tissues* based on the number of cell types present, and on the relative properties and proportions of fibers and ground substance. Both *adipose tissue* or fat (a loose connective tissue) and *tendons* (a dense connective tissue) are connective tissue proper, but they have very different structural and functional characteristics.
2. **Fluid connective tissues** have distinctive populations of cells suspended in a watery matrix that contains dissolved proteins. Two types exist: *blood* and *lymph*.
3. **Supporting connective tissues** differ from connective tissue proper in having a less diverse cell population and a matrix containing much more densely packed fibers. Supporting connective tissues protect soft tissues and support the weight of part or all of the body. The two types of supporting connective tissues are *cartilage* and *bone*. The matrix of cartilage is a gel whose characteristics vary with the predominant type of fiber. The matrix of bone is **calcified,** because it contains mineral deposits (primarily calcium salts) that provide rigidity.

## Connective Tissue Proper

Connective tissue proper contains extracellular fibers, a viscous (syrupy) ground substance, and a varied cell population (**Figure 4–8**). Some cells, including *fibroblasts, fibrocytes,*

**Figure 4–8 The Cells and Fibers of Connective Tissue Proper.** Diagrammatic and histological views of the cell types and fibers of connective tissue proper. (Microphages, not shown, are common only in damaged or abnormal tissues.)



4

*adipocytes*, and *mesenchymal cells*, function in local maintenance, repair, and energy storage. These cells are permanent residents of the connective tissue. Other cells, including *macrophages*, *mast cells*, *lymphocytes*, *plasma cells*, and *microphages*, defend and repair damaged tissues. These cells are not permanent residents; they migrate through healthy connective tissues and aggregate at sites of tissue injury. The number of cells and cell types in a tissue at any moment varies with local conditions.

## Connective Tissue Proper Cell Populations

- **Fibroblasts** (FĪ-brō-blasts) are one of the two most abundant permanent residents of connective tissue proper, and the only cells that are *always* present in it. Fibroblasts secrete hyaluronan (a polysaccharide derivative) and proteins. (Recall that hyaluronan is one of the ingredients that helps lock epithelial cells together.) In connective tissue proper, extracellular fluid, hyaluronan, and proteins interact to form the proteoglycans that make ground substance viscous. Each fibroblast also secretes protein subunits that assemble to form large extracellular fibers. ⮌ p. 51
- **Fibrocytes** (FĪ-brō-sīts) are the second most abundant fixed cell in connective tissue proper and differentiate from fibroblasts. These spindle-shaped cells maintain the connective tissue fibers of connective tissue proper.
- **Adipocytes** (AD-i-pō-sīts) are also known as fat cells. A typical adipocyte contains a single, enormous lipid droplet. The nucleus, other organelles, and cytoplasm are squeezed to one side, making a sectional view of the cell resemble a class ring. The number of adipocytes varies from one type of connective tissue to another, from one region of the body to another, and among individuals.
- **Mesenchymal cells** are stem cells that are present in many connective tissues. These cells respond to local injury or infection by dividing to produce daughter cells that differentiate into fibroblasts, macrophages, or other connective tissue cells.
- **Macrophages** (MAK-rō-fā-jez; *phagein*, to eat) are large amoeboid cells scattered throughout the matrix. These scavengers engulf damaged cells or pathogens that enter the tissue. (The name literally means "big eater.") Although not abundant, macrophages are important in mobilizing the body's defenses. When stimulated, they release chemicals that activate the immune system and attract large numbers of additional macrophages and other cells involved in tissue defense. The two classes of macrophage are *fixed macrophages*, which spend long periods in a tissue, and *free macrophages*, which migrate rapidly through tissues. In effect, fixed macrophages provide a "frontline" defense that can be reinforced by the arrival of free macrophages and other specialized cells.
- **Mast cells** are small, mobile connective tissue cells that are common near blood vessels. The cytoplasm of a mast cell is filled with granules containing **histamine** (HIS-tuh-mēn) and **heparin** (HEP-uh-rin). Histamine, released after injury or infection, stimulates local inflammation. (You are likely familiar with the inflammatory effects of histamine; people often take antihistamines to reduce cold symptoms.) *Basophils*, blood cells that enter damaged tissues and enhance the inflammation process, also contain granules of histamine and heparin.
- **Lymphocytes** (LIM-fō-sīts) migrate throughout the body, traveling through connective tissues and other tissues. Their numbers increase markedly wherever tissue damage occurs. Some lymphocytes may develop into **plasma cells,** which produce *antibodies*—proteins involved in defending the body against disease.
- **Microphages** (*neutrophils* and *eosinophils*) are phagocytic blood cells that normally move through connective tissues in small numbers. When an infection or injury occurs, chemicals released by macrophages and mast cells attract numerous microphages to the site.
- **Melanocytes** (me-LAN-ō-sīts) synthesize and store the brown pigment **melanin** (MEL-a-nin), which gives tissues a dark color. Melanocytes are common in the epithelium of the skin, where they play a major role in determining skin color. Melanocytes are also abundant in connective tissues of the eye and the dermis of the skin, although the number present differs by body region and among individuals.

**Connective Tissue Fibers** Three types of fibers occur in connective tissue: *collagen*, *reticular*, and *elastic*. Fibroblasts form all three by secreting protein subunits that interact in the matrix. Fibrocytes are responsible for maintaining these connective tissue fibers.

1. **Collagen fibers** are long, straight, and unbranched. They are the most common fibers in connective tissue proper. Each collagen fiber consists of a bundle of fibrous protein subunits wound together like the strands of a rope. Like a rope, a collagen fiber is flexible, but it is stronger than steel when pulled from either end. *Tendons*, which connect skeletal muscles to bones, consist almost entirely of collagen fibers. Typical *ligaments* are similar to tendons, but they connect one bone to another. Tendons and ligaments can withstand tremendous forces. Uncontrolled muscle contractions or skeletal movements are more likely to break a bone than to snap a tendon or a ligament.
2. **Reticular fibers** (*reticulum*, network) contain the same protein subunits as do collagen fibers, but arranged differently. Thinner than collagen fibers, reticular fibers form a branching, interwoven framework that is tough, yet flexible. Because they form a network rather than share a com-

mon alignment, reticular fibers resist forces applied from many directions. This interwoven network, called a *stroma*, stabilizes the relative positions of the functional cells, or **parenchyma** (pa-RENG-ki-ma), of organs such as the liver. Reticular fibers also stabilize the positions of an organ's blood vessels, nerves, and other structures, despite changing positions and the pull of gravity.

3. **Elastic fibers** contain the protein *elastin*. Elastic fibers are branched and wavy. After stretching, they will return to their original length. **Elastic ligaments,** which are dominated by elastic fibers, are rare but have important functions, such as interconnecting vertebrae.

**Ground Substance** Ground substance fills the spaces between cells and surrounds connective tissue fibers (**Figure 4–8**). In connective tissue proper, ground substance is clear, colorless, and viscous (due to the presence of proteoglycans and glycoproteins). ⮌ p. 54 Ground substance is dense enough that bacteria have trouble moving through it—imagine swimming in molasses. This density slows the spread of pathogens and makes them easier for phagocytes to catch.

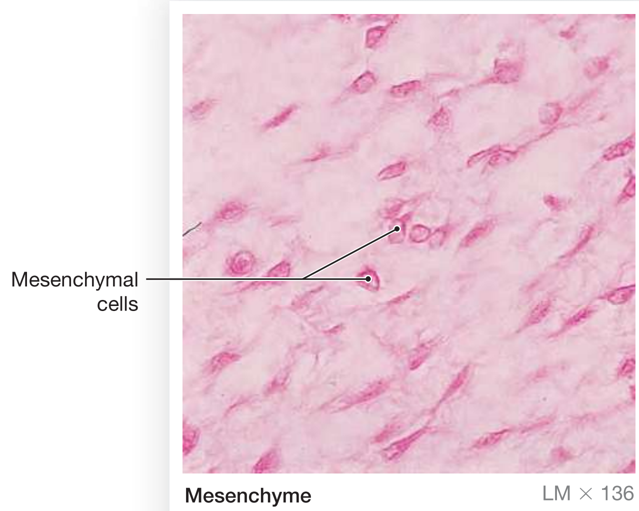
## Embryonic Connective Tissues

**Mesenchyme,** or *embryonic connective tissue*, is the first connective tissue to appear in a developing embryo. Mesenchyme contains an abundance of star-shaped stem cells (mesenchymal cells) separated by a matrix with very fine protein filaments (**Figure 4–9a**). Mesenchyme gives rise to all other connective tissues. **Mucous connective tissue** (**Figure 4–9b**), or *Wharton's jelly*, is a loose connective tissue found in many parts of the embryo, including the umbilical cord.

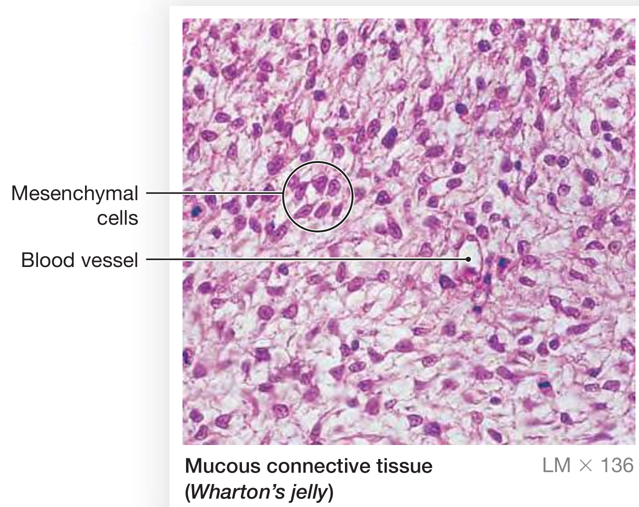
### Clinical Note

**Marfan's Syndrome** *Marfan's syndrome* is an inherited condition caused by the production of an abnormally weak form of *fibrillin*, a glycoprotein that imparts strength and elasticity to connective tissues. Because most organs contain connective tissues, the effects of this defect are widespread. The most visible sign of Marfan's syndrome involves the skeleton; most individuals with the condition are tall and have abnormally long limbs and fingers. The most serious consequences involve the cardiovascular system; about 90 percent of people with Marfan's syndrome have structural abnormalities in their cardiovascular system. The most dangerous possibility is that the weakened elastic connective tissues in the walls of major arteries, such as the aorta, may burst, causing a sudden, fatal loss of blood.

**Figure 4–9 Connective Tissues in Embryos.**




**a** This is the first connective tissue to appear in an embryo.




**b** This sample was taken from the umbilical cord of a fetus.

Adults have neither form of embryonic connective tissue. However, many adult connective tissues contain scattered mesenchymal stem cells that can assist in tissue repair after an injury.

## Loose Connective Tissues

**Loose connective tissues** are the "packing materials" of the body. They fill spaces between organs, cushion and stabilize specialized cells in many organs, and support epithelia. These tissues surround and support blood vessels and nerves, store lipids, and provide a route for the diffusion of materials. Loose connective tissues include mucous connective tissue in embryos and *areolar tissue*, *adipose tissue*, and *reticular tissue* in adults.

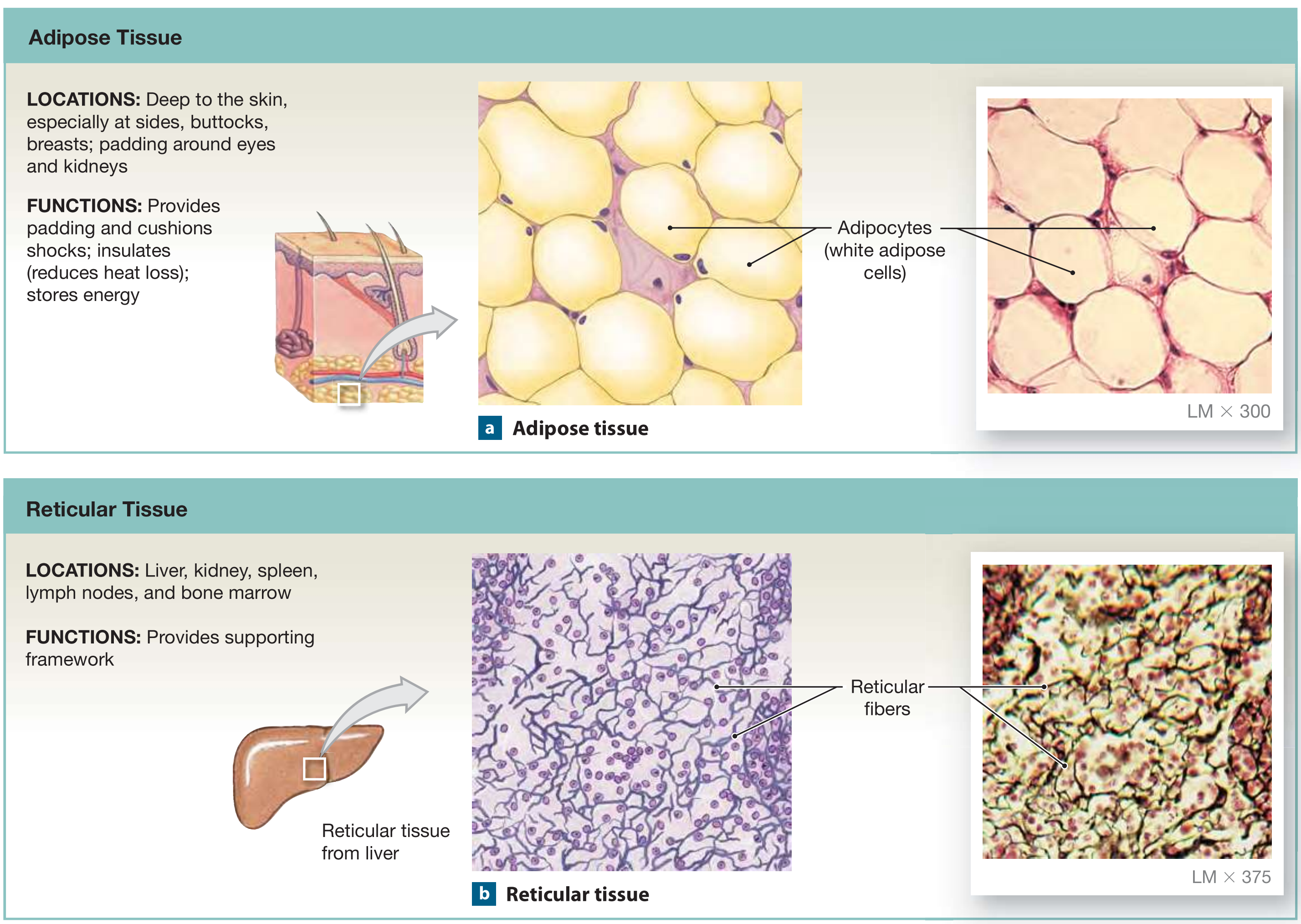
**Areolar Tissue** **Areolar tissue** (*areola*, little space) is the least specialized connective tissue in adults. It may contain all the cells and fibers of any connective tissue proper in a very loosely organized array (**Figure 4–8**). Areolar tissue has an open framework. A viscous ground substance accounts for most of its volume and absorbs shocks. Because its fibers are loosely organized, areolar tissue can distort without damage. The presence of elastic fibers makes it resilient, so areolar tissue returns to its original shape after external pressure is relieved.

Areolar tissue forms a layer that separates the skin from deeper structures. In addition to providing padding, the elastic properties of this layer allow a considerable amount of independent movement. Thus, if you pinch the skin of your arm, you will not affect the underlying muscle. Conversely, contractions of the underlying muscle do not pull against your skin; as the muscle bulges, the areolar tissue stretches. Because this tissue has an extensive blood supply, the areolar tissue layer under the skin is a common injection site for drugs.

The capillaries (thin-walled blood vessels) in areolar tissue deliver oxygen and nutrients and remove carbon dioxide and waste products. They also carry wandering cells to and from the tissue. Epithelia commonly cover areolar tissue; fibrocytes maintain the dense layer of the basement membrane that separates the two kinds of tissue. The epithelial cells rely on the diffusion of oxygen and nutrients across the basement membrane from capillaries in the underlying connective tissue.

**Adipose Tissue** The distinction between areolar tissue and fat, or **adipose tissue,** is somewhat arbitrary. Adipocytes account for most of the volume of adipose tissue (**Figure 4–10a**), but only a fraction of the volume of areolar tissue. Adipose tissue provides padding, absorbs shocks, acts as an insulator to slow heat loss through the skin, and serves as packing or filler around structures. Adipose tissue is common under the skin of the flanks (between the last rib and the hips), buttocks, and breasts.

**Figure 4–10** **Adipose and Reticular Tissues.**



It fills the bony sockets behind the eyes, surrounds the kidneys, and is common beneath the mesothelial lining of the pericardial and abdominal cavities.

Most of the adipose tissue in the body is called **white fat,** because it has a pale, yellow-white color. In infants and young children, however, the adipose tissue between the shoulder blades, around the neck, and possibly elsewhere in the upper body is highly vascularized, and the individual adipocytes contain numerous mitochondria. Together, these characteristics give the tissue a deep, rich color from which the name **brown fat** is derived. When these cells are stimulated by the nervous system, lipid breakdown accelerates. The cells do not capture the energy that is released. Instead, the surrounding tissues absorb it as heat. The heat warms the circulating blood, which distributes the heat throughout the body. In this way, an infant can increase metabolic heat generation by 100 percent very quickly. (In adults, who have little if any brown fat, shivering elevates body temperature.)

Adipocytes are metabolically active cells; their lipids are constantly being broken down and replaced. When nutrients are scarce, adipocytes deflate like collapsing balloons as their lipids are broken down and the fatty acids released to support metabolism. Because the cells are not killed but merely reduced in size, the lost weight can easily be regained in the same areas of the body. In adults, adipocytes are incapable of dividing. The number of fat cells in peripheral tissues is established in the first few weeks of a newborn's life, perhaps in response to the amount of fats in the diet. However, that is not the end of the story, because loose connective tissues also contain mesenchymal cells. If circulating lipid levels are chronically elevated, the mesenchymal cells will divide, giving rise to cells that differentiate into fat cells. As a result, areas of areolar tissue can become adipose tissue in times of nutritional plenty, even in adults.

In the procedure known as **liposuction,** unwanted adipose tissue is surgically removed. Because adipose tissue can regenerate through the differentiation of mesenchymal cells, liposuction provides only a temporary and potentially risky solution to the problem of excess weight.

**Reticular Tissue** As mentioned earlier, organs such as the spleen and liver contain **reticular tissue,** in which reticular fibers create a complex three-dimensional stroma (**Figure 4–10b**). The stroma supports the parenchyma (functional cells) of these organs. This fibrous framework is also found in the lymph nodes and bone marrow. Fixed macrophages, fibroblasts, and fibrocytes are associated with the reticular fibers, but these cells are seldom visible, because specialized cells with other functions dominate the organs.

## Dense Connective Tissues

Most of the volume of **dense connective tissues** is occupied by fibers. Dense connective tissues are often called **collagenous** (ko-LAJ-e-nus) **tissues,** because collagen fibers are the dominant type of fiber in them. The body has two types of dense connective tissues: dense regular connective tissue and dense irregular connective tissue.

In **dense regular connective tissue,** the collagen fibers are parallel to each other, packed tightly, and aligned with the forces applied to the tissue. **Tendons** are cords of dense regular connective tissue that attach skeletal muscles to bones (**Figure 4–11a**). The collagen fibers run along the longitudinal axis of the tendon and transfer the pull of the contracting muscle to the bone. **Ligaments** resemble tendons, but connect one bone to another or stabilize the positions of internal organs. An **aponeurosis** (AP-ō-noo-RŌ-sis; plural, *aponeuroses*) is a tendinous sheet that attaches a broad, flat muscle to another muscle or to several bones of the skeleton. It can also stabilize the positions of tendons and ligaments. Aponeuroses are associated with large muscles of the skull, lower back, and abdomen, and with the tendons and ligaments of the palms of the hands and the soles of the feet. Large numbers of fibroblasts are scattered among the collagen fibers of tendons, ligaments, and aponeuroses.

In contrast, the fibers in **dense irregular connective tissue** form an interwoven meshwork in no consistent pattern (**Figure 4–11b**). These tissues strengthen and support areas subjected to stresses from many directions. A layer of dense irregular connective tissue gives skin its strength. Cured leather (animal skin) is an excellent example of the interwoven nature of this tissue. Except at joints, dense irregular connective tissue forms a sheath around cartilages (the *perichondrium*) and bones (the *periosteum*). Dense irregular connective tissue also forms a thick fibrous layer called a **capsule,** which surrounds internal organs such as the liver, kidneys, and spleen and encloses the cavities of joints.

Dense regular and dense irregular connective tissues contain variable amounts of elastic fibers. When elastic fibers outnumber collagen fibers, the tissue has a springy, resilient nature that allows it to tolerate cycles of extension and recoil. Abundant elastic fibers are present in the connective tissue that supports transitional epithelia, in the walls of large blood vessels such as the aorta, and around the respiratory passageways.

**Elastic tissue** is a dense regular connective tissue dominated by elastic fibers. Elastic ligaments, which are almost completely dominated by elastic fibers, help stabilize the positions of the vertebrae of the spinal column (**Figure 4–11c**).

## Fluid Connective Tissues

*Blood* and *lymph* are connective tissues with distinctive collections of cells. The fluid matrix that surrounds the cells also includes many types of suspended proteins that do not form insoluble fibers under normal conditions.

In **blood,** the watery matrix is called **plasma.** Plasma contains blood cells and fragments of cells, collectively known as *formed elements*. There are three types of formed elements: red blood cells, white blood cells, and platelets (**Figure 4–12**).

Recall from Chapter 3 that the human body contains a large volume of extracellular fluid. This fluid includes three major subdivisions: *plasma*, *interstitial fluid*, and *lymph*. Plasma is normally confined to the vessels of the cardiovascular system, and contractions of the heart keep it in motion. **Arteries** carry blood away from the heart and into the tissues of the body. In

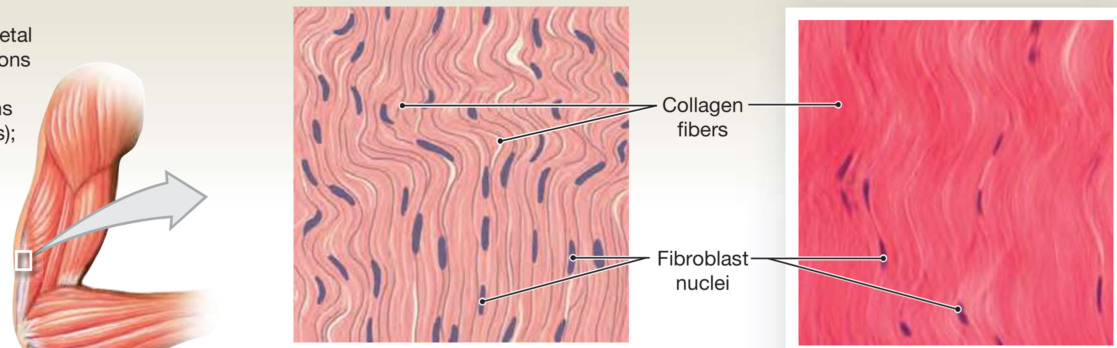


**Figure 4–11** **Dense Connective Tissues.**

### Dense Regular Connective Tissue

**LOCATIONS:** Between skeletal muscles and skeleton (tendons and aponeuroses); between bones or stabilizing positions of internal organs (ligaments); covering skeletal muscles; deep fasciae

**FUNCTIONS:** Provides firm attachment; conducts pull of muscles; reduces friction between muscles; stabilizes relative positions of bones

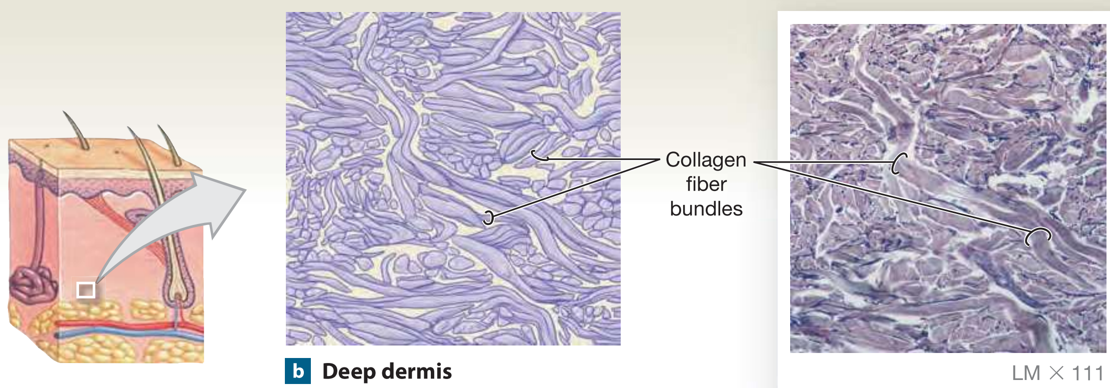



**a** **Tendon**

### Dense Irregular Connective Tissue

**LOCATIONS:** Capsules of visceral organs; periostea and perichondria; nerve and muscle sheaths; dermis

**FUNCTIONS:** Provides strength to resist forces applied from many directions; helps prevent overexpansion of organs such as the urinary bladder

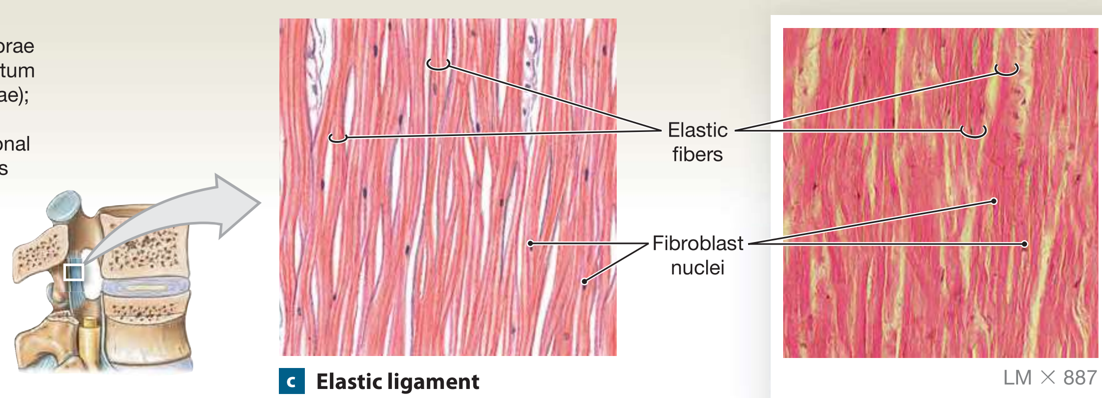



**b** **Deep dermis**

### Elastic Tissue

**LOCATIONS:** Between vertebrae of the spinal column (ligamentum flavum and ligamentum nuchae); ligaments supporting penis; ligaments supporting transitional epithelia; in blood vessel walls

**FUNCTIONS:** Stabilizes positions of vertebrae and penis; cushions shocks; permits expansion and contraction of organs

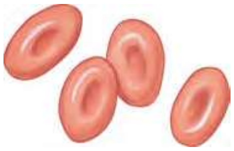



**c** **Elastic ligament**

**Figure 4–12** Formed Elements of the Blood.

**Red blood cells**

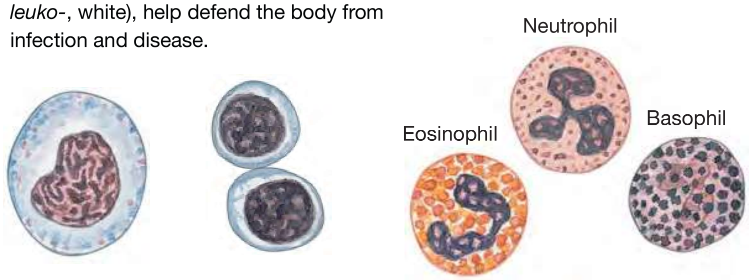
**Red blood cells,** or erythrocytes (e-RITH-rō-sīts), are responsible for the transport of oxygen (and, to a lesser degree, of carbon dioxide) in the blood.



Red blood cells account for roughly half the volume of whole blood and give blood its color.

**White blood cells**

**White blood cells**, or leukocytes (LOO-kō-sīts; *leuko-*, white), help defend the body from infection and disease.




**Monocytes** are phagocytes similar to the free macrophages in other tissues.

**Lymphocytes** are uncommon in the blood but they are the dominant cell type in lymph, the second type of fluid connective tissue.

**Eosinophils** and **neutrophils** are phagocytes. **Basophils** promote inflammation much like mast cells in other connective tissues.

**Platelets**

**Platelets** are membrane-enclosed packets of cytoplasm that function in blood clotting.

These cell fragments are involved in the clotting response that seals leaks in damaged or broken blood vessels.

those tissues, blood pressure forces water and small solutes out of the bloodstream across the walls of **capillaries,** the smallest blood vessels. This is the origin of the interstitial fluid that bathes the body's cells. The remaining blood flows from the capillaries into **veins** that return it to the heart.

**Lymph** forms as interstitial fluid enters **lymphatic vessels.** As fluid passes along the lymphatic vessels, cells of the immune system monitor the composition of the lymph and respond to signs of injury or infection. The lymphatic vessels ultimately return the lymph to large veins near the heart. This recirculation of fluid—from the cardiovascular system, through the interstitial fluid, to the lymph, and then back to the cardiovascular system—is a continuous process that is essential to homeostasis. It helps eliminate local differences in the levels of nutrients, wastes, or toxins; maintains blood volume; and alerts the immune system to infections that may be under way in peripheral tissues.

### Checkpoint

15. **Identify several functions of connective tissues.**
16. **List the three categories of connective tissues.**
17. **Identify the populations of cells found in connective tissue proper.**
18. **Lack of vitamin C in the diet interferes with the ability of fibroblasts to produce collagen. What effect might this interference have on connective tissue?**
19. **Many allergy sufferers take antihistamines to relieve their allergy symptoms. Which cells produce the molecule that this medication blocks?**
20. **Which type of connective tissue contains primarily triglycerides?**
21. **Which two types of connective tissue have a fluid matrix?**

See the blue Answers tab at the back of the book.

## 4-5 Cartilage and bone provide a strong supporting framework

*Cartilage* and *bone* are called supporting connective tissues because they provide a strong framework that supports the rest of the body. In these connective tissues, the matrix contains numerous fibers and, in bone, deposits of insoluble calcium salts.

### Cartilage

The matrix of **cartilage** is a firm gel that contains polysaccharide derivatives called **chondroitin sulfates** (kon-DROY-tin; *chondros*, cartilage). Chondroitin sulfates form complexes with proteins in the ground substance, producing proteoglycans. Cartilage cells, or **chondrocytes** (KON-drō-sīts), are the only cells in the cartilage matrix. They occupy small chambers known as **lacunae** (la-KOO-nē; *lacus*, lake). The physical properties of cartilage depend on the proteoglycans of the matrix, and on the type and abundance of extracellular fibers.

Unlike other connective tissues, cartilage is avascular, so all exchange of nutrients and waste products must occur by diffusion through the matrix. Blood vessels do not grow into cartilage because chondrocytes produce a chemical that discourages their formation. This chemical, named **antiangiogenesis factor** (*anti-*, against + *angeion*, vessel + *genno*, to produce), is now being tested as a potential anticancer agent.

Cartilage is generally set apart from surrounding tissues by a fibrous **perichondrium** (per-i-KON-drē-um; *peri-*, around). The perichondrium contains two distinct layers: an outer, fibrous region of dense irregular connective tissue, and an inner, cellular layer. The fibrous layer provides mechanical support and protection and attaches the cartilage to other structures.

The cellular layer is important to the growth and maintenance of the cartilage.

### Cartilage Growth

Cartilage grows by two mechanisms: *interstitial growth* and *appositional growth* (**Figure 4–13**).

In **interstitial growth,** chondrocytes in the cartilage matrix undergo cell division, and the daughter cells produce additional matrix (**Figure 4–13a**). This process enlarges the cartilage from within. Interstitial growth is most important during development. The process begins early in embryonic development and continues through adolescence.

In **appositional growth,** new layers of cartilage are added to the surface (**Figure 4–13b**). In this process, cells of the inner layer of the perichondrium undergo repeated cycles of division. The innermost cells then differentiate into immature chondrocytes, which begin producing cartilage matrix. As they become surrounded by and embedded in new matrix, they differentiate into mature chondrocytes. Appositional growth gradually increases the size of the cartilage by adding to its outer surface.

Both interstitial and appositional growth occur during development, although interstitial growth contributes more to the mass of the adult cartilage. Neither interstitial nor appositional growth occurs in the cartilages of normal adults. However, appositional growth may occur in unusual circumstances, such as after cartilage has been damaged or excessively stimulated by *growth hormone* from the pituitary gland. Minor damage to cartilage can be repaired by appositional growth at the damaged surface. After more severe damage, a dense fibrous patch will replace the injured portion of the cartilage.

### Types of Cartilage

The body contains three major types of cartilage: hyaline cartilage, elastic cartilage, and fibrocartilage.

1. **Hyaline cartilage** (HĪ-uh-lin; *hyalos*, glass) is the most common type of cartilage. Except inside joint cavities, a dense perichondrium surrounds hyaline cartilages. The matrix of hyaline cartilage contains closely packed collagen fibers, making it tough but somewhat flexible. Because the fibers are not in large bundles and do not stain darkly, they are not always apparent in light microscopy (**Figure 4–14a**). Examples in adults include the connections between the ribs and the sternum; the nasal cartilages and the supporting cartilages along the conducting passageways of the respiratory tract; and the *articular cartilages*, which cover opposing bone surfaces within many joints, such as the elbow and knee.
2. **Elastic cartilage** (**Figure 4–14b**) contains numerous elastic fibers that make it extremely resilient and flexible. These cartilages usually have a yellowish color on gross dissection. Elastic cartilage forms the external flap (the *auricle*, or

**Figure 4–13 The Growth of Cartilage.**

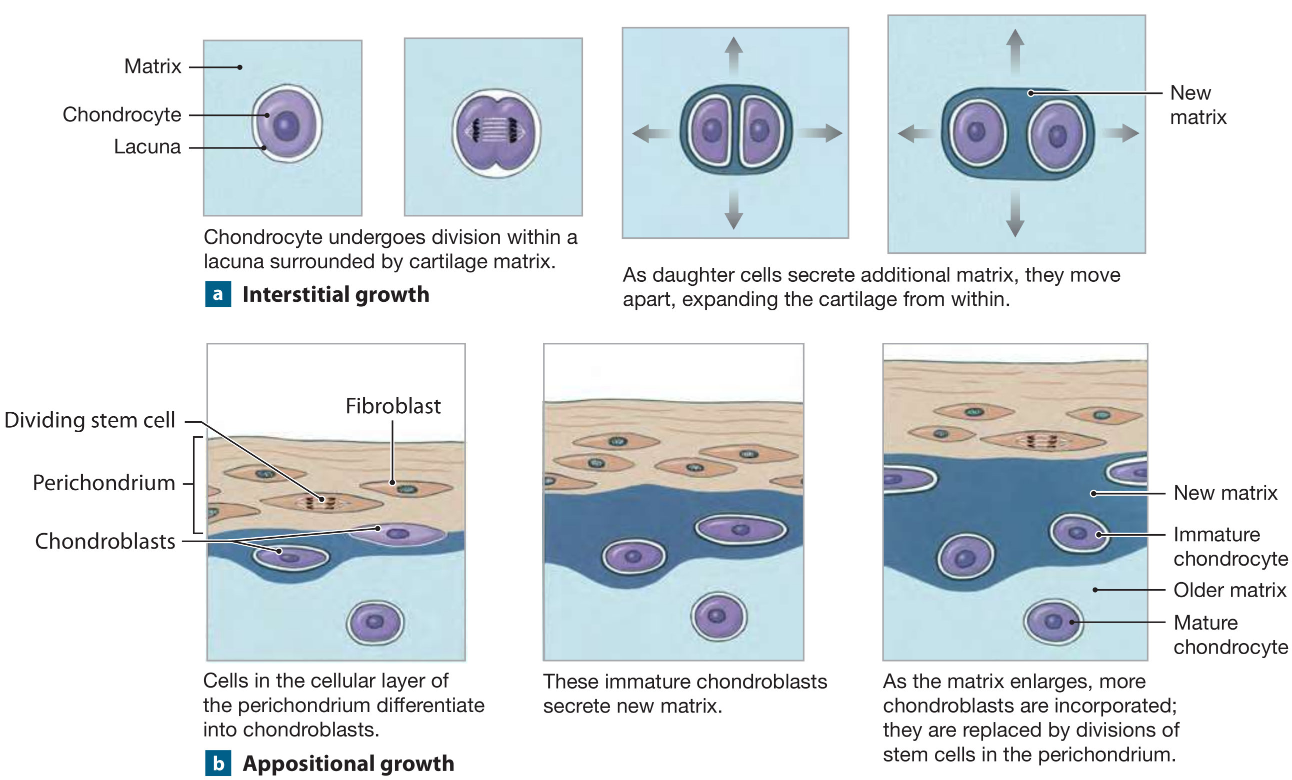
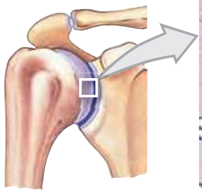


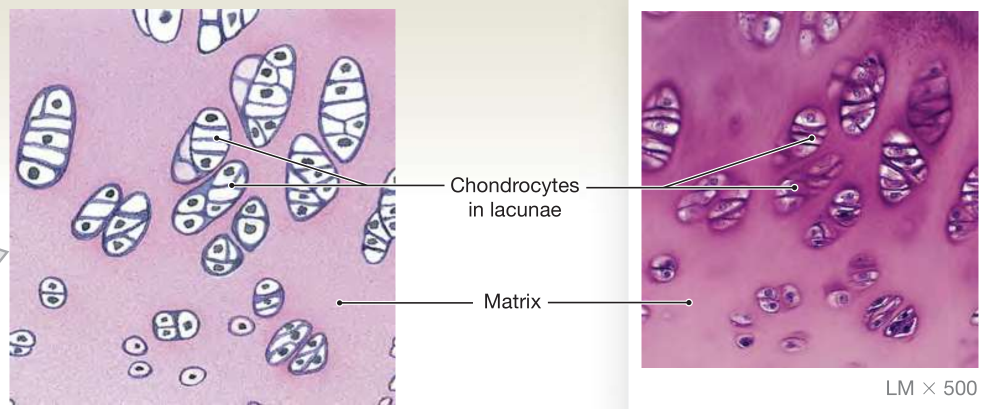
**Figure 4–14** Types of Cartilage.

## Hyaline Cartilage

**LOCATIONS:** Between tips of ribs and bones of sternum; covering bone surfaces at synovial joints; supporting larynx (voice box), trachea, and bronchi; forming part of nasal septum

**FUNCTIONS:** Provides stiff but somewhat flexible support; reduces friction between bony surfaces



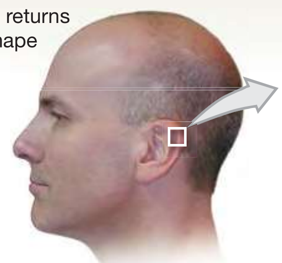


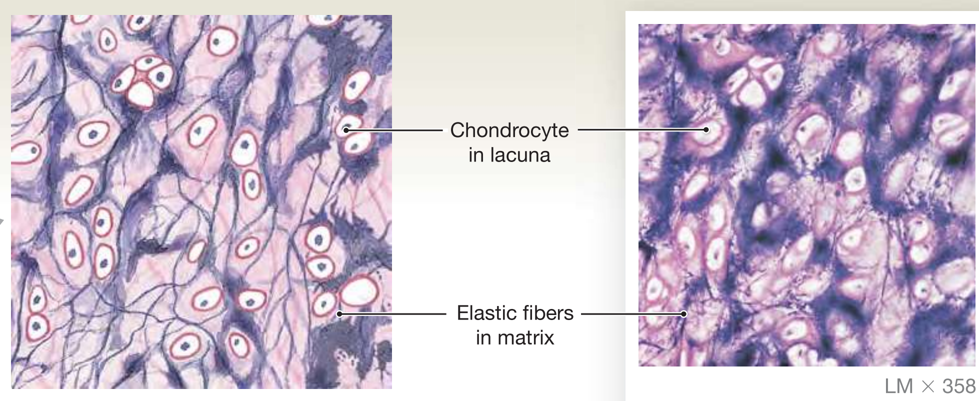

**a** **Hyaline cartilage**

## Elastic Cartilage

**LOCATIONS:** Auricle of external ear; epiglottis; auditory canal; cuneiform cartilages of larynx

**FUNCTIONS:** Provides support, but tolerates distortion without damage and returns to original shape



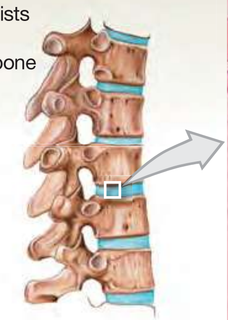


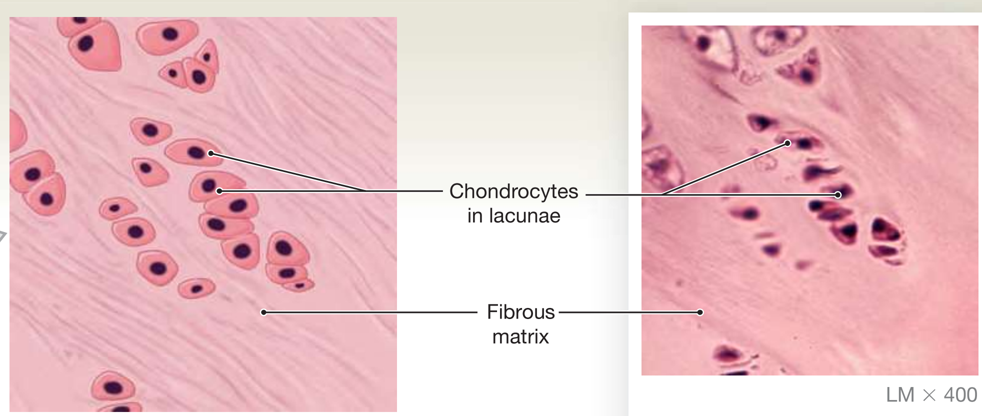

**b** **Elastic cartilage**

## Fibrocartilage

**LOCATIONS:** Pads within knee joint; between pubic bones of pelvis; intervertebral discs

**FUNCTIONS:** Resists compression; prevents bone-to-bone contact; limits movement






**c** **Fibrocartilage**

4

*pinna*) of the outer ear; the epiglottis; a passageway to the middle ear cavity (the *auditory tube*); and small cartilages in the larynx (the *cuneiform cartilages*).

3. **Fibrocartilage** has little ground substance, and its matrix is dominated by densely interwoven collagen fibers (**Figure 4–14c**), making this tissue extremely durable and tough. Pads of fibrocartilage lie between the spinal vertebrae, between the pubic bones of the pelvis, and around tendons and within or around joints. In these positions, fibrocartilage resists compression, absorbs shocks, and prevents damaging bone-to-bone contact. Cartilage heals poorly, and damaged fibrocartilage in joints such as the knee can interfere with normal movements.

Several complex joints, including the knee, contain both hyaline cartilage and fibrocartilage. The hyaline cartilage covers bony surfaces, and fibrocartilage pads in the joint prevent contact between bones during movement. Injuries to these pads do not heal, and after repeated or severe damage, joint mobility is severely reduced. Surgery generally produces only a temporary or incomplete repair.

## Bone

Because we will examine the detailed histology of **bone,** or **osseous** (OS-ē-us; *os*, bone) **tissue,** in Chapter 6, here we focus only on significant differences between cartilage and bone. The volume of ground substance in bone is very small. About two-thirds of the matrix of bone consists of a mixture of calcium salts—primarily calcium phosphate, with lesser amounts of calcium carbonate. The rest of the matrix is dominated by collagen fibers. This combination gives bone truly remarkable properties. By themselves, calcium salts are hard but rather brittle, whereas collagen fibers are stronger but relatively flexible. In bone, the presence of the minerals surrounding the collagen fibers produces a strong, somewhat flexible combination that is highly resistant to shattering. In its overall properties, bone can compete with the best steel-reinforced concrete. In essence, the collagen fibers in bone act like the steel reinforcing rods, and the mineralized matrix acts like the concrete.

**Figure 4–15** shows the general organization of osseous tissue. Lacunae in the matrix contain **osteocytes** (OS-tē-ō-sīts), or bone cells. The lacunae are typically organized around blood vessels that branch through the bony matrix. Although diffusion cannot occur through the hard matrix, osteocytes communicate with the blood vessels and with one another by means of slender cytoplasmic extensions. These extensions run through long, slender passageways in the matrix called **canaliculi** (kan-a-LIK-ū-lē; little canals). These passageways form a branching network for the exchange of materials between blood vessels and osteocytes.

Except in joint cavities, where a layer of hyaline cartilage covers bone, the surfaces are sheathed by a **periosteum** (per-ē-OS-tē-um), a layer composed of fibrous (outer) and cellular (inner) layers. The periosteum assists in the attachment of a bone to surrounding tissues and to associated tendons and ligaments. The cellular layer functions in appositional bone growth and helps in repairs after an injury. Unlike cartilage, bone undergoes extensive remodeling throughout life, and complete repairs can be made even after severe damage has occurred. Bones also respond to the stresses placed on them, growing thicker and stronger with exercise and becoming thin and brittle with inactivity.

**Table 4–2** summarizes the similarities and differences between cartilage and bone.

**Figure 4–15 Bone.** The osteocytes in bone are generally organized in groups around a central space that contains blood vessels. Bone dust produced during preparation of the section fills the lacunae and the central canal, making them appear dark in the micrograph.

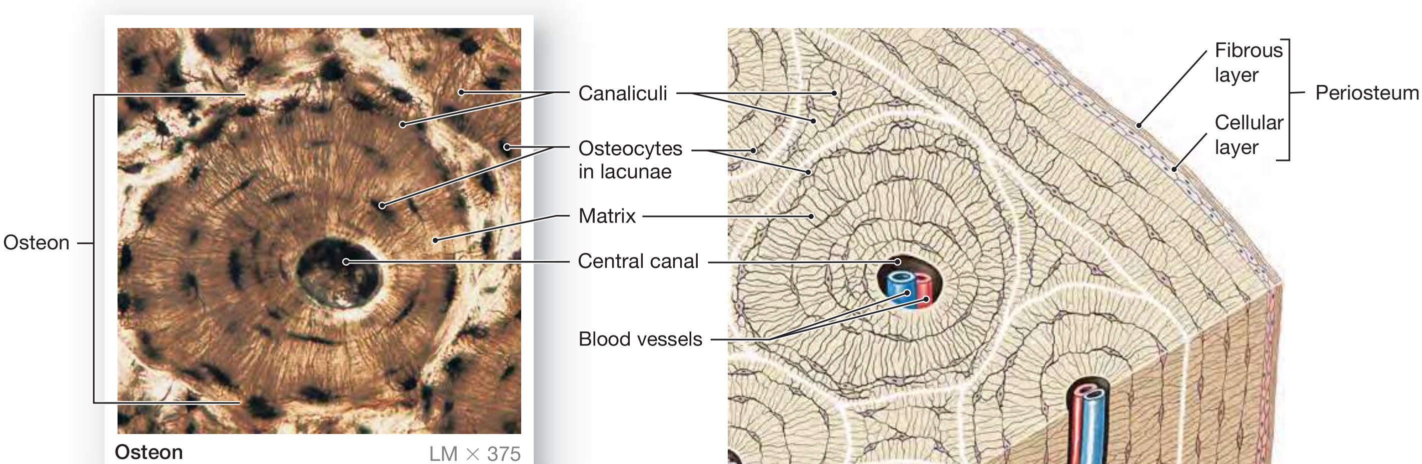


**Table 4–2 A Comparison of Cartilage and Bone**

| Characteristic | Cartilage | Bone |
|---|---|---|
| **STRUCTURAL FEATURES** | | |
| Cells | Chondrocytes in lacunae | Osteocytes in lacunae |
| Ground substance | Chondroitin sulfate (in proteoglycan) and water | A small volume of liquid surrounding insoluble crystals of calcium salts (calcium phosphate and calcium carbonate) |
| Fibers | Collagen, elastic, and reticular fibers (proportions vary) | Collagen fibers predominate |
| Vascularity | None | Extensive |
| Covering | Perichondrium (two layers) | Periosteum (two layers) |
| Strength | Limited: bends easily, but hard to break | Strong: resists distortion until breaking point |
| **METABOLIC FEATURES** | | |
| Oxygen demands | Low | High |
| Nutrient delivery | By diffusion through matrix | By diffusion through cytoplasm and fluid in canaliculi |
| Growth | Interstitial and appositional | Appositional only |
| Repair capabilities | Limited | Extensive |

**Checkpoint**

22. **Identify the two types of supporting connective tissue.**
23. **Why does bone heal faster than cartilage?**
24. **If a person has a herniated intervertebral disc, which type of cartilage has been damaged?**

See the blue Answers tab at the back of the book.

## 4-6 Tissue membranes are physical barriers of four types: mucous, serous, cutaneous, and synovial

A tissue membrane is a physical barrier. There are many different types of anatomical membranes—you encountered plasma membranes that enclose cells in Chapter 3, and you will find many other kinds of membranes in later chapters. The membranes we are concerned with here line or cover body surfaces. Each consists of an epithelium supported by connective tissue. Four such membranes occur in the body: (1) *mucous membranes*, (2) *serous membranes*, (3) the *cutaneous membrane*, and (4) *synovial membranes* (**Figure 4–16**).

### Mucous Membranes

**Mucous membranes,** or **mucosae** (mū-KŌ-sē), line passageways and chambers that communicate with the exterior, including those in the digestive, respiratory, reproductive, and urinary tracts (**Figure 4–16a**). The epithelial surfaces of these passageways must be kept moist to reduce friction and, in many cases, to facilitate absorption or secretion. The epithelial surfaces are lubricated either by mucus, produced by mucous cells or multicellular glands, or by exposure to fluids such as urine or semen. The areolar tissue component of a mucous membrane is called the **lamina propria** (PRŌ-prē-uh). We will consider the organization of specific mucous membranes in greater detail in later chapters.

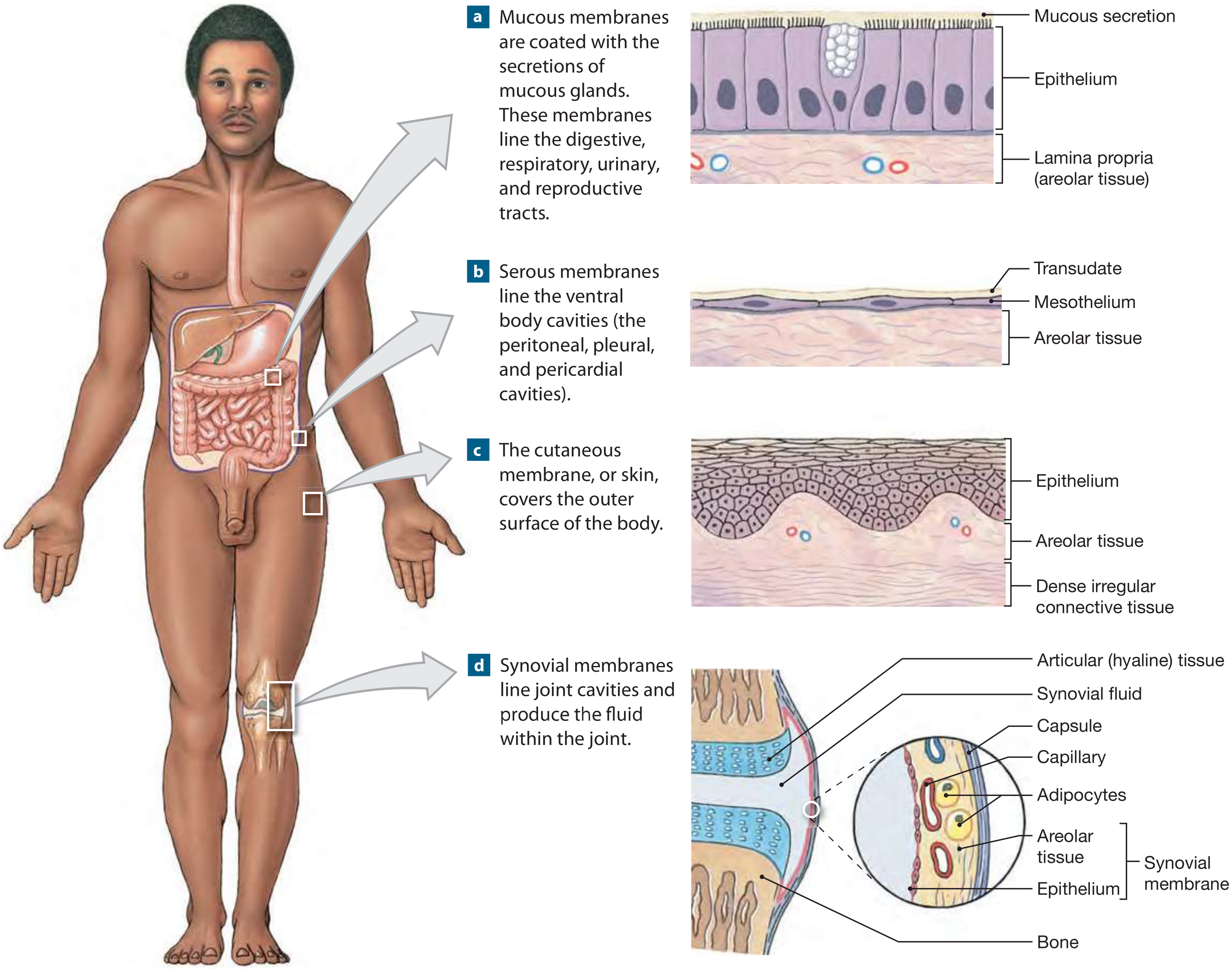
Many mucous membranes contain simple epithelia that perform absorptive or secretory functions, such as the simple columnar epithelium of the digestive tract. However, other types of epithelia may be involved. For example, a stratified squamous epithelium is part of the mucous membrane of the mouth, and the mucous membrane along most of the urinary tract contains a transitional epithelium.

### Serous Membranes

**Serous membranes** line the sealed, internal subdivisions of the ventral body cavity—cavities that are not open to the exterior. These membranes consist of a mesothelium supported by areolar tissue (**Figure 4–16b**). As you may recall from Chapter 1, the three types of serous membranes are (1) the *pleura*, which lines the pleural cavities and covers the lungs; (2) the *peritoneum*, which lines the peritoneal cavity and covers the surfaces of the enclosed organs; and (3) the *pericardium*, which lines the pericardial cavity and covers the heart. ⮌ p. 21 Serous membranes are very thin, but they are firmly attached to the body wall and to the organs they cover. When looking at an organ such as the heart or stomach, you are really seeing the tissues of the organ through a transparent serous membrane.

Each serous membrane can be divided into a *parietal portion*, which lines the inner surface of the cavity, and an opposing *visceral portion*, or **serosa,** which covers the outer surfaces of

**Figure 4–16** **Membranes.**




visceral organs. These organs often move or change shape as they perform their various functions, and the parietal and visceral surfaces of a serous membrane are in close contact at all times. Thus, the primary function of any serous membrane is to minimize friction between the opposing parietal and visceral surfaces. Friction is kept to a minimum because mesothelia are very thin and permeable; tissue fluids continuously diffuse onto the exposed surface, keeping it moist and slippery.

The fluid formed on the surfaces of a serous membrane is called a *transudate* (TRAN-sū-dāt; *trans*-, across). In healthy individuals, the total volume of transudate is extremely small—just enough to prevent friction between the walls of the cavities and the surfaces of internal organs. However, after an injury or in certain disease states, the volume of transudate may increase dramatically, complicating existing medical problems or producing new ones.

## The Cutaneous Membrane

The **cutaneous membrane,** or skin, covers the surface of the body. It consists of a stratified squamous epithelium and a layer of areolar tissue reinforced by underlying dense irregular connective tissue (**Figure 4–16c**). In contrast to serous and mucous membranes, the cutaneous membrane is thick, relatively waterproof, and usually dry. We will examine the cutaneous membrane further in Chapter 5.

## Clinical Note — Problems with Serous Membranes

### **Serous** fluid buildup is **serious**

*Pleuritis*, or *pleurisy*, is an inflammation of the pleural cavities. At first, the serous membranes become rough, and the opposing membranes may scratch against one another, producing pain and a sound known as a *pleural rub*. In general, friction between opposing layers of serous membranes may promote the formation of adhesions—fibrous connections that lock the membranes together and eliminate the friction. Adhesions also severely restrict the movement of the affected organ and may compress blood vessels or nerves. However, adhesions seldom form between the serous membranes of the pleural cavities. More commonly, continued inflammation and rubbing lead to a gradual increase in fluid production to levels well above normal. Fluid then accumulates in the pleural cavities, producing a condition known as *pleural effusion*. Pleural effusion is also caused by heart conditions that elevate the pressure in blood vessels of the lungs. As fluids build up in the pleural cavities, the lungs are compressed, making breathing difficult. The combination of severe pleural effusion and heart disease can be lethal.

*Pericarditis* is an inflammation of the pericardium. This condition may lead to pericardial effusion, an abnormal accumulation of the fluid in the pericardial cavity. When sudden or severe, the fluid buildup can seriously reduce the efficiency of the heart and restrict blood flow through major vessels.

*Peritonitis*, an inflammation of the peritoneum, can follow infection of, or injury to, the peritoneal lining. Peritonitis is a potential complication of any surgical procedure in which the peritoneal cavity is opened. Liver disease, kidney disease, or heart failure can cause an increase in the rate of fluid movement through the peritoneal lining. *Ascites* (a-SĪ-tēz), the accumulation of peritoneal fluid, creates a characteristic abdominal swelling. The distortion of internal organs by the contained fluid can lead to symptoms such as heartburn, indigestion, and low-back pain.

### Synovial Membranes

Adjacent bones often interact at joints, or *articulations*. At an articulation, the two articulating bones are very close together or in contact. Joints that permit significant amounts of movement are complex structures. Such a joint is surrounded by a fibrous capsule, and the ends of the articulating bones lie within a *joint cavity* filled with **synovial** (si-NŌ-vē-ul) **fluid** (**Figure 4–16d**). The synovial fluid is produced by a **synovial membrane,** which lines the joint cavity. A synovial membrane consists of an extensive area of areolar tissue containing a matrix of interwoven collagen fibers, proteoglycans, and glycoproteins. An incomplete layer of macrophages and specialized fibroblasts separates the areolar tissue from the joint cavity. These cells regulate the composition of the synovial fluid. Although this lining is often called an epithelium, it differs from true epithelia in four respects: (1) It develops within a connective tissue, (2) no basement membrane is present, (3) gaps of up to 1 mm may separate adjacent cells, and (4) fluid and solutes are continuously exchanged between the synovial fluid and capillaries in the underlying connective tissue.

Even though a smooth layer of articular cartilage covers the ends of the bones, the surfaces must be lubricated to keep friction from damaging the opposing surfaces. The necessary lubrication is provided by the synovial fluid, which is similar in composition to the ground substance in loose connective tissues. Synovial fluid circulates from the areolar tissue into the joint cavity and percolates through the articular cartilages, providing oxygen and nutrients to the chondrocytes. Joint movement is important in stimulating the formation and circulation of synovial fluid: If a synovial joint is immobilized for long periods, the articular cartilages and the synovial membrane undergo degenerative changes.

#### Checkpoint

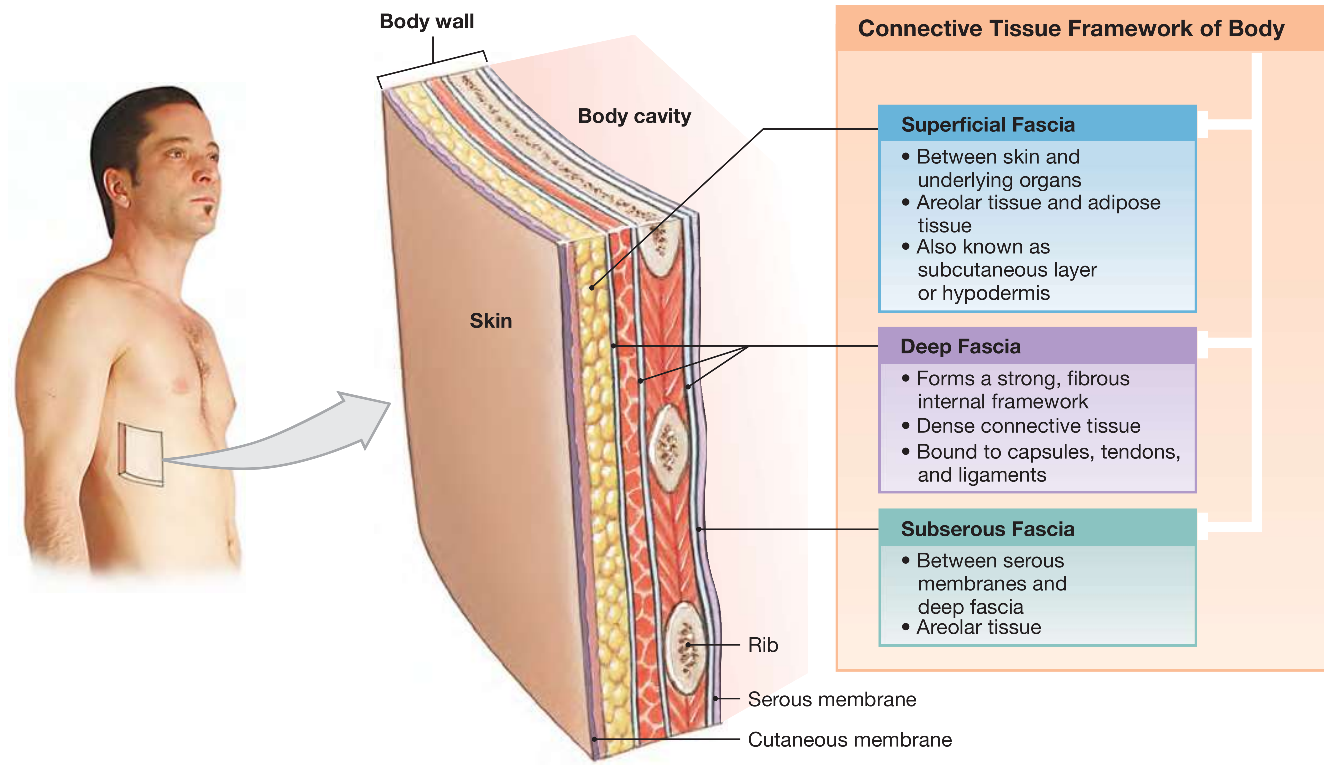
25. **Identify the four types of tissue membranes found in the body.**
26. **Which cavities in the body are lined by serous membranes?**
27. **The lining of the nasal cavity is normally moist, contains numerous mucous cells, and rests on a layer of connective tissue called the lamina propria. Which type of membrane is this?**

See the blue Answers tab at the back of the book.

## 4-7 ◗ Connective tissues create the internal framework of the body

Connective tissues provide the internal structure of the body. Layers of connective tissue surround and support the organs within the subdivisions of the ventral body cavity and connect them to the rest of the body. These layers (1) provide strength and stability, (2) maintain the relative positions of internal

**Figure 4–17 The Fasciae.** The relationships among the connective tissue elements in the body.




organs, and (3) provide a route for the distribution of blood vessels, lymphatic vessels, and nerves. **Fasciae** (FASH-ē-ē; singular, *fascia*) are connective tissue layers and wrappings that support and surround organs. We can divide the fasciae into three types of layers: the superficial fascia, the deep fascia, and the subserous fascia (**Figure 4–17**).

1. The **superficial fascia** (FASH-ē-uh) is also called the **hypodermis** (*hypo*, below + *dermis*, skin). This layer of areolar tissue and fat separates the skin from underlying tissues and organs, provides insulation and padding, and lets the skin and underlying structures move independently.
2. The **deep fascia** consists of dense irregular connective tissue. The organization of the fibers resembles that of plywood: In each layer all the fibers run in the same direction, but the orientation of the fibers changes from layer to layer. This arrangement helps the tissue resist forces coming from many directions. The tough capsules that surround most organs, including the kidneys and the organs in the thoracic and peritoneal cavities, are bound to the deep fascia. The perichondrium around cartilages, the periosteum around bones and the ligaments that interconnect them, and the connective tissues of muscle (including tendons) are also connected to the deep fascia. The dense connective tissue components are interwoven. For example, the deep fascia around a muscle blends into the tendon, whose fibers intermingle with those of the periosteum. This arrangement creates a strong, fibrous network and binds structural elements together.
3. The **subserous fascia** is a layer of areolar tissue that lies between the deep fascia and the serous membranes that line body cavities. Because this layer separates the serous membranes from the deep fascia, movements of muscles or muscular organs do not severely distort the delicate body cavity linings.

**Checkpoint**

28. **A sheet of tissue has many layers of collagen fibers that run in different directions in successive layers. Which type of tissue is this?**

See the blue Answers tab at the back of the book.

## 4-8 ◗ The three types of muscle tissue are skeletal, cardiac, and smooth

Epithelia cover surfaces and line passageways; connective tissues support and interconnect parts of the body. Together, these tissues provide a strong, interwoven framework within which the organs of the body can function. Several vital functions involve movement of one kind or another—movement of materials along the digestive tract, movement of blood within the vessels of the cardiovascular system, or movement of the body from one place to another. Movement is produced by **muscle tissue,** which is specialized for contraction. Muscle cells possess organelles and properties distinct from those of other cells.

There are three types of muscle tissue: (1) *skeletal muscle*, which forms the large muscles responsible for gross body movements; (2) *cardiac muscle*, found only in the heart and responsible for the circulation of blood; and (3) *smooth muscle*, found in the walls of visceral organs and a variety of other locations, where it provides elasticity, contractility, and support. The contraction mechanism is similar in all three types of muscle tissue, but the muscle cells differ in internal organization. We will examine only general characteristics at this point, because each type of muscle is described more fully in Chapter 10.

## Skeletal Muscle Tissue

**Skeletal muscle tissue** contains very large muscle cells—up to 0.3 m (1 ft) or more in length. Because the individual muscle cells are relatively long and slender, they are usually called **muscle fibers.** Each muscle fiber is described as *multinucleate*, because it has several hundred nuclei distributed just inside the plasma membrane (**Figure 4–18a**). Skeletal muscle fibers are incapable of dividing, but new muscle fibers are produced through the divisions of **myosatellite cells** *(satellite cells)*, stem cells that persist in adult skeletal muscle tissue. As a result, skeletal muscle tissue can at least partially repair itself after an injury.

As noted in Chapter 3, the cytoskeleton contains actin and myosin filaments. ⮌ p. 69 In skeletal muscle fibers, however, these filaments are organized into repeating groups that give the cells a *striated*, or banded, appearance. The *striations*, or bands, are easily seen in light micrographs. Skeletal muscle fibers do not usually contract unless stimulated by nerves, and the nervous system provides voluntary control over their activities. Thus, skeletal muscle is called **striated voluntary muscle.**

### Tips & Tricks

Associate the sound of the word **stri**ated with the sound of the word **stri**ped.

A *skeletal muscle* is an organ of the muscular system, and although muscle tissue predominates, it contains all four types of body tissue. Within a skeletal muscle, adjacent skeletal muscle fibers are tied together by collagen and elastic fibers that blend into the attached tendon or aponeurosis. The tendon or aponeurosis conducts the force of contraction, often to a bone of the skeleton. Thus, when the muscles contract, they pull on the attached bone, producing movement.

## Cardiac Muscle Tissue

**Cardiac muscle tissue** is located only in the heart. A typical cardiac muscle cell, also known as a **cardiocyte,** is smaller than a skeletal muscle cell (**Figure 4–18b**). A typical cardiac muscle cell has one centrally positioned nucleus, but some cardiocytes have as many as five. Prominent striations resemble those of skeletal muscle; the actin and myosin filaments are arranged the same way in both cell types.

Cardiac muscle cells form extensive connections with one another. As a result, cardiac muscle tissue consists of a branching network of interconnected muscle cells. The connections occur at specialized regions known as **intercalated discs.** At an intercalated disc, the membranes are locked together by desmosomes, proteoglycans, and gap junctions. Ion movement through gap junctions helps synchronize the contractions of the cardiac muscle cells, and the desmosomes and proteoglycans lock the cells together during a contraction. Cardiac muscle tissue has a very limited ability to repair itself. Although some cardiac muscle cells do divide after an injury to the heart, the repairs are incomplete and some heart function is usually lost.

Cardiac muscle cells do not rely on nerve activity to start a contraction. Instead, specialized cardiac muscle cells called *pacemaker cells* establish a regular rate of contraction. Although the nervous system can alter the rate of pacemaker cell activity, it does not provide voluntary control over individual cardiac muscle cells. Therefore, cardiac muscle is called **striated involuntary muscle.**

## Smooth Muscle Tissue

**Smooth muscle tissue** is located in the walls of blood vessels, around hollow organs such as the urinary bladder, and in layers around the respiratory, cardiovascular, digestive, and reproductive tracts. A smooth muscle cell is a small, spindle-shaped cell with tapering ends and a single, oval nucleus (**Figure 4–18c**). Smooth muscle cells can divide; hence, smooth muscle tissue can regenerate after an injury.

The actin and myosin filaments in smooth muscle cells are organized differently from those of skeletal and cardiac muscles. One result of this difference is that smooth muscle tissue has no striations. Smooth muscle cells may contract on their own, with gap junctions between adjacent cells coordinating the contractions of individual cells. The contraction of some smooth muscle tissue can be controlled by the nervous system, but contractile activity is not under voluntary control. (Imagine the degree of effort that would be required to exert conscious control over the smooth muscles along the 8 m [26 ft.] of digestive tract, not to mention the miles of blood vessels!) Because the nervous system usually does not provide voluntary control over smooth muscle contractions, smooth muscle is known as **nonstriated involuntary muscle.**

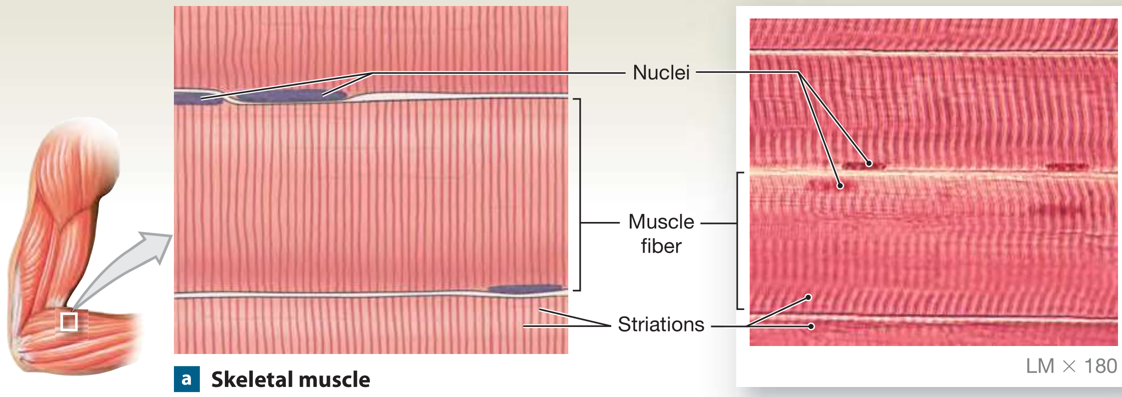
**Figure 4–18** Muscle Tissue.

## Skeletal Muscle Tissue

Cells are long, cylindrical, striated, and multinucleate.

**LOCATIONS:** Combined with connective tissues and neural tissue in skeletal muscles

**FUNCTIONS:** Moves or stabilizes the position of the skeleton; guards entrances and exits to the digestive, respiratory, and urinary tracts; generates heat; protects internal organs



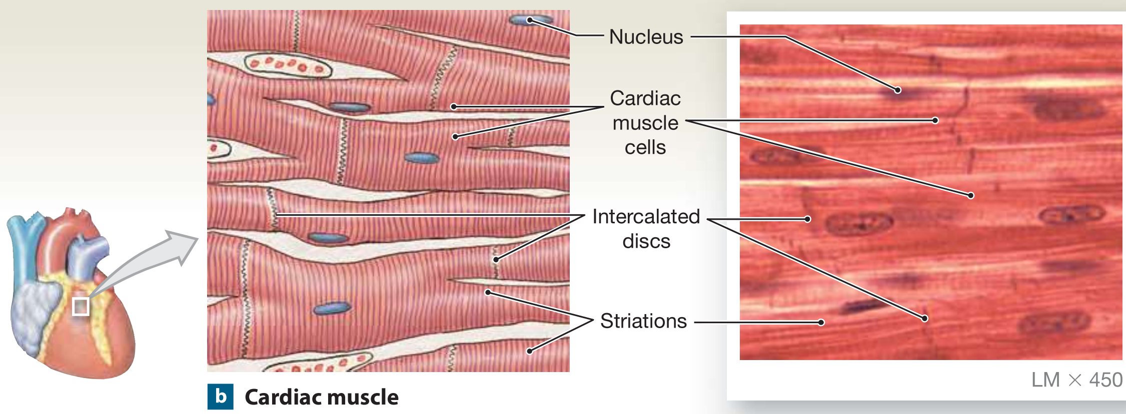

**a** Skeletal muscle

## Cardiac Muscle Tissue

Cells are short, branched, and striated, usually with a single nucleus; cells are interconnected by intercalated discs.

**LOCATION:** Heart

**FUNCTIONS:** Circulates blood; maintains blood (hydrostatic) pressure



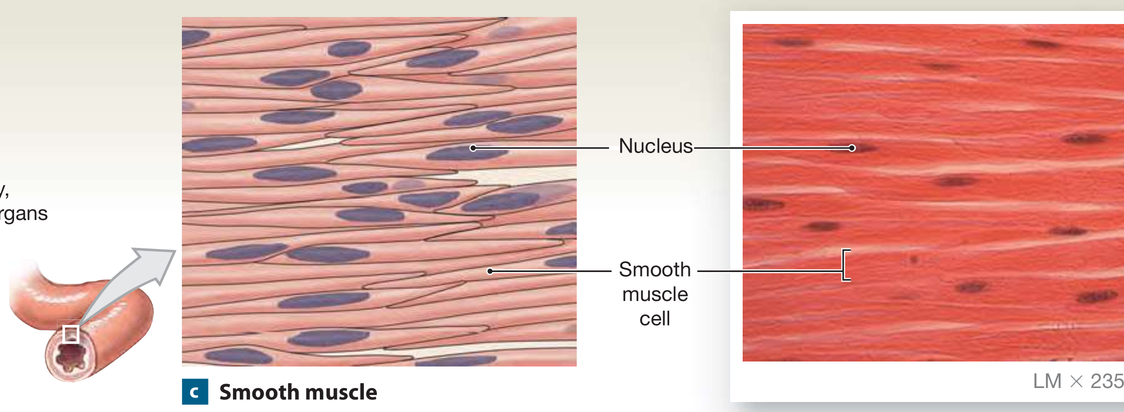

**b** Cardiac muscle

## Smooth Muscle Tissue

Cells are short, spindle-shaped, and nonstriated, with a single, central nucleus.

**LOCATIONS:** Found in the walls of blood vessels and in digestive, respiratory, urinary, and reproductive organs

**FUNCTIONS:** Moves food, urine, and reproductive tract secretions; controls diameter of respiratory passageways; regulates diameter of blood vessels




**c** Smooth muscle

## Checkpoint

29. **Identify the three types of muscle tissue in the body.**
30. **Which type of muscle tissue has small, tapering cells with single nuclei and no obvious striations?**
31. **If skeletal muscle cells in adults are incapable of dividing, how is skeletal muscle repaired?**

See the blue Answers tab at the back of the book.

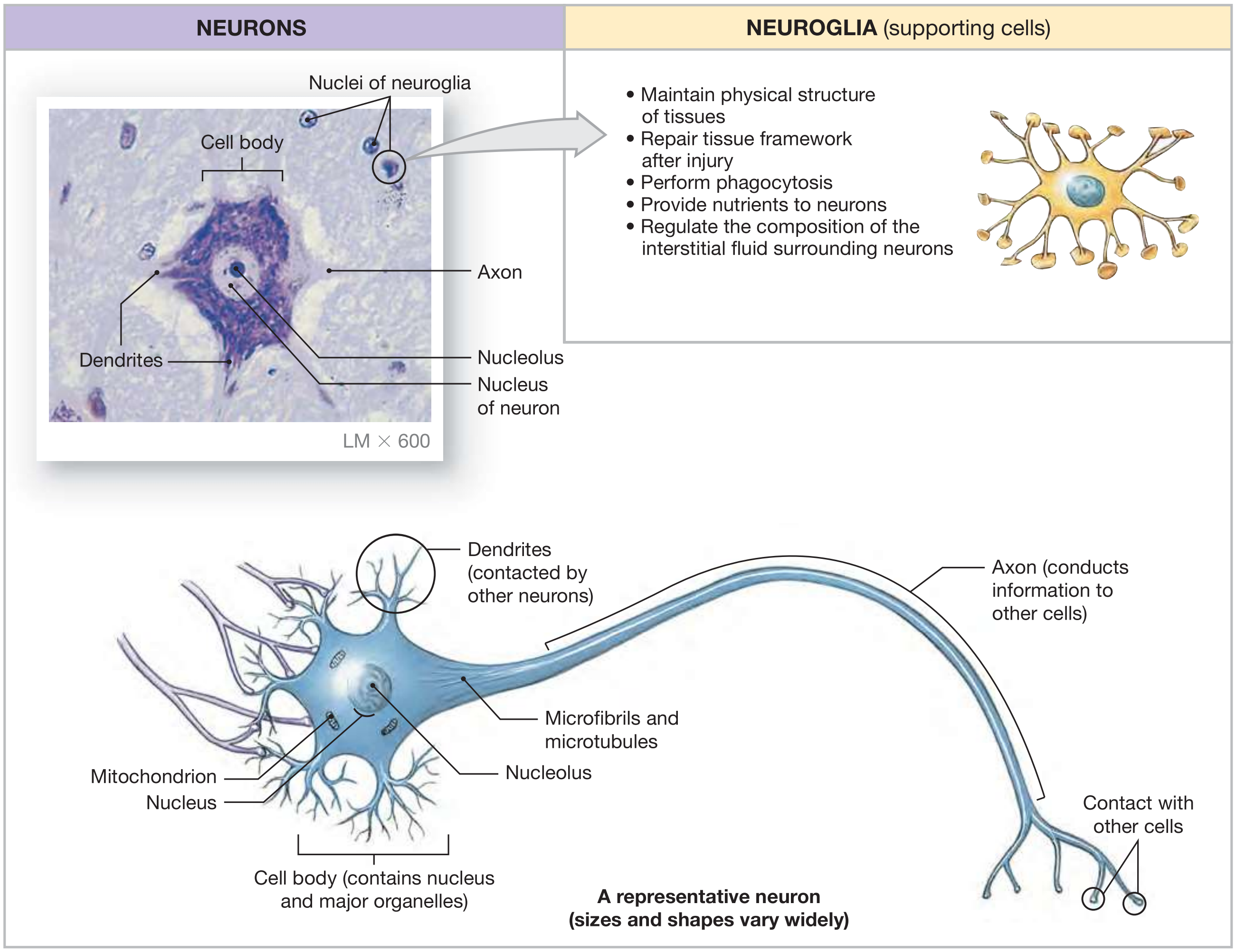
## 4-9 ◗ Neural tissue responds to stimuli and conducts electrical impulses throughout the body

**Neural tissue,** which is also known as *nervous tissue* or *nerve tissue*, is specialized for the conduction of electrical impulses from one region of the body to another. Ninety-eight percent of the neural tissue in the body is concentrated in the brain and spinal cord, which are the control centers of the nervous system.

Neural tissue contains two basic types of cells: (1) **neurons** (NOOR-onz; *neuro*, nerve) and (2) several kinds of supporting cells, collectively called **neuroglia** (noo-ROG-lē-uh), or *glial cells* (*glia*, glue). Our conscious and unconscious thought processes reflect the communication among neurons in the brain. Such communication involves the propagation of electrical impulses, in the form of changes in the transmembrane potential. Information is conveyed both by the frequency and by the pattern of the impulses. Neuroglia support and repair neural tissue and supply nutrients to neurons.

The longest cells in your body are neurons, many of which are as much as a meter (39 in.) long. Most neurons cannot divide under normal circumstances, so they have a very limited ability to repair themselves after injury. A typical neuron has a large **cell body** with a large nucleus and a prominent nucleolus (**Figure 4–19**). Extending from the cell body are many branching processes (projections or outgrowths) termed **dendrites** (DEN-drīts; *dendron*, a tree), and one **axon.** The dendrites receive information, typically from other neurons, and the axon conducts that information to

**Figure 4–19** Neural Tissue.



other cells. Because axons tend to be very long and slender, they are also called **nerve fibers.** In Chapter 12 we will further examine the properties of neural tissue.

**Tips & Tricks**

To remember the direction of electrical impulses in a neuron, associate the "t" in dendri**t**e with "**t**o" and the "a" in **a**xon with "**a**way."

**Checkpoint**

32. **A tissue contains irregularly shaped cells with many fibrous projections, some several centimeters long. These are probably which type of cell?**

See the blue Answers tab at the back of the book.

## 4-10 ◗ The response to tissue injury involves inflammation and regeneration

In this section, we consider the basics of the repair process after an injury, focusing on the interaction among different tissues. Our example includes connective tissue (blood), an epithelium (the endothelia of blood vessels), a muscle tissue (smooth muscle in the vessel walls), and neural tissue (sensory nerve endings). In later chapters, especially Chapters 5 and 22, we will examine inflammation and regeneration in more detail.

### Inflammation

Many stimuli—including impact, abrasion, distortion, chemical irritation, infection by pathogenic organisms (such as bacteria or viruses), and extreme temperatures (hot or cold)—can produce inflammation. Each of these stimuli kills cells, damages fibers, or injures the tissue in some other way. Such changes alter the chemical composition of the interstitial fluid: Damaged cells release prostaglandins, proteins, and potassium ions, and the injury itself may have introduced foreign proteins or pathogens into the body.

Tissue conditions soon become even more abnormal. **Necrosis** (ne-KRŌ-sis), the tissue destruction that occurs after cells have been damaged or killed, begins several hours after the original injury. Lysosomal enzymes cause the damage. Through widespread autolysis, lysosomes release enzymes that first destroy the injured cells and then attack surrounding tissues. ⮌ p. 73 The result may be an accumulation of debris, fluid, dead and dying cells, and necrotic tissue components collectively known as **pus.** An accumulation of pus in an enclosed tissue space is an **abscess. Spotlight Figure 4–20** shows the tissue response to injury and the process of tissue regeneration.

### Regeneration

Each organ has a different ability to regenerate after injury—an ability that can be directly linked to the pattern of tissue organization in the injured organ. Epithelia, connective tissues (except cartilage), and smooth muscle tissue usually regenerate well, whereas other muscle tissues and neural tissue regenerate relatively poorly if at all. The skin, which is dominated by epithelia and connective tissues, regenerates rapidly and completely after injury. (We will consider the process in Chapter 5.) In contrast, damage to the heart is much more serious. Although the connective tissues of the heart can be repaired, the majority of damaged cardiac muscle cells are replaced only by fibrous tissue. The permanent replacement of normal tissue by fibrous tissue is called *fibrosis* (fī-BRŌ-sis). Fibrosis in muscle and other tissues may occur in response to injury, disease, or aging (**Spotlight Figure 4–20**).

**Checkpoint**

33. **Identify the two phases in the response to tissue injury.**

See the blue Answers tab at the back of the book.

## 4-11 ◗ With advancing age, tissue repair declines and cancer rates increase

In this section we briefly consider two important effects of aging on tissues: the body's decreased ability to repair damage to tissues, and an increase in the occurrence of cancer.

### Aging and Tissue Structure

Tissues change with age, and the speed and effectiveness of tissue repairs decrease. Repair and maintenance activities throughout the body slow down; the rate of energy consumption in general declines. All these changes reflect various hormonal alterations occurring with age, often coupled with a reduction in physical activity and the adoption of a more sedentary lifestyle. These factors combine to alter the structure and chemical composition of many tissues. Epithelia get thinner and connective tissues more fragile. Individuals bruise easily and bones become brittle; joint pain and broken bones are common in the elderly. Because cardiac muscle cells and neurons are not normally replaced, cumulative damage can eventually cause major health problems, such as cardiovascular disease or deterioration in mental functioning.

# Spotlight

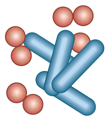
**Figure 4–20**

## Tissue Repair

**Tissues are not isolated; they combine to form organs with diverse functions. Therefore, any injury affects several types of tissue simultaneously. To preserve homeostasis, the tissues must respond in a coordinated way. The restoration of homeostasis involves two related processes: inflammation and regeneration.**

### Exposure to Pathogens and Toxins

Injured tissue contains an abnormal concentration of pathogens, toxins, waste products, and the chemicals from injured cells.



stimulates

### Mast Cell Activation

When an injury damages connective tissue, mast cells release a variety of chemicals. This process, called mast cell activation, stimulates inflammation.


Histamine
Heparin
Prostaglandins

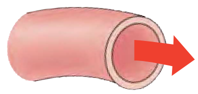
When a tissue is injured, a general defense mechanism is activated.

## INFLAMMATION

**Inflammation** produces several familiar indications of injury, including swelling, redness, warmth, and pain. Inflammation may also result from the presence of pathogens, such as harmful bacteria, within the tissues; the presence of these pathogens constitutes an **infection.**

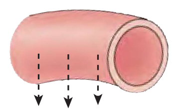
### Increased Blood Flow

In response to the released chemicals, blood vessels dilate, increasing blood flow through the damaged tissue.



### Increased Vessel Permeability

Vessel dilation is accompanied by an increase in the permeability of the capillary walls. Plasma now diffuses into the injured tissue, so the area becomes swollen.



### Pain

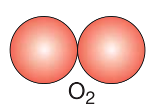
The abnormal conditions within the tissue and the chemicals released by mast cells stimulate nerve endings that produce the sensation of pain.


### Increased Local Temperature

The increased blood flow and permeability causes the tissue to become warm and red.

### Increased Oxygen and Nutrients

Vessel dilation, increased blood flow, and increased vessel permeability result in enhanced delivery of oxygen and nutrients.

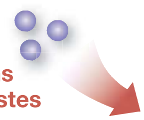



### Increased Phagocytosis

Phagocytes in the tissue are activated, and they begin engulfing tissue debris and pathogens.

### Removal of Toxins and Wastes

Enhanced circulation carries away toxins and waste products, distributing them to the kidneys for excretion, or to the liver for inactivation.




### Inflammation Subsides

Over a period of hours to days, the cleanup process generally succeeds in eliminating the inflammatory stimuli.

### Regeneration

**Regeneration** is the repair that occurs after the damaged tissue has been stabilized and the inflammation has subsided. Fibroblasts move into the area, laying down a collagenous framework known as scar tissue. Over time, scar tissue is usually "remodeled" and gradually assumes a more normal appearance.

Inhibits mast cell activation

Normal tissue conditions restored

In later chapters, we will consider the effects of aging on specific organs and systems. Some of these effects are genetically programmed. For example, the chondrocytes of older individuals produce a slightly different form of proteoglycan than do those of younger people. This difference probably accounts for the thinner and less resilient cartilage of older people. In some cases, the tissue degeneration can be temporarily slowed or even reversed. Age-related reduction in bone strength, a condition called *osteoporosis*, typically results from a combination of inactivity, low dietary calcium levels, and a reduction in circulating sex hormones. A program of exercise that includes weight-bearing activity, calcium supplements, and medication can generally maintain healthy bone structure for many years.

## Aging and Cancer Incidence

Cancer rates increase with age, and about 25 percent of all people in the United States develop cancer at some point in their lives. It has been estimated that 70–80 percent of cancer cases result from chemical exposure, environmental factors, or some combination of the two, and 40 percent of those cancers are caused by cigarette smoke. Each year in the United States, more than 500,000 individuals die of cancer, making it second only to heart disease as a cause of death. We discussed the development and growth of cancer in Chapter 3. ↺ p. 100

This chapter concludes the introductory portion of this text. In combination, the four basic tissue types described here form all of the organs and systems discussed in subsequent chapters.

### Checkpoint

34. **Identify some age-related factors that affect tissue repair and structure.**

See the blue Answers tab at the back of the book.

## Related Clinical Terms

**autopsy:** An examination of a dead body to discover the cause of death or the extent of disease.

**biopsy:** An examination of tissue removed from a living body to discover the presence, cause, or extent of disease.

**cachexia:** Weakness and wasting of the body due to severe chronic illness.

**carcinoma:** A cancer arising in the epithelial tissue of the skin or of the lining of the internal organs.

**immunotherapy:** The prevention or treatment of disease with substances that stimulate the immune response.

**lesion:** A region in an organ or tissue that has suffered damage from injury or disease; a wound, ulcer, abscess, or tumor, for example.

**metaplasia:** A reversible structural change that alters the character of a tissue.

**pathologist:** A physician who specializes in the study of disease processes in tissues and body fluids.

**remission:** Abatement, ending, or lessening in severity of the signs and symptoms of a disease.

**sarcoma:** A malignant tumor of connective or other nonepithelial tissue.

**tissue engineering:** Tissue is either grown in or outside of a body to be transplanted into a patient or used for testing.

**tissue rejection:** Occurs when a transplant recipient's immune system attacks a transplanted organ or tissue.

**tissue transplantation:** Moving tissues (or organs) from one body and placing them into another body by medical procedures for the purpose of replacing the recipient's damaged or failing tissue (or organ).

**tumor grading:** A system used to classify cancer cells in terms of how abnormal they look under a microscope and how quickly the tumor is likely to grow and spread.

**tumor staging:** Defining at what point the patient is in the development of the malignant disease when the diagnosis is made.

**xenotransplant:** The process of grafting or transplanting organs or tissues between members of different species.

# Chapter Review

## Study Outline

### An Introduction to the Tissue Level of Organization p. 109

1. Tissues are structures with discrete structural and functional properties that combine to form organs.

### 4-1 The four tissue types are epithelial, connective, muscle, and neural p. 109

2. **Tissues** are collections of specialized cells and cell products that perform a relatively limited number of functions. The four *tissue types* are *epithelial tissue*, *connective tissue*, *muscle tissue*, and *neural tissue*.
3. **Histology** is the study of tissues.

### 4-2 Epithelial tissue covers body surfaces, lines cavities and tubular structures, and serves essential functions p. 109

4. **Epithelial tissue** includes epithelia and glands. An **epithelium** is an **avascular** layer of cells that forms a barrier that provides

protection and regulates permeability. **Glands** are secretory structures derived from epithelia. Epithelial cells may show **polarity,** an uneven distribution of cytoplasmic components.

5. A **basement membrane (basal lamina)** attaches epithelia to underlying connective tissues.
6. Epithelia provide physical protection, control permeability, provide sensation, and produce specialized secretions. Gland cells are epithelial cells that produce secretions. In **glandular epithelia,** most cells produce secretions.
7. Epithelial cells are specialized to perform secretory or transport functions and to maintain the physical integrity of the epithelium. *(Figure 4–1)*
8. Many epithelial cells have microvilli.
9. The coordinated beating of the cilia on a **ciliated epithelium** moves materials across the epithelial surface.
10. Cells can attach to other cells or to extracellular protein fibers by means of **cell adhesion molecules (CAMs)** or at specialized attachment sites called **cell junctions.** The three major types of cell junctions are **tight junctions, gap junctions,** and **desmosomes.** *(Figure 4–2)*
11. The inner surface of each epithelium is connected to a two-part basement membrane consisting of a *clear layer* and a *dense layer*. Divisions by **germinative cells** continually replace the short-lived epithelial cells.

## 4-3 ◗ Cell shape and number of layers determine the classification of epithelia p. 113

12. Epithelia are classified on the basis of the number of cell layers and the shape of the cells at the apical surface.
13. A **simple epithelium** has a single layer of cells covering the basement membrane; a **stratified epithelium** has several layers. The cells in a **squamous epithelium** are thin and flat. Cells in a **cuboidal epithelium** resemble hexagonal boxes; those in a **columnar epithelium** are taller and more slender. *(Table 4–1; Figures 4–3* to *4–5)*
14. Epithelial cells (or structures derived from epithelial cells) that produce secretions are called *glands*. **Exocrine glands** discharge secretions onto the body surface or into **ducts,** which communicate with the exterior. *Hormones*, the secretions of **endocrine glands,** are released by gland cells into the surrounding interstitial fluid.
15. A glandular epithelial cell may release its secretions by merocrine, apocrine, or holocrine modes. In **merocrine secretion,** the most common mode, the product is released through exocytosis. **Apocrine secretion** involves the loss of both the secretory product and cytoplasm. Unlike the other two methods, **holocrine secretion** destroys the gland cell, which becomes packed with secretions and then bursts. *(Figure 4–6)*
16. In epithelia that contain scattered gland cells, individual secretory cells are called **unicellular glands. Multicellular glands** are organs that contain glandular epithelia that produce exocrine or endocrine secretions.
17. Exocrine glands can be classified on the basis of structure as **unicellular exocrine glands (mucous cells)** or as **multicellular exocrine glands.** Multicellular exocrine glands can be further classified according to structure. *(Figure 4–7)*

## 4-4 ◗ Connective tissue provides a protective structural framework for other tissue types p. 120

18. **Connective tissues** are internal tissues with many important functions: establishing a structural framework; transporting fluids and dissolved materials; protecting delicate organs; supporting, surrounding, and interconnecting tissues; storing energy reserves; and defending the body from microorganisms.
19. All connective tissues contain specialized cells and a **matrix,** composed of extracellular protein fibers and a **ground substance.**
20. **Connective tissue proper** is connective tissue that contains varied cell populations and fiber types surrounded by a syrupy ground substance. *(Figure 4–8)*
21. **Fluid connective tissues** have distinctive populations of cells suspended in a watery matrix that contains dissolved proteins. The two types of fluid connective tissues are *blood* and *lymph*.
22. **Supporting connective tissues** have a less diverse cell population than connective tissue proper and a dense matrix with closely packed fibers. The two types of supporting connective tissues are *cartilage* and *bone*.
23. Connective tissue proper contains fibers, a viscous ground substance, and a varied population of cells, including **fibroblasts, fibrocytes, macrophages, adipocytes, mesenchymal cells, melanocytes, mast cells, lymphocytes,** and **microphages.**
24. The three types of fibers in connective tissue are **collagen fibers, reticular fibers,** and **elastic fibers.**
25. The first connective tissue to appear in an embryo is **mesenchyme,** or *embryonic connective tissue*.
26. Connective tissue proper is classified as either **loose connective tissue** or **dense connective tissue.** Loose connective tissues are mesenchyme and **mucous connective tissues** in the embryo; **areolar tissue; adipose tissue,** including **white fat** and **brown fat;** and **reticular tissue.** Most of the volume in dense connective tissue consists of fibers. The two types of dense connective tissue are **dense regular connective tissue** and **dense irregular connective tissue** in the adult. *(Figures 4–9* to *4–11)*
27. **Blood** and **lymph** are connective tissues that contain distinctive collections of cells in a fluid matrix.
28. Blood contains *formed elements*: **red blood cells** (*erythrocytes*), **white blood cells** (*leukocytes*), and **platelets.** The watery matrix of blood is called **plasma.** *(Figure 4–12)*
29. **Arteries** carry blood away from the heart and toward **capillaries,** where water and small solutes move into the interstitial fluid of surrounding tissues. **Veins** return blood to the heart.
30. Lymph forms as interstitial fluid enters the **lymphatic vessels,** which return lymph to the cardiovascular system.

## 4-5 ◗ Cartilage and bone provide a strong supporting framework p. 127

31. Cartilage and bone are called supporting connective tissues because they support the rest of the body.
32. Chondrocytes rely on diffusion through the avascular matrix to obtain nutrients.
33. **Cartilage** grows by two mechanisms: **interstitial growth** and **appositional growth.** *(Figure 4–13)*
34. The matrix of cartilage is a firm gel that contains **chondroitin sulfates** (used to form proteoglycans) and cells called **chondrocytes.** Chondrocytes occupy chambers called **lacunae.** A fibrous **perichondrium** separates cartilage from surrounding tissues. The three types of cartilage are **hyaline cartilage, elastic cartilage,** and **fibrocartilage.** *(Figure 4–14)*

35. **Bone,** or **osseous tissue,** consists of **osteocytes,** little ground substance, and a dense, mineralized matrix. Osteocytes are situated in lacunae. The matrix consists of calcium salts and collagen fibers, giving it unique properties. *(Figure 4–15; Table 4–2)*
36. Osteocytes depend on diffusion through **canaliculi** for nutrient intake.
37. Each bone is surrounded by a **periosteum** with fibrous and cellular layers.

4

### 4-6 Tissue membranes are physical barriers of four types: mucous, serous, cutaneous, and synovial p. 131

38. Membranes form a barrier or interface. Epithelia and connective tissues combine to form membranes that cover and protect other structures and tissues. *(Figure 4–16)*
39. **Mucous membranes** line cavities that communicate with the exterior. They contain areolar tissue called the **lamina propria.**
40. **Serous membranes** line the body's sealed internal cavities. They form a fluid called a *transudate*.
41. The **cutaneous membrane,** or skin, covers the body surface.
42. **Synovial membranes** form an incomplete lining within the cavities of synovial joints.

### 4-7 Connective tissues create the internal framework of the body p. 133

43. Internal organs and systems are tied together by a network of connective tissue proper. This network consists of the **superficial fascia** (the **subcutaneous layer,** or *hypodermis*, separating the skin from underlying tissues and organs), the **deep fascia** (dense connective tissue), and the **subserous fascia** (the layer between the deep fascia and the serous membranes that line body cavities). *(Figure 4–17)*

### 4-8 The three types of muscle tissue are skeletal, cardiac, and smooth p. 134

44. **Muscle tissue** is specialized for contraction. *(Figure 4–18)*
45. The cells of **skeletal muscle tissue** are *multinucleate*. Skeletal muscle, or **striated voluntary muscle,** produces new fibers by the division of **myosatellite cells.**
46. **Cardiocytes,** the cells of **cardiac muscle tissue,** occur only in the heart. Cardiac muscle, or **striated involuntary muscle,** relies on *pacemaker cells* for regular contraction.
47. **Smooth muscle tissue,** or **nonstriated involuntary muscle,** is not striated. Smooth muscle cells can divide and therefore regenerate after injury has occurred.

### 4-9 Neural tissue responds to stimuli and conducts electrical impulses throughout the body p. 137

48. **Neural tissue** conducts electrical impulses, which convey information from one area of the body to another.
49. Cells in neural tissue are either neurons or neuroglia. **Neurons** transmit information as electrical impulses. Several kinds of **neuroglia** exist, and their basic functions include supporting neural tissue and helping supply nutrients to neurons. *(Figure 4–19)*
50. A typical neuron has a **cell body, dendrites,** and an **axon,** or **nerve fiber.** The axon carries information to other cells.

### 4-10 The response to tissue injury involves inflammation and regeneration p. 138

51. Any injury affects several types of tissue simultaneously, and they respond in a coordinated manner. After an injury, homeostasis is restored by two processes: inflammation and regeneration.
52. **Inflammation,** or the **inflammatory response,** isolates the injured area while damaged cells, tissue components, and any dangerous microorganisms (which could cause **infection**) are cleaned up. **Regeneration** is the repair process that restores normal function. *(Spotlight Figure 4–20)*

### 4-11 With advancing age, tissue repair declines and cancer rates increase p. 138

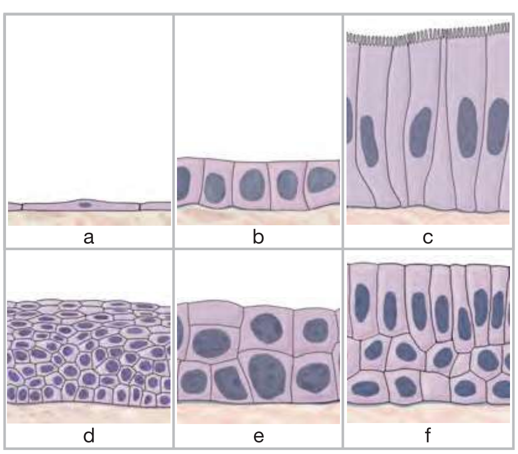
53. Tissues change with age. Repair and maintenance become less efficient, and the structure and chemical composition of many tissues are altered.
54. The incidence of cancer increases with age, with roughly three-quarters of all cases caused by exposure to chemicals or by other environmental factors, such as cigarette smoke.

## Review Questions

See the blue Answers tab at the back of the book.

### LEVEL 1 Reviewing Facts and Terms

1. Identify the six categories of epithelial tissue shown in the drawing below.




(a) ____________ (b) ____________
(c) ____________ (d) ____________
(e) ____________ (f) ____________

2. Collections of specialized cells and cell products that perform a relatively limited number of functions are called
(a) cellular aggregates. (b) tissues.
(c) organs. (d) organ systems.
(e) organisms.
3. Tissue that is specialized for contraction is
(a) epithelial tissue. (b) muscle tissue.
(c) connective tissue. (d) neural tissue.
4. A type of cell junction common in cardiac and smooth muscle tissues is the
(a) hemidesmosome. (b) basal junction.
(c) tight junction. (d) gap junction.
5. The most abundant connections between cells in the superficial layers of the skin are
(a) connexons. (b) gap junctions.
(c) desmosomes. (d) tight junctions.

6. ___________ membranes have an epithelium that is stratified and supported by dense connective tissue.
   (a) Synovial (b) Serous
   (c) Cutaneous (d) Mucous
7. Mucous secretions that coat the passageways of the digestive and respiratory tracts result from ___________ secretion.
   (a) apocrine (b) merocrine
   (c) holocrine (d) endocrine
8. Matrix is a characteristic of which type of tissue?
   (a) epithelial (b) neural
   (c) muscle (d) connective
9. Functions of connective tissue include
   (a) establishing a structural framework for the body.
   (b) storing energy reserves.
   (c) providing protection for delicate organs.
   (d) all of these.
   (e) a and c only.
10. Which of the following epithelia most easily permits diffusion?
    (a) stratified squamous (b) simple squamous
    (c) transitional (d) simple columnar
11. The three major types of cartilage in the body are
    (a) collagen, reticular, and elastic.
    (b) areolar, adipose, and reticular.
    (c) hyaline, elastic, and fibrous.
    (d) tendons, reticular, and elastic.
12. The primary function of serous membranes in the body is to
    (a) minimize friction between opposing surfaces.
    (b) line cavities that communicate with the exterior.
    (c) perform absorptive and secretory functions.
    (d) cover the surface of the body.
13. The type of cartilage growth characterized by adding new layers of cartilage to the surface is
    (a) interstitial growth.
    (b) appositional growth.
    (c) intramembranous growth.
    (d) longitudinal growth.
14. Tissue changes with age can result from
    (a) hormonal changes. (b) increased need for sleep.
    (c) improper nutrition. (d) all of these.
    (e) a and c only.
15. Axons, dendrites, and a cell body are characteristic of cells located in
    (a) neural tissue. (b) muscle tissue.
    (c) connective tissue. (d) epithelial tissue.
16. The repair process necessary to restore normal function in damaged tissues is
    (a) isolation. (b) regeneration.
    (c) reconstruction. (d) all of these.
17. What are the four essential functions of epithelial tissue?
18. Differentiate between endocrine and exocrine glands.
19. By what three methods do various glandular epithelial cells release their secretions?
20. List three basic components of connective tissues.
21. What are the four kinds of membranes composed of epithelial and connective tissue that cover and protect other structures and tissues in the body?
22. What two cell populations make up neural tissue? What is the function of each?

**LEVEL 2 Reviewing Concepts**

23. What is the difference between an exocrine secretion and an endocrine secretion?
24. A significant structural feature in the digestive system is the presence of tight junctions near the exposed surfaces of cells lining the digestive tract. Why are these junctions so important?
25. Describe the fluid connective tissues in the human body. What are the main differences between fluid connective tissues and supporting connective tissues?
26. Why are infections always a serious threat after a severe burn or abrasion?
27. A layer of glycoproteins and a network of fine protein filaments that prevents the movement of proteins and other large molecules from the connective tissue to the epithelium describes
    (a) interfacial canals. (b) the basement membrane.
    (c) the reticular lamina. (d) areolar tissue.
    (e) squamous epithelium.
28. Why does damaged cartilage heal slowly?
    (a) Chondrocytes cannot be replaced if killed, and other cell types must take their place.
    (b) Cartilage is avascular, so nutrients and other molecules must diffuse to the site of injury.
    (c) Damaged cartilage becomes calcified, thus blocking the movement of materials required for healing.
    (d) Chondrocytes divide more slowly than other cell types, delaying the healing process.
    (e) Damaged collagen cannot be quickly replaced, thereby slowing the healing process.
29. List the similarities and differences among the three types of muscle tissue.

**LEVEL 3 Critical Thinking and Clinical Applications**

30. Assuming that you had the necessary materials to perform a detailed chemical analysis of body secretions, how could you determine whether a secretion was merocrine or apocrine?
31. During a lab practical, a student examines a tissue that is composed of densely packed protein fibers that are running parallel and form a cord. There are no striations, but small nuclei are visible. The student identifies the tissue as skeletal muscle. Why is the student's choice wrong, and what tissue is he probably observing?
32. While in a chemistry lab, Jim accidentally spills a small amount of a caustic chemical on his arm. What changes in the characteristics of the skin would you expect to observe, and what would cause these changes?