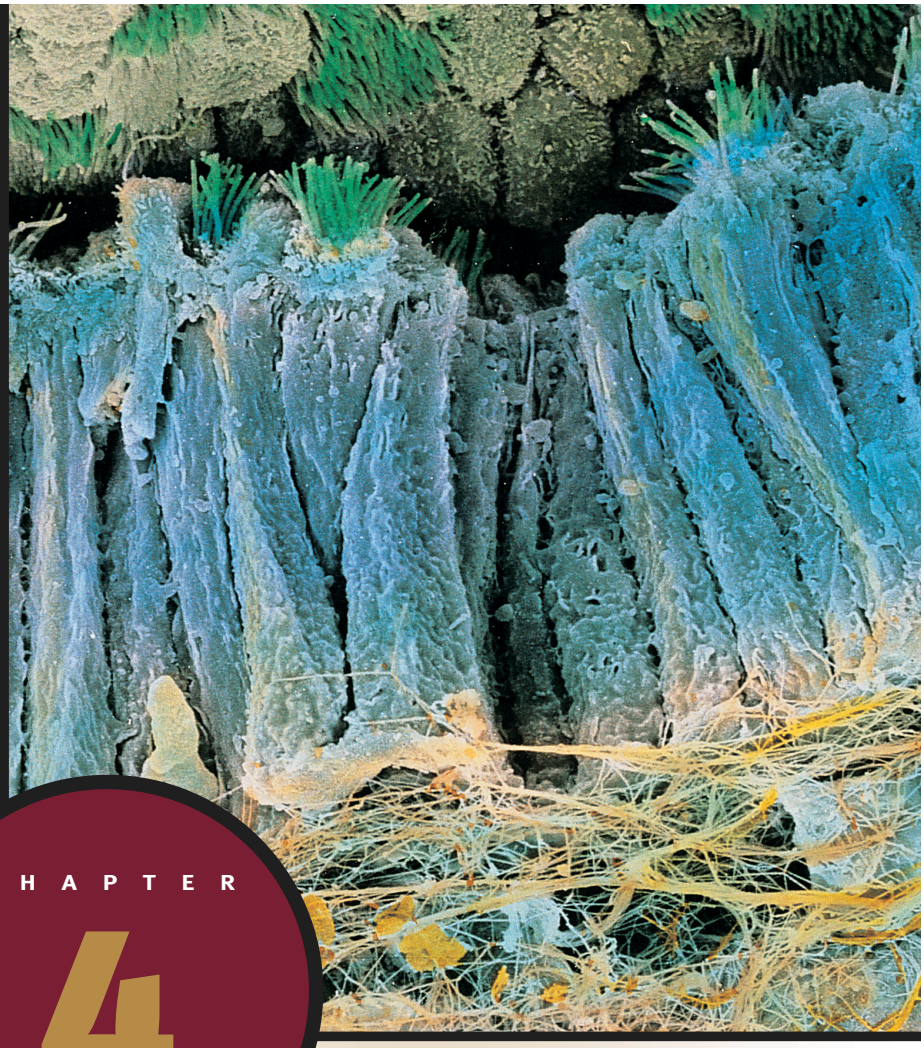
Histology: The Study of Tissues

CHAPTER 4



Colorized SEM of simple columnar epithelial cells, with cilia, of the uterine tube.

In some ways, the human body is like a complex machine such as a car. Both consist of many parts, which are made of materials consistent with their specialized functions. For example, the windows of a car are made of transparent glass, the tires are made of synthetic rubber reinforced with a variety of fibers, the engine is made of a variety of metal parts, and the hoses that move water, air, and gasoline are made of synthetic rubber or plastic. All parts of an automobile cannot be made of a single type of material. Metal capable of withstanding the heat of the engine cannot be used for windows or tires. Similarly, the many parts of the human body are made of collections of specialized cells and the materials surrounding them. Muscle cells, which contract to produce movements of the body, are structurally different and have different functions than those of epithelial cells, which protect, secrete, or absorb. Also, cells in the retina of the eye, specialized to detect light and allow us to see, do not contract like muscle cells or exhibit the functions of epithelial cells.

The structure and function of tissues are so closely related that you should be able to predict the function of a tissue when given its structure, and vice versa. Knowledge of tissue structure and function is important in understanding the structure and function of organs, organ systems, and the complete organism. This chapter begins with brief discussions of *tissues and histology* (105) and the development of *embryonic tissue* (105) and then describes the structural and functional characteristics of the major tissue types: *epithelial tissue* (105), *connective tissue* (117), *classification of connective tissue* (119), *muscle tissue* (128), and *nervous tissue* (129). In addition, the chapter provides an explanation of *membranes* (132), *inflammation* (133), and *tissue repair* (135).

Tissues and Histology

Objectives

- *List the characteristics used to classify tissues into one of the four major tissue types.*
- *Define histology and explain its importance in assessing health.*

Tissues (tish′ūz) are collections of similar cells and the substances surrounding them. Specialized cells and the extracellular matrix surrounding them form all the different tissue types found at the **tissue level of organization.** The classification of tissue types is based on the structure of the cells; the composition of the noncellular substances surrounding cells, called the **extracellular matrix;** and the functions of the cells. The four primary tissue types, which include all tissues, and from which all organs of the body are formed, are

1. epithelial tissue;
2. connective tissue;
3. muscle tissue;
4. nervous tissue.

Epithelial and connective tissues are the most diverse in form. The different types of epithelial and connective tissues are classified by structure, including cell shape, relationship of cells to one another, and the material making up the extracellular matrix. In contrast, muscle and nervous tissues are classified mainly by function.

The tissues of the body are interdependent. For example, muscle tissue cannot produce movement unless it receives oxygen carried by red blood cells, and new bone tissue cannot be formed unless epithelial tissue absorbs calcium and other nutrients from the digestive tract. Also, all tissues in the body die if cancer or some other disease destroys the tissues of vital organs such as the liver or kidneys.

Histology (his-tol′ō-jē) is the microscopic study of tissues. Much information about the health of a person can be gained by examining tissues. A **biopsy** (bī′op-sē) is the process of removing tissue samples from patients surgically or with a needle for diagnostic purposes. Examining tissue samples from individuals with various disorders can distinguish the specific disease. For example, some red blood cells have an abnormal shape in people suffering from sickle-cell disease, and red blood cells are smaller than normal in people with iron-deficiency anemia. White blood cells have an abnormal structure in people who have leukemia, and the white blood cell number can be greatly increased in people who have infections. Epithelial cells from respiratory passages have an abnormal structure in people with chronic bronchitis and in people with lung cancer. Tissue samples can be sent to a laboratory and results are reported after tissue preparation and examination. In some cases tissues can be removed surgically, prepared quickly, and results reported while the patient is still anesthetized. The appropriate surgical procedure is based to a large degree on the results. For example, the amount of tissue removed as part of breast or other types of cancer surgery can be determined by the results.

An **autopsy** (aw′top-sē) is an examination of the organs of a dead body to determine the cause of death or to study the changes caused by a disease. Microscopic examination of tissue is often part of an autopsy.

1. *Name the four primary tissue types, and list three characteristics used to classify them. How does the classification of epithelial and connective tissue differ from the classification of muscle and nervous tissue?*
2. *Define histology. Explain how microscopic examination of cells by biopsy or autopsy can diagnose some diseases.*

Embryonic Tissue

Objective

- *Name and describe the derivatives of the three embryonic germ layers.*

Approximately 13 or 14 days after fertilization, the cells that give rise to a new individual, called embryonic stem cells, form a slightly elongated disk consisting of two layers called ectoderm and endoderm. Cells of the ectoderm then migrate between the two layers to form a third layer called mesoderm. Ectoderm, mesoderm, and endoderm are called germ layers because the beginning of all adult structures can be traced back to one of them (see chapter 29).

The **endoderm** (en′dō-derm), the inner layer, forms the lining of the digestive tract and its derivatives. The **mesoderm** (mez′ō-derm), the middle layer, forms tissues such as muscle, bone, and blood vessels. The **ectoderm** (ek′tō-derm), the outer layer, forms the skin, and a portion of the ectoderm, called **neuroectoderm** (noor-ō-ek′tō-derm), becomes the nervous system (see chapter 13). Groups of cells that break away from the neuroectoderm during development, called neural crest cells, give rise to parts of the peripheral nerves (see chapters 11, 12, and 14), skin pigment (see chapter 5), and many tissues of the face.

3. *What adult structures are derived from endoderm, mesoderm, ectoderm, neuroectoderm, and neural crest cells?*

Epithelial Tissue

Objectives

- *List the features that characterize epithelium.*
- *Describe the characteristics that are used to classify epithelia.*
- *Describe the relationship between the structures of the different types of epithelia and their functions.*
- *Define the term gland, and describe the two major categories of glands.*

Epithelium (ep-i-thē′lē-ŭm; pl., epithelia, ep-i-thē′lē-ă) or **epithelial tissue** can be thought of as a protective covering of surfaces, both outside and inside the body. Characteristics common to most types of epithelium are (figure 4.1):

1. Epithelium consists almost entirely of cells, with very little extracellular material between them.
2. Epithelium covers surfaces of the body and forms glands that are derived developmentally from body surfaces. The body surfaces include the outside surface of the body, the lining of the digestive tract, the vessels, and the linings of many body cavities.

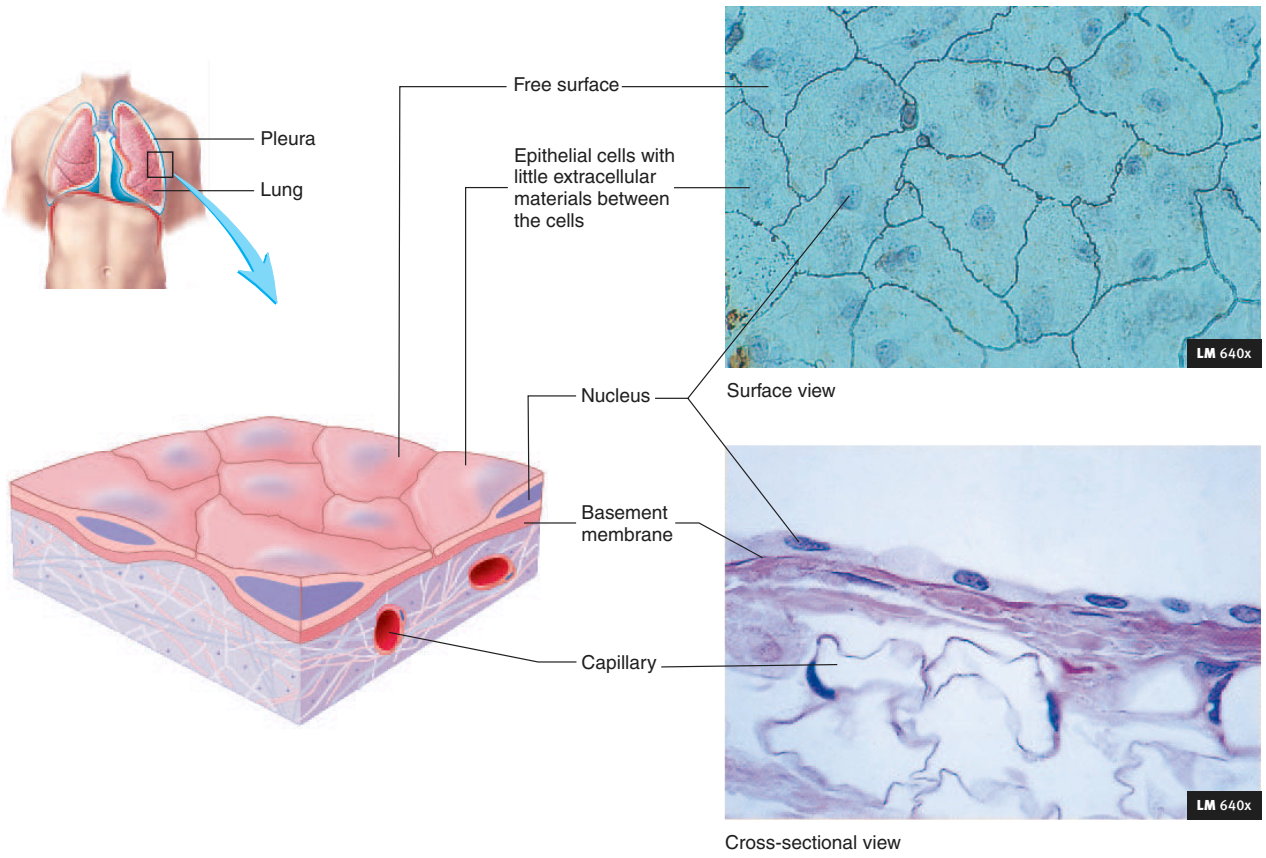


Figure 4.1 Characteristics of Epithelium

Surface and cross-sectional views of epithelium illustrate the following characteristics: little extracellular material between cells, a free surface, a basement membrane attaching epithelial cells to underlying tissues. Capillaries in connective tissue do not penetrate the basement membrane. Nutrients, oxygen, and waste products must diffuse across the basement membrane between the capillaries and the epithelial cells.

3. Most epithelial tissues have one **free,** or **apical** (ap′i-kăl), **surface** not attached to other cells; a **lateral surface,** attached to other epithelial cells; and a **basal surface.** The basal surface of most epithelial tissues is attached to a **basement membrane.** The basement membrane is a specialized type of extracellular material that is secreted by the epithelial cells and by connective tissue cells. It is like the adhesive on the underside of Scotch tape. It helps attach the epithelial cells to the underlying tissues, and it plays an important role in supporting and guiding cell migration during tissue repair. A few epithelia, such as in lymphatic capillaries and liver sinusoids, do not have basement membranes, and some epithelial tissues (e.g., in some endocrine glands) do not have a free surface or a basal surface with a basement membrane.
4. Specialized cell contacts, such as tight junctions and desmosomes, bind adjacent epithelial cells together.
5. Blood vessels do not penetrate the basement membrane to reach the epithelium; thus all gases and nutrients carried in the blood must reach the epithelium by diffusing across the basement membrane from blood vessels in the underlying connective tissue. In epithelia with many layers of cells, the most metabolically active cells are close to the basement membrane.
6. Epithelial cells retain the ability to undergo mitosis and therefore are able to replace damaged cells with new epithelial cells. Undifferentiated cells (stem cells) continuously divide and produce new cells. In some types of epithelia, such as in the skin and in the digestive tract, cells that are lost or die are continuously replaced by new cells.

Functions of Epithelia

Major functions of epithelia include:

1. *Protecting underlying structures.* Examples include the skin and the epithelium of the oral cavity, which protects the underlying structures from abrasion.
2. *Acting as barriers.* Epithelium prevents the movement of many substances through the epithelial layer. For example, the skin acts as a barrier to water and prevents water loss from the body. The skin is also a barrier that prevents the

Clinical Focus Microscopic Imaging

We see objects because light either passes through them or is reflected off them and enters our eyes (see chapter 15). We are limited, however, in what we can see with the unaided eye. Without the aid of magnifying lenses, the smallest objects we can resolve, or identify as separate objects, are approximately 100 μm, or 0.1 mm, in diameter, which is approximately the size of a fine pencil dot. Resolution is a measure of the ability to distinguish detail in small objects, and a microscope can be used to resolve structures less than 100 μm in diameter.

Two basic types of microscopes have been developed: light microscopes and electron microscopes. As their names imply, light microscopes use light to produce an image, and electron microscopes use beams of electrons. **Light microscopes** usually use transmitted light, which is light that passes through the object being examined, but some light microscopes are equipped to use reflected light. Glass lenses are used in light microscopes to magnify images, and images can either be observed directly by looking into the microscope, or the light from the images can be used to expose photographic film to make a photomicrograph of the images. Video cameras are also used to record images. The resolution of light microscopes is limited by the wavelength of light, the lower limit of which is approximately 0.1 μm—about the size of a small bacterium.

A biopsy is the process of removing tissue from living patients for diagnostic examination. For example, changes in tissue structure allow pathologists to identify tumors and to distinguish between noncancerous (benign) and cancerous (malignant) tumors. Light microscopy is used on a regular basis to examine biopsy specimens. Light microscopy is used instead of electron microscopy because less time and effort are required to prepare materials for examination, and the resolution is adequate to diagnose most conditions that cause changes in tissue structure.

Because images are usually produced using transmitted light, tissues to be examined must be cut very thinly to allow the light to pass through them. Sections are routinely cut between 1 and 20 μm thick to make them thin enough for light microscopy. To cut such thin sections, the tissue must be fixed or frozen, which is a process that preserves the tissue and makes it more rigid. Fixed tissues are then embedded in some material, such as wax or plastic, that makes the tissue rigid enough for cutting into sections. Frozen sections, which can be prepared rapidly, are rigid enough for sectioning, but tissue embedded in wax or plastic can be cut much thinner, which makes the image seen through the microscope clearer. Because most tissues are colorless and transparent when thinly sectioned, the tissue must be colored with a stain or dye so that the structural details can be seen. As a result, the colors seen in color photomicrographs are not the true colors of the tissue but instead are the colors of the stains used. The color of the stain can also provide specific information about the tissue, because special stains color only certain structures.

To see objects much smaller than a cell, such as cell organelles, an **electron microscope,** which has a limit of resolution of approximately 0.1 nm, must be used; 0.1 nm is about the size of some molecules. In objects viewed through an electron microscope, a beam of electrons either is passed through objects using a transmission electron microscope (TEM) or is reflected off the surface of objects using a scanning electron microscope (SEM). The electron beam is focused with electromagnets. For both processes, the specimen must be fixed, and for TEM the specimen must be embedded in plastic and thinly sectioned (0.01–0.15 μm thick). Care must be taken when examining specimens in an electron microscope because a focused electron beam can cause most tissues to quickly disintegrate. Furthermore, the electron beam is not visible to the human eye; thus it must be directed onto a fluorescent or photographic plate on which the electron beam is converted into a visible image. Because the electron beam does not transmit color information, electron micrographs are black and white unless color enhancement has been added using computer technology.

The magnification ability of SEM is not as great as that of TEM; however, depth of focus of SEM is much greater and allows for the production of a clearer three-dimensional image of the tissue structure.

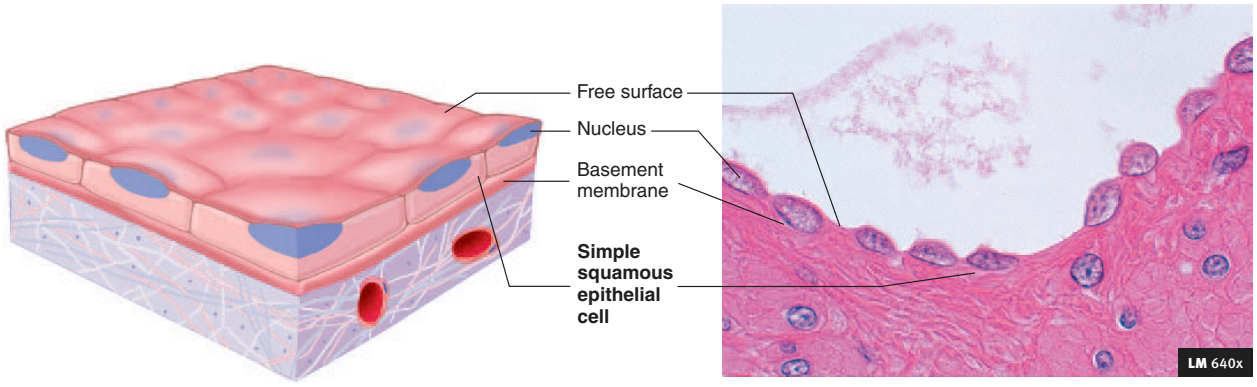
entry of many toxic molecules and microorganisms into the body.

3. *Permitting the passage of substances.* Epithelium allows the movement of many substances through the epithelial layer. For example, oxygen and carbon dioxide are exchanged between the air and blood by diffusion through the epithelium in the lungs.
4. *Secreting substances.* Examples include the sweat glands, mucous glands, and the enzyme-secreting portion of the pancreas.
5. *Absorbing substances.* The cell membranes of certain epithelial tissues contain carrier molecules (see chapter 3) that regulate the absorption of materials.

Classification of Epithelium

The major types of epithelia and their distributions are illustrated in figure 4.2. Epithelium is classified primarily according to the number of cell layers and the shape of the superficial cells. There are three major types of epithelium based on the number of cell layers in each type.

1. **Simple epithelium** consists of a single layer of cells, with each cell extending from the basement membrane to the free surface.
2. **Stratified epithelium** consists of more than one layer of cells, only one of which is attached to the basement membrane.

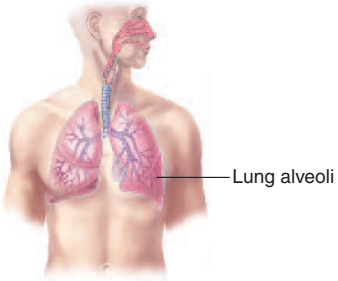


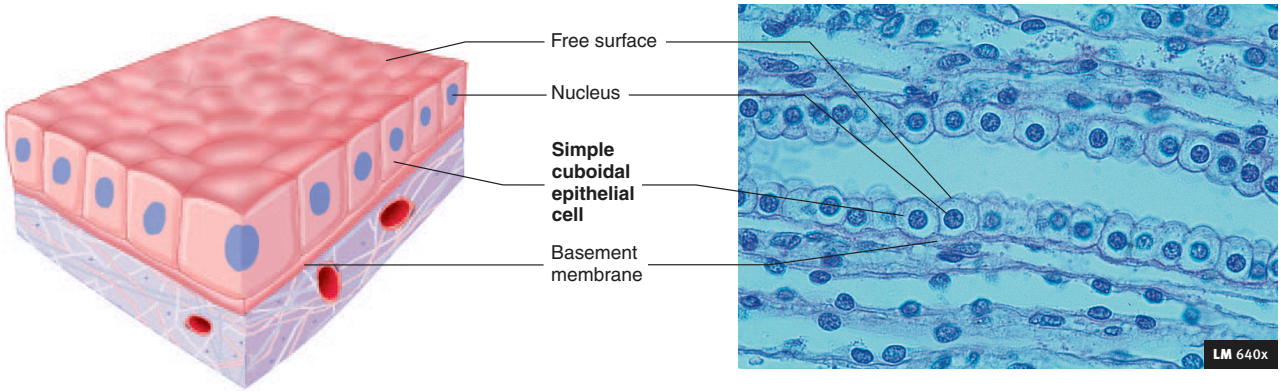
(a) **Simple squamous epithelium**

Location: Lining of blood and lymphatic vessels (endothelium) and small ducts, alveoli of the lungs, loop of Henle in kidney tubules, lining of serous membranes (mesothelium), and inner surface of the eardrum.

Structure: Single layer of flat, often hexagonal cells. The nuclei appear as bumps when viewed as a cross section because the cells are so flat.

Function: Diffusion, filtration, some protection against friction, secretion, and absorption.





(b) **Simple cuboidal epithelium**

Location: Kidney tubules, glands and their ducts, choroid plexus of the brain, lining of terminal bronchioles of the lungs, and surface of the ovaries.

Structure: Single layer of cube-shaped cells; some cells have microvilli (kidney tubules) or cilia (terminal bronchioles of the lungs).

Function: Active transport and facilitated diffusion result in secretion and absorption by cells of the kidney tubules; secretion by cells of glands and choroid plexus; movement of particles embedded in mucus out of the terminal bronchioles by ciliated cells.

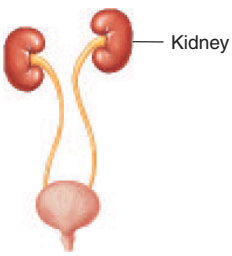
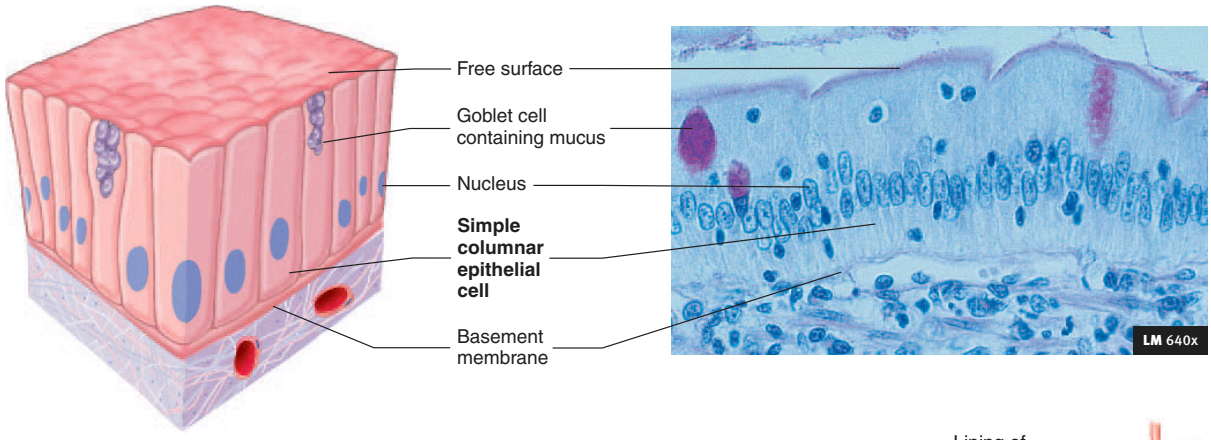
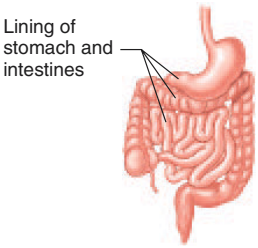


Figure 4.2 Types of Epithelium



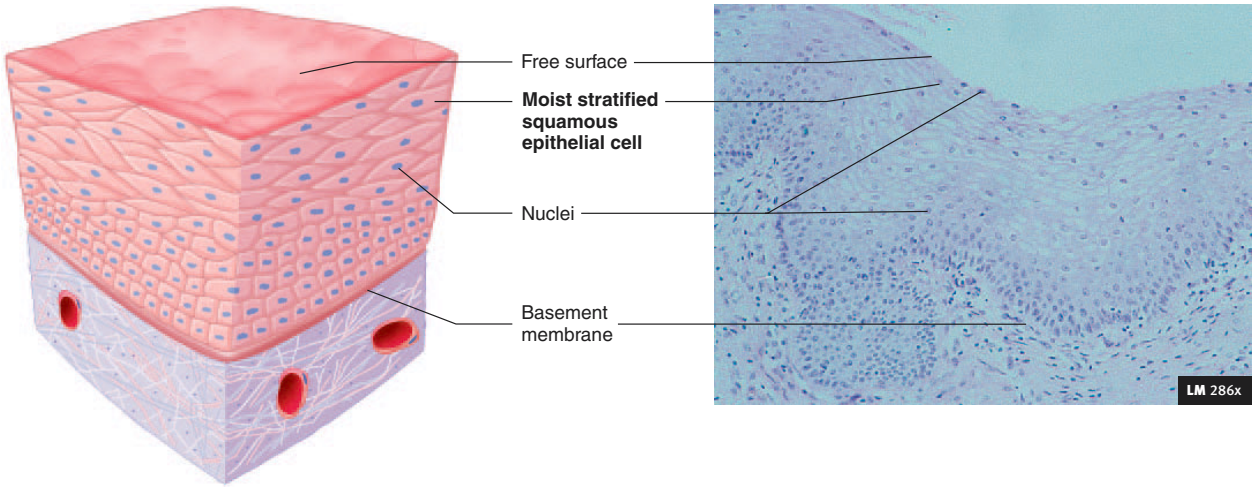


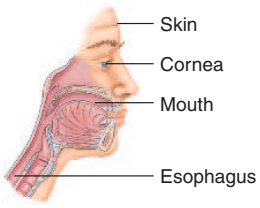
(c) **Simple columnar epithelium**

Location: Glands and some ducts, bronchioles of lungs, auditory tubes, uterus, uterine tubes, stomach, intestines, gallbladder, bile ducts, and ventricles of the brain.

Structure: Single layer of tall, narrow cells. Some cells have cilia (bronchioles of lungs, auditory tubes, uterine tubes, and uterus) or microvilli (intestines).

Function: Movement of particles out of the bronchioles of the lungs by ciliated cells; partially responsible for the movement of the oocyte through the uterine tubes by ciliated cells. Secretion by cells of the glands, the stomach, and the intestine. Absorption by cells of the intestine.





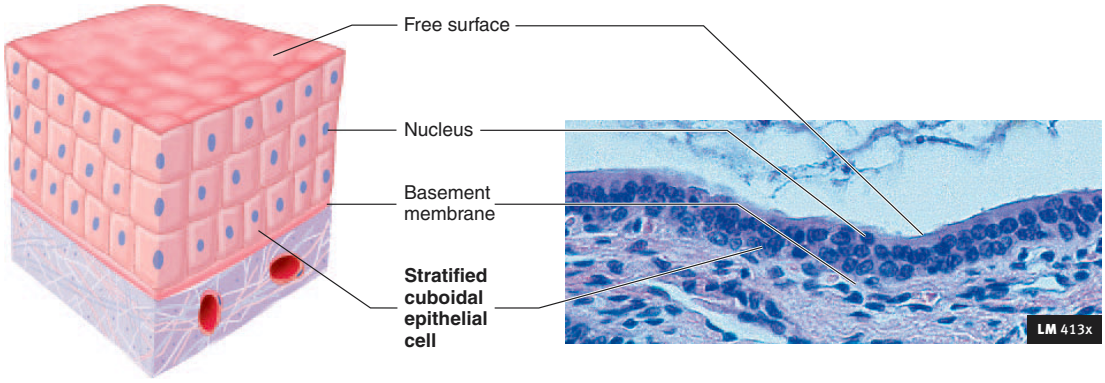
(d) **Stratified squamous epithelium**

Location: Moist–mouth, throat, larynx, esophagus, anus, vagina, inferior urethra, and cornea. Keratinized–skin.

Structure: Multiple layers of cells that are cuboidal in the basal layer and progressively flattened toward the surface. The epithelium can be moist or keratinized. In moist stratified squamous epithelium the surface cells retain a nucleus and cytoplasm. In keratinized stratified epithelium, the cytoplasm of cells at the surface is replaced by keratin, and the cells are dead.

Function: Protection against abrasion and infection.

Figure 4.2 *(continued)*

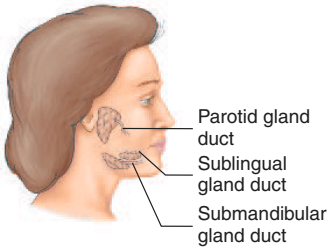


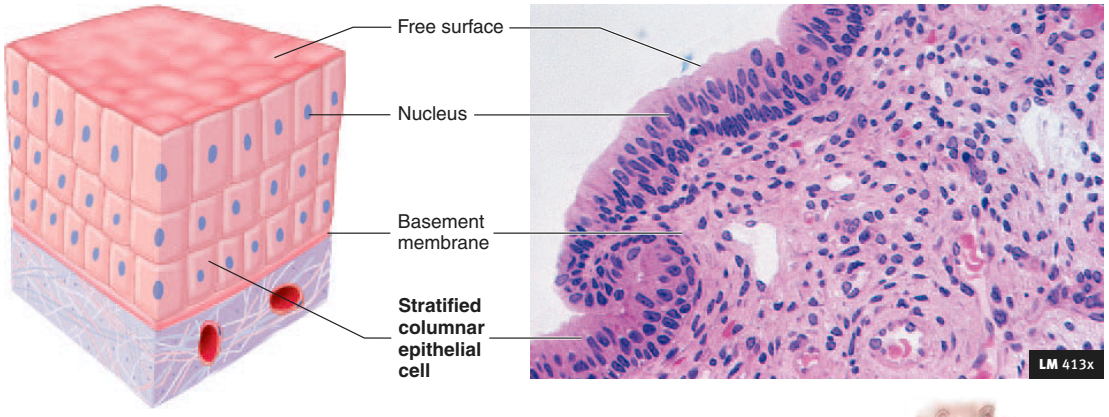
(e) **Stratified cuboidal epithelium**

Location: Sweat gland ducts, ovarian follicular cells, and salivary gland ducts.

Structure: Multiple layers of somewhat cube-shaped cells.

Function: Secretion, absorption, and protection against infection.





(f) **Stratified columnar epithelium**

Location: Mammary gland duct, larynx, and a portion of the male urethra.

Structure: Multiple layers of cells, with tall, thin cells resting on layers of more cuboidal cells. The cells are ciliated in the larynx.

Function: Protection and secretion.

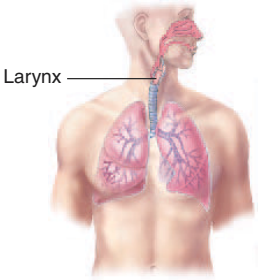
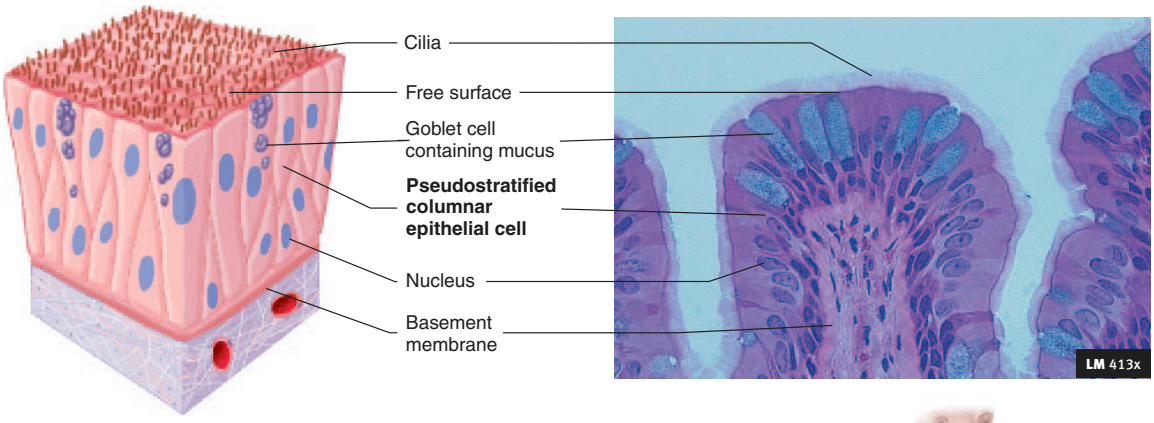


Figure 4.2 *(continued)*

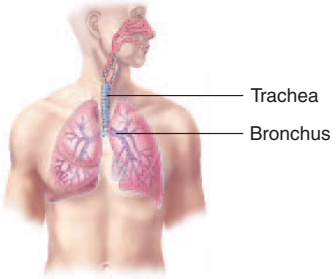


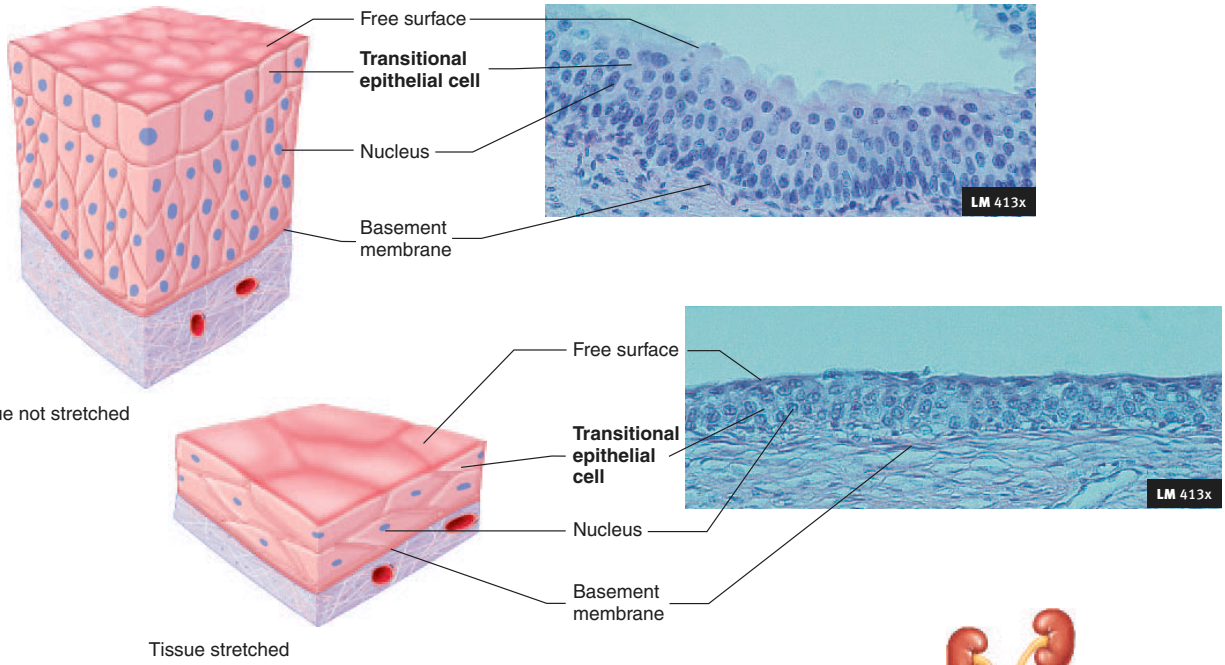
(g) **Pseudostratified columnar epithelium**

Location: Lining of nasal cavity, nasal sinuses, auditory tubes, pharynx, trachea, and bronchi of lungs.

Structure: Single layer of cells; some cells are tall and thin and reach the free surface, and others do not; the nuclei of these cells are at different levels and appear stratified; the cells are almost always ciliated and are associated with goblet cells that secrete mucus onto the free surface.

Function: Synthesize and secrete mucus onto the free surface and move mucus (or fluid) that contains foreign particles over the surface of the free surface and from passages.





(h) **Transitional epithelium**

Location: Lining of urinary bladder, ureters, and superior urethra.

Structure: Stratified cells that appear cuboidal when the organ or tube is not stretched and squamous when the organ or tube is stretched by fluid.

Function: Accommodates fluctuations in the volume of fluid in an organ or tube; protection against the caustic effects of urine.

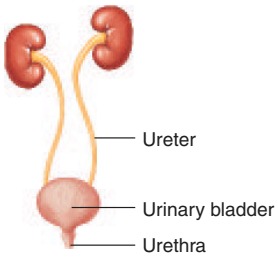


Figure 4.2 *(continued)*

3. **Pseudostratified columnar epithelium** (figure 4.2*g*) is a special type of simple epithelium. The prefix pseudo- means false, so this type of epithelium appears to be stratified but is not. It consists of one layer of cells, with all the cells attached to the basement membrane. There is an appearance of two or more layers of cells because some of the cells are tall and reach the free surface. Pseudostratified columnar epithelium is found lining some of the respiratory passages, such as the nasal cavity, trachea, and bronchi. Pseudostratified columnar epithelium secretes mucus, which covers its surface, and cilia located on the free surface move the mucus and the debris that accumulates in it over the surfaces of the respiratory passages and toward the exterior of the body.

There are three types of epithelium based on the shape of the epithelial cells.

1. **Squamous** (skwā′mŭs; flat) cells are flat or scalelike.
2. **Cuboidal** (cubelike) cells are cube-shaped; about as wide as they are tall.
3. **Columnar** (tall and thin, similar to a column) cells are taller than they are wide.

In most cases an epithelium is given two names, such as simple squamous, stratified squamous, simple columnar, or pseudostratified columnar. The first name indicates the number of layers, and the second indicates the shape of the cells (table 4.1) at the free surface.

Stratified squamous epithelium can be classified further as either moist or keratinized, according to the condition of the outermost layer of cells. **Moist stratified squamous epithelium** (figure 4.2*d*), found in areas such as the mouth, esophagus, rectum, and vagina, consists of living cells in the deepest and outermost layers. A layer of fluid covers the outermost layers of cells, which makes them moist. In contrast, **keratinized** (ker′ă-ti-nizd) **stratified squamous epithelium,** found in the skin (see chapter 5), consists of living cells in the deepest layers, and the outer layers are composed of dead cells containing the protein keratin. The dead, keratinized cells give the tissue a durable, moisture-resistant, dry character.

A unique type of stratified epithelium called **transitional epithelium** (figure 4.2*h*) lines the urinary bladder, ureters, and pelvis of the kidney including the major and minor calyces (kal′-i-sēz). These are structures where considerable expansion can occur. The shape of the cells and the number of cell layers vary, depending on whether the transitional epithelium is stretched or not. The surface cells and the underlying cells are roughly cuboidal or columnar when the epithelium is not stretched, and they become more flattened or squamouslike when the epithelium is stretched. Also, the number of layers of epithelial cells decreases in response to stretch. As the epithelium is stretched, the epithelial cells have the ability to shift on one another so that the number of layers decreases from five or six to two or three.

4. *List six characteristics common to most types of epithelium. Define free (apical), lateral, and basal surfaces of epithelial cells.*

Table 4.1 Classification of Epithelium

Number of Layers or Category	Shape of Cells
Simple (single layer of cells)	Squamous Cuboidal Columnar
Stratified (more than one layer of cells)	Squamous Moist Keratinized Cuboidal (very rare) Columnar (very rare)
Pseudostratified (modification of simple epithelium)	Columnar
Transitional (modification of stratified epithelium)	Roughly cuboidal to columnar when not stretched and squamouslike when stretched

5. *What is the basement membrane and what are its functions? Why must metabolically active epithelial cells be close to the basement membrane?*
6. *List six major functions of epithelia.*
7. *Describe simple, stratified, and pseudostratified epithelia. Distinguish between squamous, cuboidal, and columnar epithelial cells.*
8. *How do moist stratified squamous epithelium and keratinized stratified squamous epithelium differ? Where is each type found?*
9. *Describe the change in shape and number of layers that occurs in cells of transitional epithelium. Where is transitional epithelium found?*

Functional Characteristics

Epithelial tissues have many functions (table 4.2), including forming a barrier between a free surface and the underlying tissues and secreting, transporting, and absorbing selected molecules. The type and arrangement of organelles within each cell (see chapter 3), the shape of cells, and the organization of cells within each epithelial type reflect these functions. Accordingly, structural specializations of epithelial cells are consistent with the functions they perform.

Cell Layers and Cell Shapes

Simple epithelium, with its single layer of cells, covers surfaces in organs and functions to control diffusion of gases (lungs), filter blood (kidneys), secrete cellular products (glands), or absorb nutrients (intestines). The selective movement of materials through epithelium would be hindered by a stratified epithelium,

which is found in areas where protection is a major function. The multiple layers of cells in stratified epithelium are well adapted for a protective role because, as the outer cells are damaged, they are replaced by cells from deeper layers and a continuous barrier of epithelial cells is maintained in the tissue. Stratified squamous epithelium is found in areas of the body where abrasion can occur, such as the skin, mouth, throat, esophagus, anus, and vagina.

Differing functions are also reflected in cell shape. Cells that allow substances to diffuse through them and that filter are normally flat and thin. For example, simple squamous epithelium forms blood and lymphatic capillaries, the alveoli (air sacs) of the lungs, and parts of the kidney tubules. Cells that secrete or absorb are usually cuboidal or columnar. They have greater cytoplasmic volume compared to that of squamous epithelial cells; this cytoplasmic volume results from the presence of organelles responsible for the tissues' functions. For example, pseudostratified columnar epithelium, which secretes large amounts of mucus, lines the respiratory tract (see chapter 23) and contains large **goblet cells,** which are specialized columnar epithelial cells. The goblet cells contain abundant organelles responsible for the synthesis and secretion of mucus, such as ribosomes, endoplasmic reticulum, Golgi apparatuses, and secretory vesicles filled with mucus.

P R E D I C T 1

Explain the consequences of having (a) moist stratified epithelium rather than simple columnar epithelium lining the digestive tract, (b) moist stratified squamous epithelium rather than keratinized stratified squamous epithelium in the skin, and (c) simple columnar epithelium rather than moist stratified squamous epithelium lining the mouth.

Cell Surfaces

The free surfaces of epithelia can be smooth, contain microvilli, be ciliated, or be folded. Smooth surfaces reduce friction. Simple squamous epithelium with a smooth surface forms the covering of serous membranes. The lining of blood vessels is a simple squamous epithelium that reduces friction as blood flows through the vessels (see chapter 21).

Microvilli and cilia were described in chapter 3. Microvilli are nonmotile and contain microfilaments. They greatly increase surface area and are found in cells that absorb or secrete, such as the lining of the small intestine (see chapter 24). Stereocilia are elongated microvilli. They are found where absorption is an important function, and are found in places such as in the epithelium of the epididymis. Cilia are motile and contain microtubules. They move materials across the surface of the cell. Simple ciliated cuboidal, simple ciliated columnar, and pseudostratified ciliated columnar epithelia are in the respiratory tract (see chapter 23), where cilia move mucus that contains foreign particles like dust out of the respiratory passages.

Transitional epithelium has a rather unusual plasma membrane specialization: More rigid sections of membrane are separated by very flexible regions in which the plasma membrane is folded. When transitional epithelium is stretched, the folded regions of the plasma membrane can unfold. Transitional epithelium is specialized to expand. It is found in the urinary bladder, ureters, kidney pelvis, and calyces of the kidney.

Cell Connections

Lateral and basilar surfaces have structures that serve to hold cells to one another or to the basement membrane (figure 4.3). These structures do three things: (1) they mechanically bind the cells together, (2) they help form a permeability barrier, and (3) they provide a mechanism for intercellular communication. Epithelial cells secrete glycoproteins that attach the cells to the basement membrane and to one another. This relatively weak binding between cells is reinforced by **desmosomes** (dez′mō-sōmz), disk-shaped structures with especially adhesive glycoproteins that bind cells to one another and intermediate filaments that extend into the cytoplasm of the cells. Many desmosomes are found in epithelia that are subjected to stress, such as the stratified squamous epithelium of the skin. **Hemidesmosomes,** similar to one-half of a desmosome, attach epithelial cells to the basement membrane.

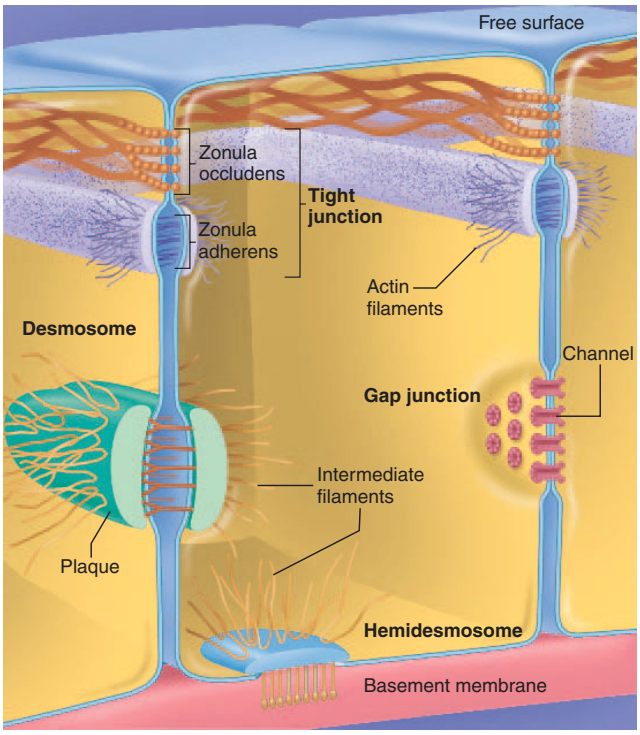


Figure 4.3 Cell Connections

Desmosomes anchor cells to one another and hemidesmosomes anchor cells to the basement membrane. Tight junctions consist of a zonula occludens and zonula adherens. Gap junctions allow adjacent cells to communicate with each other. Few cells have all of these different connections.

Table 4.2 Function and Location of Epithelial Tissue

Function	Simple Squamous Epithelium	Simple Cuboidal Epithelium	Simple Columnar Epithelium
Diffusion	Blood and lymph capillaries, alveoli of lungs, thin segment of loop of Henle		
Filtration	Bowman's capsule of kidney		
Secretion or absorption	Mesothelium (serous fluid)	Choroid plexus (produces cerebrospinal fluid), part of kidney tubule, many glands and their ducts	Stomach, small intestine, large intestine, uterus, many glands
Protection (against friction and abrasion)	Endothelium (e.g., epithelium of blood vessels) Mesothelium (e.g., epithelium of body cavities)		
Movement of mucus (ciliated)		Terminal bronchioles of lungs	Bronchioles of lungs, auditory tubes, uterine tubes, uterus
Capable of great stretching			
Miscellaneous	Lines the inner part of the eardrum, smallest ducts of glands	Surface of ovary, inside lining of eye (pigmented epithelium of retina), ducts of glands	Bile duct, gallbladder, ependyma (lining of brain ventricles and central canal of spinal cord), ducts of glands

Tight junctions hold cells together and form a permeability barrier (see figure 4.3). They consist of a zonula adherens and a zonula occludens, which are found in close association with each other. The **zonula adherens** (zō′nū-lă, zon′ū-lă ad-hēr′enz) is located between the plasma membranes of adjacent cells and acts like a weak glue that holds cells together. The zonulae adherens are best developed in simple epithelial tissues; they form a girdle of adhesive glycoprotein around the lateral surface of each cell and bind adjacent cells together. These connections are not as strong as desmosomes.

The **zonula occludens** (ō-klood′enz) forms a permeability barrier. It is formed by plasma membranes of adjacent cells that join one another in a jigsaw fashion to form a tight seal (see figure 4.3). Near the free surface of simple epithelial cells, the zonulae occludens form a ring that completely surrounds each cell and binds adjacent cells together. The zonulae occludens prevent the passage of materials between cells. For example, in the stomach and in the urinary bladder chemicals cannot pass between cells. Thus water and other substances must pass through the epithelial cells, which can actively regulate what is absorbed or secreted. Zonulae occludens are found in areas where a layer of simple epithelium forms a permeability barrier. For example, water can diffuse through epithelial cells, and active transport, cotransport, and facilitated diffusion move most nutrients through the epithelial cells of the intestine.

A **gap junction** is a small specialized contact region between cells containing protein channels that aid intercellular communication by allowing ions and small molecules to pass from one cell to another (see figure 4.3). The exact function of gap junctions in epithelium is not entirely clear, but they are important in coordinating the function of cardiac and smooth muscle tissues. Because ions can pass through the gap junctions from one cell to the next, electric signals can pass from cell to cell to coordinate the contraction of cardiac and smooth muscle cells. Thus electric signals that originate in one cell of the heart can spread from cell to cell and cause the entire heart to contract. The gap junctions between cardiac muscle cells are found in specialized cell-to-cell connections called **intercalated disks.** Gap junctions between ciliated epithelial cells may function to coordinate the movements of the cilia.

10. *What kind of functions would a single layer of epithelial cells be expected to perform? A stratified layer?*
11. *In locations in which diffusion or filtration is occurring, what shape would you expect the epithelial cells to be?*

Stratified Squamous Epithelium	Stratified Cuboidal Epithelium	Stratified Columnar Epithelium	Pseudostratified Columnar Epithelium	Transitional Epithelium
Skin (epidermis), cornea, mouth and throat, epiglottis, larynx, esophagus, anus, vagina				
			Larynx, nasal cavity, paranasal sinus, nasopharynx, auditory tube, trachea, bronchi of lungs	
				Urinary bladder, ureter, upper part of urethra
Lower part of urethra, sebaceous gland duct	Sweat gland ducts	Part of male urethra, epididymis, ductus deferens, mammary gland duct	Part of male urethra, salivary gland duct	

12. ***Why are cuboidal or columnar cells found where secretion or absorption is occurring?***
13. ***What is the function of an epithelial free surface that is smooth, has cilia, has microvilli, or is folded? Give an example of epithelium in which each surface type is found.***
14. ***Name the ways in which epithelial cells are bound to one another and to the basement membrane.***
15. ***In addition to holding cells together, name an additional function of tight junctions. What is the general function of gap junctions?***

Glands

Glands are secretory organs. Most glands are composed primarily of epithelium, with a supporting network of connective tissue. These glands develop from an infolding or outfolding of epithelium in the embryo. If the gland maintains an open contact with the epithelium from which it developed, a duct is present. Glands with ducts are called **exocrine** (ek′sō-krin) **glands,** and their ducts are lined with epithelium. Alternatively, some glands become separated from the epithelium of their origin. Glands that have no ducts are called **endocrine** (en′dō-krin) **glands.** Endocrine glands have extensive blood vessels in the connective tissue of the glands. The cellular products of endocrine glands, which are called **hormones** (hōr′mōnz), are secreted into the bloodstream and are carried throughout the body. Some of the endocrine glands, such as the adrenal gland, form from non-epithelial tissue.

Most exocrine glands are composed of many cells and are called **multicellular glands,** but some exocrine glands are composed of a single cell and are called **unicellular glands** (figure 4.4*a*). **Goblet cells** (see figure 4.2*c*) of the respiratory system are unicellular glands that secrete mucus. Multicellular glands can be classified further according to the structure of their ducts (figure 4.4*b–i*). Glands that have ducts with few branches are called **simple,** and glands with ducts that branch repeatedly are called **compound.** Further classification is based on whether the ducts end in **tubules** (small tubes) or saclike structures called **acini** (as′i-nī; grapes, suggesting a cluster of grapes or small sacs) or **alveoli** (al-vē′ō-lī; a hollow sac). Tubular glands can be classified as straight or coiled. Most tubular glands are simple and straight, simple and coiled, or compound and coiled. Acinar glands can be simple or compound.

Exocrine glands can also be classified according to how products leave the cell. **Merocrine** (mer′ō-krin) **glands,** such as water-producing sweat glands and the exocrine portion of the

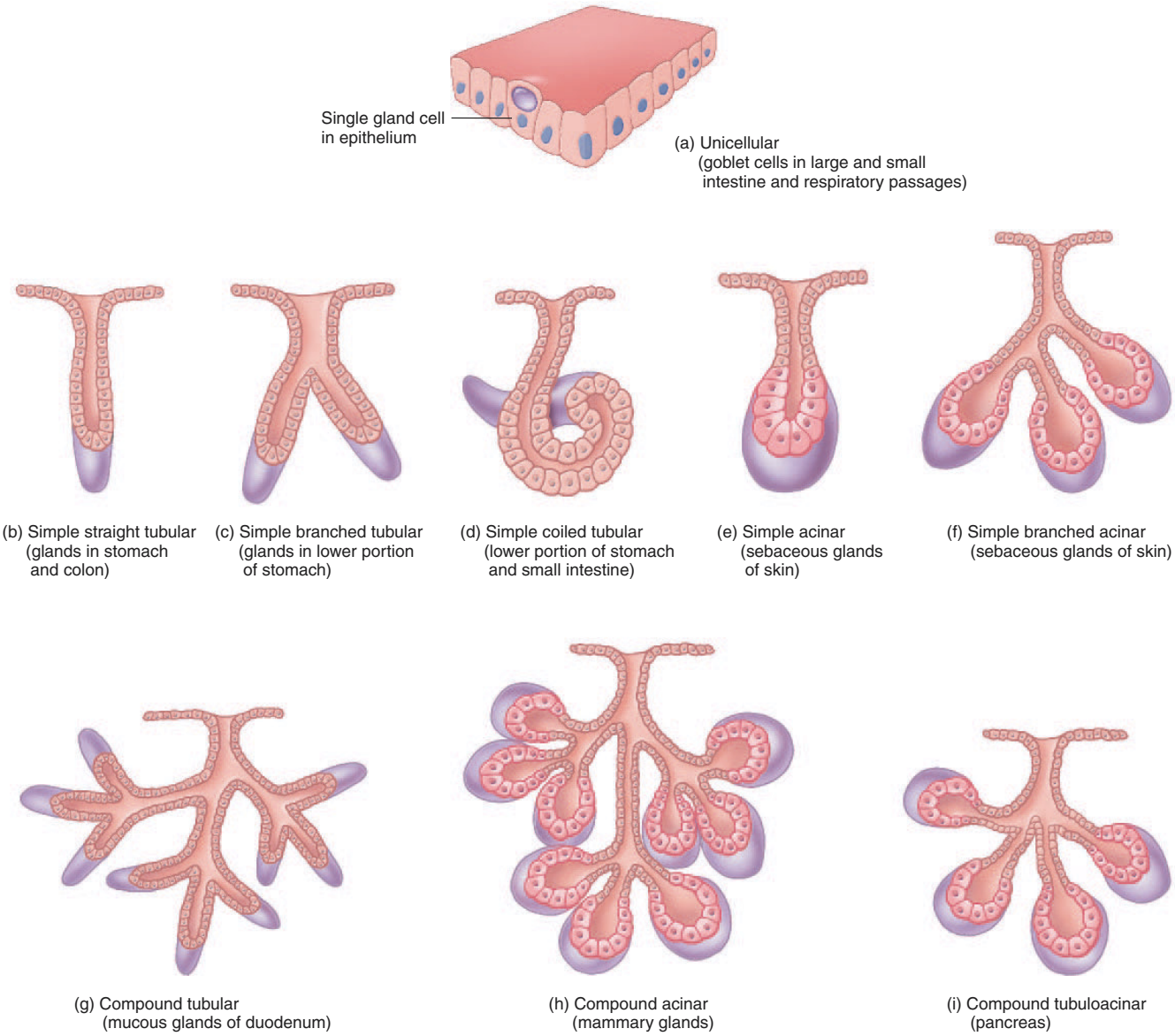


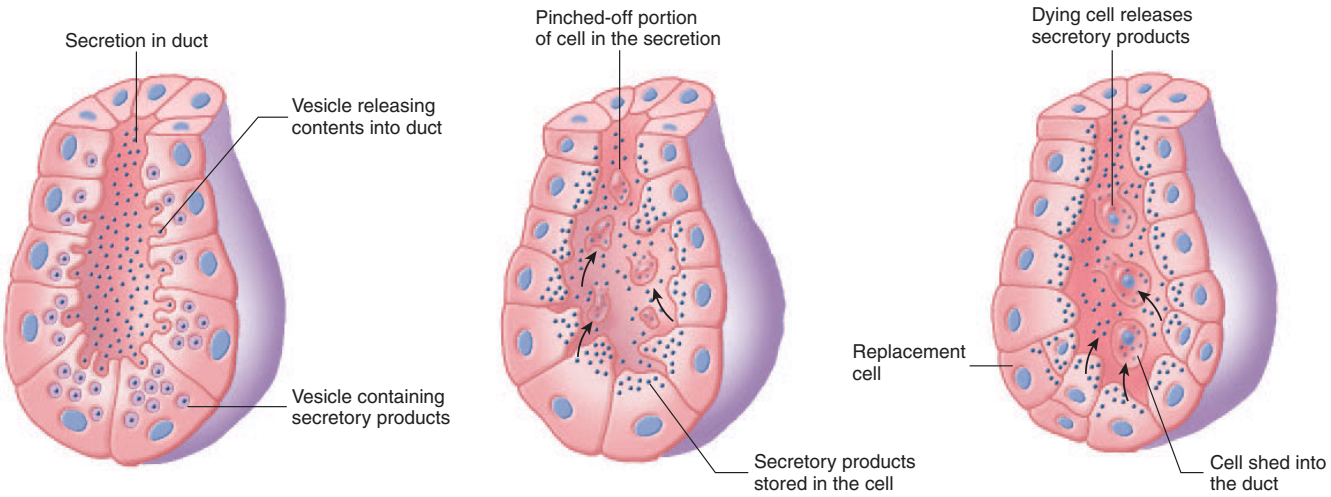
Figure 4.4 Structure of Exocrine Glands

The names of exocrine glands are based on the shapes of their secretory units and their ducts.

pancreas, secrete products with no loss of actual cellular material (figure 4.5*a*). Secretions are either actively transported or packaged in vesicles and then released by the process of exocytosis at the free surface of the cell. **Apocrine** (ap′ō-krin) **glands,** such as the milk-producing mammary glands, discharge fragments of the gland cells in the secretion (figure 4.5*b*). Products are retained within the cell, and large portions of the cell are pinched off to become part of the secretion. **Holocrine** (hol′ō-krin) **glands,** such as sebaceous (oil) glands of the skin, shed entire cells (figure 4.5*c*). Products accumulate in the cytoplasm of each epithelial cell, the cell ruptures and dies, and the entire cell becomes part of the secretion.

Endocrine glands are so variable in their structure that they are not classified easily. They are described in chapters 17 and 18.

16. *Define the term gland. Distinguish between exocrine and endocrine glands. Describe the classification scheme for multicellular exocrine glands on the basis of their duct systems.*
17. *Describe three different ways in which exocrine glands release their secretions. Give an example for each method.*



(a) **Merocrine gland**
Cells of the gland produce vesicles that contain secretory products, and the vesicles empty their contents into the duct through exocytosis.

(b) **Apocrine gland**
Secretory products are stored in the cell near the lumen of the duct. A portion of the cell near the duct that contains the secretory products is actually pinched off the cell and joins the secretion.

(c) **Holocrine gland**
Secretory products are stored in the cells of the gland. Entire cells are shed by the gland and become part of the secretion. The lost cells are replaced by other cells deeper in the gland.

Figure 4.5 Exocrine Glands and Secretion Types
Exocrine glands are classified according to the type of secretion.

Connective Tissue

Objectives

- ***List the functions of connective tissue.***
- ***List and describe the cells found in connective tissue.***
- ***Name the major large molecules of the connective tissue matrix, and explain their functions in the matrix.***

Connective tissue is abundant, and it makes up part of every organ in the body. The major structural characteristic that distinguishes connective tissue from the other three tissue types is that it consists of cells separated from each other by abundant extracellular matrix. Connective tissue structure is diverse, and it performs a variety of important functions.

Functions of Connective Tissue

Connective tissues perform the following major categories of functions:

1. *Enclosing and separating.* Sheets of connective tissues form capsules around organs such as the liver and kidneys. Connective tissue also forms layers that separate tissues and organs. For example, connective tissues separate muscles, arteries, veins, and nerves from one another.
2. *Connecting tissues to one another.* For example, tendons are strong cables, or bands, of connective tissue that attach muscles to bone, and ligaments are connective tissue bands that hold bones together.
3. *Supporting and moving.* Bones of the skeletal system provide rigid support for the body, and the semirigid cartilage supports structures such as the nose, ears, and surfaces of joints. Joints between bones allow one part of the body to move relative to other parts.
4. *Storing.* Adipose tissue (fat) stores high-energy molecules, and bones store minerals such as calcium and phosphate.
5. *Cushioning and insulating.* Adipose tissue cushions and protects the tissue it surrounds and provides an insulating layer beneath the skin that helps conserve heat.
6. *Transporting.* Blood transports substances throughout the body, such as gases, nutrients, enzymes, hormones, and cells of the immune system.
7. *Protecting.* Cells of the immune system and blood provide protection against toxins and tissue injury, as well as from microorganisms. Bones protect underlying structures from injury.

18. What is the major characteristic that distinguishes connective tissue from other tissues?
19. List the functions of connective tissue, and give an example of a connectve tissue that performs each function.

Cells of Connective Tissue

The specialized cells of the various connective tissues produce the extracellular matrix. The names of the cells end with suffixes that identify the cell functions as blasts, cytes, or clasts. **Blasts** create the matrix, **cytes** maintain it, and **clasts** break it down for remodeling. For example, **fibroblasts** are cells that form fibrous connective tissue and **fibrocytes** maintain it. **Chondroblasts** form cartilage (*chondro-* refers to cartilage) and **chondrocytes** maintain it.

Osteoblasts form bone (*osteo-* means bone), **osteocytes** maintain it, and **osteoclasts** break it down (see chapter 6).

Adipose (ad′i-pōs; fat), or **fat, cells,** also called **adipocytes** (ad′i-pō-sītz), contain large amounts of lipid. The lipid pushes the rest of the cell contents to the periphery, so that each cell appears to contain a large, centrally located lipid droplet with a thin layer of cytoplasm around it. Adipose cells are rare in some connective tissue types such as cartilage, are abundant in others such as loose connective tissue, or are predominant such as in adipose tissue.

Mast cells are commonly found beneath membranes in loose connective tissue and along small blood vessels of organs. They contain chemicals such as heparin, histamine, and proteolytic enzymes. These substances are released in response to injury such as trauma and infection and play important roles in inflammation.

White blood cells continuously move from blood vessels into connective tissues. The rate of movement increases dramatically in response to injury or infection. In addition, accumulations of lymphocytes, a type of white blood cell, are common in some connective tissues, such as in the connective tissue beneath the epithelial lining of certain parts of the digestive system.

Macrophages are found in some connective tissue types. They are derived from monocytes, a white blood cell type. Macrophages are either **fixed** and do not move through the connective tissue in which they are found or are **wandering macrophages** and move by ameboid movement through the connective tissue. Macrophages phagocytize foreign or injured cells, and they play a major role in providing protection against infections.

Undifferentiated mesenchymal cells, sometimes called **stem cells,** are embryonic cells that persist in adult connective tissue. They have the potential to differentiate to form adult cell types such as fibroblasts or smooth muscle cells in response to injury.

Extracellular Matrix

The extracellular matrix of connective tissue has three major components: (1) protein fibers, (2) ground substance consisting of nonfibrous protein and other molecules, and (3) fluid. The structure of the matrix gives connective tissue types most of their functional characteristics, such as the ability of bones and cartilage to bear weight, of tendons and ligaments to withstand tension, and of dermis of the skin to withstand punctures, abrasions, and other abuses.

Protein Fibers of the Matrix

Three types of protein fibers—collagen, reticular, and elastic fibers—help form connective tissue.

Collagen (kol′lă-jen) **fibers** consist of collagen, which is the most common protein in the body. Collagen accounts for one-fourth to one-third of the total body protein, which is approximately 6% of the total body weight. Each collagen molecule resembles a microscopic rope consisting of three polypeptide chains coiled together. Collagen is very strong and flexible but quite inelastic. There are at least 15 different types of collagen, many of which are specific to certain tissues. Collagen fibers differ in the types of amino acids that make up the polypeptide chains. Of the 15 types of collagen, 6 types are most common. Bone, dentin, and cementum contain mainly type I collagen, cartilage is mainly type II collagen, and reticular fibers are mainly type III collagen.

Reticular (re-tik′ū-lăr; netlike) **fibers** are actually very fine collagen fibers and therefore are not a chemically distinct category of fibers. They are very short, thin fibers that branch to form a network and appear different microscopically from other collagen fibers. Reticular fibers are not as strong as most collagen fibers, but networks of reticular fibers fill space between tissues and organs.

Elastic fibers contain a protein called **elastin** (ĕ-las′tin). As the name suggests, this protein is elastic with the ability to return to its original shape after being distended or compressed. Elastin gives the tissue in which it is found an elastic quality. Elastin molecules look like tiny coiled springs, and individual molecules are cross-linked to produce a large, interwoven meshwork of springlike molecules that extend through the entire tissue.

Other Matrix Molecules

Two types of large, nonfibrous molecules called hyaluronic acid and proteoglycans are part of the extracellular matrix. These molecules constitute most of the **ground substance** of the matrix, the "shapeless" background against which the collagen fibers are seen through the microscope. The molecules themselves, however, are not shapeless but are highly structured. **Hyaluronic** (hī′ă-loo-ron′ik; glassy appearance) **acid** is a long, unbranched polysaccharide chain composed of repeating disaccharide units. It gives a very slippery quality to the fluids that contain it; for that reason, it is a good lubricant for joint cavities (see chapter 8). Hyaluronic acid is also found in large quantities in connective tissue and is the major component of the vitreous humor of the eye (see chapter 15). A **proteoglycan** (prō′tē-ō-glī′kan; formed from proteins and polysaccharides) is a large molecule that consists of numerous polysaccharides, called **glycosaminoglycans** (glī′kōs-am-i-nō-glī′kan) each attached at one end to a common protein core. These **proteoglycan monomers** resemble minute pine tree branches. The protein core is the branch of the tree, and the proteoglycans are the needles. The protein cores of proteoglycan monomers can attach to a molecule of hyaluronic acid to form a **proteoglycan aggregate.** The aggregate resembles a complete pine tree, with hyaluronic acid represented by the tree trunk and the proteoglycan monomers forming the limbs. Proteoglycans trap large quantities of water, which gives them the capacity to return to their original shape when compressed or deformed. There are several different types of glycosaminoglycans, and their abundance varies with each connective tissue type.

Several **adhesive molecules** are found in ground substance. These adhesive molecules hold the proteoglycan aggregates together and to structures such as the plasma membranes. A specific adhesive molecule type predominates in certain types of ground substance. For example, **chondronectin** is in the ground substance of cartilage, **osteonectin** is in the ground substance of bone, and **fibronectin** is in the ground substance of fibrous connective tissues.

20. Explain the difference between connective tissue cells that are termed blast, cyte, or clast cells.

21. Describe and give the functions of the cells of connective tissue.

22. *What three components are found in the extracellular matrix of connective tissue? Contrast the structure and characteristics of collagen fibers, reticular fibers, and elastin fibers.*
23. *Describe the structure and function of hyaluronic acid and proteoglycan aggregates. What is the function of adhesive molecules?*

Classification of Connective Tissue

Objective

- ***List the major categories of connective tissue, and describe the characteristics of each.***

Connective tissue types blend into one another, and the transition points cannot be defined precisely. As a result, the classification scheme for connective tissues is somewhat arbitrary. Classification schemes for connective tissue are influenced by (1) protein fibers and the arrangement of protein fibers in the extracellular matrix, (2) protein fibers and ground substance in the extracellular matrix, and (3) a fluid extracellular matrix. The classification of connective tissues used here is presented in Table 4.3.

The two major categories of connective tissue are embryonic and adult connective tissues.

Embryonic Connective Tissue

Embryonic connective tissue is called **mesenchyme** (mez′en-kīm). It is made up of irregularly shaped fibroblasts surrounded by abundant semifluid extracellular matrix in which delicate collagenous fibers are distributed (figure 4.6*a*). It forms in the embryo during the third and fourth weeks of development from mesoderm and neural crest cells (see chapter 29), and all adult connective tissue types develop from it. By 8 weeks of development most of the mesenchyme has become specialized to form types of connective tissue seen in adults as well as muscle, blood vessels, and other tissues. The major source of remaining embryonic connective tissue in the newborn is found in the umbilical cord, where it is called **mucous connective tissue** or **Wharton's jelly** (figure 4.6*b*). The structure of mucous connective tissue is similar to mesenchyme.

Table 4.3 Classification of Connective Tissue

A. Embryonic connective tissue
   1. Mesenchyme
   2. Mucous
B. Adult connective tissue
   1. Loose
   2. Dense
      a. Irregularly arranged
         1. Collagenous
         2. Elastic
      b. Regularly arranged
         1. Collagenous
         2. Elastic
   3. Special properties
      a. Adipose
      b. Reticular
   4. Cartilage
   5. Bone
   6. Hemopoietic tissue and blood

Adult Connective Tissue

Adult connective tissue consists of six types: loose, dense, connective tissue with special properties, cartilage, bone, and blood.

Loose Connective Tissue

Loose connective tissue (figure 4.7*a*) which is sometimes referred to as **areolar** (ă-rē′ō-lăr; area) **tissue,** consists of protein fibers that form a lacy network with numerous fluid-filled spaces. Areolar tissue is the "loose packing" material of most organs and other tissues, and attaches the skin to underlying tissues. It contains collagen, reticular, and elastic fibers and a variety of cells. For example, fibroblasts produce the fibrous matrix, macrophages move through the tissue engulfing bacteria and cell debris, mast cells contain chemicals that help mediate inflammation, and lymphocytes are involved in immunity. The loose packing of areolar tissue is often associated with other connective tissue types such as reticular tissue and fat (adipose tissue).

Dense Connective Tissue

Protein fibers of **dense connective tissue** form thick bundles and fill nearly all of the extracellular space. Most of the cells of developing dense connective tissue are spindle-shaped fibroblasts. Once the fibroblasts become completely surrounded by matrix, they are fibrocytes. Dense connective tissue can be subdivided into two major groups: regular and irregular.

Dense regular connective tissue has protein fibers in the extracellular matrix that are oriented predominantly in one direction. **Dense regular collagenous connective tissue** (figure 4.7*b*) has abundant collagen fibers. The collagen fibers give this tissue a white appearance. Dense regular collagenous connective tissue forms structures such as tendons, which connect muscles to bones (see chapter 11), and most ligaments, which connect bones to bones (see chapter 8). The collagen fibers of dense connective tissue resist stretching and give the tissue considerable strength in the direction of the fiber orientation. Tendons and most ligaments consist almost entirely of thick bundles of densely packed parallel collagen fibers with the orientation of the collagen fibers in one direction which makes the tendons and ligaments very strong cable-like structures.

The general structure of tendons and ligaments is similar, but major differences between them exist. The differences include the following: (1) collagen fibers of ligaments are often less compact, (2) some fibers of many ligaments are not parallel, and (3) ligaments usually are more flattened than tendons and form sheets or bands of tissues.

Dense regular elastic connective tissue (figure 4.7*c*) consists of parallel bundles of collagen fibers and abundant elastic fibers. The elastin in elastic ligaments gives them a slightly yellow color. Dense regular elastic connective tissue forms some elastic ligaments, such as those in the vocal folds and the **nuchal** (noo′kăl; back of the neck) **ligament,** which lies along the posterior of the neck and helps hold the head upright. When elastic ligaments are stretched, they tend to shorten to their original length, much like an elastic band.

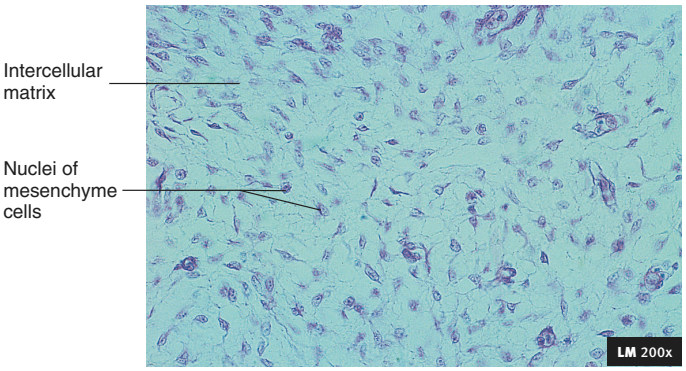
P R E D I C T 2

Explain the advantages of having elastic ligaments that extend from vertebra to vertebra in the vertebral column and why it would be a disadvantage if tendons, which connect skeletal muscles to bone, were elastic.

Dense irregular connective tissue contains protein fibers arranged as a meshwork of randomly oriented fibers. Alternatively, the fibers within a given layer of dense irregular connective tissue can be oriented in one direction whereas the fibers of adjacent layers are oriented at nearly right angles to that layer. Dense irregular connective tissue forms sheets of connective tissue that have strength in many directions, but less strength in any single direction than does regular connective tissue.

P R E D I C T 3

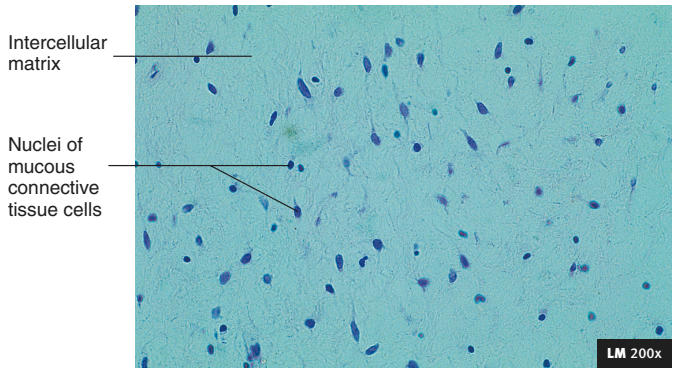
Scars consist of dense irregular connective tissue made of collagen fibers. Vitamin C is required for collagen synthesis. Predict the effect of scurvy, which is a nutritional disease caused by vitamin C deficiency, on wound healing.



(a) **Mesenchyme**

Location: Mesenchyme is the embryonic tissue from which connective tissues, as well as other tissues, arise.

Structure: The mesenchymal cells are irregularly shaped. The extracellular matrix is abundant and contains scattered reticular fibers.



(b) **Mucous connective tissue**

Location: Umbilical cord of newborn.

Structure: Mucous tissue is mesenchymal tissue that remains unspecialized. The cells are irregularly shaped. The extracellular matrix is abundant and contains scattered reticular fibers.

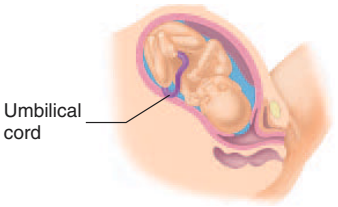
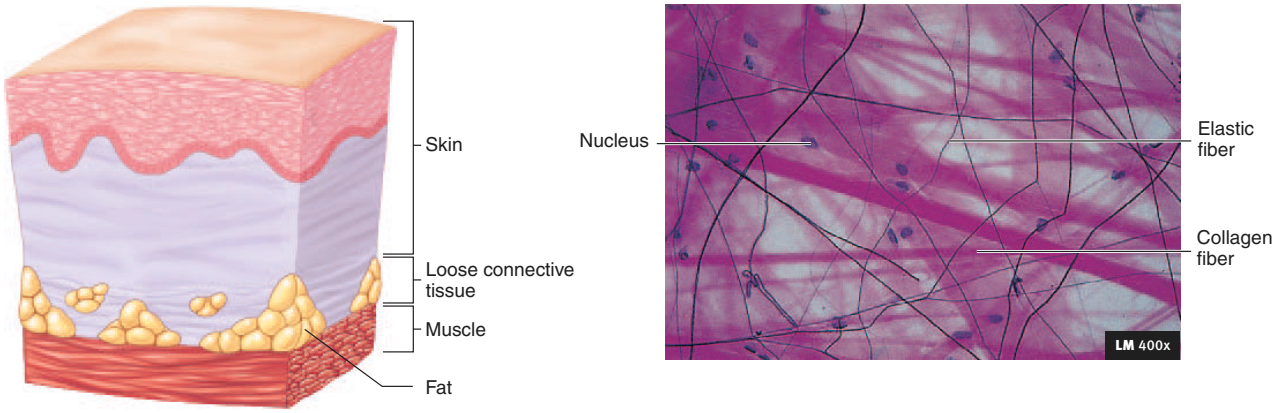


Figure 4.6 Embryonic Connective Tissue

Dense irregular collagenous connective tissue (figure 4.7*d*) forms most of the dermis of the skin, which is the tough, inner portion of the skin (see chapter 5) and of the connective tissue capsules that surround organs such as the kidney and spleen.

Dense irregular elastic connective tissue (figure 4.7*e*) is found in the wall of elastic arteries. In addition to collagen fibers, oriented in many directions, there are abundant elastic fibers in the layers of this tissue.

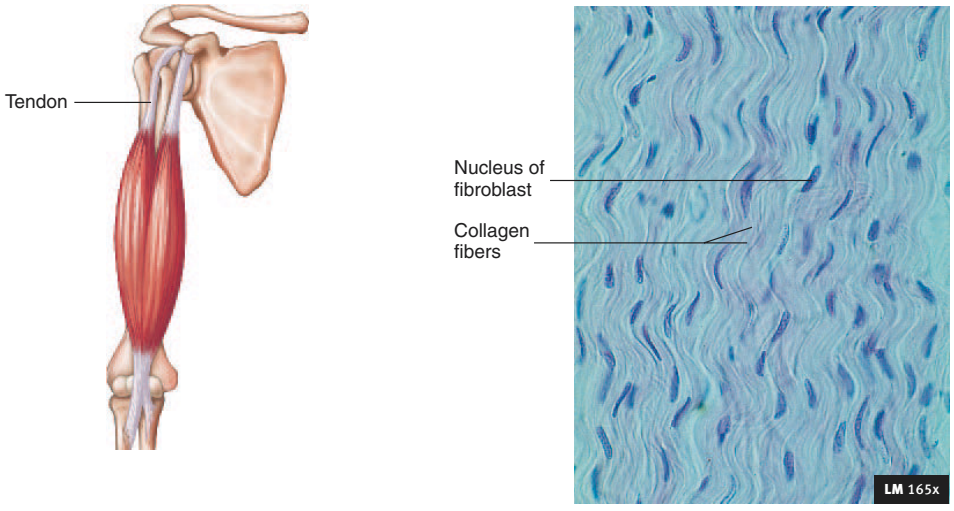


(a) **Loose, or areolar, connective tissue**

Location: Widely distributed throughout the body; substance on which epithelial basement membranes rest; packing between glands, muscles, and nerves. Attaches the skin to underlying tissues.

Structure: Cells (e.g., fibroblasts, macrophages, and lymphocytes) within a fine network of mostly collagen fibers. Often merges with denser connective tissue.

Function: Loose packing, support, and nourishment for the structures with which it is associated.



(b) **Dense regular collagenous connective tissue**

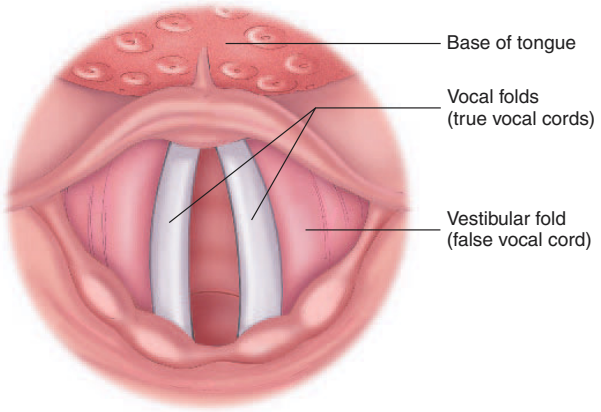
Location: Tendons (attach muscle to bone) and ligaments (attach bones to each other).

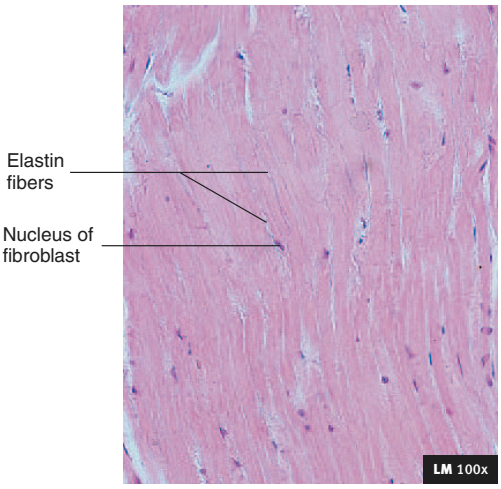
Structure: Matrix composed of collagen fibers running in somewhat the same direction.

Function: Ability to withstand great pulling forces exerted in the direction of fiber orientation, great tensile strength, and stretch resistance.

Figure 4.7 Types of Connective Tissue

24. *List the two types of embryonic connective tissue. To what does mesenchyme give rise in the adult?*
25. *Describe the fiber arrangement in loose (areolar) connective tissue. What are the functions of this tissue type?*
26. *Structurally and functionally, what is the difference between dense regular connective tissue and dense irregular connective tissue?*
27. *Name the two kinds of dense regular connective tissue, and give an example of each. Do the same for dense irregular connective tissue.*



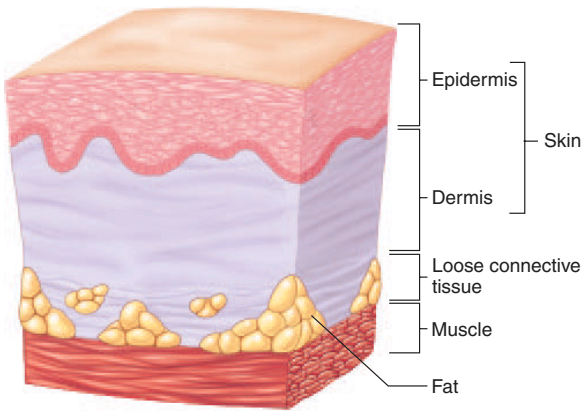


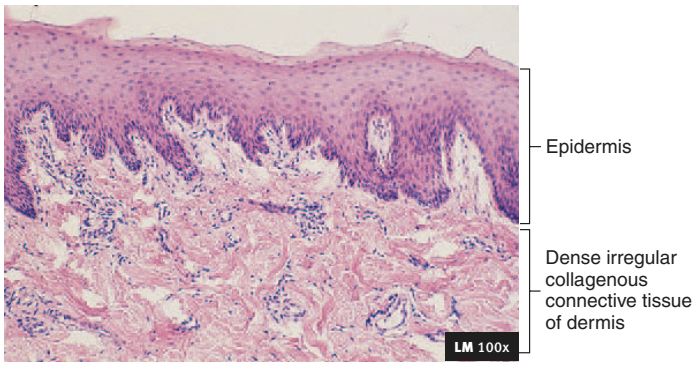
(c) **Dense regular elastic connective tissue**

Location: Ligaments between the vertebrae and along the dorsal aspect of the neck (nucha) and in the vocal cords.

Structure: Matrix composed of regularly arranged collagen fibers and elastin fibers.

Function: Capable of stretching and recoiling like a rubber band with strength in the direction of fiber orientation.





(d) **Dense irregular collagenous connective tissue**

Location: Sheaths; most of the dermis of the skin; organ capsules and septa; outer covering of body tubes.

Structure: Matrix composed of collagen fibers that run in all directions or in alternating planes of fibers oriented in a somewhat single direction.

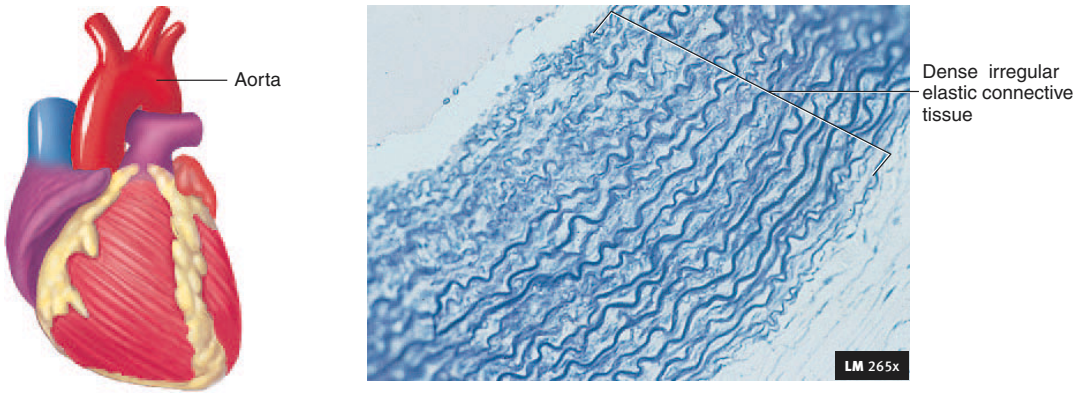
Function: Tensile strength capable of withstanding stretching in all directions.

Figure 4.7 *(continued)*

Connective Tissue with Special Properties

Adipose tissue and reticular tissue are connective tissues with special properties. **Adipose tissue** (figure 4.7*f*) consists of adipocytes, or fat cells, which contain large amounts of lipid. Unlike other connective tissue types, adipose tissue is composed of large cells and a small amount of extracellular matrix that consists of loosely arranged collagen and reticular fibers with some scattered elastic fibers. Blood vessels form a network in the extracellular matrix. The fat cells are usually arranged in clusters or lobules separated from one another by loose connective tissue. Adipose tissue functions as an insulator, a protective tissue, and a site of energy storage. Lipids take up less space per calorie than either carbohydrates or proteins and therefore are well adapted for energy storage.

Adipose tissue exists in both yellow (white) and brown forms. **Yellow adipose** tissue is by far the most abundant. Yellow adipose tissue appears white at birth, but it turns yellow with age because of the accumulation of pigments such as carotene, a plant pigment that humans can metabolize as a source of vitamin A.

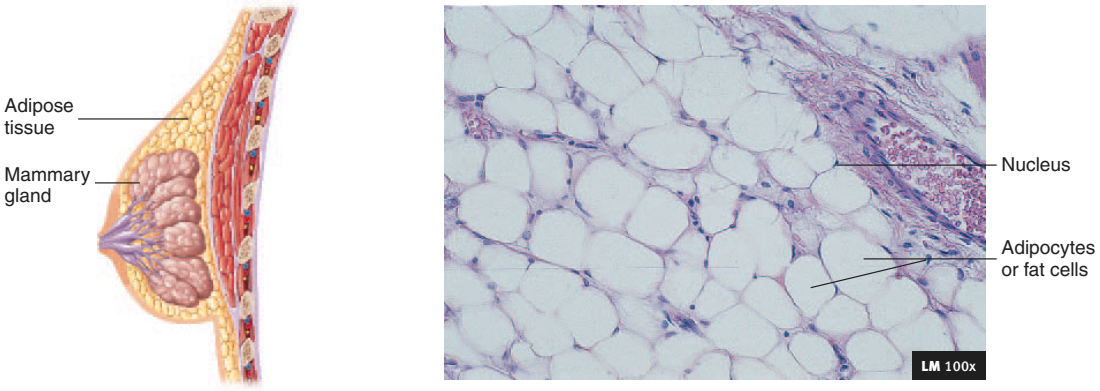


(e) **Dense irregular elastic connective tissue**

Location: Elastic arteries.

Structure: Matrix composed of bundles and sheets of collagenous and elastin fibers oriented in multiple directions.

Function: Capable of strength with stretching and recoil in several directions.



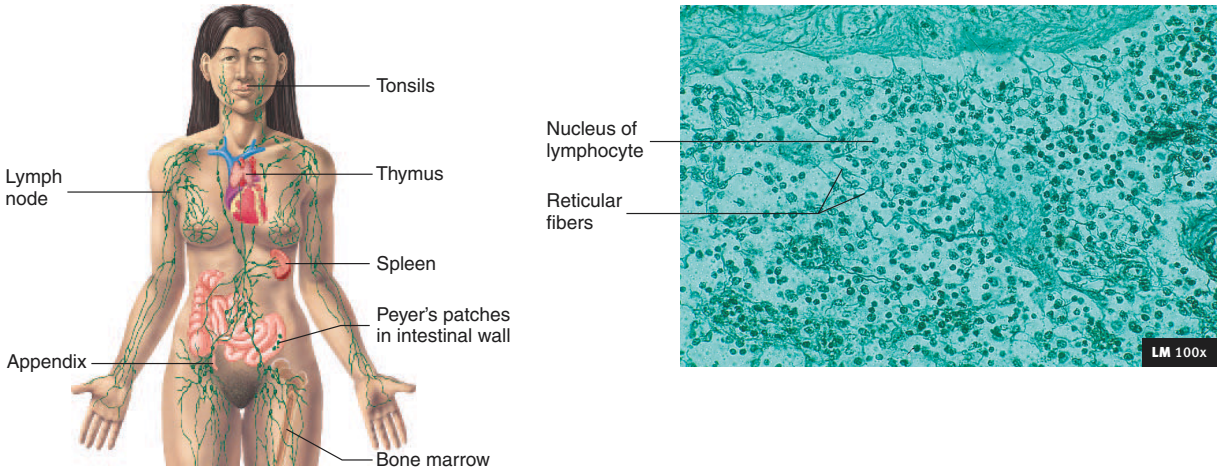
(f) **Adipose tissue**

Location: Predominantly in subcutaneous areas, mesenteries, renal pelvis, around kidneys, attached to the surface of the colon, mammary glands, and in loose connective tissue that penetrates into spaces and crevices.

Structure: Little extracellular matrix surrounding cells. The adipocytes, or fat cells, are so full of lipid that the cytoplasm is pushed to the periphery of the cell.

Function: Packing material, thermal insulator, energy storage, and protection of organs against injury from being bumped or jarred.

Figure 4.7 *(continued)*



(g) **Reticular tissue**

Location: Within the lymph nodes, spleen, and bone marrow.

Structure: Fine network of reticular fibers irregularly arranged.

Function: Provides a superstructure for the lymphatic and hemopoietic tissues.

Figure 4.7 *(continued)*

Storage, insulation, and protection are functions of yellow adipose tissue. Brown adipose tissue is found only in specific areas of the body such as the axillae (armpits), neck, and near the kidneys. The brown color results from the cytochrome pigments in its numerous mitochondria and its abundant blood supply. Although brown fat is much more prevalent in babies than in adults, it is difficult to distinguish brown fat from yellow fat in babies because the color difference between them is not great. Brown fat is specialized to generate heat as a result of oxidative metabolism of lipid molecules in mitochondria and can play a significant role in body temperature regulation in newborn babies.

Reticular tissue forms the framework of lymphatic tissue (figure 4.7*g*), such as in the spleen and lymph nodes, as well as in bone marrow and the liver. It is characterized by a network of reticular fibers and reticular cells. **Reticular cells** produce the reticular fibers and remain closely attached to them. The spaces between the reticular fibers can contain a wide variety of other cells, such as dendritic cells, which look very much like reticular cells but are cells of the immune system, macrophages, and blood cells (see chapter 22).

28. *What feature of the extracellular matrix distinguishes adipose tissue from other connective tissue types? What is an adipocyte?*
29. *List the functions of adipose tissue. Name the two types of adipose tissue. Which one is important in generating heat?*
30. *What is the function of reticular tissue? Where is it found?*

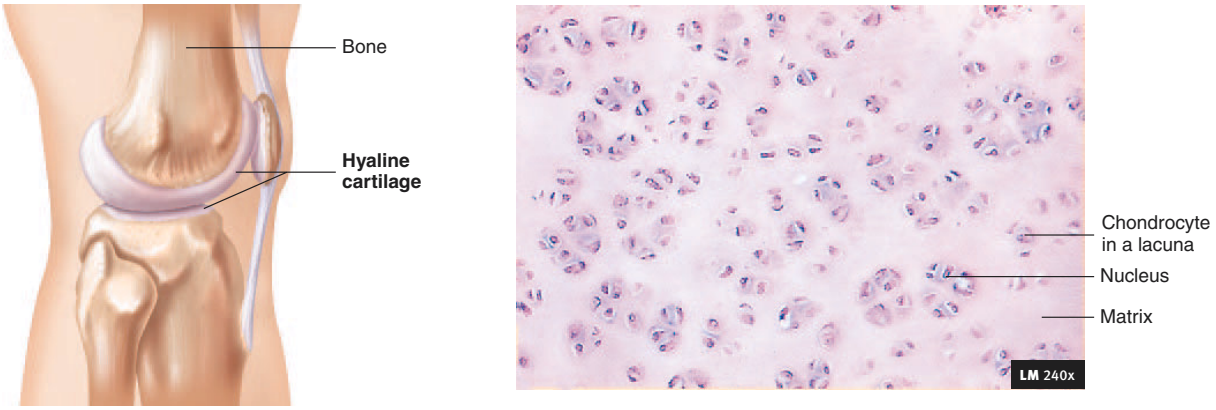
Cartilage

Cartilage (kar′ti-lij) is composed of cartilage cells, or **chondrocytes** (kon′drō-sītz), located in spaces called **lacunae** (lă-koo′nē) within an extensive and relatively rigid matrix. Next to bone, cartilage is the firmest structure in the body. The matrix contains protein fibers, ground substance, and fluid. The protein fibers are collagen fibers or, in some cases, collagen and elastic fibers. The ground substance consists of proteoglycans and other organic molecules. Most of the proteoglycans in the matrix form aggregates with hyaluronic acid. Within the cartilage matrix, proteoglycan aggregates function as minute sponges capable of trapping large quantities of water. This trapped water allows cartilage to spring back after being compressed. The collagen fibers give cartilage considerable strength.

The surface of nearly all cartilage is surrounded by a layer of dense irregular connective tissue called the **perichondrium** (per-i-kon′drē-ŭm). The structure of the perichondrium is described in more detail in chapter 6. Cartilage cells arise from the perichondrium and secrete cartilage matrix. Once completely surrounded by matrix the cartilage cells are called chondrocytes and the spaces in which they are located are called lacunae. Cartilage has no blood vessels or nerves except those of the perichondrium; it therefore heals very slowly after an injury because the cells and nutrients necessary for tissue repair cannot reach the damaged area easily.

There are three types of cartilage.

1. **Hyaline** (hī′ă-lin) **cartilage** has large amounts of both collagen fibers and proteoglycans (figure 4.7*h*). Collagen fibers are evenly dispersed throughout the ground



(h) **Hyaline cartilage**

Location: Growing long bones, cartilage rings of the respiratory system, costal cartilage of ribs, nasal cartilage, articulating surface of bones, and the embryonic skeleton.

Structure: Collagen fibers are small and evenly dispersed in the matrix, making the matrix appear transparent. The cartilage cells, or chondrocytes, are found in spaces, or lacunae, within the firm but flexible matrix.

Function: Allows growth of long bones. Provides rigidity with some flexibility in the trachea, bronchi, ribs, and nose. Forms rugged, smooth, yet somewhat flexible articulating surfaces. Forms the embryonic skeleton.

Figure 4.7 *(continued)*

substance, and in joints, hyaline cartilage has a very smooth surface. Specimens appear to have a glassy, translucent matrix when viewed through a microscope. Hyaline cartilage is found in areas in which strong support and some flexibility are needed, such as in the rib cage and the cartilage within the trachea and bronchi (see chapter 23). It also covers the surfaces of bones that move smoothly against each other in joints. Hyaline cartilage forms most of the skeleton before it is replaced by bone in the embryo, and it is involved in growth that increases the length of bones (see chapter 6).

2. **Fibrocartilage** has more collagen fibers than proteoglycans (figure 4.7*i*). Compared to hyaline cartilage, fibrocartilage has much thicker bundles of collagen fibers dispersed through its matrix. Fibrocartilage is slightly compressible and very tough. It is found in areas of the body where a great deal of pressure is applied to joints, such as the knee, the jaw, and between vertebrae.
3. **Elastic cartilage** has elastic fibers in addition to collagen and proteoglycans (figure 4.7*j*). The numerous elastic fibers are dispersed throughout the matrix of elastic cartilage. It is found in areas, such as the external ears, that have rigid but elastic properties.

PREDICT 4

One of several changes caused by rheumatoid arthritis in joints is the replacement of hyaline cartilage with dense irregular collagenous connective tissue. Predict the effect of replacing hyaline cartilage with fibrous connective tissue.

Bone

Bone is a hard connective tissue that consists of living cells and mineralized matrix. Bone matrix has an organic and an inorganic portion. The organic portion consists of protein fibers, primarily collagen, and other organic molecules. The mineral, or inorganic, portion consists of specialized crystals called **hydroxyapatite** (hī-drok′sē-ap-ă-tīt), which contain calcium and phosphate. The strength and rigidity of the mineralized matrix allow bones to support and protect other tissues and organs of the body. Bone cells, or **osteocytes** (os′tē-ō-sītz), are located within holes in the matrix, which are called lacunae and are similar to the lacunae of cartilage.

Two types of bone exist.

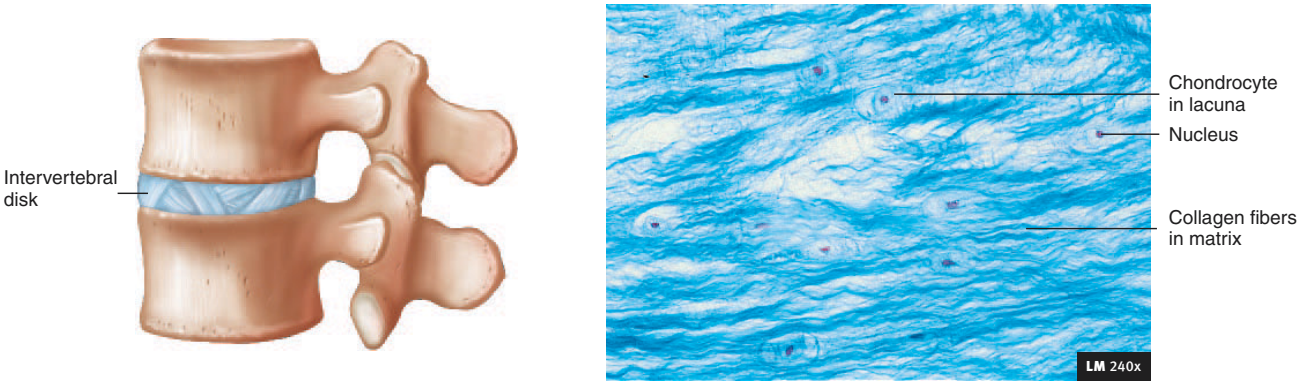
1. **Cancellous** (kan′sĕ-lŭs), or **spongy, bone** has spaces between **trabeculae** (tră-bek′ū-lē; beams), or plates, of bone and therefore resembles a sponge (figure 4.7*k*).
2. **Compact bone** is more solid with almost no space between many thin layers, or **lamellae** (lă-mel′ē; pl., lă-mel′ă; sing.) of bone (figure 4.7*l*).

Bone, unlike cartilage, has a rich blood supply. For this reason, bone can repair itself much more readily than can cartilage. Bone is described more fully in chapter 6.

Hemopoietic Tissue and Blood

Blood is unusual among the connective tissues because the matrix between the cells is liquid (figure 4.7*m*). Like many other connective tissues blood has abundant extracellular matrix. The cells of most other connective tissues are more or less stationary

within a relatively rigid matrix, but blood cells are free to move within a fluid matrix. Some blood cells leave the bloodstream and wander through other tissues. The liquid matrix of blood allows it to flow rapidly through the body, carrying food, oxygen, waste products, and other materials. The matrix of blood is also unusual in that most of it is produced by cells contained in other tissues rather than by blood cells. Blood is discussed more fully in chapter 19. **Hemopoietic** (hē′mō-poy-et′ik) **tissue** forms blood cells. Most of the hemopoietic tissue is found in **bone marrow** (mar′ō) (figure 4.7*n*), which is the soft connective tissue in the cavities of bones. Two types of bone marrow exist: **yellow marrow** and **red marrow** (see chapter 6). Yellow marrow consists of yellow adipose tissue, and red marrow consists of hemopoietic tissue surrounded by a framework of reticular fibers. Hemopoietic tissue produces red and white blood cells and is described in detail in chapter 19.

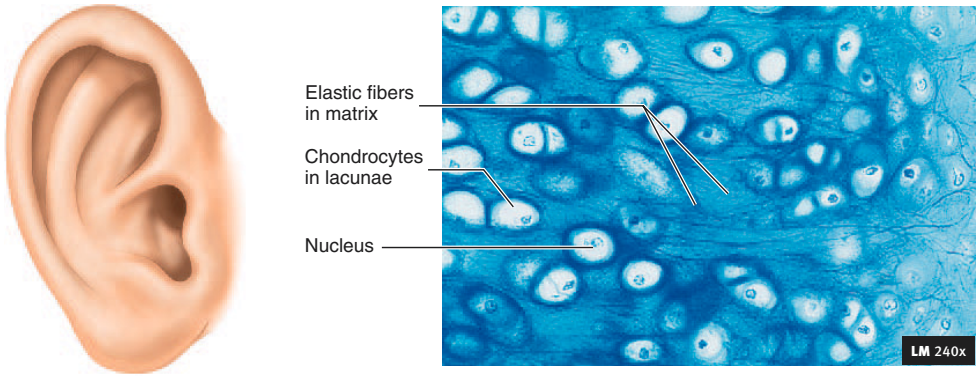


(i) **Fibrocartilage**

Location: Intervertebral disks, symphysis pubis, articular disks (e.g., knee and temporomandibular [jaw] joints).

Structure: Collagenous fibers similar to those in hyaline cartilage. The fibers are more numerous than in other cartilages and are arranged in thick bundles.

Function: Somewhat flexible and capable of withstanding considerable pressure. Connects structures subjected to great pressure.



(j) **Elastic cartilage**

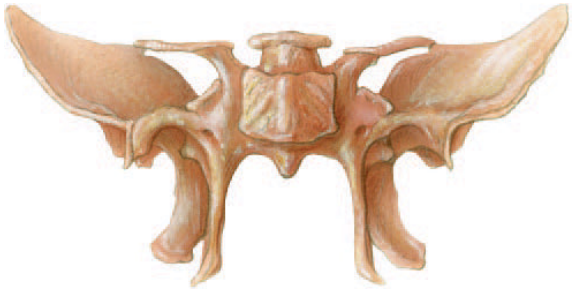
Location: External ear, epiglottis, and auditory tubes.

Structure: Similar to hyaline cartilage, but matrix also contains elastin fibers.

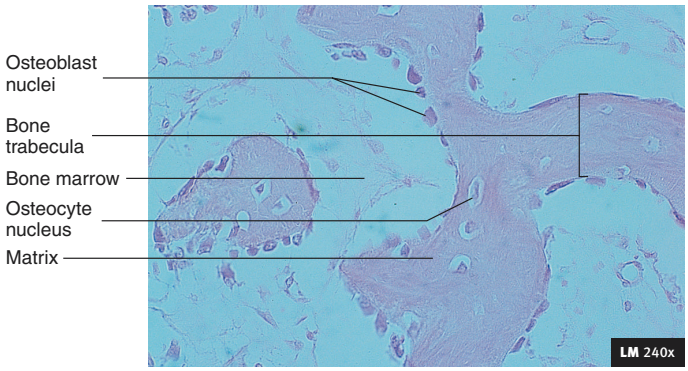
Function: Provides rigidity with even more flexibility than hyaline cartilage because elastic fibers return to their original shape after being stretched.

Figure 4.7 *(continued)*

31. *Describe the cells and matrix of cartilage. What are lacunae? What is the perichondrium? Why does cartilage heal slowly?*
32. *How do hyaline cartilage, fibrocartilage, and elastic cartilage differ in structure and function? Give an example of each.*
33. *Describe the cells and matrix of bone. Differentiate between cancellous bone and compact bone.*
34. *What characteristic separates blood from the other connective tissues?*
35. *Describe the function of hemopoietic tissue. Explain the difference between red marrow and yellow marrow.*



Irregular bone (sphenoid) from the skull

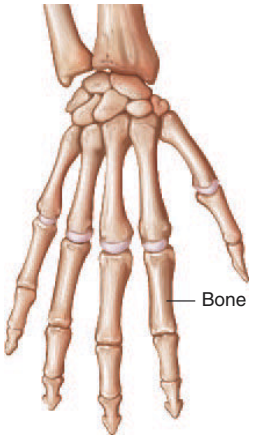


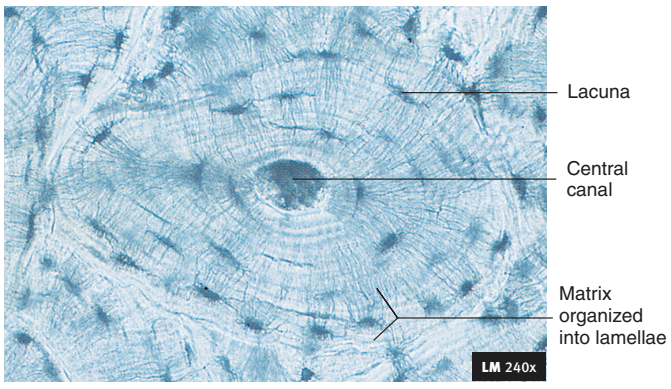
(k) **Cancellous bone**

Location: In the interior of the bones of the skull, vertebrae, sternum, and pelvis; also found in the ends of the long bones.

Structure: Latticelike network of scaffolding characterized by trabeculae with large spaces between them filled with hemopoietic tissue. The osteocytes, or bone cells, are located within lacunae in the trabeculae.

Function: Acts as a scaffolding to provide strength and support without the greater weight of compact bone.





(l) **Compact bone**

Location: Outer portions of all bones and the shafts of long bones.

Structure: Hard, bony matrix predominates. Many osteocytes (not seen in this bone preparation) are located within lacunae that are distributed in a circular fashion around the central canals. Small passageways connect adjacent lacunae.

Function: Provides great strength and support. Forms a solid outer shell on bones that keeps them from being easily broken or punctured.

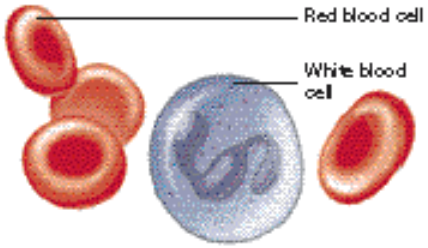
Figure 4.7 *(continued)*

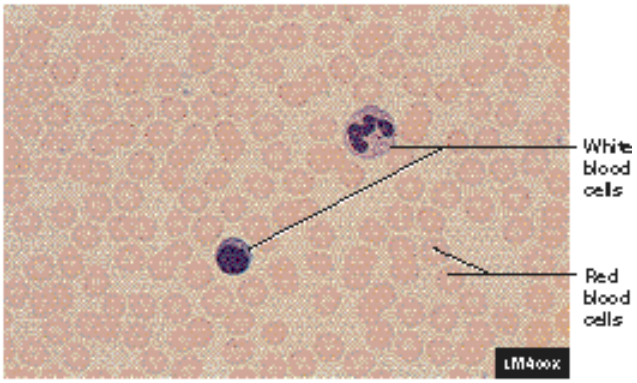
Muscle Tissue

Objectives

- *List the main characteristics of muscle tissue.*
- *Name the types of muscle tissue, and list their major characteristics.*

The main characteristic of **muscle tissue** is that it contracts or shortens with force, and therefore is responsible for movement. Muscle contraction is accomplished by the interaction of contractile proteins, which are described in chapter 9. Muscles contract to move the entire body, to pump blood through the heart and blood vessels, and to decrease the size of hollow organs, such as the stomach and urinary bladder. The three types of muscle tissue are skeletal, cardiac, and smooth muscle. The types of muscle tissue are grouped according to both structure and function (table 4.4). Muscle tissue grouped according to structure is either **striated** (strī′āt-ĕd), in which microscopic bands or striations can be seen in muscle cells,



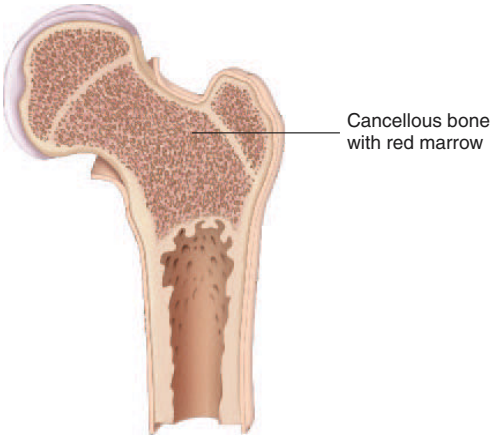


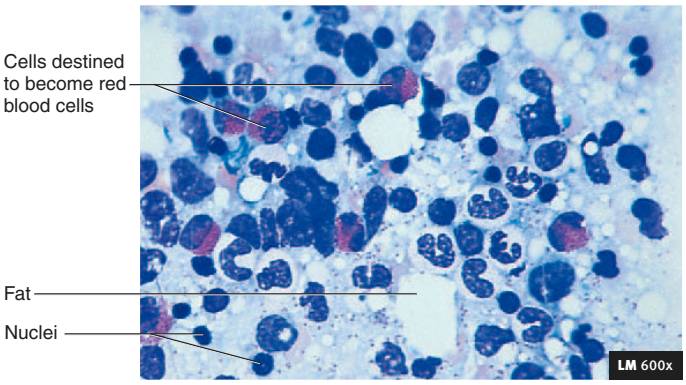
(m) Blood

Location: Within the blood vessels. Produced by the hemopoietic tissues. White blood cells frequently leave the blood vessels and enter the interstitial spaces.

Structure: Blood cells and a fluid matrix.

Function: Transports oxygen, carbon dioxide, hormones, nutrients, waste products, and other substances. Protects the body from infections and is involved in temperature regulation.





(n) **Bone marrow**

Location: Within marrow cavities of bone. Two types: yellow marrow (mostly adipose tissue) in the shafts of long bones; and red marrow (hemopoietic or blood-forming tissue) in the ends of long bones and in short, flat, and irregularly shaped bones.

Structure: Reticular framework with numerous blood-forming cells (red marrow).

Function: Production of new blood cells (red marrow); lipid storage (yellow marrow).

Figure 4.7 *(continued)*

or **nonstriated.** When classified according to function, a muscle is **voluntary,** meaning that it is usually consciously controlled, or **involuntary,** meaning that it is not normally consciously controlled. Thus the three muscle types are striated voluntary, or **skeletal muscle** (figure 4.8*a*); striated involuntary, or **cardiac muscle** (figure 4.8*b*); and nonstriated involuntary, or **smooth muscle** (figure 4.8*c*).

For most people, the term *muscle* means skeletal muscle (see chapter 9), which constitutes the meat of animals and represents a large portion of the total weight of the human body. Skeletal muscle, as the name implies, attaches to the skeleton and, by contracting, causes the major body movements. Cardiac muscle is the muscle of the heart (see chapter 20), and contraction of cardiac muscle is responsible for pumping blood. Smooth muscle is widespread throughout the body and is responsible for a wide range of functions, such as movements in the digestive, urinary, and reproductive systems.

36. *Functionally, what is unique about muscle tissue? Contrast the structure of skeletal, cardiac, and smooth muscle cells. Which of the muscle types is under voluntary control? What tasks does each type perform?*

Nervous Tissue

Objective

- *Describe the characteristics of nervous tissue.*

The fourth and final class of tissue is **nervous tissue.** It is found in the brain, spinal cord, and nerves, and is characterized by the ability to conduct electric signals called **action potentials.** It consists of neurons, which are responsible for this conductive ability, and support cells called neuroglia.

Neurons, or **nerve cells** (figure 4.9), are the actual conducting cells of nervous tissue. Just as an electrical wiring system transports electricity throughout a house, neurons transport electric signals throughout the body. They are composed of three major parts: cell body, dendrites, and axon. The **cell body** contains the nucleus and is the site of general cell functions. Dendrites and axons are two types of nerve cell processes, both consisting of projections of cytoplasm surrounded by membrane. **Dendrites** (den′drīts) usually receive action potentials and conduct them toward the cell body. They are much shorter than axons and usually taper to a fine tip. **Axons** (ak′sonz) usually conduct action potentials away from the cell body. They can be much longer than dendrites, and they have a constant diameter along their entire length.

Neurons that possess several dendrites and one axon are called **multipolar neurons** (figure 4.9*a*). Neurons that possess a single dendrite and an axon are called **bipolar neurons.** Some very specialized neurons, called **unipolar neurons** (figure 4.9*b*), have only one axon and no dendrites. Within each subgroup are many shapes and sizes of neurons, especially in the brain and the spinal cord.

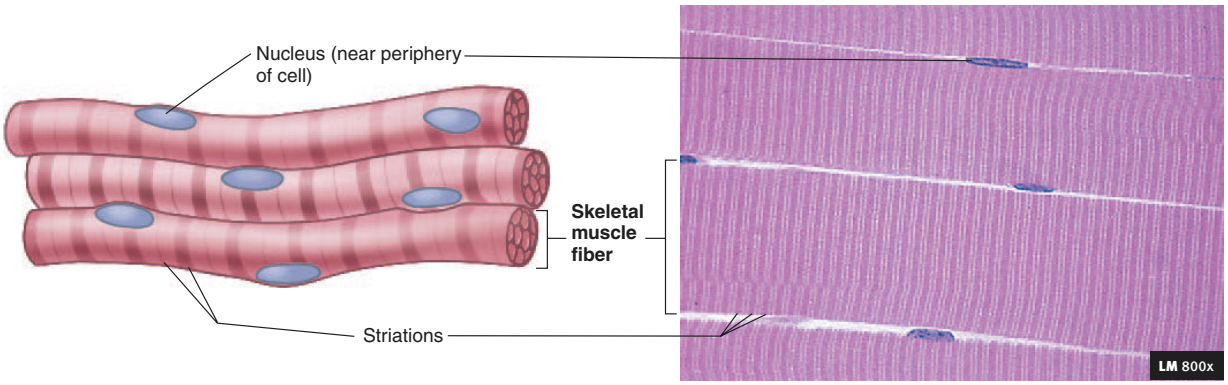
Neuroglia (noo-rog′lē-ă; nerve glue) are the support cells of the brain, spinal cord, and peripheral nerves (figure 4.10). The

Table 4.4 Comparison of Muscle Types

Features	Skeletal Muscle	Cardiac Muscle	Smooth Muscle
Location	Attached to bones	Heart	Walls of hollow organs, blood vessels, eyes, glands, and skin
Cell shape	Very long, cylindrical cells (1–40 mm in length and may extend the entire length of the muscle; 10–100 µm in diameter)	Cylindrical cells that branch (100–500 µm in length; 100–200 µm in diameter)	Spindle-shaped cells (15–200 µm in length; 5–10 µm in diameter)
Nucleus	Multinucleated, peripherally located	Single, centrally located	Single, centrally located
Striations	Yes	Yes	No
Control	Voluntary	Involuntary	Involuntary
Ability to contract spontaneously	No	Yes	Yes
Function	Body movement	Contraction provides the major force for moving blood through the blood vessels	Movement of food through the digestive tract, emptying of the urinary bladder, regulation of blood vessel diameter, change in pupil size, contraction of many gland ducts, movement of hair, and many more functions
Special features		Branching fibers, intercalated disks join the cells to each other (gap junctions)	Gap junctions

term *neuroglia* originally referred only to the support cells of the central nervous system, but it is now also applied to cells in the peripheral nervous system. Neuroglia nourish, protect, and insulate neurons. Neurons and neuroglial cells are described in greater detail in chapter 11.

37. *Functionally, what is unique about nervous tissue?*
38. *Define and list the functions of the cell body, dendrites, and axon of a neuron. Differentiate between multipolar, bipolar, and unipolar neurons.*
39. *What is the general function of neuroglia?*

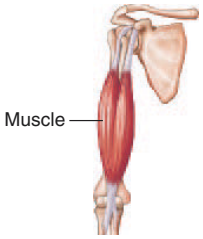


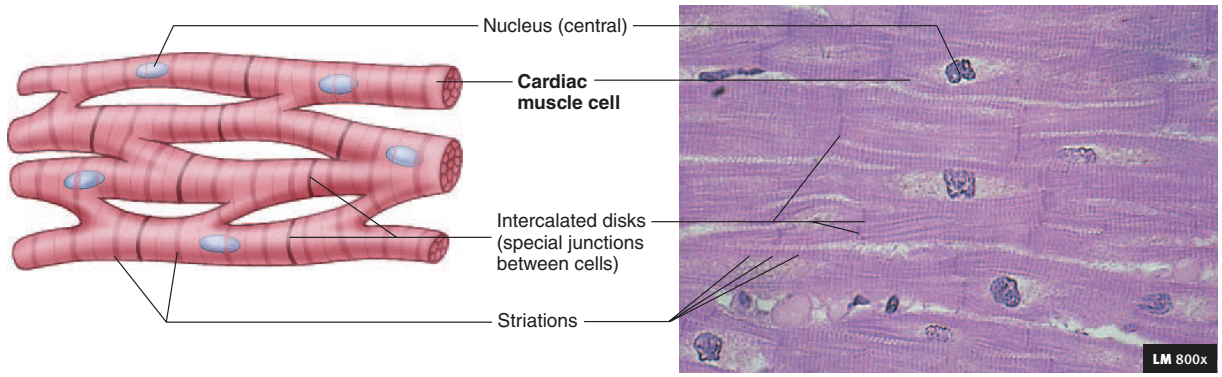
(a) **Skeletal muscle**

Location: Attaches to bone.

Structure: Skeletal muscle cells or fibers appear striated (banded). Cells are large, long, and cylindrical, with many nuclei located at the periphery.

Function: Movement of the body; under voluntary control.





(b) **Cardiac muscle**

Location: Cardiac muscle is in the heart.

Structure: Cardiac muscle cells are cylindrical and striated and have a single, centrally located nucleus. They are branched and connected to one another by intercalated disks.

Function: Pumps the blood; under involuntary control.

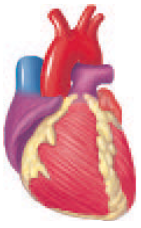
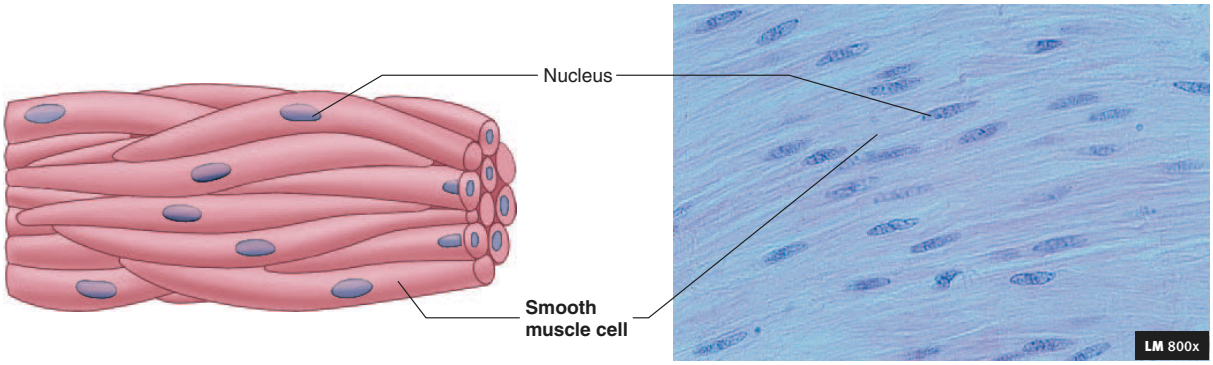


Figure 4.8 Types of Muscle Tissue



(c) **Smooth muscle**

Location: Smooth muscle is in hollow organs such as the stomach and intestine.

Structure: Smooth muscle cells are tapered at each end, are not striated, and have a single nucleus.

Function: Regulates the size of organs, forces fluid through tubes, controls the amount of light entering the eye, and produces "goose flesh" in the skin; under involuntary control.

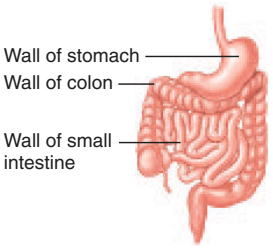
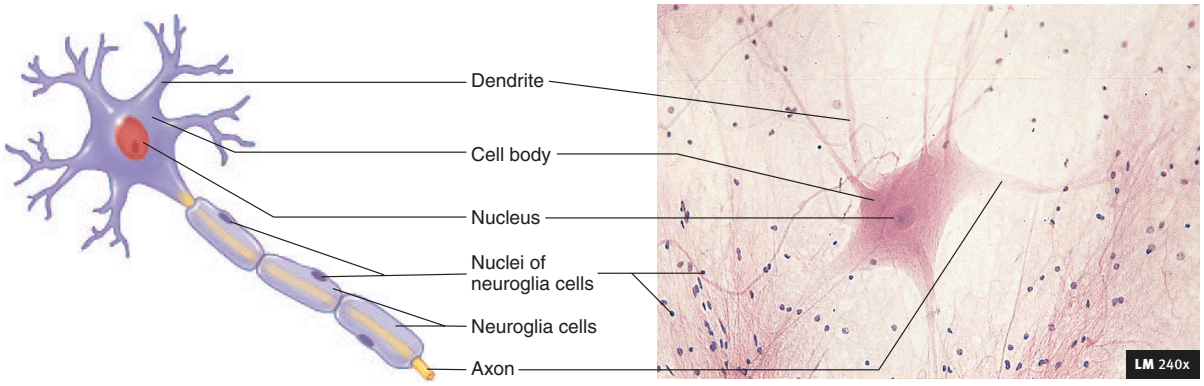


Figure 4.8 *(continued)*



(a) **Multipolar neuron**

Location: Neurons are located in the brain, spinal cord, and ganglia.

Structure: The neuron consists of dendrites, a cell body, and a long axon. Neuroglia, or support cells, surround the neurons.

Function: Neurons transmit information in the form of action potentials, store "information," and in some way integrate and evaluate data. Neuroglia support, protect, and form specialized sheaths around axons.

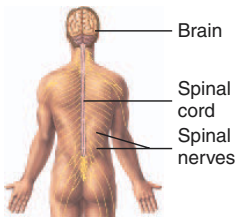
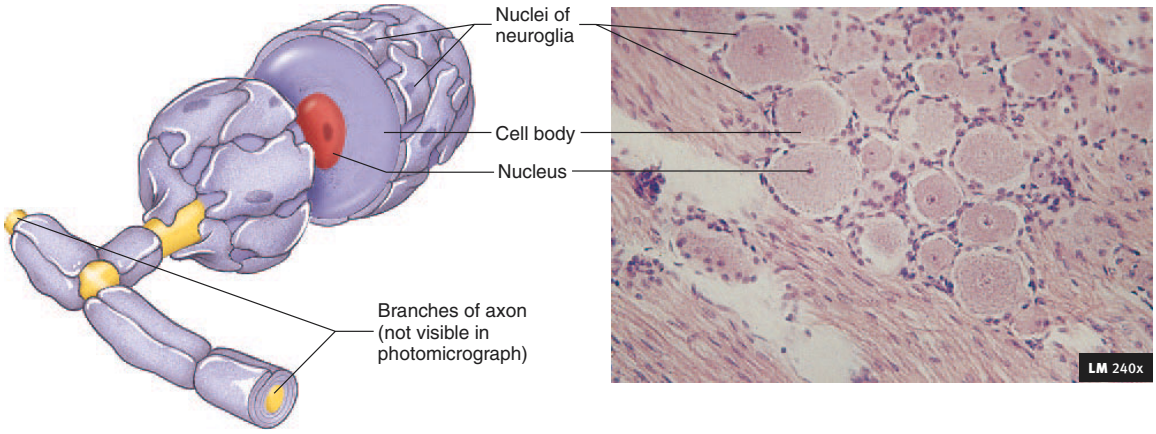


Figure 4.9 Types of Neurons



(b) **Unipolar neuron**

Location: Cell bodies are located in ganglia outside of the brain and spinal cord.

Structure: The neuron consists of a cell body with one axon.

Function: Conducts action potentials from the periphery to the brain or spinal cord.

Figure 4.9 *(continued)*

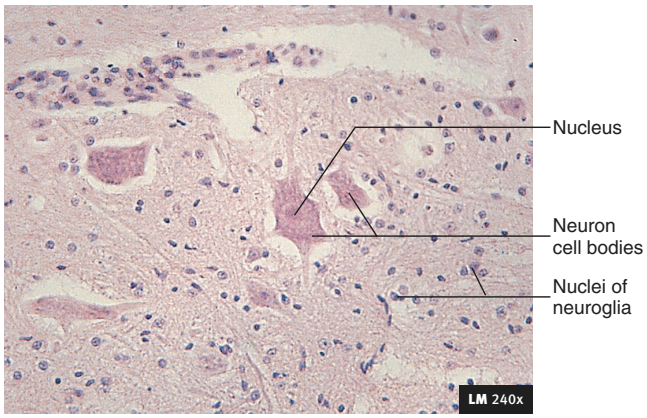


Figure 4.10 Neuroglia

Membranes

Objective

- ***List the functional and structural characteristics of mucous, serous, and synovial membranes.***

A membrane is a thin sheet or layer of tissue that covers a structure or lines a cavity. Most membranes are formed from epithelium and the connective tissue on which it rests. The three major categories of internal membranes are mucous membranes, serous membranes, and synovial membranes.

A **mucous** (mū′kŭs) **membrane** consists of epithelial cells, their basement membrane, a thick layer of loose connective tissue called the **lamina propria** (lam′i-nă prō′prē-ă), and, sometimes, a layer of smooth muscle cells. Mucous membranes line cavities and canals that open to the outside of the body, such as the digestive, respiratory, excretory, and reproductive passages (figure 4.11). Many, but not all, mucous membranes contain goblet cells or multicellular mucous glands, which secrete a viscous substance called **mucus** (mū′kŭs). The functions of the mucous membranes vary, depending on their location, and include protection, absorption, and secretion.

A **serous** (ser′ŭs) **membrane** consists of three components: a layer of simple squamous epithelium called **mesothelium** (mez-ō-thē′lē-ŭm), its basement membrane, and a delicate layer of loose connective tissue. Serous membranes line cavities such as the pericardial, pleural, and peritoneal cavities that do not open to the exterior (see figure 4.11). Serous membranes do not contain glands but are moistened by a small amount of fluid, called **serous fluid,** produced by the serous membranes. The serous fluid lubricates the serous membranes and makes their surfaces slippery. Serous membranes protect the internal organs from friction, help hold them in place, and act as selectively permeable barriers that prevent the accumulation of large amounts of fluid within the serous cavities.

Synovial (si-nō′vē-ăl) **membranes** consist of modified connective tissue cells either intermixed with part of the dense connective tissue of the joint capsule or separated from the capsule by areolar or adipose tissue. Synovial membranes line freely movable joints (see chapter 8) (see figure 4.11). They produce a fluid rich in hyaluronic acid, which makes the joint fluid very slippery, thereby facilitating smooth movement within the joint.

- ***40. Compare mucous, serous, and synovial membranes according to the type of cavity they line and their secretions.***

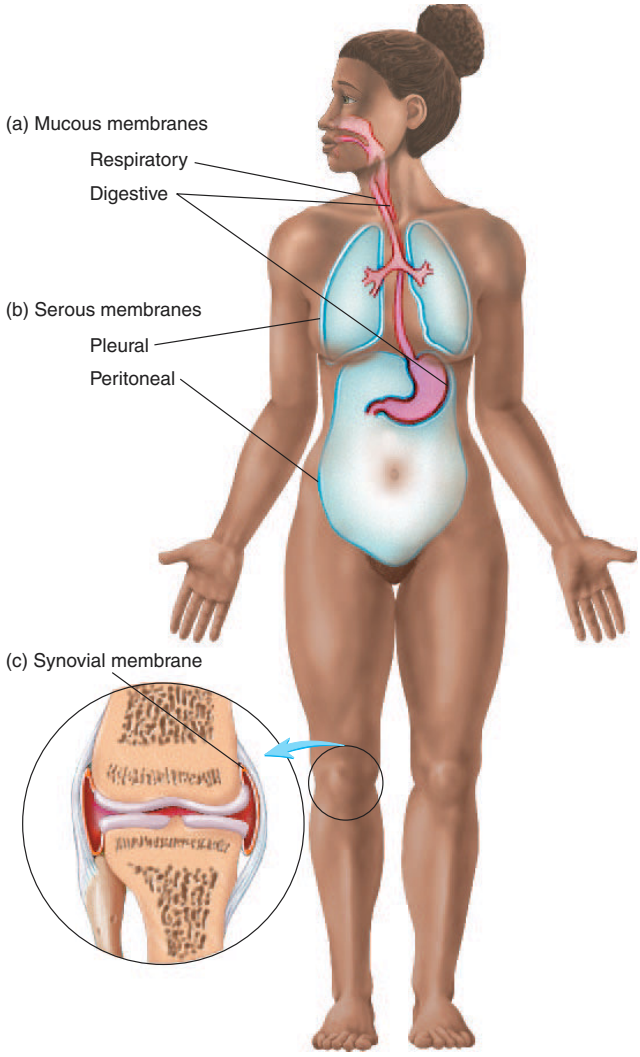


Figure 4.11 Membranes

(*a*) Mucous membranes line cavities that open to the outside and often contain mucous glands, which secrete mucus. (*b*) Serous membranes line cavities that do not open to the exterior, and do not contain glands, but do secrete serous fluid. (*c*) Synovial membranes line cavities that surround synovial joints.

Inflammation

Objective

- ***Describe the process of inflammation, and explain why inflammation is protective to the body.***

The inflammatory response occurs when tissues are damaged (figure 4.12) or in association with an immune response. Although many possible agents cause injury, such as microorganisms, cold, heat, radiant energy, chemicals, electricity, or mechanical trauma, the inflammatory response to all causes is similar. The inflammatory response mobilizes the body's defenses, isolates and destroys microorganisms and other injurious agents, and removes foreign materials and damaged cells so that tissue repair can proceed. The details of the inflammatory response are presented in chapter 22.

Inflammation produces five major manifestations: redness, heat, swelling, pain, and disturbance of function. Although unpleasant, these processes usually benefit recovery, and each of the symptoms can be understood in terms of events that occur during the inflammatory response.

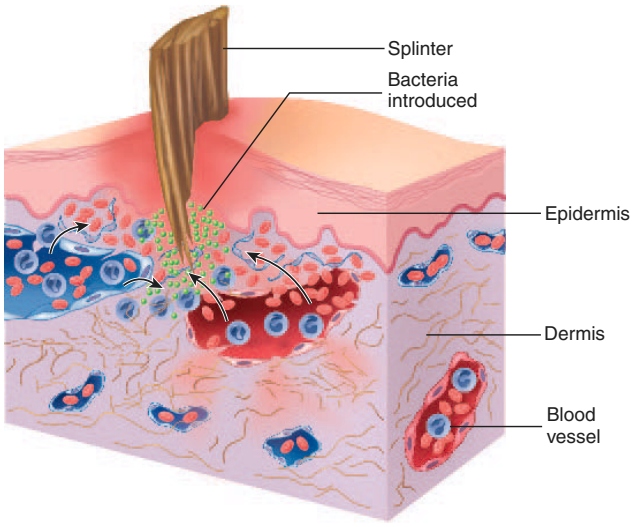
After a person is injured, chemical substances called **mediators of inflammation** are released or activated in the tissues and the adjacent blood vessels. The mediators include histamine, kinins, prostaglandins, leukotrienes, and others. Some mediators induce dilation of blood vessels and produce the symptoms of redness and heat. Dilation of blood vessels is beneficial because it increases the speed with which white blood cells and other substances important for fighting infections and repairing the injury arrive at the site of injury.

Mediators of inflammation also stimulate pain receptors and increase the permeability of blood vessels. The increased permeability allows the movement of materials such as clotting proteins and white blood cells out of the blood vessels and into the tissue, where they can deal directly with the injury. As proteins from the blood move into the tissue, they change the osmotic relationship between the blood and the tissue. Water follows the proteins by osmosis, and the tissue swells, producing **edema** (e-dē′mă). Edema increases the pressure in the tissue, which can also stimulate neurons and cause the sensation of pain.

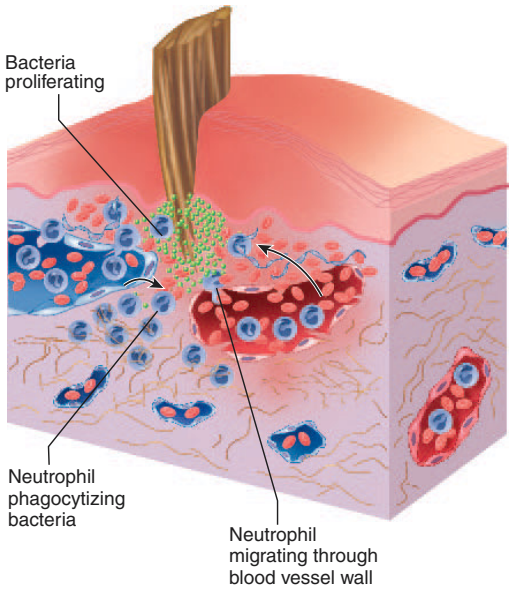
Clotting proteins found in blood diffuse into the interstitial spaces and form a clot. Clotting of blood also occurs in the more severely injured blood vessels. The effect of clotting is to isolate the injurious agent and to separate it from the remainder of the body. Foreign particles and microorganisms present at the site of injury are "walled off" from tissues by the clotting process. Pain, limitation of movement resulting from edema, and tissue destruction all contribute to the disturbance of function. This disturbance can be valuable because it warns the person to protect the injured structure from further damage. Sometimes the inflammatory response lasts longer or is more intense than is desirable, and drugs are used to suppress the symptoms. Antihistamines block the effects of histamine, aspirin prevents the synthesis of prostaglandins, and cortisone reduces the release of several mediators of inflammation. On the other hand, the inflammatory response by itself may not be enough to combat the effects of injury or fight off an infection. Medical intervention such as administering antibiotics may be required.

41. ***What is the function of the inflammatory response? Name five manifestations of the inflammatory response, and explain how each is produced.***

1. A splinter in the skin causes damage and introduces bacteria. Mediators of inflammation are released from injured tissues including damaged blood vessels. Some blood vessels are ruptured causing bleeding. Mediators of inflammation cause other blood vessels (capillaries) to begin dilating, causing the skin to become red. Mediators of inflammation also cause capillary permeability to increase, and fluid leaves the capillaries causing swelling (arrows).



2. White blood cells (e.g. neutrophils and macrophages) leave the dilated blood vessels and move to the site of bacterial infection, where they begin to phagocytize bacteria and other debris.



Process Figure 4.12 Inflammation

P R E D I C T 5

In some injuries, tissues are so severely damaged that areas exist where cells are killed and blood vessels are destroyed. For injuries such as these, where do the signs of inflammation such as redness, heat, edema, and pain occur?

Chronic Inflammation

When the agent responsible for an injury is not removed or if some interference occurs with the process of healing, the inflammatory response persists and is called **chronic inflammation.** For example, an infection of the lung can result in a brief period of inflammation followed by repair, but a prolonged infection causes chronic inflammation, which results in tissue destruction and permanent damage to the lung. Also, chronic inflammation of the stomach or small intestine may result in an ulcer. Prolonged infections, prolonged exposure to irritants such as silica in the lung, or abnormal immune responses can result in chronic inflammation. White blood cells invade areas of chronic inflammation, and ultimately healthy tissues are destroyed and replaced by a fibrous connective tissue, which is an important cause of the loss of organ function. Chronic inflammation of the lungs, the liver, the kidney, or other vital organs can lead to death.

Tissue Repair

Objective

- *Describe the major events involved in tissue repair.*

Tissue repair is the substitution of viable cells for dead cells, and it can occur by regeneration or replacement. In **regeneration** (rē′jen-er-ā′shŭn), the new cells are the same type as those that were destroyed, and normal function is usually restored. In **replacement,** a new type of tissue develops that eventually causes scar production and the loss of some tissue function. Most wounds heal through regeneration and replacement; which process dominates depends on the tissues involved and the nature and extent of the wound.

Cells are classified into three groups called labile, stable, or permanent cells, according to their ability to regenerate. **Labile cells,** including cells of the skin, mucous membranes, and hemopoietic and lymphatic tissues, continue to divide throughout life. Damage to these cells can be repaired completely by regeneration. **Stable cells,** such as connective tissues and glands, including the liver, pancreas, and endocrine glands, do not divide after growth ceases; but they do retain the ability to divide and are capable of regeneration in response to injury. **Permanent cells** have very limited ability to replicate, and, if killed, they are usually replaced by a different type of cell. Neurons fit into this category, although neurons are able to recover from damage. If the cell body of a neuron is not destroyed, most neurons can replace a damaged axon or dendrite; but if the neuron cell body is destroyed, the remainder of the neuron dies. Evidence indicates that some undifferentiated cells of the central nervous system can undergo mitosis and form functional neurons, although the degree to which mitosis occurs and its functional significance is not clear. Undifferentiated cells of skeletal and cardiac muscle also have very limited ability to regenerate in response to injury, although individual skeletal and cardiac muscle cells can repair themselves. In contrast, smooth muscle readily regenerates following injury.

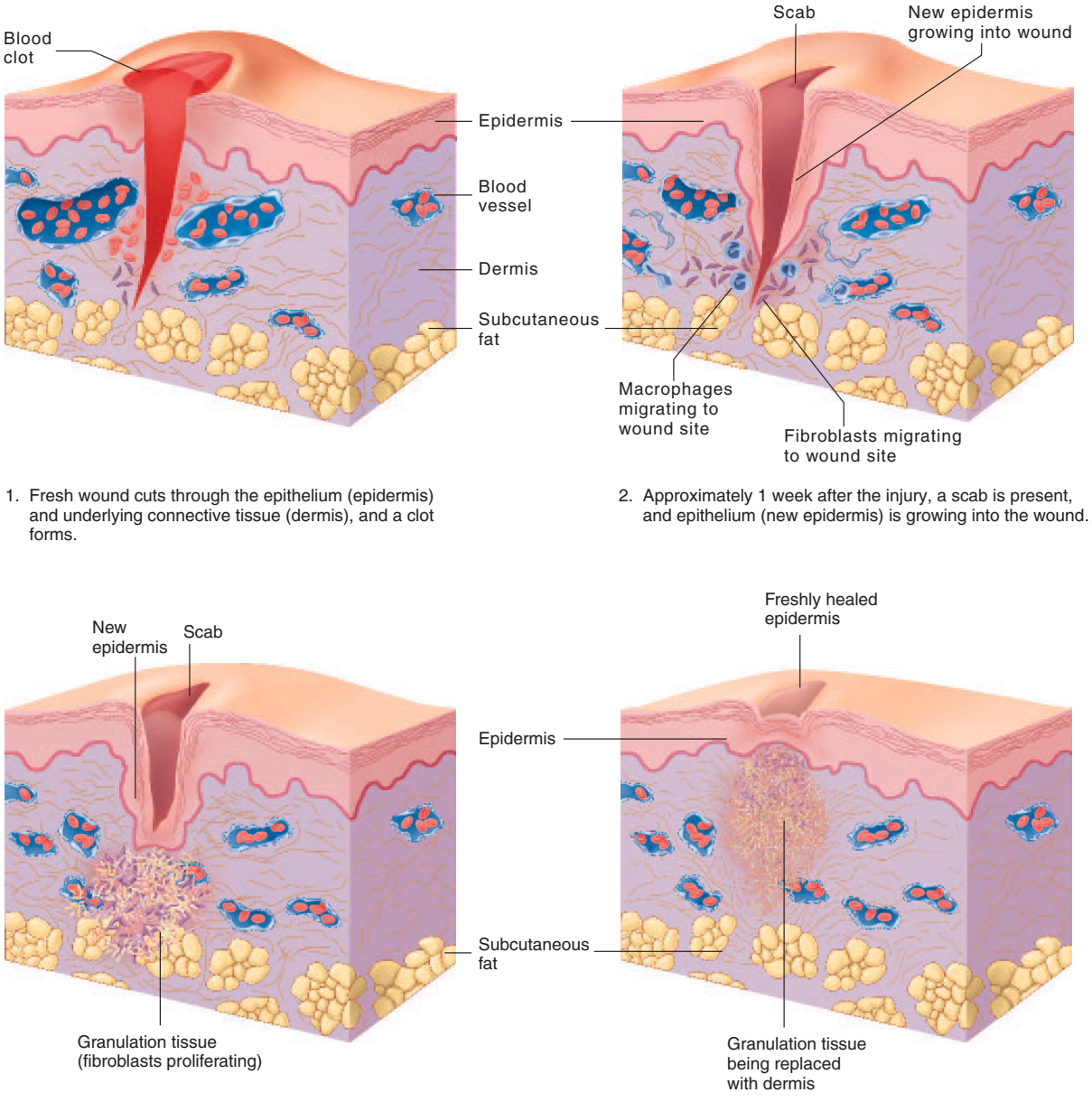
Skin repair is a good example of wound repair (figure 4.13). The basic pattern of the repair is the same for other tissues, especially ones covered by epithelium. If the edges of the wound are close together such as in a surgical incision, the wound heals by a process called **primary union,** or primary intention. If the edges are not close together, or if extensive loss of tissue has occurred, the process is called **secondary union,** or secondary intention.

In primary union, the wound fills with blood, and a clot forms (see chapter 19). The clot contains a threadlike protein, **fibrin** (fī′brin), that binds the edges of the wound together. The surface of the clot dries to form a **scab,** which seals the wound and helps prevent infection. An inflammatory response induces vasodilation and brings increased numbers of blood cells and other substances to the area. Blood vessel permeability increases, resulting in edema. Fibrin and blood cells move into the wounded tissues because of the increased vascular permeability. Fibrin acts to isolate and wall off microorganisms and other foreign matter. Some of the white blood cells that move into the tissue are phagocytic cells called **neutrophils** (noo′trō-filz; figure 4.13*b*). They ingest bacteria, thus helping to fight infection, and they also ingest tissue debris and clear the area for repair. Neutrophils are killed in this process and can accumulate as a mixture of dead cells and fluid called **pus** (pŭs).

Fibroblasts from surrounding connective tissue migrate into the clot and produce collagen and other extracellular matrix components. Capillaries grow from blood vessels at the edge of the wound and revascularize the area, and fibrin in the clot is broken down and removed. The result is the replacement of the clot by a delicate connective tissue, called **granulation tissue,** which consists of fibroblasts, collagen, and capillaries. A large amount of granulation tissue sometimes persists as a **scar** (skar), which at first is bright red because of vascularization of the tissue. Later, the scar blanches and becomes white, as collagen accumulates and the vascular channels are compressed.

Repair by secondary union proceeds in a fashion similar to healing by primary union, but some differences exist. Because the wound edges are far apart, the clot may not close the gap completely, and it takes the epithelial cells much longer to regenerate and cover the wound. With increased tissue damage, the degree of the inflammatory response is greater, more cell debris exists for the phagocytes to remove, and the risk of infection is greater. Much more granulation tissue forms, and **wound contraction** occurs as a result of the contraction of fibroblasts in the granulation tissue. Wound contraction leads to disfiguring and debilitating scars. Thus, it is advisable to suture a large wound so that it can heal by primary rather than secondary union. Healing is faster, the risk of infection is lowered, and the degree of scarring is reduced.

- *42. Define tissue repair. Differentiate between tissue repair that occurs by regeneration and by replacement.*
- *43. Compare labile cells, stable cells, and permanent cells. Give examples of each type. What is the significance of these cell types to tissue repair?*
- *44. Describe the process of wound repair. Contrast healing by primary union and secondary union.*
- *45. What is pus? Describe granulation tissue. How does granulation tissue contribute to scars and wound contraction?*



1. Fresh wound cuts through the epithelium (epidermis) and underlying connective tissue (dermis), and a clot forms.
2. Approximately 1 week after the injury, a scab is present, and epithelium (new epidermis) is growing into the wound.
3. Approximately 2 weeks after the injury, the epithelium has grown completely into the wound, and granulation tissue has formed.
4. Approximately 1 month after the injury, the wound has completely closed, the scab has been sloughed, and the granulation tissue is being replaced with dermis.

Process Figure 4.13 Tissue Repair

Tissues and Aging

Objective

- ***Describe age-related changes at the tissue level.***

Age-related changes are well documented. For example, reduced visual acuity and reduced smell, taste, and touch sensation have been documented. A clear decline in many types of athletic performance can be measured after approximately age 30–35. Ultimately there is a substantial decrease in the number of neurons and muscle cells. The functional capacity of systems such as the respiratory and cardiovascular systems declines. The rate of healing and scarring are very different in the elderly than in the very young and major changes in the structural characteristics of the skin develop. Characteristic alterations in brain function also develop in the elderly. All of these changes result in the differences between young, middle-age, and older people.

Clinical Focus Cancer Tissue

Cancer (kan′ser) is a malignant, spreading tumor and the illness that results from such a tumor. A **tumor** (too′mŏr) is any swelling, although modern usage has limited the term to swellings that involve neoplastic tissue. **Oncology** (ong-kol′ō-jē; the study of tumors) is the study of tumors and their associated problems. **Neoplasm** (nē′ō-plazm) means new growth and refers to abnormal tissue growth resulting in unusually rapid cellular proliferation that continues after normal growth of the tissue has stopped or slowed considerably. A neoplasm can be either **malignant** (mă-lig′nănt; with malice or intent to cause harm), able to spread and become worse, or **benign** (bē-nīn′; kind), not inclined to spread and not likely to become worse. Although benign tumors are usually less dangerous than malignant tumors, they can cause problems. As a benign tumor enlarges, it can compress surrounding tissues and impair their functions. In some cases (e.g., brain tumors), the result can be death.

Malignant tumors can spread by local growth and expansion or by **metastasis** (mĕ-tas′tă-sis, meaning moving to another place), which results from tumor cells separating from the main neoplasm and being carried by the lymphatic or circulatory system to a new site, where a second neoplasm forms. A **carcinoma** (kar-si-nō′mă) is a malignant neoplasm derived from epithelial tissue. A **sarcoma** (sar-kō′mă) is a malignant neoplasm derived from connective tissue.

Malignant neoplasms lack the normal growth control that is exhibited by most other adult tissues, and in many ways they resemble embryonic tissue. Rapid growth is one characteristic of embryonic tissue, but as the tissue begins to reach its adult size and function, it slows or stops growing completely. This cessation of growth is controlled at the individual cell level. Cancer results when a cell or group of cells, for some reason, breaks away from that control. This breaking loose involves the genetic machinery and can be induced by viruses, environmental toxins, and other causes. The illness associated with cancer usually occurs as the tumor invades and destroys the healthy surrounding tissues, eliminating their functions.

Cancer therapy concentrates primarily on trying to confine and then kill the malignant cells. This goal is accomplished currently by killing the tissue with x rays or lasers, by removing the tumor surgically, or by treating the patient with drugs that kill rapidly dividing cells or reduce the blood supply to the tumor. The major problem with current therapy is that some cancers cannot be removed completely by surgery or killed completely by x rays and laser therapy. These treatments can also kill normal tissue adjacent to the tumor. Many drugs used in cancer therapy kill not only cancer tissue but also other rapidly growing tissues, such as bone marrow, where new blood cells are produced, and the lining of the intestinal tract. Loss of these tissues can result in anemia, caused by the lack of red blood cells, and nausea, caused by the loss of the intestinal lining. A newer class of drugs eliminates these unwanted side effects. These drugs prevent blood vessel development, thus depriving the cancer tissue of a blood supply, rather than attacking dividing cells. Other normal tissues, in which cells divide rapidly, have well-established blood vessels and are, therefore, not affected by these drugs.

Promising anticancer therapies are being developed in which cells responsible for immune responses can be stimulated to recognize tumor cells and destroy them. A major advantage in such anticancer treatments is that the cells of the immune system can specifically attack the tumor cells and not other, healthy tissues.

At the tissue level, age-related changes affect cells and the extracellular materials produced by them. In general, cells divide more slowly in older than in younger people. Collagen fibers become more irregular in structure, even though they may increase in number. As a consequence, connective tissues with abundant collagen, such as tendons and ligaments, become less flexible and more fragile. Elastic fibers fragment, bind to calcium ions, and become less elastic. Consequently, elastic connective tissues, such as elastic ligaments, become less elastic.

Changes in the structure of elastic and collagen fibers of arterial walls cause them to become less elastic. Atherosclerosis results as plaques form in the walls of blood vessels, which contain collagen fibers, lipids, and calcium deposits (see chapter 21). These changes result in reduced blood supply to tissues and increased susceptibility to blockage and rupture. The rate of red blood cell synthesis declines in the elderly as well. Reduced flexibility and elasticity of connective tissue is responsible for increased wrinkling of skin as well as the increased tendency for bones to break in older people.

Injuries in the very young heal more rapidly and more completely than in older people. A fracture in the femur of an infant is likely to heal quickly and eventually leave no evidence of the fracture in the bone. A similar fracture in an adult heals more slowly and a scar, seen in x rays of the bone, is likely to persist throughout life.

- ***46. Describe the age-related changes that occur in cells such as nerve cells, muscle cells, and cells of hemopoietic tissues.***
- ***47. Describe the age-related changes in tissues with abundant collagen and elastic fibers.***

S U M M A R Y

Tissues and Histology (p. 105)

1. Tissues are collections of similar cells and the substances surrounding them.
2. The four primary tissue types are epithelial, connective, muscle, and nervous tissues.
3. Histology is the microscopic study of tissues.

Embryonic Tissue (p. 105)

All four of the primary tissue types are derived from each of the three germ layers (mesoderm, ectoderm, and endoderm).

Epithelial Tissue (p. 105)

1. Epithelium consists of cells with little extracellular matrix, it covers surfaces, it has a basement membrane, and it does not have blood vessels.
2. The basement membrane is secreted by the epithelial cells and attaches the epithelium to the underlying tissues.

Classification of Epithelium

1. Simple epithelium has a single layer of cells, stratified epithelium has two or more layers, and pseudostratified epithelium has a single layer that appears stratified.
2. Cells can be squamous (flat), cuboidal, or columnar.
3. Stratified squamous epithelium can be moist or keratinized.
4. Transitional epithelium is stratified, with cells that can change shape from cuboidal to flattened.

Functional Characteristics

1. Simple epithelium is usually involved in diffusion, filtration, secretion, or absorption. Stratified epithelium serves a protective role. Squamous cells function in diffusion and filtration. Cuboidal or columnar cells, with a larger cell volume that contains many organelles, secrete or absorb.
2. A smooth free surface reduces friction (mesothelium and endothelium), microvilli increase absorption (intestines), and cilia move materials across the free surface (respiratory tract and uterine tubes). Transitional epithelium has a folded surface that allows the cell to change shape, and the number of cells making up the epithelial layers changes.
3. Cells are bound together mechanically by glycoproteins, desmosomes, and the zonulae adherens and to the basement membrane by hemidesmosomes. The zonulae occludens and zonulae adherens form a permeability barrier or tight junction, and gap junctions allow intercellular communication.

Glands

1. Glands are organs that secrete. Exocrine glands secrete through ducts, and endocrine glands release hormones that are absorbed directly into the blood.
2. Glands are classified as unicellular or multicellular. Goblet cells are unicellular glands. Multicellular exocrine glands have ducts, which are simple or compound (branched). The ducts can be tubular or end in small sacs (acini or alveoli). Tubular glands can be straight or coiled.
3. Glands are classified according to their mode of secretion. Merocrine glands (pancreas) secrete substances as they are produced, apocrine glands (mammary glands) accumulate secretions that are released when a portion of the cell pinches off, and holocrine glands (sebaceous glands) accumulate secretions that are released when the cell ruptures and dies.

Connective Tissue (p. 117)

Connective tissue is distinguished by its extracellular matrix.

Cells of Connective Tissue

1. The extracellular matrix results from the activity of specialized connective tissue cells; in general, blast cells form the matrix, cyte cells maintain it, and clast cells break it down. Fibroblasts form protein fibers of many connective tissues, osteoblasts form bone, and chondroblasts form cartilage.
2. Adipose (fat) cells, mast cells, white blood cells, macrophages, and mesenchymal cells (stem cells) are commonly found in connective tissue.

Extracellular Matrix

The extracellular matrix of connective tissue has protein fibers, ground substance, and fluid as major components.

Protein Fibers of the Matrix

1. Collagen fibers structurally resemble ropes. They are strong and flexible but resist stretching.
2. Reticular fibers are fine collagen fibers that form a branching network that supports other cells and tissues.
3. Elastin fibers have a structure similar to a spring. After being stretched they tend to return to their original shape.

Other Matrix Molecules

1. Hyaluronic acid makes fluids slippery.
2. Proteoglycan aggregates trap water, which gives tissues the capacity to return to their original shape when compressed or deformed.
3. Adhesive molecules hold proteoglycans together and to plasma membranes.

Classification of Connective Tissue (p. 119)

Connective tissue is classified according to the type of protein and the proportions of protein, ground substance, and fluid in the matrix.

Embryonic Connective Tissue

Mesenchyme arises early, consists of irregularly shaped cells and abundant matrix, and gives rise to adult connective tissue.

Adult Connective Tissue

1. ***Loose Connective Tissue***
   - Loose (areolar) connective tissue has many different cell types and a random arrangement of protein fibers with space between the fibers. This tissue fills spaces around the organs and attaches the skin to underlying tissues.
2. ***Dense Connective Tissue***
   - Dense regular connective tissue is composed of fibers arranged in one direction, which provides strength in a direction parallel to the fiber orientation. Two types of dense regular connective tissue exist: collagenous (tendons and most ligaments) and elastic (ligaments of vertebrae).
   - Dense irregular connective tissue has fibers organized in many directions, which produces strength in different directions. Two types of dense irregular connective tissue exist: collagenous (capsules of organs and dermis of skin) and elastic (large arteries).

3. *Connective Tissue with Special Properties*
   - Adipose tissue has fat cells (adipocytes) filled with lipid and very little extracellular matrix (a few reticular fibers).
     Adipose tissue functions as energy storage, insulation, and protection.
     Adipose tissue can be yellow (white) or brown. Brown fat is specialized for generating heat.
   - Reticular tissue is a network of reticular fibers and forms the framework of lymphoid tissue, bone marrow, and the liver.
   - Hemopoietic tissue, or red bone marrow, is the site of blood cell formation, and yellow bone marrow is a site of fat storage.

4. *Cartilage*
   - Cartilage has a relatively rigid matrix composed of protein fibers and proteoglycan aggregates. The major cell type is the chondrocyte, which is located within lacunae.
     Hyaline cartilage has evenly dispersed collagen fibers that provide rigidity with some flexibility. Examples include the costal cartilage, the covering over the ends of bones in joints, the growing portion of long bones, and the embryonic skeleton.
     Fibrocartilage has collagen fibers arranged in thick bundles, it can withstand great pressure, and it is found between vertebrae, in the jaw, and in the knee.
     Elastic cartilage is similar to hyaline cartilage, but it has elastin fibers. It is more flexible than hyaline cartilage. It is found in the external ear.

5. *Bone*
   Bone cells, or osteocytes, are located in lacunae that are surrounded by a mineralized matrix (hydroxyapatite) that makes bone very hard. Cancellous bone has spaces between bony trabeculae, and compact bone is more solid.

6. *Hemopoietic Tissue and Blood*
   - Blood cells are suspended in a fluid matrix.
   - Hemopoietic tissue forms blood cells.

Muscle Tissue (p. 128)

1. Muscle tissue has the ability to contract.
2. Skeletal (striated voluntary) muscle attaches to bone and is responsible for body movement. Skeletal muscle cells are long, cylindrically shaped cells with many peripherally located nuclei.
3. Cardiac (striated involuntary) muscle cells are cylindrical, branching cells with a single, central nucleus. Cardiac muscle is found in the heart and is responsible for pumping blood through the circulatory system.
4. Smooth (nonstriated involuntary) muscle forms the walls of hollow organs, the iris of the eye, and other structures. Its cells are spindle-shaped with a single, central nucleus.

Nervous Tissue (p. 129)

1. Nervous tissue has the ability to conduct electric impulses and is composed of neurons (conductive cells) and neuroglia (support cells).
2. Neurons have cell processes called dendrites and axons. The dendrites can receive electric impulses, and the axons can conduct them. Neurons can be multipolar (several dendrites and an axon), bipolar (one dendrite and one axon), or unipolar (one axon).

Membranes (p. 132)

1. Mucous membranes consist of epithelial cells, their basement membrane, the lamina propria, and, sometimes, smooth muscle cells; they line cavities that open to the outside and often contain mucous glands, which secrete mucus.
2. Serous membranes line cavities that do not open to the exterior, do not contain glands, but do secrete serous fluid.
3. Synovial membranes are formed by connective tissue and line joint cavities.

Inflammation (p. 133)

1. The function of the inflammatory response is to isolate injurious agents from the rest of the body and to attack and destroy the injurious agent.
2. The inflammatory response produces five symptoms: redness, heat, swelling, pain, and disturbance of function.

Tissue Repair (p. 135)

1. Tissue repair is the substitution of viable cells for dead ones. Tissue repair occurs by regeneration or replacement.
   - Labile cells divide throughout life and can undergo regeneration.
   - Stable cells do not ordinarily divide after growth is complete but can regenerate if necessary.
   - Permanent cells cannot replicate. If killed, permanent tissue is repaired by replacement.
2. Tissue repair by primary union occurs when the edges of the wound are close together. Secondary union occurs when the edges are far apart.

Tissues and Aging (p. 136)

1. Age-related changes in tissues result from reduced rates of cell division and changes in the extracellular fibers.
2. Collagen fibers become less flexible and have reduced strength.
3. Elastic fibers become fragmented and less elastic.

REVIEW AND COMPREHENSION

1. Given these characteristics:
   1. capable of contraction
   2. covers free body surfaces
   3. lacks blood vessels
   4. composes various glands
   5. anchored to connective tissue by a basement membrane

   Which of these are characteristics of epithelial tissue?
   a. 1,2,3
   b. 2,3,5
   c. 3,4,5
   d. 1,2,3,4
   e. 2,3,4,5

2. Which of these embryonic germ layers gives rise to muscle, bone, and blood vessels?
   a. ectoderm
   b. endoderm
   c. mesoderm

3. A tissue that covers a surface, is one cell layer thick, and is composed of flat cells is
   a. simple squamous epithelium.
   b. simple cuboidal epithelium.
   c. simple columnar epithelium.
   d. stratified squamous epithelium.
   e. transitional epithelium.

4. Epithelium composed of two or more layers of cells with only the deepest layer in contact with the basement membrane is known as
   a. stratified epithelium.
   b. simple epithelium.
   c. pseudostratified epithelium.
   d. columnar epithelium.
   e. cuboidal epithelium.
5. Stratified epithelium is usually found in areas of the body where the principal activity is
   a. filtration.
   b. protection.
   c. absorption.
   d. diffusion.
   e. secretion.
6. Which of these characteristics do *not* describe moist stratified squamous epithelium?
   a. many layers of cells
   b. surface cells are flat
   c. surface cells are living
   d. found in the skin
   e. outer layers covered by fluid
7. In parts of the body such as the urinary bladder, where considerable expansion occurs, one can expect to find which type of epithelium?
   a. cuboidal
   b. pseudostratified
   c. transitional
   d. squamous
   e. columnar
8. A tissue that contains cells with these characteristics:
   1. covers a surface
   2. one layer of cells
   3. cells are flat

   Performs which of the following functions?
   a. phagocytosis
   b. active transport
   c. secretion of many complex lipids and proteins
   d. is adapted to allow certain substances to diffuse across it
   e. protection from abrasion
9. Epithelial cells with microvilli are most likely found
   a. lining blood vessels.
   b. lining the lungs.
   c. in serous membranes.
   d. lining the digestive tract.
   e. in the skin.
10. Pseudostratified ciliated columnar epithelium can be found lining the
    a. digestive tract.
    b. trachea.
    c. thyroid gland.
    d. kidney tubules.
    e. urinary bladder.
11. A type of cell connection whose *only* function is to prevent the cells from coming apart is the
    a. desmosome.
    b. gap junction.
    c. tight junction.
12. Those glands that lose their connection with epithelium during embryonic development and secrete their cellular products into the bloodstream are called _____ glands.
    a. apocrine
    b. endocrine
    c. exocrine
    d. holocrine
    e. merocrine
13. Glands that accumulate secretions and release them only when the individual secretory cells rupture and die are called _____ glands.
    a. apocrine
    b. holocrine
    c. merocrine
14. A gland has a duct that branches repeatedly, and the ducts end in saclike structures. This describes a _____ gland.
    a. simple tubular
    b. compound tubular
    c. simple coiled tubular
    d. simple acinar
    e. compound acinar
15. The fibers in dense connective tissue are produced by
    a. fibroblasts.
    b. adipocytes.
    c. osteoblasts.
    d. osteoclasts.
    e. macrophages.
16. Mesenchymal cells
    a. form embryonic connective tissue.
    b. give rise to all adult connective tissues.
    c. in adults produce new connective tissue cells in response to injury.
    d. all of the above
17. A tissue with a large number of collagen fibers organized parallel to each other would most likely be found in
    a. a muscle.
    b. a tendon.
    c. adipose tissue.
    d. a bone.
    e. cartilage.
18. Extremely delicate fibers that make up the framework for organs such as the liver, spleen, and lymph nodes are
    a. elastic fibers.
    b. reticular fibers.
    c. microvilli.
    d. cilia.
    e. collagen fibers.
19. In which of these locations would dense irregular elastic connective tissue be found?
    a. ligaments
    b. nuchal ligament
    c. dermis of skin
    d. large arteries
    e. adipose tissue
20. Which of these is *not* true of adipose tissue?
    a. site of energy storage
    b. a type of connective tissue
    c. acts as a protective cushion
    d. brown adipose is found only in babies
    e. functions as a heat insulator
21. Which of these types of connective tissue has the smallest amount of extracellular matrix?
    a. adipose
    b. bone
    c. cartilage
    d. loose connective tissue
    e. blood
22. Given these characteristics:
    1. cells located in lacunae
    2. proteoglycans in ground substance
    3. no collagen fibers present
    4. perichondrium on surface
    5. heals rapidly after injury

Which of these characteristics apply to cartilage?
a. 1,2,3
b. 1,2,4
c. 2,4,5
d. 1,2,4,5
e. 2,3,4,5

23. Fibrocartilage is found
a. in the cartilage of the trachea.
b. in the rib cage.
c. in the external ear.
d. on the surface of bones in moveable joints.
e. between vertebrae.

24. A tissue in which cells are located in lacunae surrounded by a hard matrix of hydroxyapatite is
a. hyaline cartilage.
b. bone.
c. nervous tissue.
d. dense regular collagenous connective tissue.
e. fibrocartilage.

25. Which of these characteristics apply to smooth muscle?
a. striated, involuntary
b. striated, voluntary
c. unstriated, involuntary
d. unstriated, voluntary

26. Which of these statements about nervous tissue is *not* true?
a. Neurons have cytoplasmic extensions called axons.
b. Electric signals (action potentials) are conducted along axons.
c. Bipolar neurons have two axons.
d. Neurons are nourished and protected by neuroglia.
e. Dendrites receive electric signals and conduct them toward the cell body.

27. Linings of the digestive, respiratory, excretory, and reproductive passages are composed of
a. serous membranes.
b. mucous membranes.
c. mesothelium.
d. synovial membranes.
e. endothelium.

28. Chemical mediators of inflammation
a. cause blood vessels to constrict.
b. decrease the permeability of blood vessels.
c. initiate processes that lead to edema.
d. help to prevent clotting.
e. decrease pain.

29. Which of these types of cells are labile?
a. neurons
b. skin
c. liver
d. pancreas

30. Permanent cells
a. divide and replace damaged cells in replacement tissue repair.
b. form granulation tissue.
c. are responsible for removing scar tissue.
d. are usually replaced by a different cell type if they are destroyed.
e. are replaced during regeneration tissue repair.

Answers in Appendix F

CRITICAL THINKING

1. Given the observation that a tissue has more than one layer of cells lining a free surface, (1) list the possible tissue types that exhibit those characteristics, and (2) explain what additional observations need to be made to identify the tissue as a specific tissue type.
2. A patient suffered from kidney failure a few days after he was exposed to a toxic chemical. A biopsy of his kidney indicated that many of the thousands of epithelium-lined tubules that make up the kidney had lost the layer of simple cuboidal epithelial cells that normally line them, although the basement membranes appeared to be mostly intact. Predict how likely this person is to fully recover.
3. Compare the cell shapes and surface specializations of an epithelium that functions to resist abrasion to those of an epithelium that functions to carry out absorption of materials.
4. Tell how to distinguish between a gland that produces a merocrine secretion and a gland that produces a holocrine secretion. Assume that you have the ability to chemically analyze the composition of secretions.
5. Indicate whether the following statement is appropriate or not: "If a tissue is capable of contracting, is under involuntary control, and has mononucleated cells, it is smooth muscle." Explain your answer.
6. Antihistamines block the effect of a chemical mediator of inflammation called histamine, which is released during the inflammatory response. What effect does administering antihistamines have on the inflammatory response, and is use of an antihistamine beneficial?

Answers in Appendix G

ANSWERS TO PREDICT QUESTIONS

1. a. Secretion of mucus and digestive enzymes and the absorption of nutrients normally occur in the digestive tract. Simple columnar epithelial cells contain organelles that are specialized to carry out nutrient absorption and secretion of mucus and digestive enzymes. Stratified squamous epithelium is not specialized to either absorb or secrete, and the layers of epithelial cells reduce the ability of nutrient molecules to pass through them and, therefore, to be absorbed. The ability of digestive enzymes to pass through the layers of epithelial cells, and therefore be secreted, is also reduced.

b. Keratinized stratified epithelium forms a tough layer that is a barrier to the movement of water. Replacing the epithelium of skin with moist stratified squamous epithelium increases the loss of water across the skin because water can diffuse through moist stratified squamous epithelium, and it is more delicate and provides less protection than keratinized stratified squamous epithelium.

c. The stratified squamous epithelium that lines the mouth provides protection. Replacement of it with simple columnar epithelium makes the lining of the mouth much more susceptible to damage because the single layer of epithelial cells is easier to damage.

2. Elastic ligaments attached to the vertebrae help the vertebral column return to its normal upright position after it is flexed. The elastic ligaments act much like elastic bands. Tendons attach muscles to bones. When muscles contract, they pull on the tendons, which in turn pull on bones. Because they are not elastic, when the muscle pulls on the tendon, all of the force is applied to the bone, causing it to move. If tendons were elastic, when the muscle contracted, the tendon would stretch, and not all of the tension would be applied to the bone.
3. Collagen synthesis is required for scar formation. If collagen synthesis does not occur because of a lack of vitamin C or if collagen synthesis is slowed, wound healing does not occur or is slower than normal. One might expect that the density of collagen fibers in a scar is reduced and the scar is not as durable as a normal scar.
4. Hyaline cartilage provides a smooth surface so that bones in joints can move easily. When the smooth surface provided by hyaline cartilage is replaced by dense fibrous connective tissue, the smooth surface is replaced by a less smooth surface, and the movement of bones in joints is much more difficult. The increased friction helps to increase inflammation and pain that occurs in the joints of people who have rheumatoid arthritis.
5. In severely damaged tissue in which cells are killed and blood vessels are destroyed, the usual symptoms of inflammation cannot occur. Surrounding these areas of severe tissue damage, however, where blood vessels are still intact and cells are still living, the classic signs of inflammation do develop. The signs of inflammation therefore appear around the periphery of severely injured tissues.