did you know?

People who have never taken biology courses bave been known to remark, "I don't want to lift weights, because if I build muscular tissue, I am afraid it will turn to fat when I stop lifting." Of course, muscular tissue is specialized for its contractile function, and does not "turn into" fat tissue, which is specialized for energy storage. As people age, skeletal muscles do atropby, or shrink, over the years. Adipose tissue tends to grow. While some of these changes in body composition appear to be an inevitable part of the aging process, scientists believe much of the loss of muscular tissue can be

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prevented with exercise training.

 $A_{\rm s\,you}$ learned in the previous chapter, cells are highly organized living units,

but they typically do not function alone. Instead, cells work together in groups called tissues. A tissue is a group of similar cells, usually with a common embryonic origin, that function together to carry out specialized activities. Histology (hiss-TOL-ō-jē; hist- = tissue; -logy = study of) is the science that deals with the study of tissues. A pathologist (pa-THOL-ō-gist; patho- = disease) is a physician who specializes in laboratory studies of cells and tissues to help other physicians make accurate diagnoses. One of the principal functions of a pathologist is to examine tissues for any changes that might indicate disease.

looking back to move ahead . .

- Levels of Organization and Body Systems (page 2)
- A Generalized View of the Cell (page 45)
- Phagocytosis (page 51)
- Cytosol (page 52)
- Organelles (page 52)
- Cilia (page 54)

TYPES OF TISSUES

OBJECTIVE • Name four basic types of tissue that make up the human body and state the characteristics of each.

Body tissues are classified into four basic types based on their structure and functions:

- 1. Epithelial tissue (ep'-i-THĒ-lē-al) covers body surfaces; lines body cavities, hollow organs, and ducts (tubes); and forms glands.
- 2. Connective tissue protects and supports the body and its organs, binds organs together, stores energy reserves as fat, and provides immunity.
- 3. Muscular tissue generates the physical force needed to make body structures move.
- 4. Nervous tissue detects changes inside and outside the body and initiates and transmits nerve impulses (action potentials) that coordinate body activities to help maintain homeostasis.

Epithelial tissue and most types of connective tissue are discussed in detail in this chapter. The structure and functions of bone tissue and blood (connective tissues), muscular tissue, and nervous tissue are examined in detail in later chapters.

Most epithelial cells and some muscle and nerve cells are tightly joined into functional units by points of contact between their plasma membranes called *cell junctions*. Some cell junctions fuse cells together so tightly that they prevent substances from passing between the cells. This fusion is very important for tissues that line the stomach, intestines, and urinary bladder because it prevents the contents of these organs from leaking out. Other cell junctions hold cells together so that they don't separate while performing their functions. Still other cell junctions form channels that allow ions and molecules to pass between cells. This permits cells in a tissue to communicate with each other and it also enables nerve or muscle impulses to spread rapidly among cells.

CHECKPOINT

- Define a tissue. What are the four basic types of body tissues?
- 2. Why are cell junctions important?

EPITHELIAL TISSUE

OBJECTIVES • Discuss the general features of epithelial tissue.

• Describe the structure, location, and function of the various types of epithelial tissue.

Epithelial tissue, or more simply epithelium (plural is epithelia), may be divided into two types: (1) covering and lining epithelium and (2) glandular epithelium. As its name suggests, covering and lining epithelium forms the outer covering of the skin and the outer covering of some internal organs. It also lines body cavities; blood vessels; ducts; and the interiors of the respiratory, digestive, urinary, and reproductive systems. It makes up, along with nervous tissue, the parts of the sense organs for hearing, vision, and touch. Glandular epithelium makes up the secreting portion of glands, such as sweat glands.

General Features of Epithelial Tissue

As you will see shortly, there are many different types of epithelia, each with characteristic structure and functions. However, all of the different types of epithelial tissue also have features in common. General features of epithelial tissue include the following:

- 1. Epithelium consists largely or entirely of closely packed cells with little extracellular material between them, and the cells are arranged in continuous sheets, in either single or multiple layers.
- 2. Epithelial cells have an apical (free) surface, which is exposed to a body cavity, lining of an internal organ, or the exterior of the body; lateral surfaces, which face adjacent cells on either side; and a basal surface, which is attached to a basement membrane. In discussing epithelia with multiple layers, the term apical layer refers to the most superficial layer of cells, whereas the term basal layer refers to the deepest layer of cells. The basement membrane is a thin extracellular structure composed mostly of protein fibers. It is located between the epithelium and the underlying connective tissue layer and helps bind and support the epithelium.
- 3. Epithelia are avascular (a- = without; vascular = blood vessels); that is, they lack blood vessels. The vessels that supply nutrients to and remove wastes from epithelia are located in adjacent connective tissues. The exchange of materials between epithelium and connective tissue occurs by diffusion.
- 4. Epithelia have a nerve supply.
- 5. Because epithelium is subject to a certain amount of wear and tear and injury, it has a high capacity for renewal by cell division.

Covering and Lining Epithelium

Covering and lining epithelium, which covers or lines various parts of the body, is classified according to the arrangement of cells into layers and the shape of the cells (Figure 4.1):

1. Arrangement of cells in layers. The cells of covering and lining epithelia are arranged in one or more layers depending on the functions the epithelium performs:

Figure 4.1 Cell shapes and arrangement of layers for covering and lining epithelium.

Cell shapes and arrangement of layers are the bases for classifying covering and lining epithelium. **Basement** Arrangement membrane of layers Stratified Simple Basement membrane Cell shape Cuboidal Columnar Squamous Which cell shape is best adapted for the rapid movement of substances from one cell to another?

- a. Simple epithelium is a single layer of cells that functions in diffusion, osmosis, filtration, secretion, and absorption. Secretion is the production and release of substances such as mucus, sweat, or enzymes. Absorption is the intake of fluids or other substances such as digested food from the intestinal tract.
- **b.** Pseudostratified epithelium (pseudo- = false) appears to have multiple layers of cells because the cell nuclei lie at different levels and not all cells reach the apical surface. Cells that do extend to the apical surface may contain cilia; others (goblet cells) secrete mucus. Pseudostratified epithelium is actually a simple epithelium because all its cells rest on the basement membrane.
- c. Stratified epithelium (stratum = layer) consists of two or more layers of cells that protect underlying tissues in locations where there is considerable wear and tear.

2. Cell shapes.

- a. Squamous cells (SKWA-mus = flat) are arranged like floor tiles and are thin, which allows for the rapid passage of substances.
- b. Cuboidal cells are as tall as they are wide and are shaped like cubes or hexagons. They may have microvilli at their apical surface and function in either secretion or absorption.
- c. Columnar cells are much taller than they are wide, like columns, and protect underlying tissues. Their apical

- surfaces may have cilia or microvilli, and they often are specialized for secretion and absorption.
- d. Transitional cells change shape, from flat to cuboidal, as organs such as the urinary bladder stretch (distend) to a larger size and then collapse to a smaller size.

*Combining the two characteristics (arrangements of layers and cell shapes), the types of covering and lining epithelia are as follows:

Simple epithelium

- A. Simple squamous epithelium
- B. Simple cuboidal epithelium
- C. Simple columnar epithelium (nonciliated and ciliated)
- D. Pseudostratified columnar epithelium (nonciliated and ciliated)

II. Stratified epithelium

- A. Stratified squamous epithelium (keratinized and nonkeratinized)*
- B. Stratified cuboidal epithelium*
- C. Stratified columnar epithelium*
- D. Transitional epithelium

^{*}This classification is based on the shape of the cells in the apical layer.

Each of these covering and lining epithelia is described in the following sections and illustrated in Table 4.1. The illustration of each type consists of a photomicrograph, a corresponding diagram, and an inset that identifies a major location of the tissue in the body. Descriptions, locations, and functions of the tissues accompany each illustration.

Simple Epithelium

SIMPLE SQUAMOUS EPITHELIUM This tissue consists of a single layer of flat cells that resembles a tiled floor when viewed from its apical surface (Table 4.1A). The nucleus of each cell is a flattened oval or sphere and is centrally located. Simple squamous epithelium is found in parts of the body where filtration (kidneys) or diffusion (lungs) are priority processes. It is not found in body areas that are subjected to wear and tear.

The simple squamous epithelium that lines the heart, blood vessels, and lymphatic vessels is known as endothelium (endo- = within; -thelium = covering); the type that forms the epithelial layer of serous membranes, such as the peritoneum, is called mesothelium (meso- = middle).

SIMPLE CUBOIDAL EPITHELIUM The cuboidal shape of the cells in this tissue (Table 4.1B) is obvious only when the tissue is sectioned and viewed from the side. Cell nuclei are usually round and centrally located. Simple cuboidal epithelium is found in organs such as the thyroid gland and kidneys and performs the functions of secretion and absorption.

SIMPLE COLUMNAR EPITHELIUM When viewed from the side, the cells of simple columnar epithelium appear like columns with oval nuclei near the base of the cells. Simple columnar epithelium exists in two forms: nonciliated simple columnar epithelium and ciliated simple columnar epithelium.

Nonciliated simple columnar epithelium contains two types of cells-columnar epithelial cells with microvilli at their apical surface, and goblet cells (Table 4.1C). Microvilli, microscopic fingerlike projections, increase the surface area of the plasma membrane (see Figure 3.1 on page 45), thus increasing the rate of absorption by the cell. Goblet cells are modified columnar cells that secrete mucus, a slightly sticky fluid, at their apical surfaces. Before it is released, mucus accumulates in the upper portion of the cell, causing that area to bulge out. The whole cell then resembles a goblet or wine glass. Secreted mucus serves as a lubricant for the linings of the digestive, respiratory, reproductive, and most of the urinary tracts. Mucus also helps to trap dust entering the respiratory tract, and it prevents destruction of the stomach lining by acid secreted by the stomach.

Ciliated simple columnar epithelium (Table 4.1D) contains cells with cilia at their apical surface. In a few parts of the upper respiratory tract, ciliated columnar cells are interspersed with goblet cells. Mucus secreted by the goblet cells forms a film over the respiratory surface that traps inhaled foreign particles. The cilia wave in unison and move the mucus and any trapped foreign particles toward the throat, where it can be coughed up and swallowed or spit out. Cilia also help to move oocytes expelled by the ovaries through the uterine tubes into the uterus.

Pseudostratified Columnar Epithelium

As noted earlier, pseudostratified columnar epithelium appears to have several layers because the nuclei of the cells are at various depths (Table 4.1E). Even though all the cells are attached to the basement membrane in a single layer, some cells do not extend to the apical surface. When viewed from the side, these features give the false impression of a multilayered tissue—thus the name pseudostratified epithelium (pseudo- = false). In pseudostratified ciliated columnar epithelium, the cells that extend to the surface either secrete mucus (goblet cells) or bear cilia. The secreted mucus traps foreign particles and the cilia sweep away mucus for eventual elimination from the body. Pseudostratified nonciliated columnar epithelium contains cells without cilia and lacks goblet cells.

Stratified Epithelium

Stratified epithelium contains two or more layers of cells used for protection of underlying tissues in areas where there is considerable wear and tear. Some cells of stratified epithelia also produce secretions. The name of the specific kind of stratified epithelium depends on the shape of the cells in the apical layer.

STRATIFIED SQUAMOUS EPITHELIUM Cells in the apical layer of this type of epithelium are flat; those in the deep layers vary in shape from cuboidal to columnar (Table 4.1F). The basal (deepest) cells continually undergo cell division. As new cells grow, the cells of the basal layer are pushed upward toward the surface. As they move farther from the deeper layers and from their blood supply in the underlying connective tissue, they become dehydrated, shrunken, and harder At the apical layer, the cells lose their cell junctions and are sloughed off, but they are replaced as new cells continually emerge from the basal cells.

Stratified squamous epithelium exists in both keratinized and nonkeratinized forms. In keratinized stratified squamou. epithelium, a tough layer of keratin is deposited in the apica layer and several layers deep to it. Keratin is a tough proteir that helps protect the skin and underlying tissues from microbes, heat, and chemicals. Nonkeratinized stratified squamou epithelium, which is found, for example, lining the mouth does not contain keratin in the apical layer and several layer. deep to it and remains moist. Stratified squamous epitheliun forms the first line of defense against microbes.

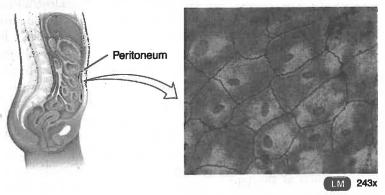
Simple Epithelium

A. Simple squamous epithelium

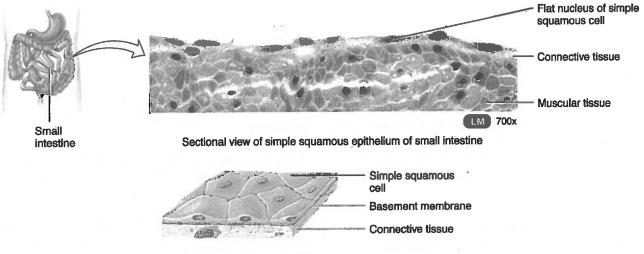
Description: Single layer of flat cells; centrally located nucleus.

Location: Lines heart, blood vessels, lymphatic vessels, air sacs of lungs, glomerular (Bowman's) capsule of kidneys, and inner surface of the tympanic membrance (eardrum); forms epithelial layer of serous membranes, such as the peritoneum.

Function: Filtration, diffusion, osmosis, and secretion in serous membranes.



Surface view of simple squamous epithelium of mesothelial lining of peritoneum



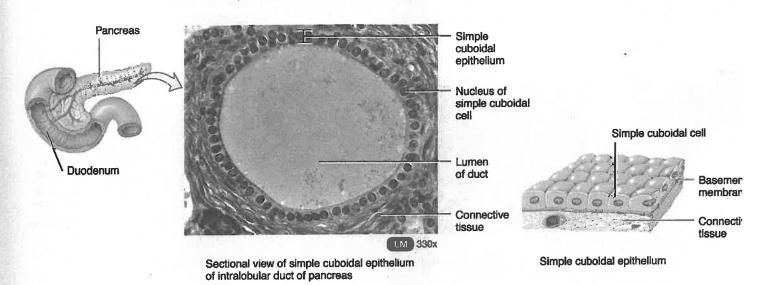
Simple squamous epithelium

B. Simple cuboidal epithelium

Description: Single layer of cube-shaped cells; centrally located nucleus.

Location: Covers surface of ovary, lines anterior surface of capsule of the lens of the eye, forms the pigmented epithelium the posterior surface of the eye, lines kidney tubules and smaller ducts of many glands, and makes up the secreting portior some glands such as the thyroid gland.

Function: Secretion and absorption.

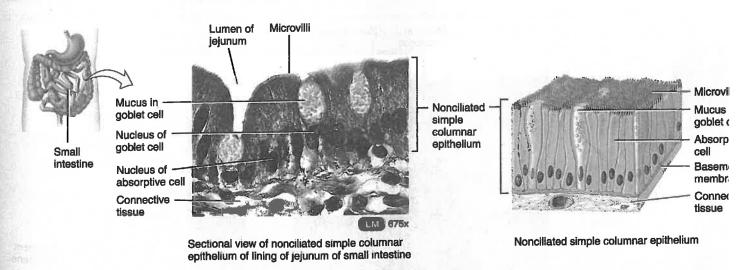


C. Nonciliated simple columnar epithelium

Description: Single layer of nonciliated column-like cells with nuclei near bases of cells; contains goblet cells and cells with microvilli in some locations.

Location: Lines most of the gastrointestinal tract (from the stomach to the anus), ducts of many glands, and gallbladder.

Function: Secretion and absorption.

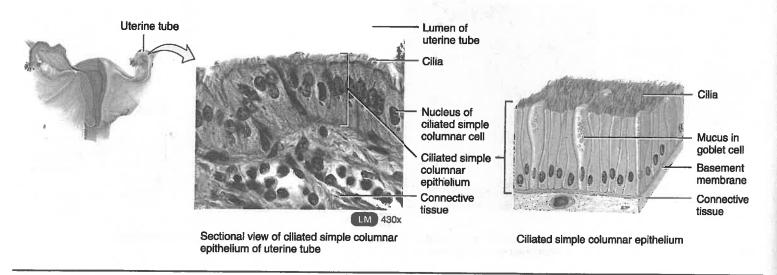


D. Cliated simple columnar epithelium

Description: Single layer of ciliated column-like cells with nuclei near bases; contains goblet cells in some locations.

Location: Lines a few portions of upper respiratory tract, uterine (fallopian) tubes, uterus, some paranasal sinuses, and central canal of spinal cord.

Function: Moves mucus and other substances by ciliary action.

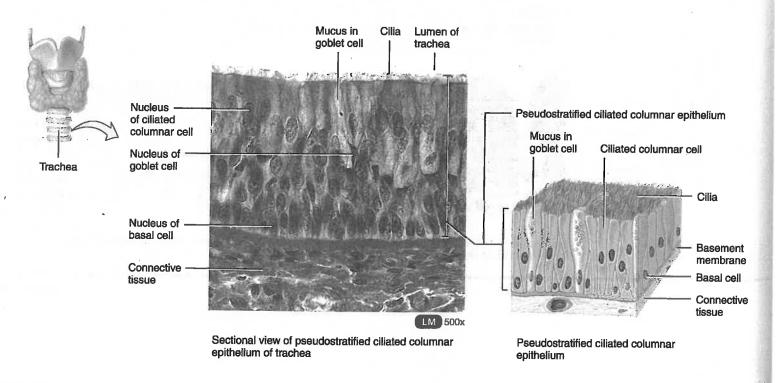


E. Pseudostratified columnar epithelium

Description: Not a true stratified tissue; nuclei of cells are at different levels, all cells are attached to basement membrane, but not all reach the apical surface.

Location: Pseudostratified ciliated columnar epithelium lines the airways of most of upper respiratory tract; pseudostratified nonciliated columnar epithelium lines larger ducts of many glands, epididymis, and part of male urethra.

Function: Secretion and movement of mucus by ciliary action.



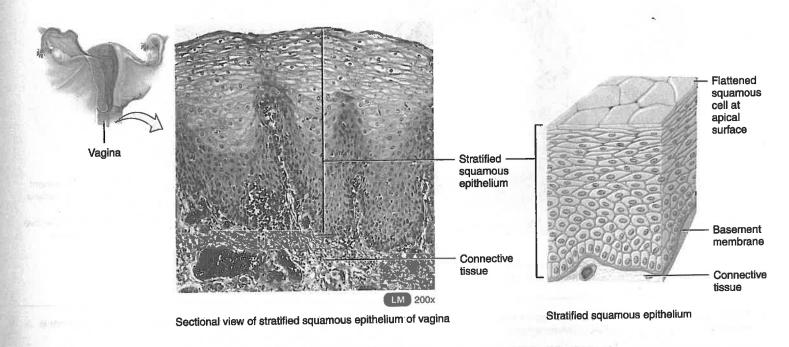
Stratified Epithelium

F. Stratified squamous epithelium

Description: Several layers of cells; cuboidal to columnar shape in deep layers; squamous cells form the apical layer and several layers deep to it; cells from the basal layer replace surface cells as they are lost.

Location: Keratinized variety forms superficial layer of skin; nonkeratinized variety lines wet surfaces, such as lining of the mouth, esophagus, part of epiglottis, part of pharynx, and vagina, and covers the tongue.

Function: Protection.

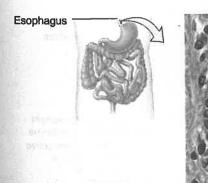


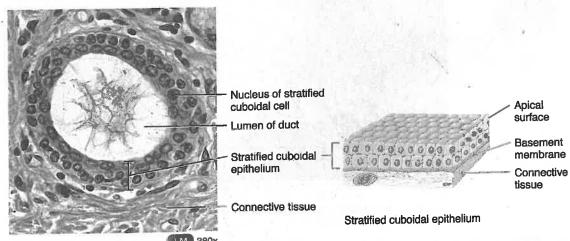
G. Stratified cuboidal epithelium

Description: Two or more layers of cells in which cells in the apical layer are cube-shaped.

Location: Ducts of adult sweat glands and esophageal glands and part of male urethra.

Function: Protection and limited secretion and absorption.





Sectional view of stratified cuboidal epithelium of the duct of an esophageal gland

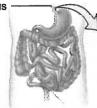
H. Stratified columnar epithelium

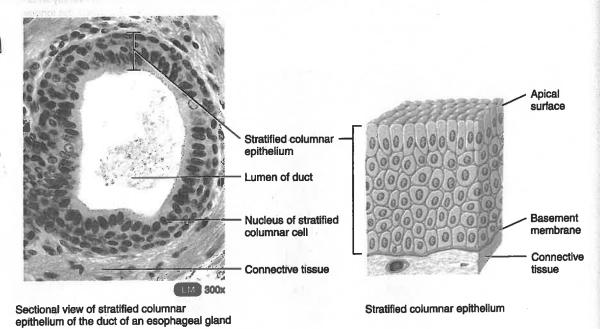
Description: Several layers of irregularly shaped cells; only the apical layer has columnar cells.

Location: Lines part of urethra, large excretory ducts of some glands such as esophageal glands, small areas in anal mucous membrane, and a part of the conjunctiva of the eye.

Function: Protection and secretion.







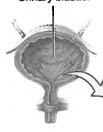
i. Transitional epithelium

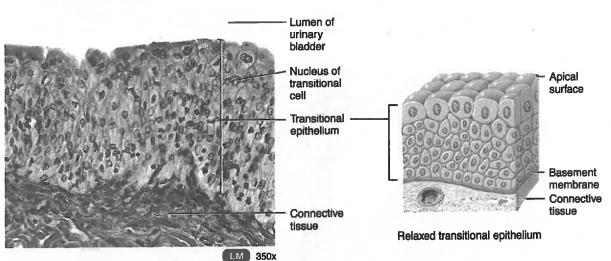
Description: Appearance is variable (transitional); shape of cells in apical layer ranges from squamous (when stretched) to cuboidal (when relaxed).

Location: Lines urinary bladder and portions of ureters and urethra.

Function: Permits distention.

Urinary bladder





Sectional view of transitional epithelium of urinary bladder in relaxed state

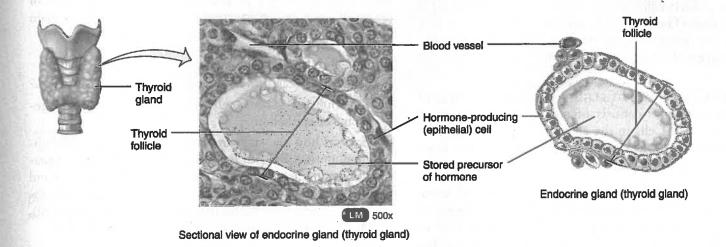
Glandular Epithelium

J. Endocrine glands

Description: Secretory products (hormones) diffuse into blood after passing through interstitial fluid.

Location: Examples include pituitary gland at base of brain, pineal gland in brain, thyroid and parathyroid glands near larynx (voice box), adrenal glands superior to kidneys, pancreas near stomach, ovaries in pelvic cavity, testes in scrotum, and thymus in thoracic cavity.

Function: Produce hormones that regulate various body activities.

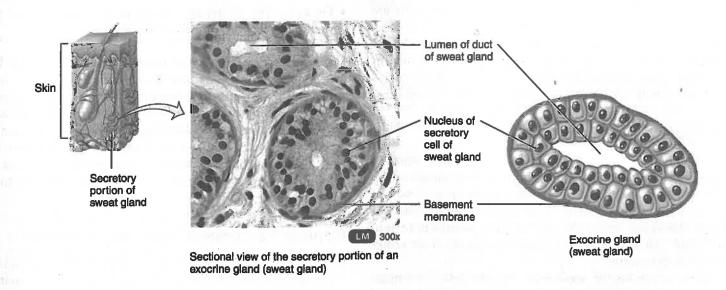


K. Exocrine glands

Description: Secretory products released into ducts.

Location: Sweat, oil, and earwax glands of the skin; digestive glands such as salivary glands, which secrete into mouth cavity, and pancreas, which secretes into the small intestine.

Function: Produce substances such as sweat, oil, earwax, saliva, or digestive enzymes.



A Papanicolaou test (pa-pa-NI-kō-lō), also called a Pap test or Pap smear, involves collection and microscopic examination of epithelial cells that have been scraped off the apical layer of a tissue. A very common type of Pap test involves examining the cells from the nonkeratinized stratified squamous epithelium of the vagina and cervix (inferior portion) of the uterus. This type of Pap test is performed mainly to detect early changes in the cells of the female reproductive system that may indicate cancer or a precancerous condition. In performing a Pap smear, a physician collects cells, which are then smeared on a microscope slide. The slides are then sent to a laboratory for analysis. An annual Pap test is recommended for all women as part of a routine pelvic exam.

STRATIFIED CUBOIDAL EPITHELIUM This fairly rare type of epithelium sometimes consists of more than two layers of cells (Table 4.1G). Cells in the apical layer are cuboidal. Its function is mainly protective; in some locations it also functions in secretion and absorption.

STRATIFIED COLUMNAR EPITHELIUM This type of tissue also is uncommon. Usually the basal layer or layers consist of shortened, irregularly shaped cells; only the apical layer of cells is columnar in form (Table 4.1H). This type of epithelium functions in protection and secretion.

Transitional Epithelium This type of stratified epithelium is variable in appearance, depending on whether the organ it lines is unstretched or stretched. In its unstretched state (Table 4.1I), transitional epithelium looks similar to stratified cuboidal epithelium, except that the cells in the apical layer tend to be large and rounded. As the cells are stretched, they become flatter, giving the appearance of stratified squamous epithelium. Because of its elasticity, transitional epithelium lines hollow structures that are subjected to expansion from within, such as the urinary bladder. It allows organs to stretch to hold a variable amount of fluid without rupturing.

Glandular Epithelium

The function of glandular epithelium is secretion, which is accomplished by glandular cells that often lie in clusters deep to the covering and lining epithelium. A *gland* may consist of one cell or a group of highly specialized epithelial cells that secrete substances into ducts (tubes), onto a surface, or into the blood. All glands of the body are classified as either endocrine or exocrine.

The secretions of *endocrine glands* (*endo*-= within; -*crine* = secretion) (Table 4.1]) enter the interstitial fluid and then diffuse into the bloodstream without flowing through a duct. These secretions, called *hormones*, regulate many metabolic and physiological activities to maintain homeostasis. The pituitary, thyroid, and adrenal glands are examples of

endocrine glands. Endocrine glands will be described in detail in Chapter 13.

Exocrine glands (exo- = outside; Table 4.1K) secrete their products into ducts that empty at the surface of covering and lining epithelium such as the skin surface or the lumen (interior space) of a hollow organ. The secretions of exocrine glands include mucus, perspiration, oil, earwax, milk, saliva, and digestive enzymes. Examples of exocrine glands are sweat glands, which produce perspiration to help lower body temperature, and salivary glands, which secrete mucus and digestive enzymes. As you will see later, some glands of the body, such as the pancreas, ovaries, and testes, contain both endocrine and exocrine tissue.

■ CHECKPOINT

- 3. What characteristics are common to all epithelial tissues?
- 4. Describe the various cell shapes and layering arrangements of epithelium.
- 5. Explain how the structure of the following kinds of epithelium is related to the functions of each: simple squamous, simple cuboidal, simple columnar (nonciliated and ciliated), pseudostratified columnar (nonciliated and ciliated), stratified squamous (keratinized and nonkeratinized), stratified cuboidal, stratified columnar, and transitional.

CONNECTIVE TISSUE

OBJECTIVES

- Discuss the general features of connective tissue.
- Describe the structure, location, and function of the various types of connective tissue.

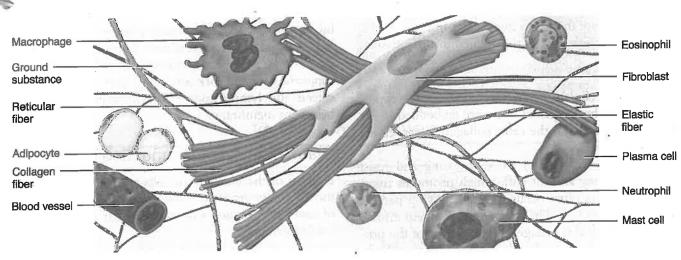
Connective tissue is one of the most abundant and widely distributed tissues in the body. In its various forms, connective tissue has a variety of functions. It binds together, supports, and strengthens other body tissues; protects and insulates internal organs; compartmentalizes structures such as skeletal muscles; is the major transport system within the body (blood, a fluid connective tissue); is the major site of stored energy reserves (adipose, or fat tissue); and is the main site of immune responses.

General Features of Connective Tissue

Connective tissue consists of two basic elements: cells and extracellular matrix. A connective tissue's extracellular matrix is the material between its widely spaced cells. The extracellular matrix consists of protein fibers and ground substance, the material between the cells and the fibers. The extracellular matrix is usually secreted by the connective tissue cells and determines the tissue's qualities. For instance, in cartilage,

Figure 4.2 Representative cells and fibers present in connective tissues.

Fibroblasts are usually the most numerous connective tissue cells.





the extracellular matrix is firm but pliable. The extracellular matrix of bone, by contrast, is hard and not pliable.

In contrast to epithelia, connective tissues do not usually occur on body surfaces. Also, unlike epithelia, connective tissues usually are highly vascular; that is, they have a rich blood supply. Exceptions include cartilage, which is avascular, and tendons, with a scanty blood supply. Except for cartilage, connective tissues, like epithelia, are supplied with nerves.

Connective Tissue Cells

The types of connective tissue cells vary according to the type of tissue and include the following (Figure 4.2):

- 1. Fibroblasts (FĪ-brō-blasts; fibro- = fibers) are large, flat cells with branching processes. They are present in several connective tissues, and usually are the most numerous. Fibroblasts migrate through the connective tissue, secreting the fibers and ground substance of the extracellular matrix.
- 2. Macrophages (MAK-rō-fā-jez; macro- = large; -phages = eaters) develop from monocytes, a type of white blood cell. Macrophages have an irregular shape with short branching projections and are capable of engulfing bacteria and cellular debris by phagocytosis.
- 3. Plasma cells are small cells that develop from a type of white blood cell called a B lymphocyte. Plasma cells secrete antibodies, proteins that attack or neutralize foreign substances in the body. Thus, plasma cells are an important part of the body's immune response.
- 4. Mast cells are abundant alongside the blood vessels that supply connective tissue. They produce histamine, a

- chemical that dilates small blood vessels as part of the inflammatory response, the body's reaction to injury or infection. Mast cells can also kill bacteria.
- 5. Adipocytes, also called fat cells or adipose cells, are connective tissue cells that store triglycerides (fats). They are found below the skin and around organs such as the heart and kidneys.

Connective Tissue Extracellular Matrix

Each type of connective tissue has unique properties, based on the specific extracellular materials between the cells. The extracellular matrix consists of a fluid, gel, or solid ground substance plus protein fibers.

Ground Substance

Ground substance, the component of a connective tissue between the cells and fibers, supports cells, binds them together, and provides a medium through which substances are exchanged between the blood and cells. The ground substance plays an active role in how tissues develop, migrate, proliferate, and change shape, and in how they carry out their metabolic functions.

Ground substance contains water and an assortment of large organic molecules, many of which are complex combinations of polysaccharides and proteins. For example, byaluronic acid (hī'-a-loo-RON-ik) is a viscous, slippery substance that binds cells together, lubricates joints, and helps maintain the shape of the eyeballs. It also appears to play a role in helping phagocytes migrate through connective tissue during development and wound repair. White blood cells, sperm cells, and some bacteria produce byaluronidase, an enzyme

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that breaks apart hyaluronic acid and causes the ground substance of connective tissue to become watery. The ability to produce hyaluronidase enables white blood cells to move through connective tissues to reach sites of infection and sperm cells to penetrate the ovum during fertilization. It also accounts for how bacteria spread through connective tissues.

Fibers

Fibers in the extracellular matrix strengthen and support connective tissues. Three types of fibers are embedded in the extracellular matrix between the cells: collagen fibers, elastic fibers, and reticular fibers.

Collagen fibers (colla = glue) are very strong and resist pulling forces, but they are not stiff, which promotes tissue flexibility. These fibers often occur in bundles lying parallel to one another (Figure 4.2). The bundle arrangement affords great strength. Chemically, collagen fibers consist of the protein collagen. This is the most abundant protein in your body, representing about 25% of total protein. Collagen fibers are found in most types of connective tissues, especially bone, cartilage, tendons, and ligaments.

Despite their strength, ligaments may be stressed beyond their normal capacity. This results in sprain, a stretched or torn ligament. The ankle joint is most frequently sprained. Because of their poor blood supply, the healing of even partially torn ligaments is a very slow process; completely torn ligaments require surgical repair.

Elastic fibers, which are smaller in diameter than collagen fibers, branch and join together to form a network within a tissue. An elastic fiber consists of molecules of a protein called elastin surrounded by a glycoprotein named fibrillin, which is essential to the stability of an elastic fiber. Elastic fibers are strong but can be stretched up to one-and-a-half times their relaxed length without breaking. Equally important, elastic fibers have the ability to return to their original shape after being stretched, a property called elasticity. Elastic fibers are plentiful in skin, blood vessel walls, and lung tissue.

Marfan syndrome (MAR-fan) is an inherited disorder caused by a defective fibrillin gene. The result is abnormal development of elastic fibers. Tissues rich in elastic fibers are malformed or weakened. Structures affected most seriously are the covering layer of bones (periosteum), the ligament that suspends the lens of the eye, and the walls of the large arteries. People with Marfan syndrome tend to be tall and have disproportionately long arms, legs, fingers, and toes. A common symptom is blurred vision caused by displacement of the lens of the eye. The most life-threatening complication of Marfan syndrome is weakening of the aorta (the main artery that emerges from the heart), which can suddenly burst.

Reticular fibers (reticul- = net), consisting of collagen and a coating of glycoprotein, provide support in the walls of blood vessels and form branching networks around fat cells, nerve fibers, and skeletal and smooth muscle cells. Produced by fibroblasts, they are much thinner than collagen fibers. Like collagen fibers, reticular fibers provide support and strength and also form the stroma (= bed or covering) or supporting framework of many soft organs, such as the spleen and lymph nodes. These fibers also help form the basement membrane.

Classification of Connective Tissues

Because of the diversity of cells and extracellular matrix and the differences in their relative proportions, the classification of connective tissues is not always clear-cut. We offer the following scheme:

- I. Loose connective tissue
 - A. Areolar connective tissue
 - B. Adipose tissue
 - C. Reticular connective tissue
- II. Dense connective tissue
 - D. Dense regular connective tissue
 - E. Dense irregular connective tissue
 - F. Elastic connective tissue
- III. Cartilage
 - G. Hyaline cartilage
 - H. Fibrocartilage
 - I. Elastic cartilage
- IV. Bone tissue
- V. Liquid connective tissue (blood tissue and lymph)

Loose Connective Tissue

The fibers in *loose connective tissue* are loosely intertwined among the many cells. The types of loose connective tissue are areolar connective tissue, adipose tissue, and reticular connective tissue.

AREOLAR CONNECTIVE TISSUE One of the most widely distributed connective tissues in the body is areolar connective tissue (a-RĒ-ō-lar; areol- = a small space). It contains several kinds of cells, including fibroblasts, macrophages, plasma cells, mast cells, adipocytes, and a few white blood cells (Table 4.2A). All three types of fibers—collagen, elastic, and reticular—are arranged randomly throughout the tissue. Combined with adipose tissue, areolar connective tissue forms the subcutaneous layer, the layer of tissue that attaches the skin to underlying tissues and organs.

ADIPOSE TISSUE Adipose tissue is a loose connective tissue in which the cells, called *adipocytes* (*adipo-* = fat), are specialized for storage of triglycerides (fats) (Table 4.2B). Because the cell fills up with a single, large triglyceride droplet, the

cytoplasm and nucleus are pushed to the periphery of the cell. Adipose tissue is found wherever areolar connective tissue is located. Adipose tissue is a good insulator and can therefore reduce heat loss through the skin. It is a major energy reserve and generally supports and protects various organs. As the amount of adipose tissue increases with weight gain, new blood vessels form. Thus, an obese person has many more blood vessels than does a lean person, a situation that can cause high blood pressure, since the heart has to work harder. A surgical procedure, called liposuction (lip- = fat) or suction lipectomy (-ectomy = to cut out), involves suctioning out small amounts of adipose tissue from various areas of the body. The technique can be used as a body-contouring procedure in regions such as the thighs, buttocks, arms, breasts, and abdomen. Postsurgical complications that may develop include fat emboli (clots), infection, fluid depletion, injury to internal structures, and severe postoperative pain.

Table 4.2 Connective Tissues

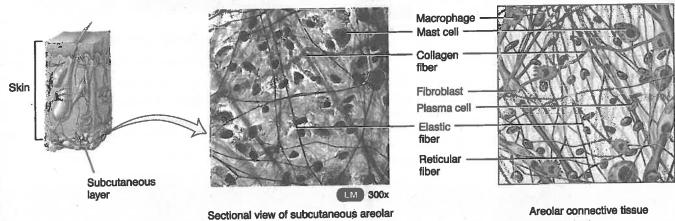
Loose Connective Tissue

Areolar connective tiesua

Description: Consists of fibers (collagen, elastic, and reticular) and several kinds of cells (fibroblasts, macrophages, plasma cells, adipocytes, and mast cells) embedded in a semifluid ground substance.

Location: Subcutaneous layer deep to skin; superficial region of dermis of skin; lamina propria of mucous membranes; and around blood vessels, nerves, and body organs.

Function: Strength, elasticity, and support.



connective tissue

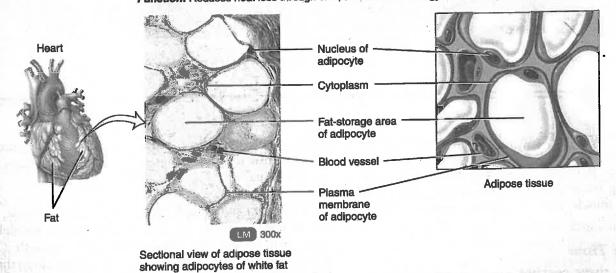
Areolar connective tissue

B. Adipose tissue

Description: Consists of adipocytes, cells specialized to store triglycerides (fats) as a large centrally located droplet; nucleus and cytoplasm are peripherally located.

Location: Subcutaneous layer deep to skin, around heart and kidneys, yellow bone marrow, and padding around joints and behind eyeball in eye socket.

Function: Reduces heat loss through skin, serves as an energy reserve, supports, and protects.



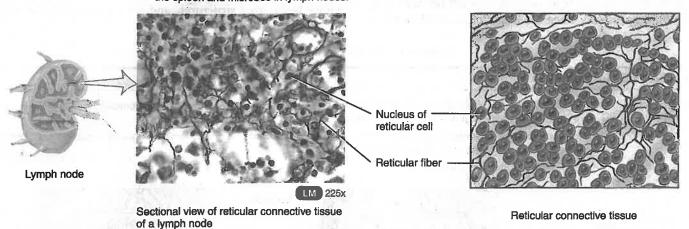
Loose Connective Tissue

C. Reticular connective tissue

Description: A network of interlacing reticular fibers and reticular cells.

Location: Stroma (supporting framework) of liver, spleen, lymph nodes; red bone marrow, which gives rise to blood cells; reticular lamina of the basement membrane; and around blood vessels and muscles.

Function: Forms stroma of organs, binds together smooth muscle tissue célls; filters and removes worn-out blood cells in the spleen and microbes in lymph nodes.



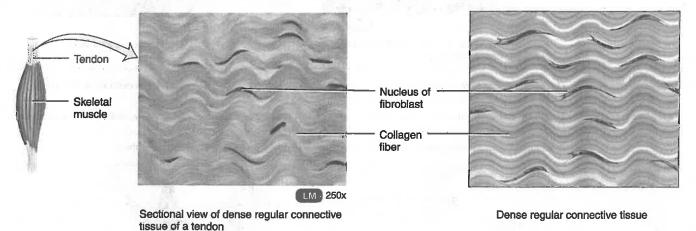
Dense Connective Tissue

D. Dense regular connective tissue

Description: Extracellular matrix looks shiny white; consists mainly of collagen fibers regularly arranged in bundles; fibroblasts present in rows between bundles.

Location: Forms tendons (attach muscle to bone), most ligaments (attach bone to bone), and aponeuroses (sheetlike tendons that attach muscle to muscle or muscle to bone).

Function: Provides strong attachment between various structures.



RECTICULAR CONNECTIVE TISSUE Reticular connective tissue consists of fine interlacing reticular fibers and reticular cells (Table 4.2C). Reticular connective tissue forms the stroma (supporting framework) of certain organs, helps bind together smooth muscle cells, and filters worn-out blood cells and bacteria.

Dense Connective Tissue

Dense connective tissue contains more numerous, thicker, and denser fibers but fewer cells than loose connective

tissue. There are three types: dense regular connective tissue, dense irregular connective tissue, and elastic connective tissue.

DENSE REGULAR CONNECTIVE TISSUE In this tissue, bundles of collagen fibers are arranged regularly in parallel patterns that provide the tissue with great strength (Table 4.2D). The tissue structure withstands pulling along the axis of the fibers. Fibroblasts, which produce the fibers and ground substance, appear in rows between the fibers. The

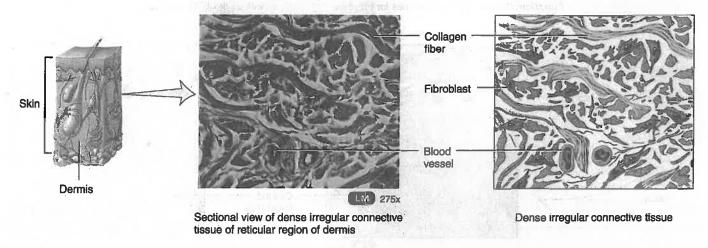
Loose Connective Tissue

E. Dense irregular connective tissue

Description: Consists predominantly of collagen fibers randomly arranged and a few fibroblasts.

Location: Fasciae (tissue beneath skin and around muscles and other organs), deeper region of dermis of skin, periosteum of bone, perichondrium of cartilage, joint capsules, membrane capsules around various organs (kidneys, liver, testes, lymph nodes), pericardium of the heart, and heart valves.

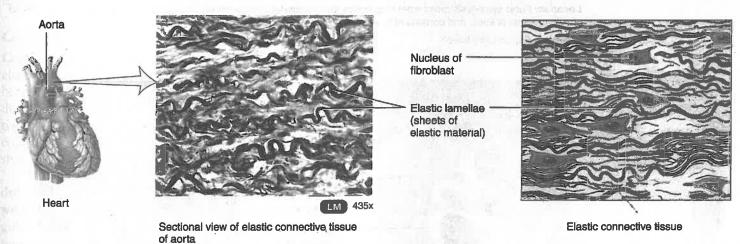
Function: Provides strength.



F. Elastic connective tissue

Description: Consists predominantly of freely branching elastic fibers, fibroblasts are present in spaces between fibers. **Location:** Lung tissue, walls of elastic arteries, trachea, bronchial tubes, true vocal cords, suspensory ligament of penis, and ligaments between vertebrae.

Function: Allows stretching of various organs.



(continues)

tissue is silvery white and tough, yet somewhat pliable. Examples are tendons and most ligaments.

DENSE IRREGULAR CONNECTIVE TISSUE This tissue contains collagen fibers that are packed more closely together than in loose connective tissue and are usually irregularly arranged (Table 4.2E). It is found in parts of the body where pulling forces are exerted in various directions. The tissue usually occurs in sheets, such as in the dermis of the skin, which underlies the epidermis. Heart valves, the perichon-

drium (the membrane surrounding cartilage), and the periosteum (the membrane surrounding bone) are considered dense irregular connective tissues, despite a fairly orderly arrangement of their collagen fibers.

ELASTIC CONNECTIVE TISSUE Branching elastic fibers predominate in elastic connective tissue (Table 4.2F), giving the unstained tissue a yellowish color. Fibroblasts are present in the spaces between the fibers. Elastic connective tissue is quite strong and can recoil to its original shape after

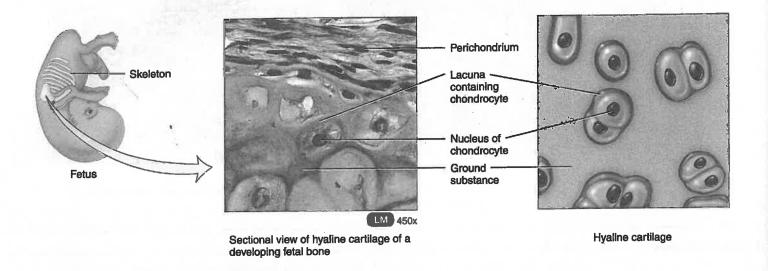
Cartilage

G. Hyaline cartilage

Description: Consists of a bluish-white, shiny ground substance with fine collagen fibers and many chondrocytes; most abundant type of cartilage.

Location: Ends of long bones, anterior ends of ribs, nose, parts of larynx, trachea, bronchi, bronchial tubes, and embryonic and fetal skeleton.

Function: Provides smooth surfaces for movement at joints, as well as flexibility and support.

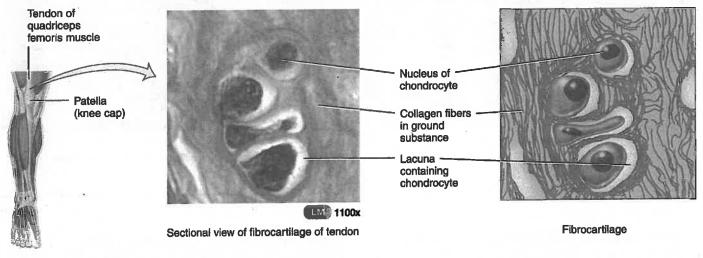


H. Fibrocartilage

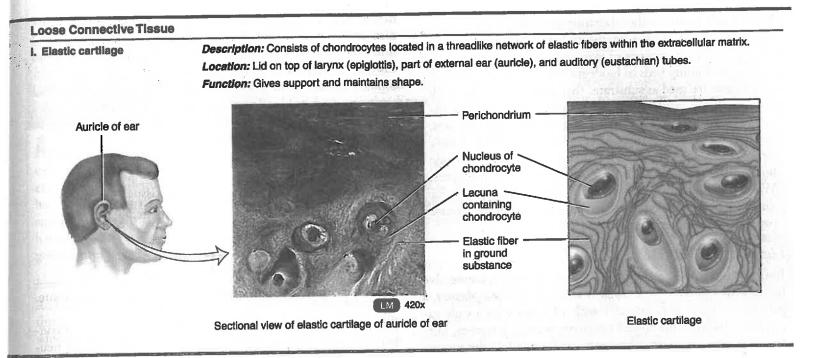
Description: Consists of chondrocytes scattered among bundles of collagen fibers within the extracellular matrix.

Location: Pubic symphysis (point where hip bones join anteriorly), intervertebral discs (discs between vertebrae), menisci (cartilage pads) of knee, and portions of tendons that insert into cartilage.

Function: Support and fusion.



Portion of right lower limb



being stretched. Elasticity is important to the normal functioning of lung tissue, which recoils as you exhale, and elastic arteries, whose recoil between heart beats helps maintain blood flow.

Cartilage

Cartilage consists of a dense network of collagen fibers and elastic fibers firmly embedded in chondroitin sulfate, a rubbery component of the ground substance. Cartilage can endure considerably more stress than loose and dense connective tissues. While the strength of cartilage is due to its collagen fibers, its resilience (ability to assume its original shape after deformation) is due to chondroitin sulfate.

The cells of mature cartilage, called *chondrocytes* (KONdrō-sīts; *chondro-* = cartilage), occur singly or in groups within spaces called *lacunae* (la-KOO-nē = little lakes; singular is *lacuna*) in the extracellular matrix. The surface of most cartilage is surrounded by a membrane of dense irregular connective tissue called the *perichondrium* (per'-i-KONdrē-um; *peri-* = around). Unlike other connective tissues, cartilage has no blood vessels or nerves, except in the perichondrium. Since cartilage has no blood supply, it heals poorly following an injury. The three types of cartilage are hyaline cartilage, fibrocartilage, and elastic cartilage.

HYALINE CARTILAGE This type of cartilage contains a restlient gel as its ground substance and appears in the body as a bluish-white, shiny substance. The fine collagen fibers are not visible with ordinary staining techniques, and prominent chondrocytes are found in lacunae (Table 4.2G). Most

hyaline cartilage is surrounded by a perichondrium. The exceptions are the articular cartilage in joints and the epiphyseal plates, the regions where bones lengthen as a person grows. Hyaline cartilage is the most abundant cartilage in the body. It affords flexibility and support and, at joints, reduces friction and absorbs shock. Hyaline cartilage is the weakest of the three types of cartilage.

FIBROCARTILAGE Chondrocytes are scattered among clearly visible bundles of collagen fibers within the extracellular matrix of this type of cartilage (Table 4.2H). Fibrocartilage lacks a perichondrium. This tissue combines strength and rigidity and is the strongest of the three types of cartilage. One location of fibrocartilage is in the discs between vertebrae (backbones).

ELASTIC CARTILAGE In elastic cartilage, chondrocytes are located within a threadlike network of elastic fibers within the extracellular matrix (Table 4.2I). A perichondrium is present. Elastic cartilage provides strength and elasticity and maintains the shape of certain structures, such as the external ear.

Bone Tissue

Bonès are organs composed of several different connective tissues, including **bone** or osseous tissue (OS-ē-us). Bone tissue has several functions. It supports soft tissues, protects delicate structures, and works with skeletal muscles to generate movement. Bone stores calcium and phosphorus; stores red bone marrow, which produces blood cells; and houses yellow bone marrow, a storage site for triglycerides. The details of bone tissue are presented in Chapter 6.

The technology of tissue engineering has allowed scientists to grow new tissues in the laboratory to replace damaged tissues in the body. Tissue engineers have already developed laboratory-grown versions of skin and cartilage. In the procedure, scaffolding beds of biodegradable synthetic materials or collagen are used as substrates that permit body cells such as skin cells or cartilage cells to be cultured. As the cells divide and assemble, the scaffolding degrades, and the new, permanent tissue is then implanted in the patient. Other structures being developed by tissue engineers include bones, tendons, heart valves, bone marrow, and intestines. Work is also underway to develop insulin-producing cells for diabetics, dopamine-producing cells for Parkinson disease patients, and even entire livers and kidneys.

Liquid, Connective Tissue

BLOOD TISSUE **Blood rissue** (or simply blood) is a connective tissue with a liquid extracellular matrix called blood plasma, a pale yellow fluid that consists mostly of water with a wide variety of dissolved substances: nutrients, wastes, enzymes, hormones, respiratory gases, and ions. Suspended in the plasma are red blood cells, white blood cells, and platelets. **Red blood cells** transport oxygen to body cells and remove carbon dioxide from them. **White blood cells** are involved in phagocytosis, immunity, and allergic reactions. **Platelets** participate in blood clotting. The details of blood are considered in Chapter 14.

LYMPH Lymph is a fluid that flows in lymphatic vessels. It is a connective tissue that consists of several types of cells in a clear extracellular matrix similar to blood plasma but with much less protein. The details of lymph are considered in Chapter 17.

CHECKPOINT

- **6.** What are the features of the cells, ground substance, and fibers that make up connective tissue?
- 7. How are the structures of the following connective tissues related to their functions: areolar connective tissue, adipose tissue, reticular connective tissue, dense regular connective tissue, dense irregular connective tissue, elastic connective tissue, hyaline cartilage, fibrocartilage, elastic cartilage, bone tissue, blood tissue, and lymph?

MUSCULAR TISSUE

OBJECTIVES • Describe the functions of muscular tissue.

 Contrast the locations of the three types of muscular tissue.

Muscular tissue consists of elongated cells called muscle fibers that are highly specialized to generate force. As a result of this characteristic, muscular tissue produces motion, maintains posture, and generates heat. It also offers protection. Based on

its location and certain structural and functional characteristics, muscular tissue is classified into three types: skeletal, cardiac, and smooth. Skeletal muscle tissue is named for its location—it is usually attached to the bones of the skeleton. Cardiac muscle tissue forms the bulk of the wall of the heart. Smooth muscle tissue is located in the walls of hollow internal structures such as blood vessels, airways to the lungs, the stomach, intestines, gallbladder, and urinary bladder. The details of muscular tissue are presented in Chapter 8.

■ CHECKPOINT

- 8. What are the functions of muscular tissue?
- 9. Name the three types of muscular tissue.

NERVOUS TISSUE

OBJECTIVE • Describe the functions of nervous tissue.

Despite the awesome complexity of the nervous system, it consists of only two principal types of cells: neurons and neuroglia. Neurons (neur-= nerve, nerve tissue, nervous system) or nerve cells, are sensitive to various stimuli. They convert stimuli into nerve impulses (action potentials) and conduct these impulses to other neurons, to muscle fibers, or to glands. Neuroglia (noo-RŌG-lē-a; -glia = glue) do not generate or conduct nerve impulses, but they do have many other important supportive functions. The detailed structure and function of neurons and neuroglia are considered in Chapter 9.

CHECKPOINT

10. How do neurons differ from neuroglia?

MEMBRANES

OBJECTIVES e Define a membrane.

• Describe the classification of membranes.

Membranes are flat sheets of pliable tissue that cover or line a part of the body. The combination of an epithelial layer and an underlying connective tissue layer constitutes an epithelial membrane. The principal epithelial membranes of the body are mucous membranes, serous membranes, and the cutaneous membrane, or skin. (Skin is discussed in detail in Chapter 5 and will not be discussed here.) Another kind of membrane, a synovial membrane, lines joints and contains connective tissue but no epithelium.

Mucous Membranes

A mucous membrane or mucosa (mū-KŌ-sa) lines a body cavity that opens directly to the exterior. Mucous membranes line the entire digestive, respiratory, and reproductive systems and much of the urinary system. The epithelial layer of a

Excess Adiposity — Too Much of a Good Thing

Adipose tissue contains adipocytes, cells specialized for the function of energy storage. Adequate energy storage has been vital to the survival of our species through the ages. But what happens when we have too much of a good thing?

Excess Adiposity: Too Much Fat

Adiposity becomes too much of a good thing when it leads to health problems, which can include hypertension (high blood pressure), poor blood sugar regulation (including type 2 diabetes), heart disease, certain cancers, gallstones, arthritis, and lower backaches. In general, the risk of health problems associated with excess adipose tissue increases in a dose-dependent fashion: The greater the excess weight, the greater the risk. People with a great deal of excess fat have a much higher risk for health problems than people who are only slightly too fat. But the health effects of excess fat depend on several important factors besides quantity of adipose tissue.

Location of Adipose Tissue

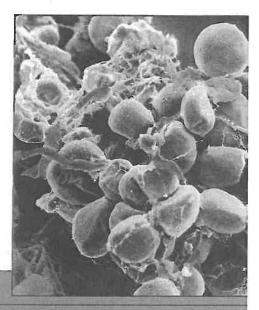
People who carry extra fat on the torso are at greater risk for hypertension, type 2 diabetes, and artery disease than people whose extra fat resides in the hips and thighs. Especially risky is excess fat stored around the viscera (such as the abdominal organs). Adipocytes in this area appear to be more "metabolically active" than those under the skin. Visceral fat affects blood sugar and blood fat regulation, which in turn can lead to the health problems mentioned above.

Family Medical History and Age

Excess body fat is especially risky for people who have already developed. fat-related health problems, or who have a family history of these disorders. On the other hand, people over 70 years old may benefit from a little extra adipose tissue. Many health professionals recommend an extra 10 or 15 pounds for people over 70 to help them resist wasting if they should become ill.

Beware the Deadly Sins: Gluttony and Sloth

People with a moderate amount of excess adipose tissue who eat a healthy diet and exercise regularly have health risks similar to those of their leaner peers. This observation suggests that some of the health risks seen in overweight people may be caused by poor health habits (such as too much food, too much alcohol, or too little exercise) rather than by the presence of excess adipose tissue.



- ► THINK IT OVER . . .
- Why do you think body weight alone is not always a good measure of adiposity, or a good predictor of bealth risks associated with excess adipose tissue?

mucous membrane secretes mucus, which prevents the cavities from drying out. It also traps particles in the respiratory passageways, lubricates and absorbs food as it moves through the gastrointestinal tract, and secretes digestive enzymes. The connective tissue layer helps bind the epithelium to the underlying structures. It also provides the epithelium with oxygen and nutrients and removes wastes via its blood vessels.

Serous Membranes

A serous membrane (serous = watery) lines a body cavity that does not open directly to the exterior, and it also covers the organs that lie within the cavity. Serous membranes consist of two parts: a parietal layer and a visceral layer. The parietal layer (pa-RI-e-tal; pariet- = wall) is the part attached to the cavity wall, and the visceral layer (viscer- = body organ) is the part that covers and attaches to the organs inside these cavities. Each layer consists of areolar connective tissue cov-

ered by mesothelium. Mesothelium is a simple squamous epithelium. It secretes serous fluid, a watery lubricating fluid that allows organs to glide easily over one another or to slide against the walls of cavities.

The serous membrane lining the thoracic cavity and covering the lungs is the pleura. The serous membrane lining the heart cavity and covering the heart is the pericardium. The serous membrane lining the abdominal cavity and covering the abdominal organs is the peritoneum.

Synovial Membranes

Synovial membranes (sin-O-vē-al) line the cavities of some joints. They are composed of areolar connective tissue and adipose tissue with collagen fibers; they do not have an epithelial layer. Synovial membranes contain cells (synoviocytes) which secrete synovial fluid. This fluid lubricates the ends of bones as they move at joints, nourishes the cartilage

covering the bones, and removes microbes and debris from the joint cavity.

CHECKPOINT

11. Define the following kinds of membranes: mucous, serous, cutaneous, and synovial.

12. Where is each type of membrane located in the body? What are their functions?

TISSUE REPAIR: RESTORING HOMEOSTASIS

OBJECTIVE • Describe the role of tissue repair in restoring homeostasis.

Tissue repair is the process that replaces worn-out, damaged, or dead cells. New cells originate by cell division from the stroma, the supporting connective tissue, or from the harmonian part of the tissue or organ. In adults, each of the four basic tissue types (epithelial, connective, muscular, and nervous) has a different capacity for replenishing parenchymal cells lost by damage, disease, or other processes.

Epithelial cells, which endure considerable wear and tear (and even injury) in some locations, have a continuous capacity for renewal. In some cases, immature, undifferentiated cells called *stem cells* divide to replace lost or damaged cells. For example, stem cells reside in protected locations in the epithelia of the skin and gastrointestinal tract to replenish cells sloughed from the apical layer.

Some connective tissues also have a continuous capacity for renewal. One example is bone, which has an ample blood supply. Other connective tissues such as cartilage can replenish cells less readily in part because of a poor blood supply.

Muscular tissue has a relatively poor capacity for renewal of lost cells. Cardiac muscle fibers can be produced from stem cells under special conditions (see page 367). Skeletal muscle tissue does not divide rapidly enough to replace extensively damaged muscle fibers. Smooth muscle fibers can proliferate to some extent, but they do so much more slowly than the cells of epithelial or connective tissues.

Nervous tissue has the poorest capacity for renewal. Although experiments have revealed the presence of some stem cells in the brain, they normally do not undergo mitosis to replace damaged neurons.

If parenchymal cells accomplish the repair, tissue regeneration is possible, and a near-perfect reconstruction of the injured tissue may occur. However, if fibroblasts of the stroma are active in the repair, the replacement tissue will be a new connective tissue. The fibroblasts synthesize collagen and other extracellular matrix materials that aggregate to form scar tissue, a process known as fibrosis. Because scar tissue is

not specialized to perform the functions of the parenchymal tissue, the original function of the tissue or organ is impaired.

Scar tissue can form adhesions, abnormal joining of tissues. Adhesions commonly form in the abdomen around a site of previous inflammation such as an inflamed appendix, and they can develop after surgery. Although adhesions do not always cause problems, they can decrease tissue flexibility, cause obstruction (such as in the intestine), and make a subsequent operation more difficult.

■ CHECKPOINT

13. How are stromal and parenchymal repair of a tissue different?

AGING AND TISSUES

OBJECTIVE ® Describe the effects of aging on tissues.

Generally, tissues heal faster and leave less obvious scars in the young than in the aged. In fact, surgery performed on fetuses leaves no scars. The younger body is generally in a better nutritional state, its tissues have a better blood supply, and its cells have a higher metabolic rate. Thus, cells can synthesize needed materials and divide more quickly. The extracellular components of tissues also change with age. Glucose, the most abundant sugar in the body, plays a role in the aging process. Glucose is haphazardly added to proteins inside and outside cells, forming irreversible cross-links between adjacent protein molecules. With advancing age, more cross-links form, which contributes to the stiffening and loss of elasticity that occur in aging tissues. Collagen fibers, responsible for the strength of tendons, increase in number and change in quality with aging. Elastin, another extracellular component, is responsible for the elasticity of blood vessels and skin. It thickens, fragments, and acquires a greater affinity for calcium with age-changes that may also be associated with the development of atherosclerosis, the deposition of fatty materials in arterial walls.

■ CHECKPOINT

14. What common changes occur in epithelial and connective tissues with aging?

Now that you have an understanding of tissues, we will look at the organization of tissues into organs and organs into systems. In the next chapter we will consider how the skin and other organs function as components of the integumentary system.



Sjögren's Syndrome

Sjögren's syndrome (SHŌ-grenz) is a common autoimmune disease that causes inflammation and destruction of exocrine glands, especially the lacrimal (tear) glands and salivary glands. Signs of Sjögren's syndrome include dryness of the eyes, mouth, nose, ears, skin, and vagina, and salivary gland enlargement. Systemic effects include fatigue, arthritis, difficulty in swallowing, pancreatitis (inflammation of the pancreas), pleuritis (inflammation of the pleurae of the lungs), and muscle and joint pain. The disorder affects females more than males by a ratio of 9 to 1. About 20% of older adults experience some signs of Sjögren's syndroms. Treatment is supportive, including using artifical tears to moisten the eyes, sipping fluids, chewing sugarless gum, using a saliva substitute to moisten the mouth, and using moisturing creams for the skin.

Systemic Lupus Erythematosus

Systemic lupus erythematosus (er-i-thē-ma-TŌ-sus), SLE, or simply lupus, is a chronic inflammatory disease of connective tissue oc-

curring mostly in nonwhite women during their childbearing year It is an autoimmune disease that can cause tissue damage in ever body system. The disease, which can range from a mild condition most patients to a rapidly fatal disease, is marked by periods of exa erbation and remission. Although the cause of SLE is unknown, g netic, environmental, and hormonal factors all have been implicated. The genetic component is suggested by studies of twins ar family history. Environmental factors include viruses, bacterichemicals, drugs, exposure to excessive sunlight, and emotion stress. Sex hormones, such as estrogens, may also trigger SLE.

Signs and symptoms of SLE include painful joints, low-grafever, fatigue, mouth ulcers, weight loss, enlarged lymph nodes at spleen, sensitivity to sunlight, rapid loss of large amounts of sca hair, and anorexia. A distinguishing feature of lupus is an eruptic across the bridge of the nose and cheeks called a "butterfly rash Other skin lesions may occur, including blistering and ulceratio The erosive nature of some SLE skin lesions was thought to reser ble the damage inflicted by the bite of a wolf—thus, the name lup (= wolf). The most serious complications of the disease involve i flammation of the kidneys, liver, spleen, lungs, heart, brain, at gastrointestinal tract. Because there is no cure for SLE, treatment supportive, including anti-inflammatory drugs, such as aspirin, at immunosuppressive drugs.

MEDICAL TERMINOLOGY AND CONDITIONS

Tissue rejection An immune response of the body directed at foreign proteins in a transplanted tissue or organ; immunosuppressive drugs, such as cyclosporine, have largely overcome tissue rejection in heart-, kidney-, and liver-transplant patients.

Tissue transplantation The replacement of a diseased or injured tissue or organ; the most successful transplants involve use of a person's own tissues or those from an identical twin.

Xenotransplantation (zen'-ō-trans'-plan-TĀ-shun; xeno- = strang foreign) The replacement of a diseased or injured tissue or org with cells or tissues from an animal. Only a few cases of successful xenotransplantation exist to date.

STUDY OUTLINE

Types of Tissues (p. 73)

- A tissue is a group of similar cells that usually has a similar embryological origin and is specialized for a particular function.
- 2. The various tissues of the body are classified into four basic types: epithelial, connective, muscular, and nervous.

Epitheliai Tissue (p. 73)

- 1. The general types of epithelia include covering and lining epithelium and glandular epithelium.
- 2. Some general characteristics of epithelium: It consists mostly of cells with little extracellular material, is arranged in sheets, is

- attached to connective tissue by a basement membrane, is avas cular (no blood vessels), has a nerve supply, and can replac itself.
- 3. Epithelial layers can be simple (one layer) or stratified (severa layers). The cell shapes may be squamous (flat), cuboidal (cube like), columnar (rectangular), or transitional (variable).
- 4. Simple squamous epithelium consists of a single layer of flacells (Table 4.1A). It is found in parts of the body where filtration or diffusion are priority processes. One type, endothelium lines the heart and blood vessels. Another type, mesothelium forms the serous membranes that line the thoracic and abdominal cavities and cover the organs within them.

94 Chapter 4 Tissues

- 5. Simple cuboidal epithelium consists of a single layer of cubeshaped cells that function in secretion and absorption (Table 4.1B). It is found covering the ovaries, in the kidneys and eyes, and lining some glandular ducts.
- 6. Nonciliated simple columnar epithelium consists of a single layer of nonciliated rectangular cells (Table 4.1C). It lines most of the gastrointestinal tract. Specialized cells containing microvilli perform absorption. Goblet cells secrete mucus.
- 7. Ciliated simple columnar epithelium consists of a single layer of ciliated rectangular cells (Table 4.1D). It is found in a few portions of the upper respiratory tract, where it moves foreign particles trapped in mucus out of the respiratory tract.
- 8. Pseudostratified columnar epithelium has only one layer but gives the appearance of many (Table 4.1E).
- 9. Stratified squamous epithelium consists of several layers of cells; cells in the apical layer and several layers deep to it are flat '(Table 4.1F). It is protective. A nonkeratinized variety lines the mouth; a keratinized variety forms the epidermis, the most superficial layer of the skin.
- 10. Stratified cuboidal epithelium consists of several layers of cells; cells in the apical layer are cube-shaped (Table 4.1G). It is found in adult sweat glands and a portion of the male urethra.
- 11. Stratified columnar epithelium consists of several layers of cells; cells in the apical layer are column-shaped (Table 4.1H). It is found in a portion of the male urethra and large excretory ducts of some glands.
- 12. Transitional epithelium consists of several layers of cells whose appearance varies with the degree of stretching (Table 4.1I). It lines the urinary bladder.
- 13. A gland is a single cell or a group of epithelial cells adapted for secretion.
- 14. Endocrine glands secrete hormones into interstitial fluid and then the blood (Table 4.1J).
- 15. Exocrine glands (mucous, sweat, oil, and digestive glands) secrete into ducts or directly onto a free surface (Table 4.1K).

Connective Tissue (p. 82)

- 1. Connective tissue is one of the most abundant body tissues.
- 2. Connective tissue consists of cells and an extracellular matrix of ground substance and fibers; it has abundant matrix with relatively few cells. It does not usually occur on free surfaces, has a nerve supply (except for cartilage), and is highly vascular (except for cartilage, tendons, and ligaments).
- 3. Cells in connective tissue include fibroblasts (secrete matrix), macrophages (perform phagocytosis), mast cells (produce histamine), and adipocytes (store fat).
- 4. The ground substance and fibers make up the extracellular matrix.
- 5. The ground substance supports and binds cells together, provides a medium for the exchange of materials, and is active in influencing cell functions.
- 6. The fibers in the extracellular matrix provide strength and support and are of three types: (a) collagen fibers (composed of collagen) are found in large amounts in bone, tendons, and lig-

- aments; (b) elastic fibers (composed of elastin, fibrillin, and other glycoproteins) are found in skin, blood vessel walls, and lungs; and (c) reticular fibers (composed of collagen and glycoprotein) are found around fat cells, nerve fibers, and skeletal and smooth muscle cells.
- Connective tissue is subdivided into loose connective tissue, dense connective tissue, cartilage, bone tissue, and liquid connective tissue (blood tissue and lymph).
- 8. Loose connective tissue includes areolar connective tissue, adipose tissue, and reticular connective tissue.
- 9. Areolar connective tissue consists of the three types of fibers, several cells, and a semifluid ground substance (Table 4.2A). It is found in the subcutaneous layer; in mucous membranes; and around blood vessels, nerves, and body organs.
- 10. Adipose tissue consists of adipocytes, which store triglycerides (Table 4.2B). It is found in the subcutaneous layer, around organs, and in the yellow bone marrow.
- 11. Reticular connective tissue consists of reticular fibers and reticular cells and is found in the liver, spleen, and lymph nodes (Table 4.2C).
- 12. Dense connective tissue includes dense regular connective tissue, dense irregular connective tissue, and elastic connective tissue.
- 13. Dense regular connective tissue consists of parallel bundles of collagen fibers and fibroblasts (Table 4.2D). It forms tendons, most ligaments, and aponeuroses.
- 14. Dense irregular connective tissue consists of usually randomly arranged collagen fibers and a few fibroblasts (Table 4.2E). It is found in fasciae, the dermis of skin, and membrane capsules around organs.
- 15. Elastic connective tissue consists of branching elastic fibers and fibroblasts (Table 4.2F). It is found in the walls of large arteries, lungs, trachea, and bronchial tubes.
- 16. Cartilage contains chondrocytes and has a rubbery matrix (chondroitin sulfate) containing collagen and elastic fibers.
- 17. Hyaline cartilage is found in the embryonic skeleton, at the ends of bones, in the nose, and in respiratory structures (Table 4.2G). It is flexible, allows movement, and provides support.
- 18. Fibrocartilage is found in the pubic symphysis, intervertebral discs, and menisci (cartilage pads) of the knee joint (Table 4.2H).
- 19. Elastic cartilage maintains the shape of organs such as the epiglottis of the larynx, auditory (eustachian) tubes, and external ear (Table 4.2I).
- 20. Bone or osseous tissue supports, protects, helps provide movement, stores minerals, and houses blood-forming tissue.
- 21. Blood tissue is liquid connective tissue that consists of blood plasma and formed elements—red blood cells, white blood cells, and platelets. Its cells transport oxygen and carbon dioxide, carry on phagocytosis, participate in allergic reactions, provide immunity, and bring about blood clotting. Lymph, the extracellular fluid that flows in lymphatic vessels, is also a liquid connective tissue. It is a clear fluid similar to blood plasma but with less protein.

Muscular Tissue (p. 90)

- Muscular tissue consists of cells (called muscle fibers) that are specialized for contraction. It provides motion, maintenance of posture, heat production, and protection.
- 2. Skeletal muscle tissue is attached to bones, cardiac muscle tissue forms most of the heart wall, and smooth muscle tissue is found in the walls of hollow internal structures (blood vessels and viscera).

Nervous Tissue (p. 90)

- 1. The nervous system is composed of neurons (nerve cells) and neuroglia (protective and supporting cells).
- 2. Neurons are sensitive to stimuli, convert stimuli into nerve impulses, and conduct nerve impulses.

Membranes (p. 90)

1. An epithelial membrane consists of an epithelial layer overlying a connective tissue layer. Examples are mucous, serous, and cutaneous membranes.

- 2. Mucous membranes line cavities that open to the exterior, sur as the gastrointestinal tract.
- 3. Serous membranes line closed cavities (pleura, pericardiu peritoneum) and cover the organs in the cavities. These mer branes consist of parietal and visceral layers.
- 4. Synovial membranes line joint cavities, bursae, and tende sheaths and consist of areolar connective tissue instead of e ithelium.

Tissue Repair: Restoring Homeostasis (p. 92)

- Tissue repair is the replacement of worn-out, damaged, or de cells by healthy ones.
- 2. Stem cells may divide to replace lost or damaged cells.

Aging and Tissues (p. 92)

- 1. Tissues heal faster and leave less obvious scars in the you than in the aged; surgery performed on fetuses leaves no sca
- 2. The extracellular components of tissues, such as collagen a elastic fibers, also change with age.

SELF-QUIZ

- 1. Epithelial tissue functions in
 - a. conducting nerve impulses b. storing fat
 - c. covering and lining the body and its parts
 - d. movement
- e. storing minerals
- 2. Epithelial tissue is classified according to
 - a. its location
 - b. its function
 - c. the composition of the extracellular matrix
 - d. the shape and arrangement of its cells
 - e. whether it is under voluntary or involuntary control
- 3. Muçous membranes are
 - a. composed of three layers
 - b. found in body cavities that open to the body's exterior
 - c. located at the ends of bones
 - d. found lining the thoracic cavity
 - e. capable of producing synovial fluid
- 4. Which of the following is NOT a type of connective tissue?
 - a. blood b. adipose c. reticular
 - d. simple cuboidal e. cartilage
- 5. Which of the following is true concerning connective tissue?
 - a. Except for cartilage, connective tissue has a rich blood supply.
 - **b.** Connective tissue is classified according to cell shape and arrangement.
 - c. The cells of connective tissue are generally closely joined.
 - d. Loose connective tissue consists of many fibers arranged in a regular pattern.
 - **c.** The fibers in connective tissue are composed of lipids.

- 6. Match the following tissue types with their descriptions.
 - ____ a. fat storage
 - ____ b. waterproofs the skin
 - c. forms the stroma (framework) of many organs,
 - ____ d. composes the intervertebral discs
 - ____ e. stores red bone marrow, protects, supports
 - ___ f. found in the walls of hollow organs
 - g. found in lungs, involved in diffusion
 - ____ h. found in kidney tubules, involved in absorption

- A. simple cuboidal epithelium
- B. simple squamous epithelium
- C. adipose
- D. fibrocartilage
- E. reticular connectiv
- F. smooth muscle
- G. keratinized stratific squamous epithelia
- H. bone

- 7. If you were going to design a hollow organ that needed to pand and have stretchability, which of the following epithe and connective tissues might you use?
 - a. transitional epithelium and elastic connective tissue
 - b. stratified columnar epithelium and adipose tissue
 - c. simple columnar epithelium and dense regular connective
 - d. simple squamous epithelium and hyaline cartilage
 - e. transitional epithelium and reticular connective tissue

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- 8. Which of the following statements is NOT true concerning epithelial tissue?
 - a. The cells of epithelial tissue are closely packed.
 - b. The basal layer of cells rests on a basement membrane.
 - c. Epithelial tissue has a nerve supply.
 - d. Epithelial tissue undergoes rapid rates of cell division.
 - e. Epithelial tissue is well supplied with blood vessels.
- 9. Where would you find smooth muscle tissue?
 - a. the heart b. attached to bones c. in joints
 - d. in the discs between the vertebrae e. in the walls of hollow organs
- 10. A connective tissue with a liquid extracellular matrix is
 - a. elastic cartilage
 - **b.** blood
- c. areolar
- d. reticular

- e. osseous
- 11. The interior of your nose is lined with
 - a, a mucous membrane
 - b. smooth muscle tissue
 - c. a synovial membrane
 - d. keratinized stratified squamous epithelium
 - e. a serous membrane
- 12. The four main types of tissue are
 - a. epithelial, embryonic, blood, nervous
 - b. blood, connective, muscular, nervous
 - c. connective, epithelial, muscular, nervous
 - d. stratified, muscular, striated, nervous
 - e. epithelial, connective, muscular, membranous
- 13. Which of the following materials would NOT be found in the extracellular matrix of connective tissue?
 - a. collagen fibers
- **b.** elastic fibers
- c. keratin

- d. reticular fibers
- e. hyaluronic acid

- 14. Which connective tissue cells secrete antibodies?
 - a. mast cells b. adipocytes c. macrophages
 - d. plasma cells
- e. chondrocytes
- 15. Modified columnar epithelial cells that secrete mucus are _ cells.
 - a. ciliated
- b. keratinized
- c. mast
- d. fibroblast

- e. goblet
- 16. Which tissue forms the bulk of the heart wall?
 - a. skeletal muscle
- b. nervous
- d. cardiac muscle
- e. smooth muscle
- 17. Stratified squamous epithelium functions in
 - a. protection and secretion b. contraction
- c. absorption
- **d.** stretching e. transport
- 18. What tissue type is found in tendons?
 - a. dense irregular connective tissue b. elastic connective c. dense regular connective tissue
 - d. pseudostratified epithelium
- e. areolar tissue
- 19. In what tissue type would you find stores of calcium and phosphorus?
 - a. bone b. hyaline cartilage
 - c. fibrocartilage
 - d. dense irregular connective tissue
- e. elastic cartilage
- 20. Which of the following statements is true concerning glandular tissue?
 - a. Endocrine glands are composed of connective tissue; exocrine glands are composed of modified epithelium.
 - b. Endocrine gland secretions diffuse into the bloodstream; exocrine gland secretions enter ducts.
 - c. A sweat gland is an example of an endocrine gland.
 - d. Endocrine glands contain ducts; exocrine glands
 - e. Exocrine glands produce substances known as hormones.

CRITICAL THINKING APPLICATIONS

- Your young nephew can't wait to get his eyebrow pierced like his big brother. In the meantime, he's walking around with sewing needles stuck through his fingertips. There is no visible bleeding. What type of tissue has he pierced? (Be specific.) How do you know?
- 2. Collagen is the new "miracle" cosmetic. It's advertised to give you shiny hair and glowing skin, and can be injected to reduce wrinkles. What is collagen? If you wanted to launch your own line of cosmetics, what tissue or structure would supply you with abundant collagen?
- Your lab partner Samir put a tissue slide labeled uterine tube under the microscope. He focused the slide and exclaimed, "Look! It's all hairy." Explain to Samir what the "hair" really is.
- You've gone out to eat at your favorite fast-food joint, Goodbody's Fried Chicken Emporium. A health-food zealot grabs your chicken leg and declares, "This is all fat!" Using your knowledge of tissues, defend your dinner choice.



ANSWERS TO FIGURE QUESTIONS

- Substances would move most rapidly through squamous cells because they are so thin.
- 4.2 Fibroblasts secrete the fibers and ground substance of the extracellular matrix.