TABLE 5.4	Epithelial Tissues		
Type	**Description**	**Function**	**Location**
Simple squamous epithelium	Single layer, flattened cells	Filtration, diffusion, osmosis, covers surface	Air sacs of lungs, walls of capillaries, linings of blood and lymph vessels
Simple cuboidal epithelium	Single layer, cube-shaped cells	Secretion, absorption	Surface of ovaries, linings of kidney tubules, and linings of ducts of certain glands
Simple columnar epithelium	Single layer, elongated cells	Protection, secretion, absorption	Linings of uterus, stomach, and intestines
Pseudostratified columnar epithelium	Single layer, elongated cells	Protection, secretion, movement of mucus and substances	Linings of respiratory passages
Stratified squamous epithelium	Many layers, top cells flattened	Protection	Outer layer of skin, linings of oral cavity, vagina, and anal canal
Stratified cuboidal epithelium	2–3 layers, cube-shaped cells	Protection	Linings of larger ducts of mammary glands, sweat glands, salivary glands, and pancreas
Stratified columnar epithelium	Top layer of elongated cells, lower layers of cube-shaped cells	Protection, secretion	Part of the male urethra and parts of the pharynx
Transitional epithelium	Many layers of cube-shaped and elongated cells	Distensibility, protection	Inner lining of urinary bladder and linings of ureters and part of urethra
Glandular epithelium	Unicellular or multicellular	Secretion	Salivary glands, sweat glands, endocrine glands

Connective Tissues

General Characteristics

Connective tissues (kŏ-nek'tiv tish'ūz) comprise much of the body and are the most abundant type of tissue by weight. They bind structures, provide support and protection, serve as frameworks, fill spaces, store fat, produce blood cells, protect against infections, and help repair tissue damage.

Connective tissue cells are farther apart than epithelial cells, and they have an abundance of **extracellular matrix** (eks"trah-sel'u-lar ma'triks) between them. This extracellular matrix consists of fibers and a *ground substance* whose consistency varies from fluid to semisolid to solid. The ground substance binds, supports, and provides a medium through which substances may be transferred between the blood and cells within the tissue. Clinical Application 5.1 discusses the extracellular matrix and its relationship to disease.

Connective tissue cells can usually divide. These tissues have varying degrees of vascularity, but in most cases, they have good blood supplies and are well nourished. Some connective tissues, such as bone and cartilage, are quite rigid. Loose connective tissue (areolar), adipose tissue, and dense connective tissue are more flexible.

Major Cell Types

Connective tissues contain a variety of cell types. Some of them are called *fixed cells* because they reside in the specific connective tissue type for an extended period of time. These include fibroblasts and mast cells. Other cells, such as macrophages, are *wandering cells*. They move through and appear in tissues temporarily, usually in response to an injury or infection.

The **fibroblast** (fi'bro-blast) is the most common kind of fixed cell in connective tissues. These large, star-shaped cells produce fibers by secreting proteins into the extracellular matrix of connective tissues (fig. 5.13).

Macrophages (mak'ro-fājez), or histiocytes, originate as white blood cells (see chapter 14, p. 538) and are almost as numerous as fibroblasts in some connective tissues. They are usually attached to fibers but can detach and actively move about. Macrophages are specialized for phagocytosis. Because they function as scavenger cells that can clear foreign particles from tissues, macrophages are an important defense against infection (fig. 5.14). They also play a role in immunity (see chapter 16, p. 639).

Mast cells are large and are widely distributed in connective tissues, where they are usually located near

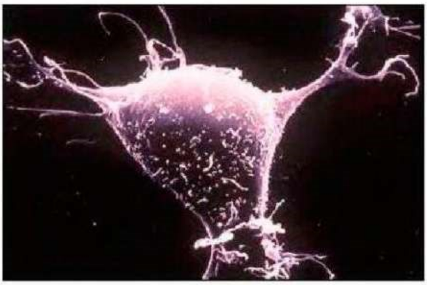

FIGURE 5.13
A scanning electron micrograph of a fibroblast (4,000×).

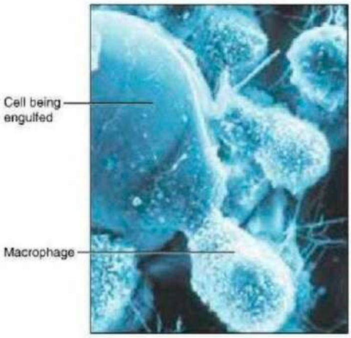

FIGURE 5.14
Macrophages are scavenger cells common in connective tissues. This scanning electron micrograph shows a number of macrophages engulfing parts of a larger cell (3,330×).

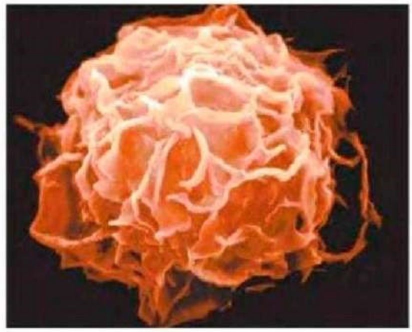

FIGURE 5.15
Scanning electron micrograph of a mast cell (6,600×).

blood vessels (fig. 5.15). They release *heparin*, a compound that prevents blood clotting. Mast cells also release *histamine*, a substance that promotes some of the reactions associated with inflammation and allergies, such as asthma and hay fever (see chapter 16, p. 637).

> Release of histamine stimulates inflammation by dilating the small arterioles that feed capillaries, the tiniest blood vessels. The resulting swelling and redness is inhospitable to infectious bacteria and viruses and also dilutes toxins. Inappropriate histamine release as part of an allergic response can be most uncomfortable. Allergy medications called antihistamines counter this misplaced inflammation.

Connective Tissue Fibers

Fibroblasts produce three types of connective tissue fibers: collagenous fibers, elastic fibers, and reticular fibers. Of these, collagenous and elastic fibers are the most abundant.

Collagenous (kol-laj′ĕ-nus) **fibers** are thick threads of the protein **collagen** (kol′ah-jen), which is the major structural protein of the body. Collagenous fibers are grouped in long, parallel bundles, and they are flexible but only slightly elastic (fig. 5.16). More importantly, they have great tensile strength—that is, they can resist considerable pulling force. Thus, collagenous fibers are important components of body parts that hold structures together, such as *ligaments* (which connect bones to bones) and *tendons* (which connect muscles to bones).

Tissue containing abundant collagenous fibers is called *dense connective tissue*. Such tissue appears white, and for this reason collagenous fibers of dense connective tissue are sometimes called white fibers. *Loose connective tissue*, on the other hand, has sparse collagenous fibers. Clinical Application 5.2, figure 5.17, and table 5.5 concern disorders that result from abnormal collagen.

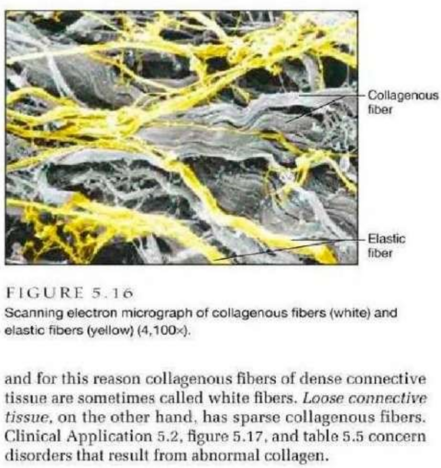

FIGURE 5.16
Scanning electron micrograph of collagenous fibers (white) and elastic fibers (yellow) (4,100×).

> When skin is exposed to prolonged and intense sunlight, connective tissue fibers lose elasticity, and the skin stiffens and becomes leathery. In time, the skin may sag and wrinkle. Collagen injections may temporarily smooth out wrinkles. However, collagen applied as a cream to the skin does not combat wrinkles because collagen molecules are far too large to actually penetrate the skin.

5.1 CLINICAL APPLICATION

A New View of the Body's Glue: The Extracellular Matrix

The traditional description of connective tissue matrix as "intercellular material" suggested that it merely fills the spaces between cells. However, when cell biologists looked beyond the abundant collagens that comprise much of the matrix, they discovered a complex and changing mix of different molecules that modifies the tissue to suit different organs and conditions. Not only does this material outside cells—the extracellular matrix, or ECM—serve as a scaffolding to organize cells into tissues, but it relays the biochemical signals that control cell division, differentiation, repair, and migration.

The ECM has two basic components: the basement membrane that covers cell surfaces, and the rest of the material between cells, called the interstitial matrix. The basement membrane is mostly composed of tightly packed collagenous fibers with large, cross-shaped glycoproteins called laminins extending out. The laminins (and other glycoproteins such as fibronectin and tenascin) extend across the interstitial matrix and touch receptors, called integrins, on other cells. The ECM, then, connects cells into tissues. It is versatile, with at least twenty types of collagen and precursor versions of important molecules, including hormones, enzymes, growth factors, and immune system biochemicals (cytokines). These molecules are activated under certain conditions.

The components of the ECM are always changing, as its cells synthesize proteins while enzymes called proteases break down specific proteins. The balance of components is important to maintaining and repairing organ structure. Disrupt the balance, and disease can result. Here are three common examples:

Cancer

The spread of a cancerous growth takes advantage of the normal ability of fibroblasts to contract as they close a wound, where they are replaced with normal epithelium. Chemical signals from existing cancer cells cause fibroblasts to become more contractile (myofibroblasts), as well as to take on the characteristics of cancer cells. At the same time, alterations in laminins loosen the connections of the fibroblasts to surrounding cells. This abnormal flexibility enables the changed fibroblasts to migrate, helping the cancer spread. Normally, fibroblasts secrete abundant collagen (figure 5A).

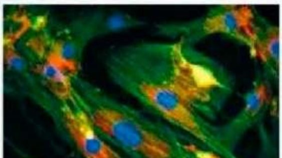

FIGURE 5A
The fibroblast connective tissue cells shown here have been taken from fetal skin. Fibroblasts are responsible for forming connective tissue by secreting extracellular matrix material such as collagen. (Immunofluorescent light micrograph, 225×.) Fibroblasts produce abundant collagens, of various types. Collagens make up more than half of the extracellular matrix in most parts of the body. The extracellular matrix is particularly important before birth, when organs form.

Liver Fibrosis

In fibrosis, a part of all chronic liver diseases, collagen deposition increases so that the ECM exceeds its normal 3% of the organ. Normally, liver ECM sculpts a framework that supports the epithelial and vascular tissues. In response to a damaging agent such as a virus, alcohol, or a toxic drug, hepatic stellate cells secrete collagenous fibers in the areas where the epithelium and blood vessels meet. Such limited fibrosis seals off the affected area, preventing its spread. But if the process continues—if an infection is not treated or the noxious stimulus not removed—the ECM grows and becomes redistributed in a way that blocks the interaction between liver cells and the bloodstream. The liver tissue eventually hardens, a dangerous condition called *cirrhosis*.

Heart Failure and Atherosclerosis

The heart's ECM organizes cells into a three-dimensional network that coordinates their contractions into the rhythmic heartbeat necessary to pump blood. It consists of collagen, fibronectin, laminin, and elastin surrounding cardiac muscle cells and myofibroblasts, and is also in the walls of arteries. Heart failure and atherosclerosis reflect imbalances of collagen production and degradation. As in the liver, the natural response of ECM buildup is to wall off an area where circulation is blocked, but if it continues, the extra scaffolding stiffens the heart, which can ultimately lead to heart failure. In atherosclerosis, excess ECM accumulates on the interior linings of arteries, blocking blood flow. During a myocardial infarction (heart attack), collagen synthesis and deposition increase in affected and nonaffected heart parts, which is why damage can continue even after pain starts.

TABLE 5.5 Collagen Disorders		
Disorder	**Molecular Defect**	**Signs and Symptoms**
Chondrodysplasia	Collagen chains are too wide and asymmetric	Stunted growth; deformed joints
Dystrophic epidermolysis bullosa	Breakdown of collagen fibrils that attach skin layers to each other	Stretchy, easily scarred skin; lax joints
Hereditary osteoarthritis	Substituted amino acid in collagen chain alters shape	Painful joints
Marfan syndrome	Too little fibrillin, an elastic connective tissue protein	Long limbs, sunken chest, lens dislocation, spindly fingers, weakened aorta
Osteogenesis imperfecta type I	Too few collagen triple helices	Easily broken bones; deafness; blue sclera (whites of the eyes)
Stickler syndrome	Short collagen chains	Joint pain; degeneration of retina and fluid around it

FIGURE 5.17
Abnormal collagen causes the stretchy skin of Ehlers-Danlos syndrome type I.

Elastic fibers are composed of a springlike protein called **elastin.** These fibers branch, forming complex networks in various tissues. They are weaker than collagenous fibers but very elastic. That is, they are easily stretched or deformed and will resume their original lengths and shapes when the force acting upon them is removed. Elastic fibers are common in body parts that are normally subjected to stretching, such as the vocal cords and air passages of the respiratory system. Elastic fibers are sometimes called yellow fibers, because tissues amply supplied with them appear yellowish (see fig. 5.16).

> Surgeons use elastin in foam, powder, or sheet form to prevent scar tissue adhesions from forming at the sites of tissue removal. Elastin is produced in bacteria that contain human genes that instruct them to manufacture the human protein. This is cheaper than synthesizing elastin chemically and safer than obtaining it from cadavers.

Reticular fibers are very thin collagenous fibers. They are highly branched and form delicate supporting networks in a variety of tissues, including those of the spleen. Table 5.6 summarizes the components of connective tissue.

1. What are the general characteristics of connective tissue?
2. What are the major types of fixed cells in connective tissue?
3. What is the primary function of fibroblasts?
4. What are the characteristics of collagen and elastin?

TABLE 5.6 Components of Connective Tissue		
Component	**Characteristic**	**Function**
Fibroblasts	Widely distributed, large, star-shaped cells	Secrete proteins that become fibers
Macrophages	Motile cells sometimes attached to fibers	Clear foreign particles from tissues by phagocytosis
Mast cells	Large cells, usually located near blood vessels	Release substances that may help prevent blood clotting and promote inflammation
Collagenous fibers (white fibers)	Thick, threadlike fibers of collagen with great tensile strength	Hold structures together
Elastic fibers (yellow fibers)	Bundles of microfibrils embedded in elastin	Provide elastic quality to parts that stretch
Reticular fibers	Thin fibers of collagen	Form supportive networks within tissues

5.2 CLINICAL APPLICATION

Abnormalities of Collagen

Much of the human body consists of the protein collagen. It accounts for more than 60% of the protein in bone and cartilage and provides 50%–90% of the dry weight of skin, ligaments, tendons, and the dentin of teeth. Collagen is in the eyes, blood vessel linings, basement membranes, and connective tissue. It is not surprising that defects in collagen cause a variety of medical problems.

Collagen abnormalities are devastating because this protein has an extremely precise structure that is easily disrupted, even by slight alterations that might exert little noticeable effect in other proteins. Collagen is sculpted from a precursor molecule called procollagen. Three procollagen chains coil and entwine to form a very regular triple helix.

Triple helices form as the procollagen is synthesized, but once secreted from the cell, the helices are trimmed. The collagen fibrils continue to associate outside the cell, building the networks that hold the body together. Collagen is rapidly synthesized and assembled into its rigid architecture. Many types of mutations can disrupt the protein's structure, including missing procollagen chains, kinks in the triple helix, failure to cut mature collagen, and defects in aggregation outside the cell.

Knowing which specific mutations cause disorders offers a way to identify the condition before symptoms arise. This can be helpful if early treatment can follow. A woman who has a high risk of developing hereditary osteoporosis, for example, might take calcium supplements before symptoms appear. Aortic aneurysm is a more serious connective tissue disorder that can be presymptomatically detected if the underlying mutation is discovered. In aortic aneurysm, a weakened aorta (the largest blood vessel in the body, which emerges from the heart) bursts. Knowing that the mutant gene has not been inherited can ease worries—and knowing that it has been inherited can warn affected individuals to have frequent ultrasound exams so that aortic weakening can be detected early enough to correct with surgery. ■

Categories of Connective Tissues

Connective tissue is broken down into two categories. *Connective tissue proper* includes loose connective tissue, adipose tissue, reticular connective tissue, dense connective tissue, and elastic connective tissue. The *specialized connective tissues* include cartilage, bone, and blood. Each type of connective tissue is described in the following sections.

Loose Connective Tissue

Loose connective tissue, or **areolar tissue** (ah-re′o-lar tish′u), forms delicate, thin membranes throughout the body. The cells of this tissue, mainly fibroblasts, are located some distance apart and are separated by a gel-like ground substance that contains many collagenous and elastic fibers that fibroblasts secrete (fig. 5.18).

Loose connective tissue binds the skin to the underlying organs and fills spaces between muscles. It lies beneath most layers of epithelium, where its many blood vessels nourish nearby epithelial cells.

Adipose Tissue

Adipose tissue (ad′ĭ-pōs tish′u), or fat, is another form of connective tissue. Certain cells within connective tissue (adipocytes) store fat in droplets within their cytoplasm. At first, these cells resemble fibroblasts, but as they accumulate fat, they enlarge, and their nuclei are pushed to one side (fig. 5.19). When adipocytes become so abundant that they crowd out other cell types, they form adipose tissue. This tissue lies beneath the skin, in spaces between muscles, around the kidneys, behind the eyeballs, in certain abdominal membranes, on the surface of the heart, and around certain joints.

Adipose tissue cushions joints and some organs, such as the kidneys. It also insulates beneath the skin, and it stores energy in fat molecules.

A person is born with a certain number of fat cells. Because excess food calories are likely to be converted to fat and stored, the amount of adipose tissue in the body reflects diet or an endocrine disorder. During a period of fasting, adipose cells may lose their fat droplets, shrink, and become more like fibroblasts again.

> Infants and young children have a continuous layer of adipose tissue just beneath the skin, which gives their bodies a rounded appearance. In adults, this subcutaneous fat thins in some regions and remains thick in others. For example, in males, adipose tissue usually thickens in the upper back, arms, lower back, and buttocks; in females, it is more likely to develop in the breasts, buttocks, and thighs.

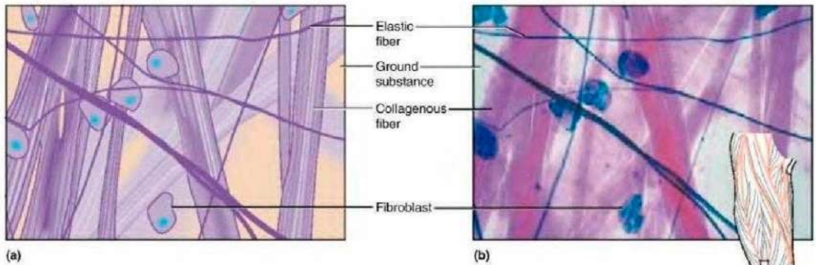

FIGURE 5.18
Loose connective tissue, or areolar tissue, contains numerous fibroblasts that produce collagenous and elastic fibers (700×).

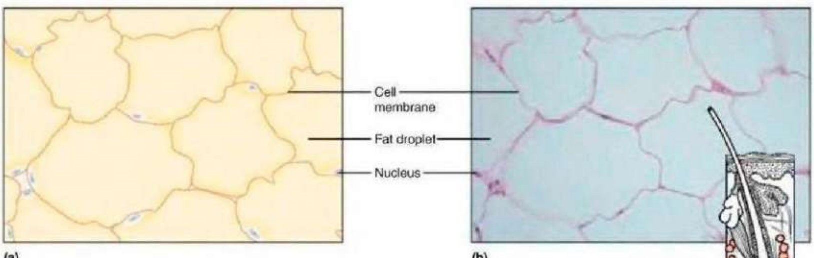

FIGURE 5.19
Adipose tissue cells contain large fat droplets that push the nuclei close to the cell membranes (450×).

Reticular Connective Tissue

Reticular connective tissue is composed of thin, collagenous fibers in a three-dimensional network. It helps provide the framework of certain internal organs, such as the liver, spleen, and lymphatic organs (fig. 5.20).

Dense Connective Tissue

Dense connective tissue consists of many closely packed, thick, collagenous fibers, a fine network of elastic fibers, and a few cells, most of which are fibroblasts. Subclasses of this tissue are regular or irregular, according to how organized the fiber patterns are.

Collagenous fibers of regular dense connective tissue are very strong, enabling the tissue to withstand pulling forces (fig. 5.21). It often binds body parts together, as parts of tendons and ligaments. The blood supply to regular dense connective tissue is poor, slowing tissue repair. This is why a sprain, which damages tissues surrounding a joint, may take considerable time to heal.

Fibers of irregular dense connective tissue are thicker, interwoven, and more randomly organized. This allows the tissue to sustain tension exerted from many different directions. Irregular dense connective tissue is found in the dermis, the inner skin layer.

Elastic Connective Tissue

Elastic connective tissue mainly consists of yellow, elastic fibers in parallel strands or in branching networks. Between these fibers are collagenous fibers and fibroblasts. This tissue is found in the attachments between bones of the spinal column (ligamenta flava). It is also in the layers within the walls of certain hollow internal organs, including the larger arteries, some portions of the heart, and the larger airways, where it imparts an elastic quality (fig. 5.22).

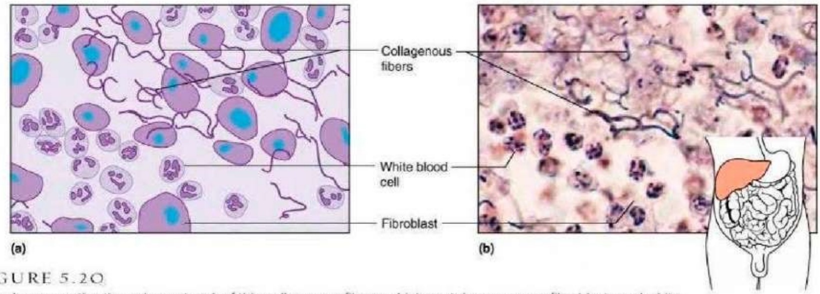

FIGURE 5.20
Reticular connective tissue is a network of thin collagenous fibers, which contains numerous fibroblasts and white blood cells (250× micrograph enlarged to 1,000×).

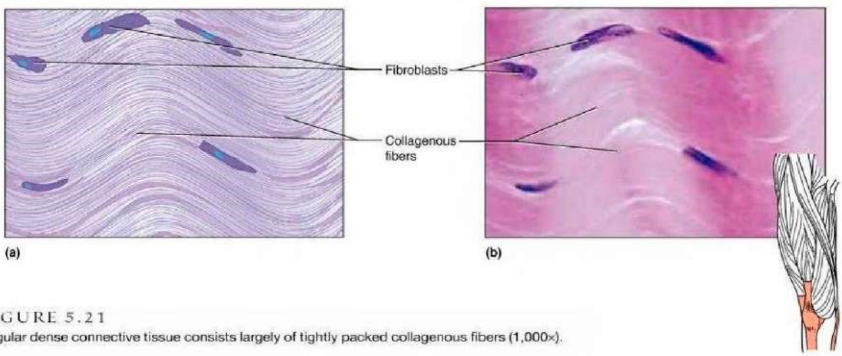

FIGURE 5.21
Regular dense connective tissue consists largely of tightly packed collagenous fibers (1,000×).

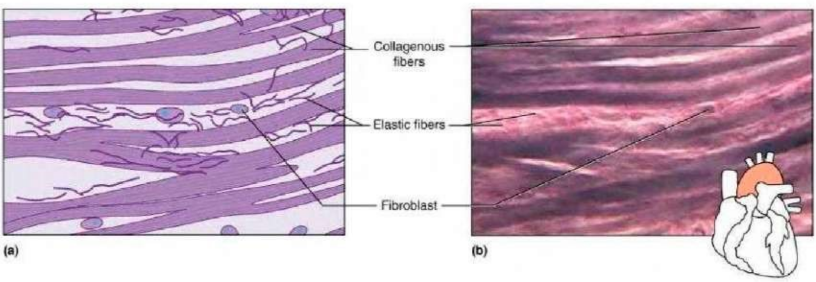

FIGURE 5.22
Elastic connective tissue contains many elastic fibers with collagenous fibers between them (170× micrograph enlarged to 680×).

1. Differentiate between loose connective tissue and dense connective tissue.
2. What are the functions of adipose tissue?
3. Distinguish between reticular and elastic connective tissues.

Cartilage

Cartilage (kar'ti-lij) is a rigid connective tissue. It provides support, frameworks, attachments, protects underlying tissues, and forms structural models for many developing bones.

Cartilage extracellular matrix is abundant and is largely composed of collagenous fibers embedded in a gel-like ground substance. This ground substance is rich in a protein-polysaccharide complex (chondromucoprotein) and contains a large volume of water. Cartilage cells, or **chondrocytes** (kon'dro-sītz), occupy small chambers called *lacunae* (lah-ku'ne) and lie completely within the matrix.

A cartilaginous structure is enclosed in a covering of connective tissue called *perichondrium*. Although cartilage tissue lacks a direct blood supply, blood vessels are in the surrounding perichondrium. Cartilage cells near the perichondrium obtain nutrients from these vessels by diffusion, which is aided by the water in the extracellular matrix. This lack of a direct blood supply is why torn cartilage heals slowly, and why chondrocytes do not divide frequently.

The three types of cartilage are distinguished by their different types of extracellular matrix. Hyaline cartilage has very fine collagenous fibers in its extracellular matrix, elastic cartilage contains a dense network of elastic fibers, and fibrocartilage has many large collagenous fibers.

Hyaline cartilage (fig. 5.23), the most common type, looks somewhat like white glass. It is found on the ends of bones in many joints, in the soft part of the nose, and in the supporting rings of the respiratory passages. Parts of an embryo's skeleton begin as hyaline cartilage "models" that bone gradually replaces. Hyaline cartilage is also important in the development and growth of most bones (see chapter 7, p. 198).

Elastic cartilage (fig. 5.24) is more flexible than hyaline cartilage because its extracellular matrix contains many elastic fibers. It provides the framework for the external ears and parts of the larynx.

Fibrocartilage (fig. 5.25), a very tough tissue, contains many collagenous fibers. It is a shock absorber for structures that are subjected to pressure. For example, fibrocartilage forms pads (intervertebral discs) between the individual bones (vertebrae) of the spinal column. It also cushions bones in the knees and in the pelvic girdle.

Bone

Bone (osseous tissue) is the most rigid connective tissue. Its hardness is largely due to mineral salts, such as calcium phosphate and calcium carbonate, between cells. This extracellular matrix also contains abundant collagenous fibers, which are flexible and reinforce the mineral components of bone.

Bone internally supports body structures. It protects vital structures in the cranial and thoracic cavities and is an attachment for muscles. Bone also contains red marrow, which forms blood cells. It stores and releases inorganic chemicals such as calcium and phosphorus.

Bone matrix is deposited by bone cells, called **osteoblasts** (os'te-o-blastz), in thin layers called *lamellae*, which form concentric patterns around capillaries located within tiny longitudinal tubes called *central*, or *Haversian, canals*. Osteoblasts are located in lacunae where they mature into osteocytes and are rather evenly

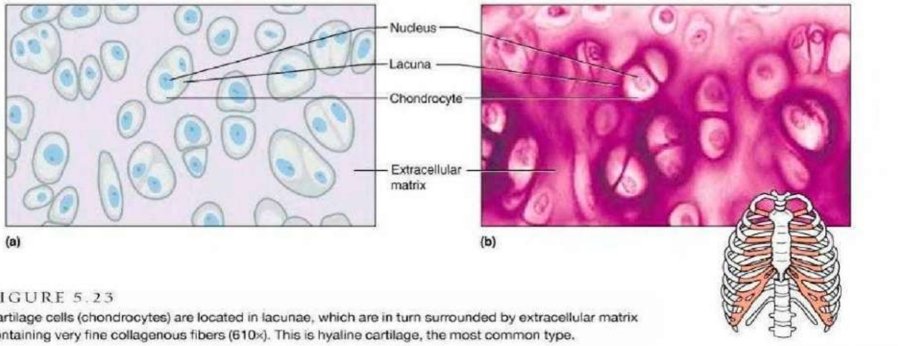

FIGURE 5.23
Cartilage cells (chondrocytes) are located in lacunae, which are in turn surrounded by extracellular matrix containing very fine collagenous fibers (610×). This is hyaline cartilage, the most common type.

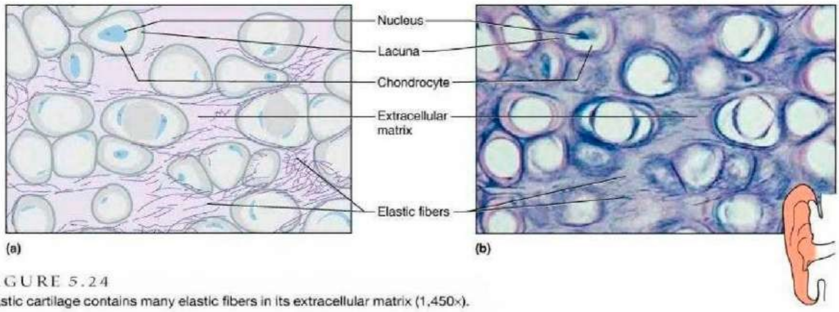

FIGURE 5.24
Elastic cartilage contains many elastic fibers in its extracellular matrix (1,450×).

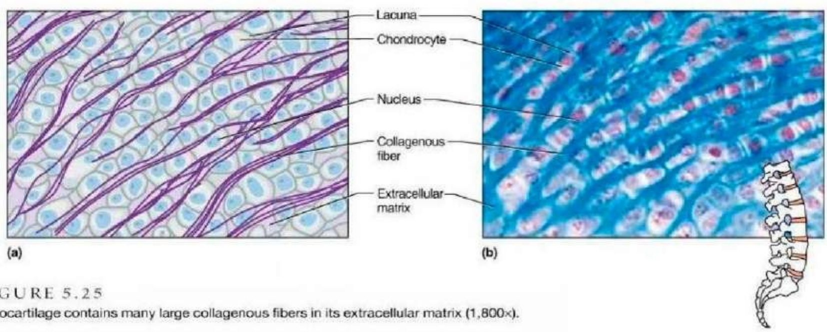

FIGURE 5.25
Fibrocartilage contains many large collagenous fibers in its extracellular matrix (1,800×).

spaced within the lamellae. Consequently, osteocytes also form concentric circles (fig. 5.26).

In a bone, the osteocytes and layers of extracellular matrix, which are concentrically clustered around a central canal, form a cylinder-shaped unit called an **osteon** (os′te-on), or a Haversian system. Many of these units cemented together form the substance of bone (see chapter 7, p. 195).

Each central canal contains a blood vessel, so every bone cell is fairly close to a nutrient supply. In addition, the bone cells have many cytoplasmic processes that extend outward and pass through minute tubes in the extracellular matrix called *canaliculi*. Gap junctions attach these cellular processes to the membranes of nearby cells (see chapter 3, p. 80). As a result, materials can move rapidly between blood vessels and bone cells. Thus, in spite of its inert appearance, bone is a very active tissue. Injured bone heals much more rapidly than does injured cartilage.

Blood

Blood, another type of connective tissue, is composed of cells that are suspended in a fluid extracellular matrix called *plasma*. These cells include *red blood cells, white blood cells,* and cellular fragments called *platelets* (fig. 5.27). Red blood cells transport gases; white blood cells fight infection; and platelets are involved in blood clotting. Most blood cells form in special tissues (hematopoietic tissues) in red marrow within the hollow parts of certain bones. Blood is described in chapter 14.

Of the blood cells, only the red cells function entirely within the blood vessels. White blood cells typically migrate from the blood through capillary walls. They enter connective tissues where they carry on their major activities, and they usually reside there until they die. Table 5.7 lists the characteristics of the types of connective tissue.

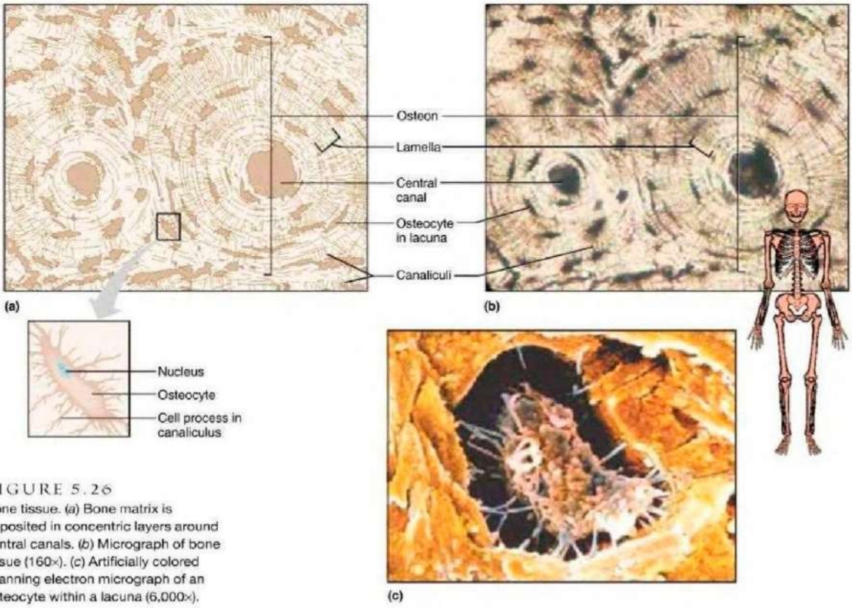

FIGURE 5.26
Bone tissue. (*a*) Bone matrix is deposited in concentric layers around central canals. (*b*) Micrograph of bone tissue (160×). (*c*) Artificially colored scanning electron micrograph of an osteocyte within a lacuna (6,000×).

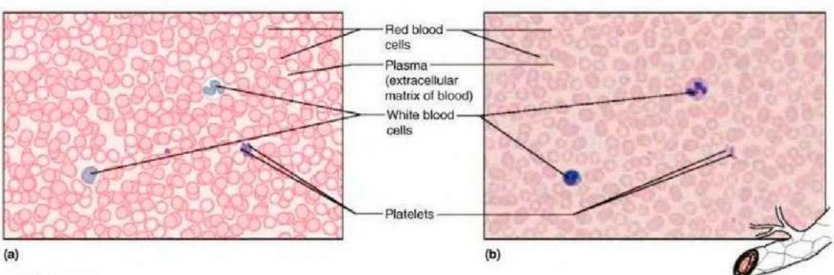

FIGURE 5.27
Blood tissue consists of red blood cells, white blood cells, and platelets suspended in a fluid extracellular matrix (425×).

TABLE 5.7	Connective Tissues		
Type	**Description**	**Function**	**Location**
Loose connective tissue	Cells in fluid-gel matrix	Binds organs, holds tissue fluids	Beneath the skin, between muscles, beneath epithelial tissues
Adipose tissue	Cells in fluid-gel matrix	Protects, insulates, and stores fat	Beneath the skin, around the kidneys, behind the eyeballs, on the surface of the heart
Reticular connective tissue	Cells in fluid-gel matrix	Supports	Walls of liver, spleen, and lymphatic organs
Dense connective tissue	Cells in fluid-gel matrix	Binds organs	Tendons, ligaments, dermis
Elastic connective tissue	Cells in fluid-gel matrix	Provides elastic quality	Connecting parts of the spinal column, in walls of arteries and airways
Hyaline cartilage	Cells in solid-gel matrix	Supports, protects, provides framework	Ends of bones, nose, and rings in walls of respiratory passages
Elastic cartilage	Cells in solid-gel matrix	Supports, protects, provides flexible framework	Framework of external ear and part of larynx
Fibrocartilage	Cells in solid-gel matrix	Supports, protects, absorbs shock	Between bony parts of spinal column, parts of pelvic girdle, and knee
Bone	Cells in solid matrix	Supports, protects, provides framework	Bones of skeleton, middle ear
Blood	Cells and platelets in fluid matrix	Transports gases, defends against disease, clotting	Throughout the body within a closed system of blood vessels and heart chambers

1. Describe the general characteristics of cartilage.
2. Explain why injured bone heals more rapidly than does injured cartilage.
3. What are the major components of blood?

Types of Membranes

After discussing epithelial and connective tissues, membranes are better understood. **Epithelial membranes** are thin, sheetlike structures that are usually composed of epithelial and underlying connective tissues, covering body surfaces and lining body cavities. The three major types of epithelial membranes are *serous, mucous,* and *cutaneous.*

Serous (se'rus) **membranes** line the body cavities that do not open to the outside and reduce friction between the organs and cavity walls. They form the inner linings of the thorax and abdomen, and they cover the organs within these cavities (see figs. 1.11 and 1.12). A serous membrane consists of a layer of simple squamous epithelium (mesothelium) and a thin layer of loose connective tissue. Cells of a serous membrane secrete watery *serous fluid,* which helps lubricate membrane surfaces.

Mucous (mu'kus) **membranes** line the cavities and tubes that open to the outside of the body. These include the oral and nasal cavities and the tubes of the digestive, respiratory, urinary, and reproductive systems. A mucous membrane consists of epithelium overlying a layer of loose connective tissue; however, the type of epithelium varies with the location of the membrane. For example, stratified squamous epithelium lines the oral cavity, pseudostratified columnar epithelium lines part of the nasal cavity, and simple columnar epithelium lines the small intestine. Goblet cells within a mucous membrane secrete *mucus.*

Another epithelial membrane is the **cutaneous** (ku-ta'ne-us) **membrane,** more commonly called *skin.* It is part of the integumentary system described in detail in chapter 6.

Some membranes are composed entirely of connective tissues. These include **synovial membrane** (sĭ-no've-al mem'brānz), lining joints and discussed further in chapter 8 (pp. 265–266).

1. Name the four types of membranes, and explain how they differ.
2. Explain how the membrane types differ.

Muscle Tissues

General Characteristics

Due to their elongated shape, the cells in **muscle tissues** are sometimes called *muscle fibers.* Muscle tissues are contractile; they can shorten and thicken. As they contract, muscle cells pull at their attached ends, which moves body parts. The three types of muscle tissue (skeletal, smooth, and cardiac) are discussed further in chapter 9.

Skeletal Muscle Tissue

Skeletal muscle tissue (fig. 5.28) forms muscles that usually attach to bones and that are controlled by conscious