CHAPTER 5

TISSUES

CHAPTER OUTLINE

KEY TERMS

collagen
connective tissue
epithelial tissue
gland
histogenesis
histology
inflammation
matrix
mucous membrane
muscle tissue
nervous tissue
regeneration
serous membrane
squamous
tissue

A ***tissue*** is a group of similar cells that perform a common function. Each tissue specializes in performing at least one unique function that helps maintain homeostasis, ensuring the survival of the whole body. The arrangement of cells in a tissue may form a thin sheet only one cell deep, whereas the cells of other tissues form huge masses containing millions of cells. Regardless of the size, shape, or arrangement of cells in a tissue, they all are surrounded by or embedded in a nonliving intercellular material that often is called simply ***matrix.***

Tissues differ regarding the amount and kind of intercellular, or "between-the-cells," matrix. The unique and specialized nature of the matrix in bone and cartilage, for example, contributes to the strength and resiliency of the body. Some tissues contain almost no intercellular matrix. Other tissues are almost entirely matrix—with only a few cells present. Some types of tissue matrix contain fibers that make them flexible or elastic; some contain mineral crystals that make them rigid, and others are very fluid.

It is primarily the intercellular junctions, such as the desmosomes and tight junctions described in a previous chapter (see Chapter 3, p. 86), that hold groups of cells together to form tissues found in sheets or other continuous masses of cells. The tissue that forms the outer layer of skin is held together this way. In other tissues, the matrix holds the cells together—if they are held together at all. For example, the fibers and crystals of bone matrix hold bone tissue together, whereas the fluid nature of blood matrix (plasma) does not hold blood tissue in a solid mass at all.

The four major types of human tissue that were introduced in Chapter 1 are described in more detail in this chapter. An understanding of the major tissue types will help you understand the next higher levels of organization in the body—organs and organ systems. Eventually, your knowledge of ***histology*** (the biology of tissues) will give you a better appreciation for the nature of the whole body.

PRINCIPAL TYPES OF TISSUE

Although a number of subtypes are present in the body, all tissues can be classified by their structure and function into four principal types:

1. **Epithelial tissue** covers and protects the body surface, lines body cavities, specializes in moving substances into and out of the blood (secretion, excretion, and absorption), and forms many glands.
2. **Connective tissue** is specialized to support the body and its parts, to connect and hold them together, to transport substances through the body, and to protect it from foreign invaders. The cells in connective tissue are often relatively far apart and separated by large quantities of nonliving matrix.
3. **Muscle tissue** produces movement; it moves the body and its parts. Muscle cells are specialized for contractility and produce movement by the shortening of contractile units found in the cytoplasm.
4. **Nervous tissue** is the most complex tissue in the body. It specializes in communication between the various parts of the body and in integration of their activities. This tissue's major function is the generation of complex messages for the coordination of body functions.

EMBRYONIC DEVELOPMENT OF TISSUES

The four major tissues of the body appear early in the embryonic period of development (first 2 months after conception). After fertilization has occurred, repeated cell divisions soon convert the single-celled zygote into a hollow ball of cells called a **blastocyst.** The blastocyst implants in the uterus, and within 2 weeks the cells move and regroup in an orderly way into three **primary germ layers** called ***endoderm, mesoderm,*** and ***ectoderm*** (Figure 5-1). The process by which blastocyst cells move and then differentiate into the three primary germ layers is called **gastrulation.** During this process the cells in each germ layer become increasingly differentiated to form specific tissues and eventually give rise to the structures listed in Figure 5-1, *B.*

In summary, some epithelial tissues develop from each of the primary germ layers, whereas connective and muscle tissues arise from mesoderm, and nerve tissue develops from ectoderm. The process of the primary germ layers differentiating into the different kinds of tissues is called ***histogenesis.*** Chapter 33 provides additional details of human development, including a discussion of differentiation of organs and body systems.

1. Name the four basic tissue types and give the major function of each.
2. What is a primary germ layer?

EPITHELIAL TISSUE

TYPES AND LOCATIONS OF EPITHELIAL TISSUE

Epithelial tissue, or **epithelium,** often is subdivided into two types: (1) **membranous** (covering or lining) epithelium and (2) **glandular** epithelium. Membranous epithelium covers the body and some of its parts and lines the serous cavities (pleural, pericardial, and peritoneal), the blood and lymphatic vessels, and the respiratory, digestive, and genitourinary tracts. Glandular epithelium is grouped in solid cords or specialized follicles that form the secretory units of endocrine and exocrine glands.

FUNCTIONS OF EPITHELIAL TISSUE

Epithelial tissues have a widespread distribution throughout the body and serve several important functions:

Protection. Generalized protection is the most important function of membranous epithelium. It is the relatively tough and impermeable epithelial covering of the skin that protects the body from mechanical and chemical injury and also from invading bacteria and other disease-causing microorganisms.

Sensory functions. Epithelial structures specialized for sensory functions are found in the skin, nose, eye, and ear.

Secretion. Glandular epithelium is specialized for secretory activity. Secretory products include hormones, mucus, digestive juices, and sweat.

Absorption. The lining epithelium of the gut and respiratory tract allows for the absorption of nutrients from the gut and the exchange of respiratory gases between air in the lungs and the blood.

Excretion. The specialized epithelial lining of kidney tubules makes the excretion and concentration of excretory products in the urine possible.

GENERALIZATIONS ABOUT EPITHELIAL TISSUE

Most epithelial tissues are characterized by extremely limited amounts of intercellular, or matrix, material. This explains their characteristic appearance, when viewed under a light microscope, of a continuous sheet of cells packed tightly together. With the electron microscope, however, narrow spaces—about 20 nanometers (one millionth of an inch) wide—can be seen around the cells. These spaces, like other intercellular spaces, contain interstitial fluid.

Sheets of epithelial cells compose the surface layer of skin and of mucous and serous membranes. The epithelial tissue attaches to an underlying layer of connective tissue by means of a thin noncellular layer of adhesive, permeable material called the **basement membrane** (Figure 5-2). Both epithelial and connective tissue cells synthesize the basement membrane, which is made up of glycoprotein material secreted by the epithelial components and a fine mesh of fibers produced by the connective tissue cells. Histologists refer to the glycoprotein material secreted by the epithelial cells as the *basal lamina* and to the connective tissue fibers as the *reticular lamina.* The union of basal and reticular lamina forms the basement membrane. Adhesive molecules called *integrins* help bind the cytoskeletons of the epithelial cells to the fibers of the basement membrane, forming a strong connection.

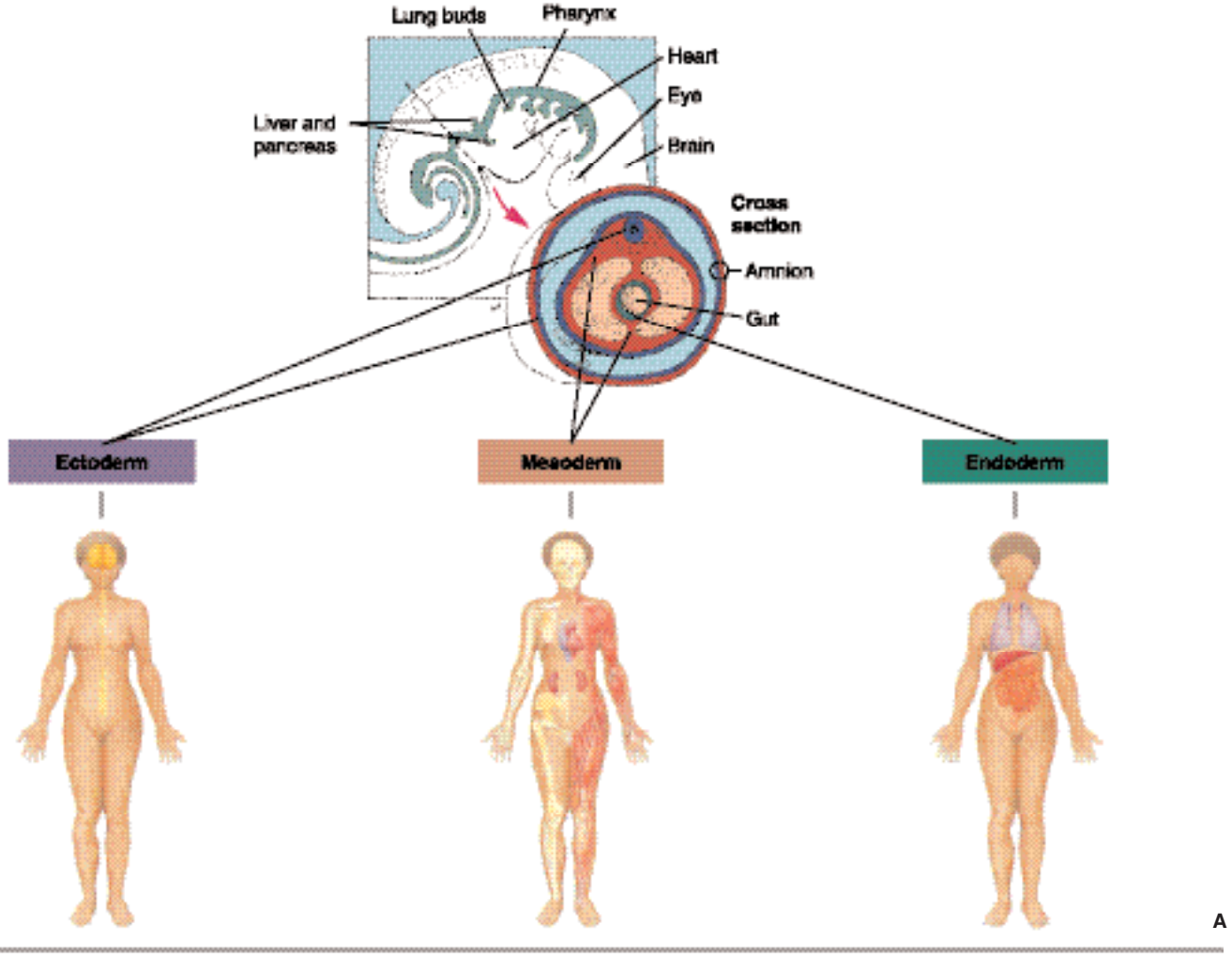


Figure 5-1 **Primary germ layers.** *A,* Illustration shows the primary germ layers and the body systems into which they develop. **B,** Structures derived from primary germ layers.

Epithelial tissues contain no blood vessels. As a result, epithelium is said to be **avascular** (*a,* "without"; *vascular,* "vessels"). Hence oxygen and nutrients must diffuse from capillaries in the underlying connective tissue through the permeable basement membrane to reach living epithelial cells.

At intervals between adjacent epithelial cells, their plasma membranes are modified to hold the cells together. These specialized intercellular structures, such as **desmosomes** and **tight junctions,** are described in Chapter 3. Epithelial cells can reproduce themselves. They frequently go through the process of cell division. Because epithelial cells in many locations meet considerable wear and tear, this fact has practical importance. It means, for example, that new cells can replace old or destroyed epithelial cells in the skin or in the lining of the gut or respiratory tract.

CLASSIFICATION OF EPITHELIAL TISSUE

Membranous Epithelium

Classification Based on Cell Shape. The shape of membranous epithelial cells may be used for classification purposes. Four cell shapes, called ***squamous,*** **cuboidal, columnar,** and **pseudostratified columnar,** are used in this classification scheme (see Figure 5-2). Squamous (Latin, "scaly") cells are flat and platelike. Cuboidal cells, as the name implies, are cube-shaped and have more cytoplasm than the scalelike squamous cells. Columnar epithelial cells are higher than they are wide and appear narrow and cylin-

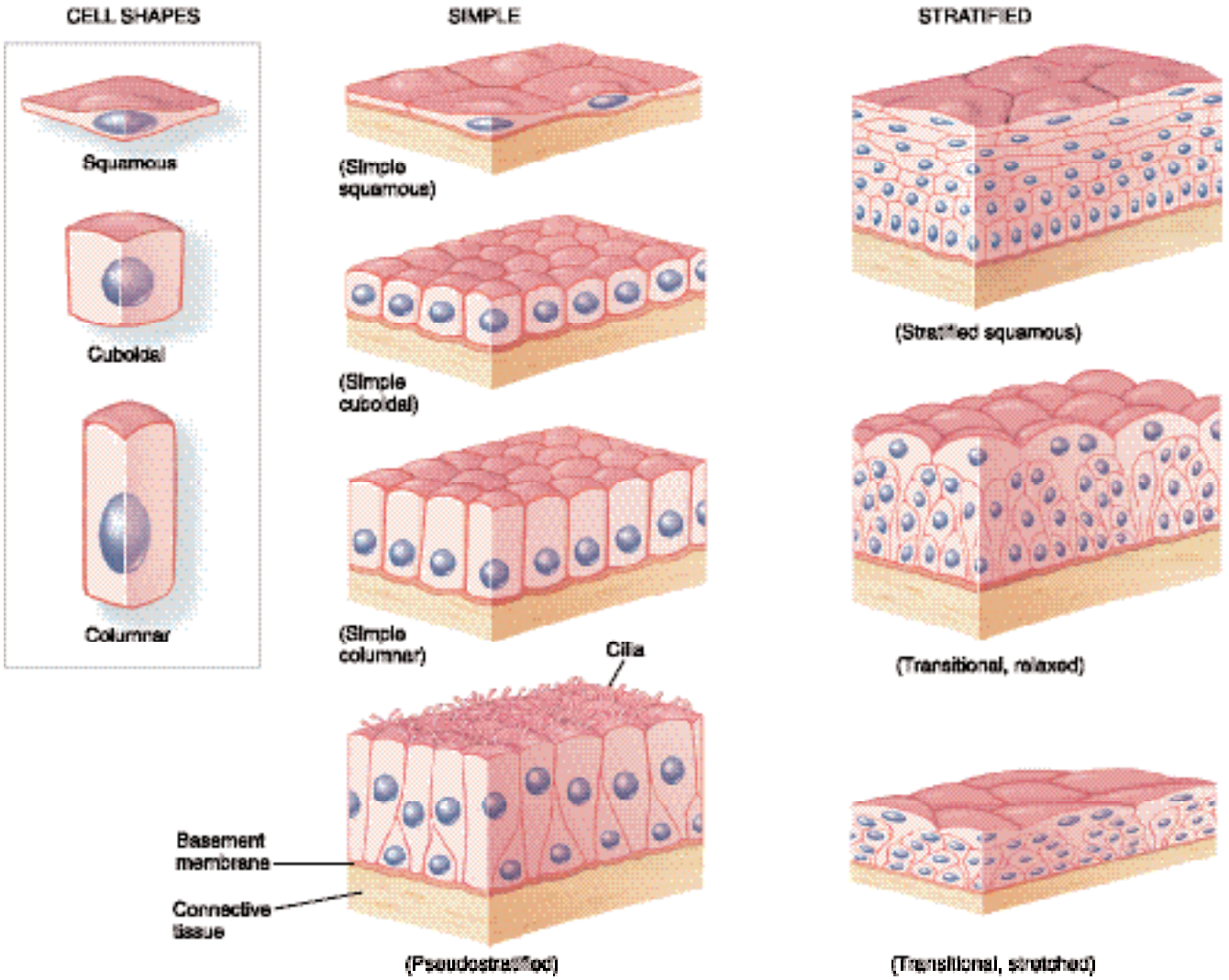


Figure 5-2 Classification of epithelial tissues. The tissues are classified according to the shape and arrangement of cells. The color scheme of these drawings is based on a common staining technique used by histologists called *hematoxylin and eosin (H&E)* staining. H&E staining usually renders the cytoplasm pink and the chromatin inside the nucleus a purplish color. The cellular membranes, including the plasma membrane and nuclear envelope, usually do not pick up any stain and thus are transparent.

drical. Pseudostratified columnar epithelium has only one layer of oddly shaped columnar cells. Although each cell touches the basement membrane, the tops of some pseudostratified cells do not fully extend to the surface of the membrane. Also, some nuclei are near the "top" of the cell and some near the "bottom" of the cell—rather than all nuclei being near the bottom. The result is a false *(pseudo)* appearance of layering, or stratification, when only a single layer of cells is present.

Classification Based on Layers of Cells. In most cases the location and function of membranous epithelium determine whether or not its cells will be stacked and layered or arranged in a sheet one cell-layer thick. Arrangement of epithelial cells in a single layer is called **simple epithelium.** If epithelial cells are layered one on another, the tissue is called **stratified epithelium. Transitional epithelium** (described later) is a unique arrangement of differing cell shapes in a stratified, or layered, epithelial sheet.

If membranous or covering epithelium is classified by the shape and layering of its cells, the specific types listed in Table 5-1 are possible. Notice that stratified tissue types are named for the shape of cells in their top layer only. Each type is described in the paragraphs that follow, and selected examples are illustrated in Figures 5-3 to 5-10.

Simple Epithelium

SIMPLE SQUAMOUS EPITHELIUM. Simple squamous epithelium consists of only one layer of flat, scalelike cells (Figure 5-3). Consequently, substances can readily diffuse or filter through this type of tissue. The microscopic air sacs (alveoli) of the lungs, for example, are composed of this kind of tissue, as are the linings of blood and lymphatic vessels and the surfaces of the pleura, pericardium, and peritoneum (Figure 5-4).

Table 5-1 Classification Scheme for Membranous Epithelial Tissues

Shape of Cells*	Tissue Type
One layer	
Squamous	Simple squamous
Cuboidal	Simple cuboidal
Columnar	Simple columnar
Pseudostratified columnar	Pseudostratified columnar
Several layers	
Squamous	Stratified squamous
Cuboidal	Stratified cuboidal
Columnar	Stratified columnar
(Varies)	Transitional

*In the top layer (if more than one layer in the tissue).

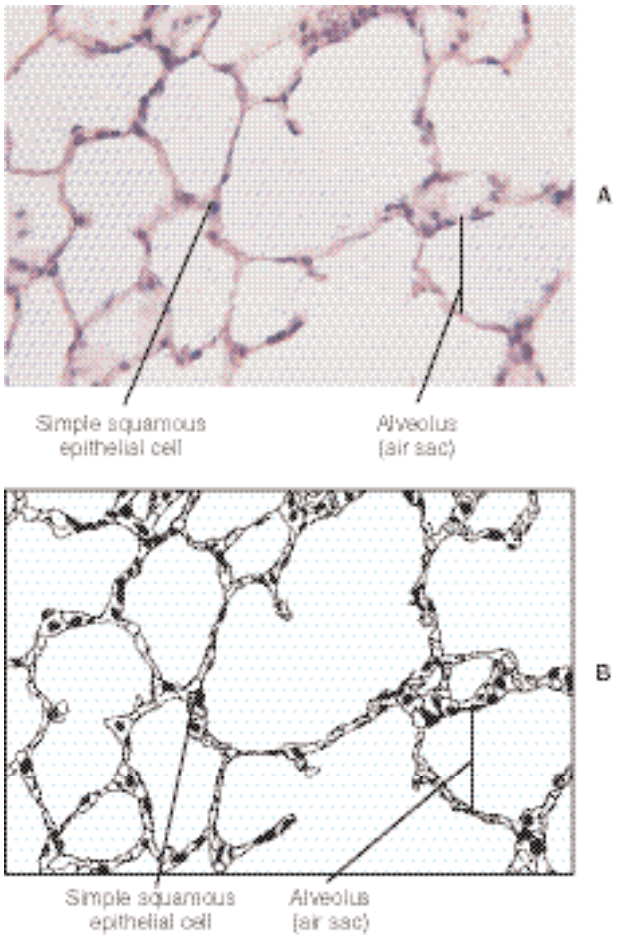
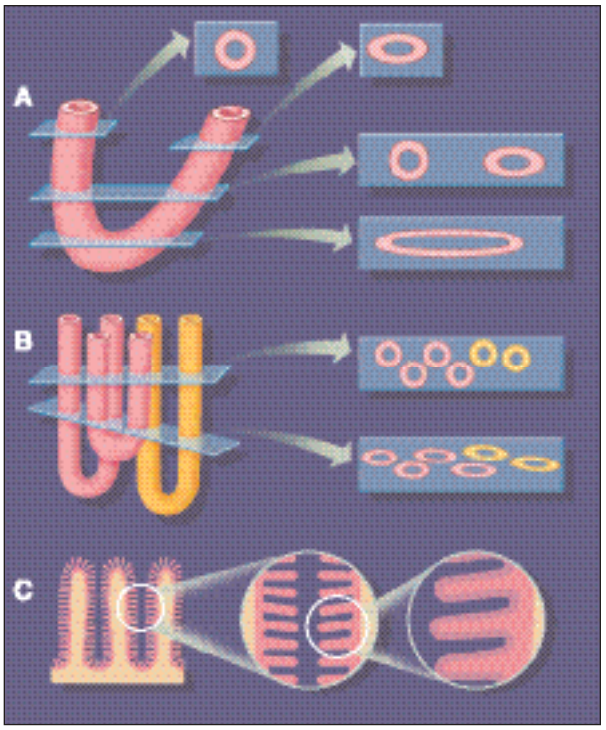


Figure 5-3 Simple squamous epithelium. **A**, Photomicrograph of lung tissue shows thin simple squamous epithelium lining the tiny air sacs of the lung. Notice how the H&E staining (see Figure 5-2) renders the cytoplasm of each cell pink and each nucleus a purplish color. **B**, Sketch of micrograph showing the outlines of cellular membranes that are transparent in the photomicrograph.

Box 5-1

Imagining Cross Sections

When you look at photomicrographs of epithelial tissues or other structures that are tubelike, saclike, or folded into complex shapes, it is sometimes hard to imagine what you are really looking at. As diagram **A** shows, when you cut a tube on a cross section, the slice looks like a ring (if cut at a right angle) or oval (if cut an oblique, or slanted, angle). Diagram **A** also shows that if the tube is bent where the cut is made, it also can look like an oval on your slide. Diagram **B** shows what happens when you have many tubes next to one another–your slice has many round or oval rings (depending on the angle of the cut). Compare Diagram **A** to Figure 5-5. Can you imagine the type of tissue that produced this slice? Diagram **C** shows what can happen when a membrane such as the intestinal lining is folded into complex shapes. The slice may look like a sort of zigzag line of cells, or if it is at a high magnification, it may just look like a series of parallel rows. Look at Figure 5-6. Can you imagine what the original tissue must have looked like? Look ahead to Figures 25-9 through 25-21. Can you "see" the context or "situation" of the various tissue slices? Try sketching out the "big picture" of the context of various tissue samples shown in the photomicrographs of this chapter, then keep them in your notebook. By doing so, you'll be preparing yourself for later chapters (and later courses) by learning to identify the context of a tissue "on sight."



Cross sections.

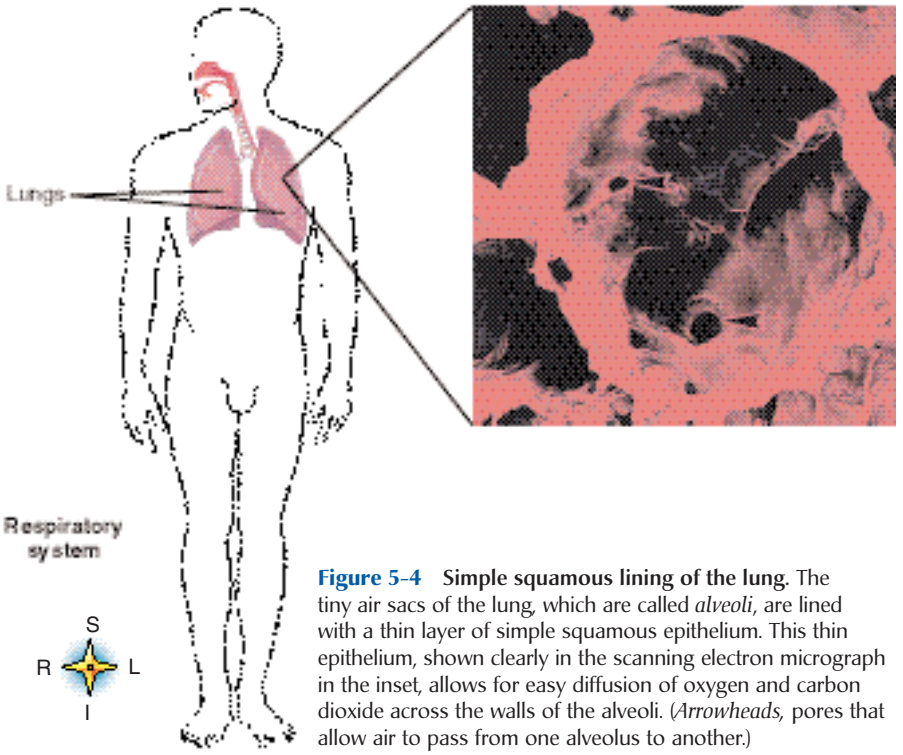


Figure 5-4 Simple squamous lining of the lung. The tiny air sacs of the lung, which are called *alveoli*, are lined with a thin layer of simple squamous epithelium. This thin epithelium, shown clearly in the scanning electron micrograph in the inset, allows for easy diffusion of oxygen and carbon dioxide across the walls of the alveoli. (*Arrowheads,* pores that allow air to pass from one alveolus to another.)

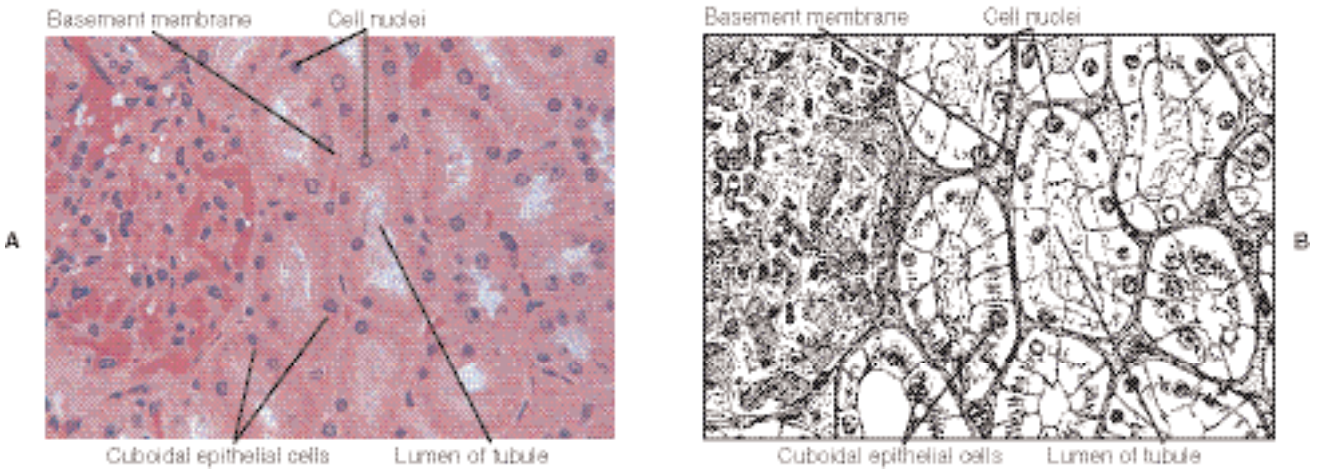


Figure 5-5 Simple cuboidal epithelium. **A**, Photomicrograph of kidney tubules shows the single layer of cuboidal cells touching a basement membrane. **B**, Sketch of micrograph. Note the cuboidal cells that enclose the tubule opening (lumen).

(Blood and lymphatic vessel linings are called **endothelium,** and the surfaces of the pleura, pericardium, and peritoneum are called **mesothelium.** Some histologists classify these as connective tissue because of their embryological origin.)

Simple cuboidal epithelium. Simple cuboidal epithelium is composed of one layer of cuboidal cells resting on a basement membrane (Figure 5-5). This type of epithelium is seen in many types of glands and their ducts. It also is found in the ducts and tubules of other organs, such as the kidney.

Simple columnar epithelium. Simple columnar epithelium composes the surface of the mucous membrane that lines the stomach, intestine, uterus, uterine tubes, and parts of the respiratory tract (Figure 5-6). It consists of a single layer of cells, many of which have a modified structure. Three common modifications are goblet cells, cilia, and microvilli. Goblet cells have large, secretory vesicles, which give them the appearance of a goblet. The vesicles contain mucus, which goblet cells produce in great quantity and secrete onto the surface of the epithelial membrane. Mucus is a solution of water, electrolytes, and glycoproteins. In the intestine the plasma membranes of many columnar cells extend out in hundreds and hundreds of microscopic finger-like projections called **microvilli.** By greatly increasing the surface area of the intestinal mucosa, microvilli make it

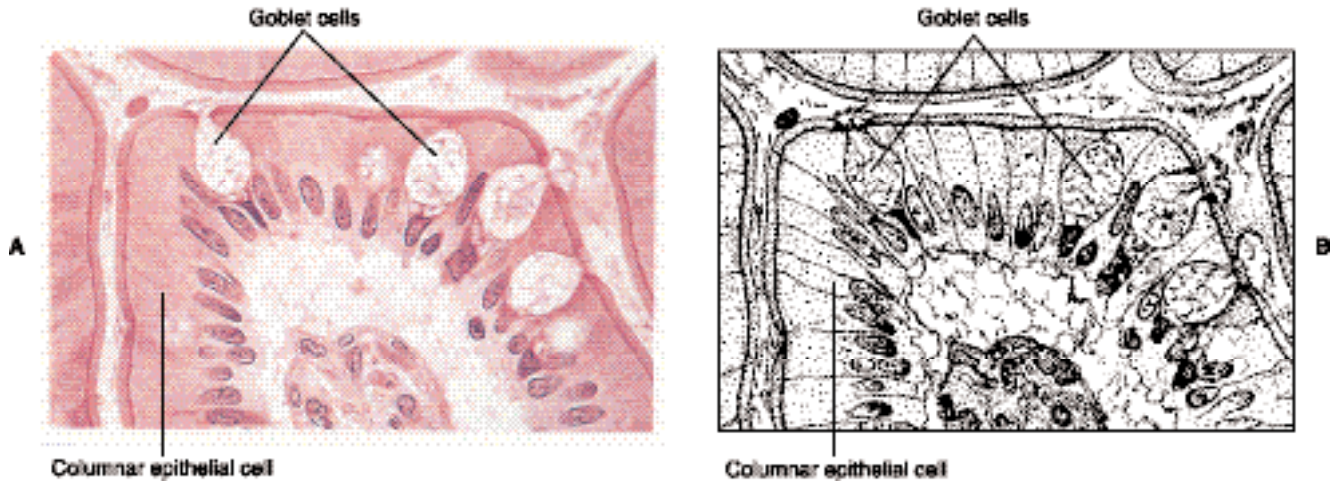


Figure 5-6 **Simple columnar epithelium.** **A**, Photomicrograph of simple columnar epithelium. **B**, Sketch of photomicrograph. Note the goblet, or mucus-producing, cells present.

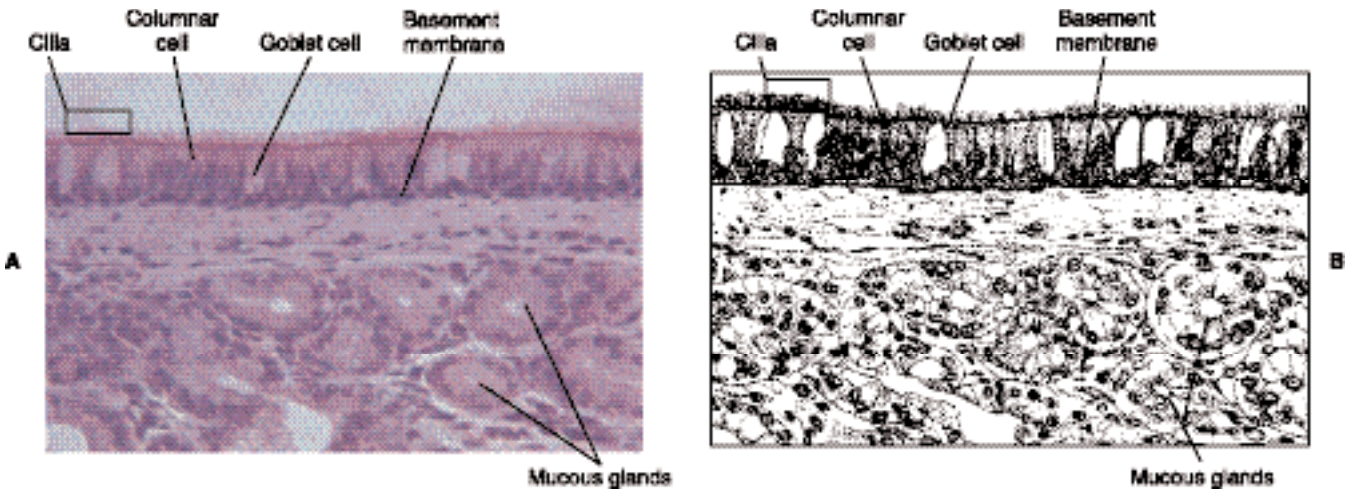


Figure 5-7 **Pseudostratified ciliated epithelium.** **A**, This photomicrograph of the trachea shows that each irregularly shaped columnar cell touches the underlying basement membrane. **B**, Sketch of photomicrograph. Placement of cell nuclei at irregular levels in the cells gives a false (pseudo) impression of stratification.

especially well suited for absorbing nutrients and fluids from the intestine.

Pseudostratified columnar epithelium. Pseudostratified columnar epithelium is found lining the air passages of the respiratory system and certain segments of the male reproductive system such as the urethra (Figure 5-7). Although appearing to be stratified, only a single layer of irregularly shaped columnar cells touches the basement membrane. The cells are of differing heights, and many are not tall enough to reach the upper surface of the epithelial sheet. This fact, coupled with placement of cell nuclei at odd and irregular levels in the cells, gives a false (pseudo) impression of stratification. Mucus-secreting goblet cells are numerous and cilia are present. In the respiratory system air passages, uniform motion of the cilia causes a thin layer of tacky mucus to move in one direction over the free surface of the epithelium. As a result, dust particles in the air are trapped and moved toward the mouth and away from the delicate lung tissues.

Stratified Epithelium

Stratified squamous (keratinized) epithelium. Stratified squamous epithelium is characterized by multiple layers of cells with typical flattened squamous cells at the free, or outer surface, of the epithelial sheet (Figure 5-8). The presence of keratin in these cells contributes to the protective qualities of skin covering the body surface. Details of the histology of this type of epithelium are presented in Chapter 6.

Stratified squamous (nonkeratinized) epithelium. Nonkeratinized stratified squamous epithelium is found

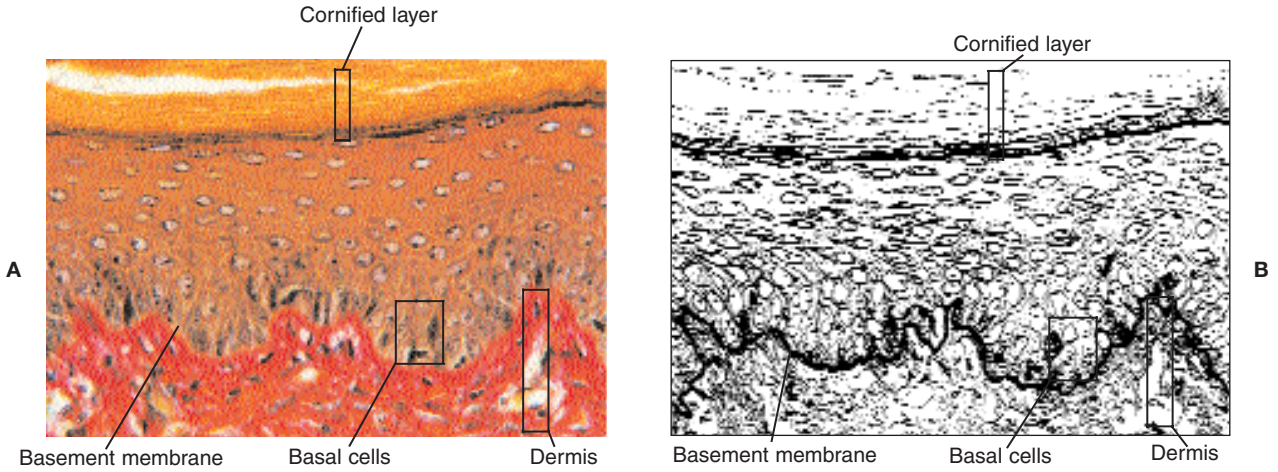


Figure 5-8 **Stratified squamous (keratinized) epithelium.** **A**, Photomicrograph of the skin shows cells becoming progressively flattened and scalelike as they approach the surface and are lost. **B**, Sketch of photomicrograph. The outer surface of this epithelial sheet contains many flattened cells, which have lost their nuclei.

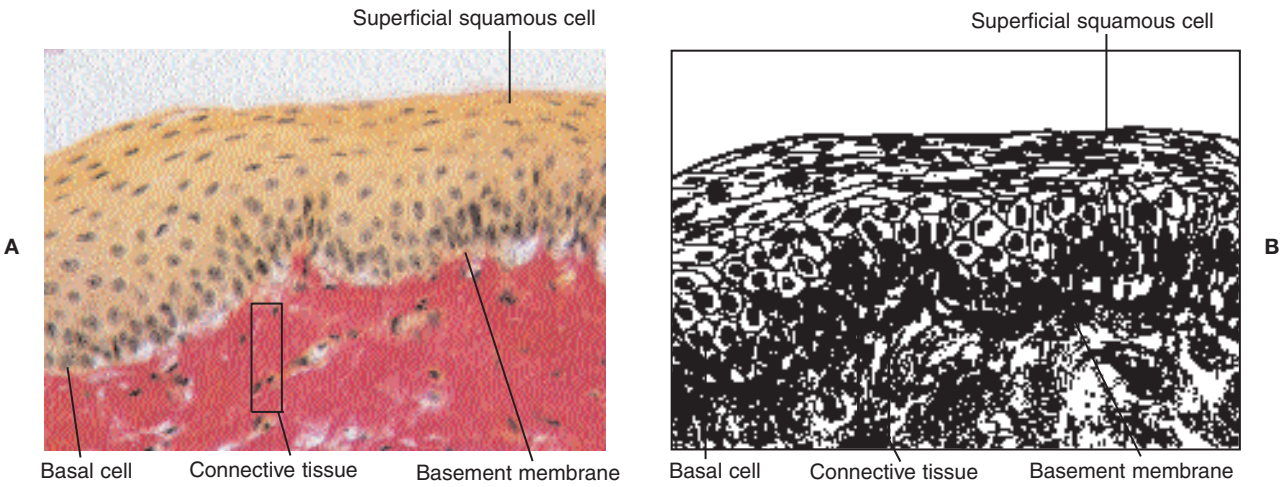


Figure 5-9 **Stratified squamous (nonkeratinized) epithelium.** **A**, Photomicrograph of vaginal tissue. Each cell in the layer is flattened near the surface and attached to the sheet. No flaking of dead cells from the surface occurs. **B**, Sketch of photomicrograph. All cells have nuclei. Compare with Figure 5-8.

lining the vagina, mouth, and esophagus (Figure 5-9). Its free surface is moist, and the outer epithelial cells, unlike those found in the skin, do not contain keratin. This type of epithelium serves a protective function.

Stratified cuboidal epithelium. The cuboidal variety of stratified epithelium also serves a protective function. Typically, two or more rows of low cuboidal cells are arranged randomly over a basement membrane. Stratified cuboidal epithelium can be located in the sweat gland ducts, in the pharynx, and over parts of the epiglottis.

Stratified columnar epithelium. Although this protective epithelium has multiple layers of columnar cells, only the most superficial cells are truly columnar in appearance. Epithelium of this type is found in few places in the human body. It is located in segments of the male urethra and in the mucous layer near the anus.

Stratified transitional epithelium. Transitional epithelium is a stratified tissue typically found in body areas, such as the wall of the urinary bladder, that are subjected to stress and tension changes (Figure 5-10). In many instances, 10 or more layers of cuboidal cells of varying shapes are present in the absence of stretching or tension. As tension increases, the epithelial sheet is expanded, the number of observable cell layers decreases, and cell shape changes from cuboidal to squamous in appearance. This ability of transitional epithelium to stretch protects the bladder wall and other distensible structures that it lines from tearing when stretched with great force.

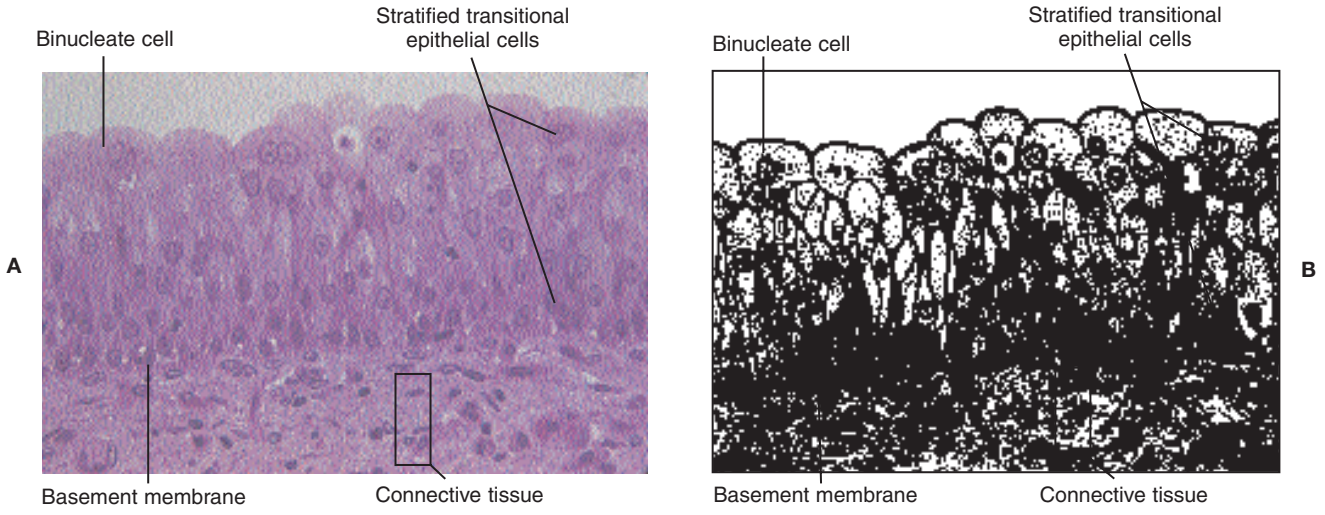


Figure 5-10 **Transitional epithelium.** **A**, Photomicrograph of the urinary bladder shows that cell shape is variable from cuboidal to squamous. Several layers of cells are present. Intermediate and surface cells do not touch basement membrane. **B**, Sketch of photomicrograph.

Glandular Epithelium

Epithelium of the glandular type is specialized for secretory activity. Regardless of the secretory product produced, glandular activity depends on complex and highly regulated cellular activities requiring the expenditure of stored energy.

Unlike the single or layered cells of membranous epithelium typically found in protective coverings or linings, glandular epithelial cells may function singly as **unicellular glands,** or they may function in clusters, solid cords, or specialized follicles as **multicellular glands.** Glandular secretions may be discharged into ducts, into the lumen of hollow visceral structures, onto the body surface, or directly into the blood.

All ***glands*** in the body can be classified as either exocrine or endocrine glands. **Exocrine glands,** by definition, discharge their secretion products into ducts. The salivary glands are typical exocrine glands. The secretion product (saliva) is produced in the gland and then discharged into a duct that transports it to the mouth. **Endocrine glands** are often called *ductless glands* because they discharge their secretion products (hormones) directly into the blood or interstitial fluid. The pituitary, thyroid, and adrenal glands are typical endocrine glands.

Structural Classification of Exocrine Glands. Multicellular exocrine glands are most often classified by structure, using the shape of their ducts and the complexity (branching) of their duct systems as distinguishing characteristics. Shapes include **tubular** and **alveolar** (saclike). **Simple** exocrine glands have only one duct leading to the surface, and **compound** exocrine glands have two or more ducts. Table 5-2 describes some of the major structural types of exocrine glands. Figure 5-11 shows examples of exocrine glands in the lining of the stomach.

Functional Classification of Exocrine Glands. In addition to structural differences, exocrine glands also differ in the method by which they discharge their secretion products from the cell. Using these functional criteria, three types of exocrine glands may be identified (Figure 5-12):

1. Apocrine
2. Holocrine
3. Merocrine

Apocrine glands collect their secretory products near the apex, or tip, of the cell and then release them into a duct by pinching off the distended end. This process results in some loss of cytoplasm and damage to the cell. Recovery and repair of cells are rapid, however, and continued secretion occurs. The milk-producing mammary glands are examples of apocrine-type glands.

Holocrine glands—such as the sebaceous glands that produce oil to lubricate the skin—collect their secretory product inside the cell and then rupture completely to release it. These cells literally self-destruct to complete their function.

Merocrine glands discharge their secretion product directly through the cell or plasma membrane. This discharge process is completed without injury to the cell wall and without loss of cytoplasm. Only the secretion product passes from the glandular cell into the duct. Most secretory cells are of this type. The salivary glands are examples of merocrine-type exocrine glands.

1. List at least three functions of epithelial tissue.
2. What are the three basic shapes of epithelial cells?
3. Distinguish between a simple epithelial tissue and a stratified epithelial tissue.
4. How do exocrine glands secrete their products?

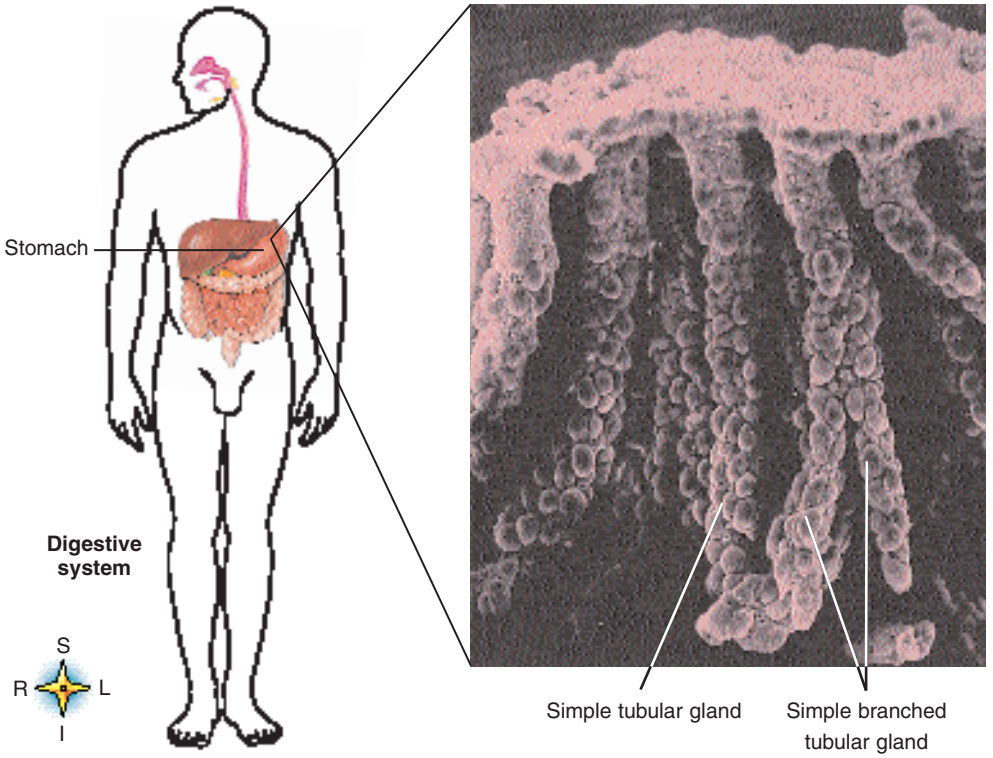


Figure 5–11 Exocrine glands in the stomach. The inset shows a scanning electron micrograph of exocrine glands, called *gastric glands,* in the lining of the stomach. These glands produce gastric juice—a mixture of water, mucus, enzymes, acid, and other substances.

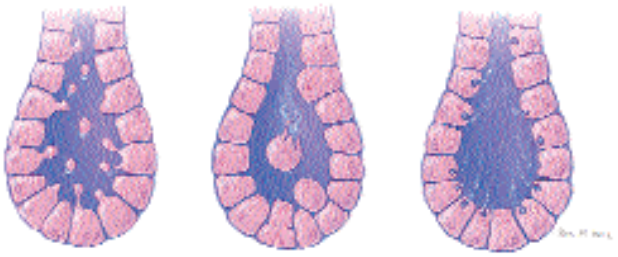


Figure 5–12 Three types of exocrine glands. Here exocrine glands are classified by method of secretion.

CONNECTIVE TISSUE

Connective tissue is one of the most widespread tissues in the body, found in or around nearly every organ of the body. It exists in more varied forms than the other three basic tissues: delicate tissue-paper webs, tough resilient cords, rigid bones, and a fluid, namely, blood, are all forms of connective tissue.

FUNCTIONS OF CONNECTIVE TISSUE

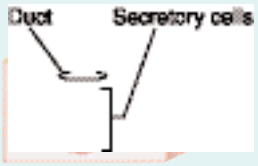
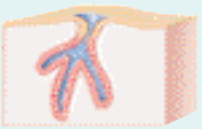
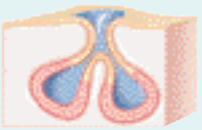
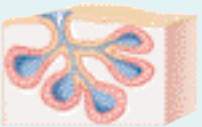
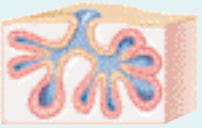
Connective tissue connects, supports, transports, and defends. It connects tissues to each other, for example. It also connects muscles to muscles, muscles to bones, and bones to bones. It forms a supporting framework for the body as a whole and for its organs individually. One kind of connective tissue—blood—transports a large array of substances between parts of the body. And finally, several kinds of connective tissue cells defend us against microorganisms and other invaders.

CHARACTERISTICS OF CONNECTIVE TISSUE

Connective tissue consists predominantly of intracellular material called ***matrix.*** Embedded in the matrix are relatively few cells, varying numbers and kinds of fibers, fluid, and perhaps other material called **ground substance.** The qualities of the matrix and fibers largely determine the structural characteristics of each type of connective tissue. The matrix of blood, for example, is a fluid (plasma). It contains numerous blood cells but no fibers, except when it coagulates. Some connective tissues have the consistency of a soft gel, some are firm but flexible, some hard and rigid, some tough, others delicate—and in each case it is their matrix and extracellular fibers that make them so.

A connective tissue's matrix contains one or more of the following kinds of fibers: collagenous (or white), reticular, or elastic. Fibroblasts and some other cells produce these protein fibers. Collagenous fibers are tough and strong, reticular fibers are delicate, and elastic fibers are extensible and elastic. Collagenous or white fibers are made of ***collagen*** and often occur in bundles—an arrangement that provides great tensile strength. Reticular fibers, in contrast, occur in networks and, although delicate, support small structures such as capillaries and nerve fibers. Reticular fibers are made of a specialized type of collagen called *reticulin.* Collagen, in its hydrated form, is known as gelatin. Of all the hundreds of different protein compounds in the body, collagen is the most abundant. Biologists estimate that it constitutes somewhat more than one fourth of all the protein in the body. And interestingly, one of the most basic factors in the aging process, according to some researchers, is the change in the molecular structure of collagen that occurs gradually with the passage of years.

Table 5-2 Structural Classification of Multicellular Exocrine Glands

Shape*	Complexity†		Type	Example
Tubular (single, straight)	Simple		Simple tubular	Intestinal glands
Tubular (coiled)	Simple		Simple coiled tubular	Sweat glands
Tubular (multiple)	Simple		Simple branched tubular	Gastric (stomach) glands
Alveolar (single)	Simple		Simple alveolar	Sebaceous (skin oil) glands
Alveolar (multiple)	Simple		Simple branched alveolar	Sebaceous glands
Tubular (multiple)	Compound		Compound tubular	Mammary glands
Alveolar (multiple)	Compound		Compound alveolar	Mammary glands
Some tubular; some alveolar	Compound		Compound tubuloalveolar	Salivary glands

*Shape of the distal secreting units of the gland.
†Number of ducts *reaching the surface.*

Elastic fibers are made of a protein called **elastin,** which returns to its original length after being stretched. Elastic fibers are found in "stretchy" tissues, such as the cartilage of the external ear.

In addition to protein fibers, the matrix of connective tissues contain a number of *proteoglycans* made up of polysaccharide chains often containing *glucosamine* and bound to a protein core. These chemicals make the matrix fluid thick enough to be a barrier to bacteria and other microbes. They also form transparent lubricant and help hold the tissue together. Among the more notable of these compounds are *hyaluronic acid* and *chondroitin sulfate*.

CLASSIFICATION OF CONNECTIVE TISSUE

Connective tissues have been classified by histologists in several different ways. Usually they are placed into different categories or types according to the structural characteristics of the intercellular material. The classification scheme we

have adopted here is widely used and includes most of the major types:

1. Fibrous
    a. Loose, ordinary (areolar)
    b. Adipose
    c. Reticular
    d. Dense
2. Bone
3. Cartilage
    a. Hyaline
    b. Fibrocartilage
    c. Elastic
4. Blood

Fibrous tissues such as areolar, adipose, reticular, and dense fibrous tissues have extracellular fibers as their predominant feature. The type and arrangement of the extracellular fibers

Table 5-3 Tissues

Tissue	Location	Function
Epithelial		
Membranous		
Simple squamous	Alveoli of lungs	Absorption by diffusion of respiratory gases between alveolar air and blood
	Lining of blood and lymphatic vessels (called endothelium; classified as connective tissue by some histologists)	Absorption by diffusion, filtration, osmosis
	Surface layer of pleura, pericardium, peritoneum (called mesothelium; classified as connective tissue by some histologists)	Absorption by diffusion and osmosis; also, secretion
Stratified squamous	Surface of mucous membrane lining mouth, esophagus, and vagina	Protection
	Surface of skin (epidermis)	Protection
Transitional	Surface of mucous membrane lining urinary bladder and ureters	Permits stretching
Simple columnar	Surface layer of mucous lining of stomach, intestines, and part of respiratory tract	Protection; secretion; absorption; moving of mucus (by ciliated columnar epithelium)
Stratified columnar	Lining of portions of the male urethra; mucous membrane near anus (rare)	Protection
Pseudostratified columnar	Surface of mucous membrane lining trachea, large bronchi, nasal mucosa, and parts of male reproductive tract (epididymis and vas deferens); lines large ducts of some glands (e.g., parotid)	Protection
Simple cuboidal	Ducts and tubules of many organs, including exocrine glands and kidneys	Secretion; absorption
Stratified cuboidal	Ducts of sweat glands; lining of pharynx; covering portion of epiglottis	Protection
Glandular	Glands	Secretion
Connective		
Fibrous		
Loose, ordinary (areolar)	Between other tissues and organs	Connection
	Superficial fascia	Connection
Adipose (fat)	Under skin	Protection
	Padding at various points	Insulation Support Reserve food
Reticular	Inner framework of spleen, lymph nodes, bone marrow	Support
	Filtration	

are what distinguish members of the group from each other. Bone is considered a separate category of connective tissue because it has fibers and a hard mineral ground substance. Cartilage is yet another category because, besides fibers, it has a specialized ground substance that traps water to form a firm gel. Blood, the last category listed, is characterized by the lack of fibers in its matrix. These major types of connective tissues are described further in the following pages and in Table 5-3.

FIBROUS CONNECTIVE TISSUE

Loose Connective Tissue (Areolar)

Loose connective tissue, shown in Figure 5-13, is often called *loose, ordinary connective tissue,* or *areolar tissue.* It is loose because it is stretchable, and ordinary because it is one of the most widely distributed of all tissues. It is common and ordinary, not special like some kinds of connective tissue (e.g., bone and cartilage) that help form comparatively few struc-

Table 5-3 Tissues—cont'd

Tissue	Location	Function
Dense fibrous		
Regular	Tendons	Flexible but strong connection
	Ligaments	
	Aponeuroses	
Irregular	Deep fascia	Connection
	Dermis	Support
	Scars	
	Capsule of kidney, etc.	
Bone	Skeleton	Support
		Protection
		Calcium reservoir
Cartilage		
Hyaline	Part of nasal septum	
	Covering articular surfaces of bones	
	Larynx	
	Rings in trachea and bronchi	Firm but flexible support
Fibrocartilage	Disks between vertebrae	
	Symphysis pubis	
Elastic	External ear	
	Eustachian tube	
Blood	In the blood vessels	Transportation
		Protection
Muscle		
Skeletal (striated voluntary)	Muscles that attach to bones	Movement of bones
	Extrinsic eyeball muscles	Eye movements
	Upper third of esophagus	First part of swallowing
Smooth (nonstriated, involuntary, or visceral)	In walls of tubular viscera of digestive, respiratory, and genitourinary tracts	Movement of substances along respective tracts
	In walls of blood vessels and large lymphatic vessels	Change diameter of blood vessels, thereby aiding in regulation of blood pressure
	In ducts of glands	Movement of substances along ducts
	Intrinsic eye muscles (iris and ciliary body)	Change diameter of pupils and shape of lens
	Arrector muscles of hairs	Erection of hairs (gooseflesh)
Cardiac (striated involuntary)	Wall of heart	Contraction of heart
Nervous		
	Brain	Excitability
	Spinal cord	Conduction
	Nerves	

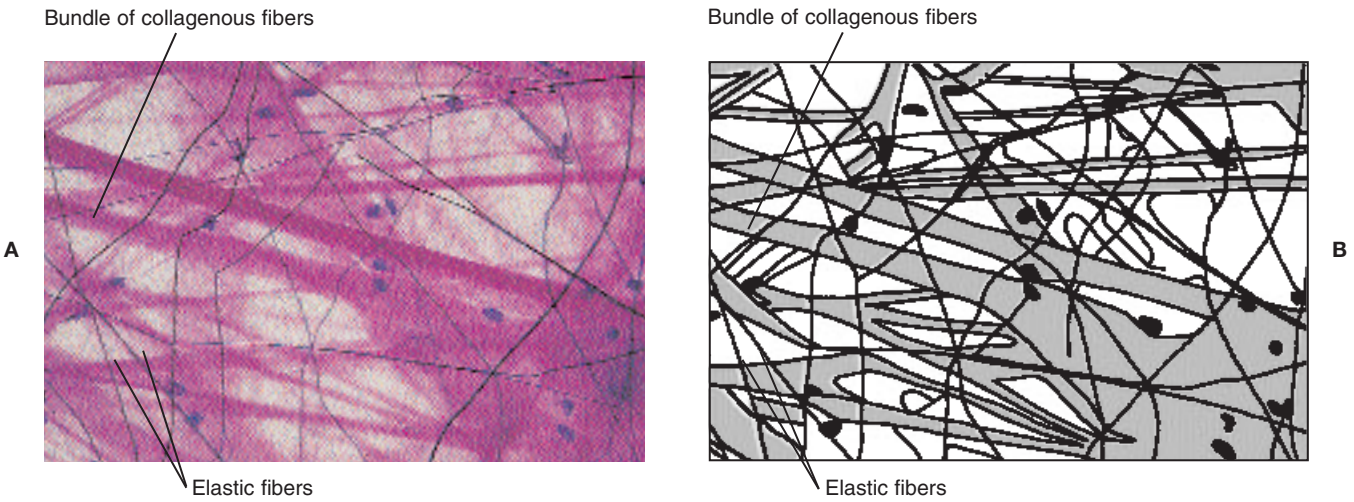


Figure 5-13 **Loose, ordinary (areolar) connective tissue.** **A,** Photomicrograph. Notice how the H&E staining (see Figure 5-2) renders the bundles of collagen fibers a pinkish color and the elastin fibers and cell nuclei a purplish color. **B,** Sketch of photomicrograph. Note the loose arrangement of fibers compared with fibers in Figures 5-17 and 5-19.

tures. *Areolar* was the early name for the loose, ordinary connective tissue that connects many adjacent structures of the body. It acts like a glue spread between them—but an elastic glue that permits movement. The word **areolar** means "like a small space" and refers to the bubbles that appear as areolar tissue is pulled apart during dissection.

The matrix of areolar tissue is a soft, thick gel mainly because it contains hyaluronic acid. An enzyme, hyaluronidase, can change the matrix from its thick gel state to a watery consistency. Physicians have made use of this knowledge for many years. They frequently inject a commercial preparation of hyaluronidase with drugs or fluids. By decreasing the viscosity (thickness) of intercellular material, the enzyme hastens diffusion and absorption of the injected material and lessens tissue tension and pain. Some bacteria, notably *pneumococci* and *streptococci,* spread through connective tissues by secreting hyaluronidase.

The matrix of areolar tissue contains numerous fibers and cells, typically many interwoven collagenous and elastic fibers and about a half dozen kinds of cells. **Fibroblasts** usually are present in the greatest numbers in areolar tissue, and **macrophages** are second. Fibroblasts synthesize the gel-like ground substance and the fibers present in it. Macrophages (also known by several other names, for example, *histiocytes* and *resting wandering cells*) carry on phagocytosis and so are classified as phagocytes. Phagocytosis is part of the body's vital complex of defense mechanisms. Other kinds of cells found in loose, ordinary connective tissue are mast cells, some wandering white blood cells (leukocytes), an occasional fat cell, and some plasma cells. Macrophages and mast cells are derived from white blood cells.

Adipose Tissue. **Adipose tissue** differs from loose, ordinary connective tissue mainly in that it contains predominantly fat cells and many fewer fibroblasts, macrophages, and mast cells (Figure 5-14). Adipose tissue forms supporting, protective pads around the kidneys and various other structures. It also serves two other functions: it constitutes a storage depot for excess food, and it acts as an insulating material to conserve body heat. Figure 5-15 shows the location of the main fat storage areas.

Reticular Tissue. A three-dimensional web, that is, a reticular network, identifies **reticular tissue** (Figure 5-16). Slender, branching reticular fibers with reticular cells overlying them compose the reticular meshwork. Branches of the cytoplasm of reticular cells follow the branching reticular fibers.

Reticular tissue forms the framework of the spleen, lymph nodes, and bone marrow. It functions as part of the body's complex mechanism for defending itself against microorganisms and injurious substances. The reticular meshwork filters injurious substances out of the blood and lymph, and the reticular cells phagocytose (engulf and destroy) them. Another function of reticular cells is to make reticular fibers.

Dense Fibrous Tissue. **Dense fibrous tissue** consists mainly of fibers packed densely in the matrix. It contains relatively few fibroblast cells. Some dense fibrous tissues are designated as *regular* and others are designated as *irregular,* depending on the arrangement of fibers. In dense fibrous (regular) tissues, the bundles of fibers are arranged in regular, parallel rows (Figure 5-17). A structure composed of dense fibrous (regular) tissue is predominantly bundles of collagenous fibers and is flexible but possesses great tensile strength. These characteristics are desirable in structures that anchor muscle to bone, such as tendons (Figure 5-18). Ligaments (which connect bone to bone) instead have a predominance of elastic fibers. Hence ligaments exhibit some degree of elasticity. In dense fibrous (irregular) tissues, the

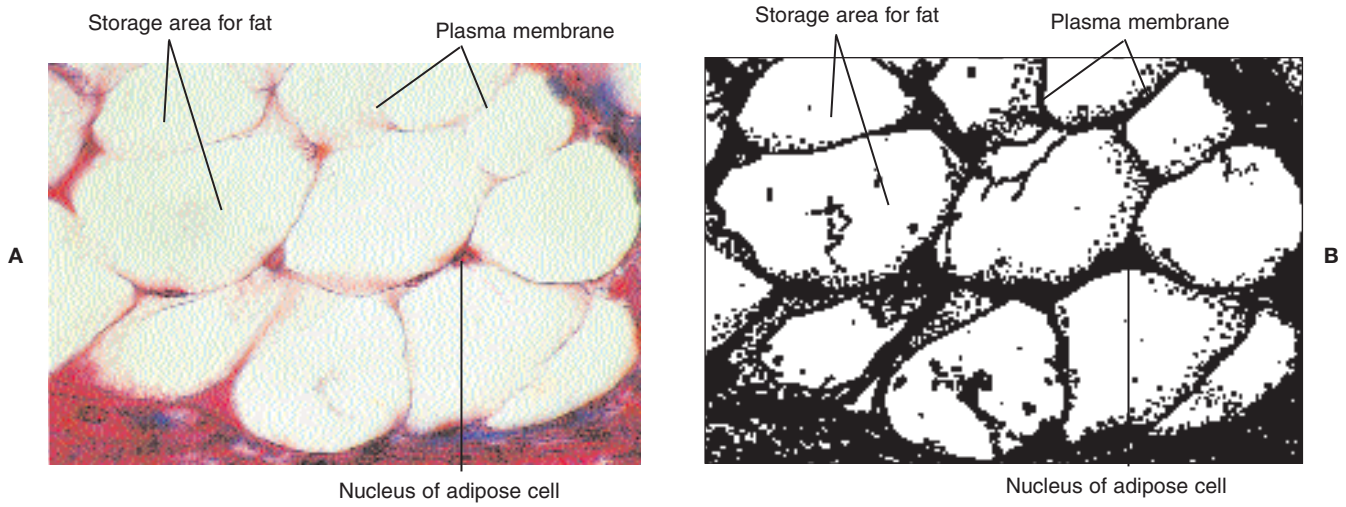


Figure 5-14 **Adipose tissue.** **A**, Photomicrograph. **B**, Sketch of photomicrograph. Note the large storage spaces for fat inside the adipose tissue cells.

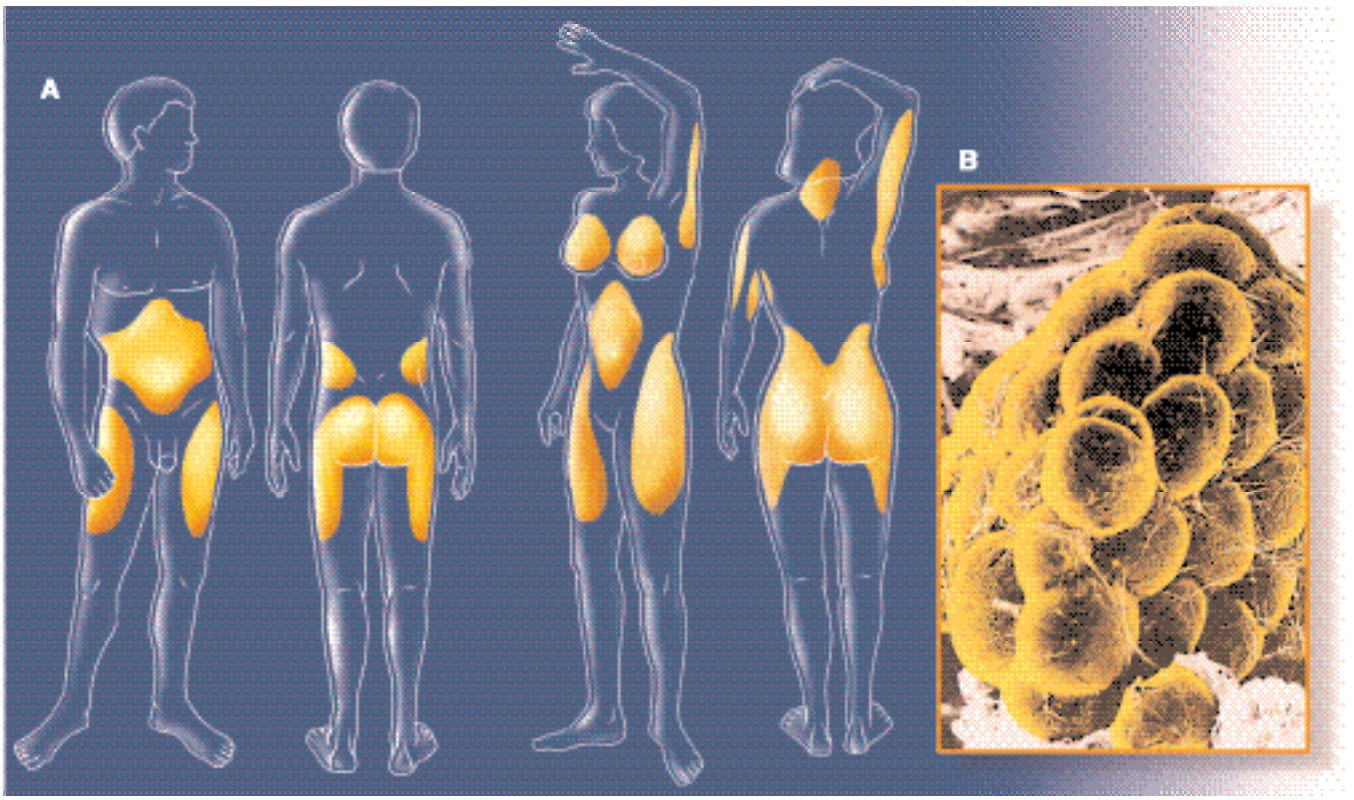


Figure 5-15 **Fat storage areas.** **A**, The different distribution of fat in male and female bodies. **B**, Electron micrograph of a cluster of adipose cells held together by a network of fine reticular fibers (× 150).

bundles of fibers are not arranged in parallel rows (Figure 5-19). Instead, the fibers intertwine to form a thick mat of strong connective tissue that can withstand stresses applied from any direction. Dense fibrous (irregular) tissue forms the strong inner skin layer called the *dermis*. It also forms the outer capsule of such organs as the kidney and the spleen.

Bone Tissue

Bone, or *osseous tissue,* is one of the most highly specialized forms of connective tissue. The mature cells of bone, osteocytes, are embedded in a unique matrix material containing both organic collagen material and mineral salts. The inorganic (bone salt) portion makes up about 65% of the

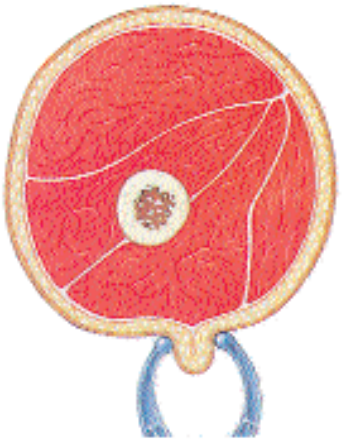
Box 5-2 SPORTS AND FITNESS

Tissues and Fitness

Achieving and maintaining an ideal body weight is a health-conscious goal. However, a better indicator of health and fitness is **body composition.** Exercise physiologists assess body composition to identify the percentage of the body made of lean tissue and the percentage made of fat. Body fat percentage often is determined by using calipers to measure the thickness of skin folds at certain locations on the body (see figures). The thickness measurements, which reflect the volume of adipose tissues under the skin, are then used to estimate the percentage of fat in the entire body. A much more accurate method is to weigh a subject totally immersed in a tank of water. Fat has a very low density and thus increases the buoyancy of the body. Thus the lower a person's weight is while immersed, the higher the body fat percentage.

A person with low body weight may still have a high ratio of fat to muscle, an unhealthy condition. In this case the individual is "underweight" but "overfat." In other words, fitness depends more on the percentage and ratio of specific tissue types than the overall amount of tissue present. Therefore one goal of a good fitness program is a desirable body fat percentage. For men, the ideal is 15% to 18%, and for women, the ideal is 20% to 22%.

Because fat contains stored energy (measured in calories), a low fat percentage means a low energy reserve. High body fat percentages are associated with several life-threatening conditions, including cardiovascular disease. A balanced diet and an exercise program ensure that the ratio of fat to muscle tissue stays at a level appropriate for maintaining homeostasis.



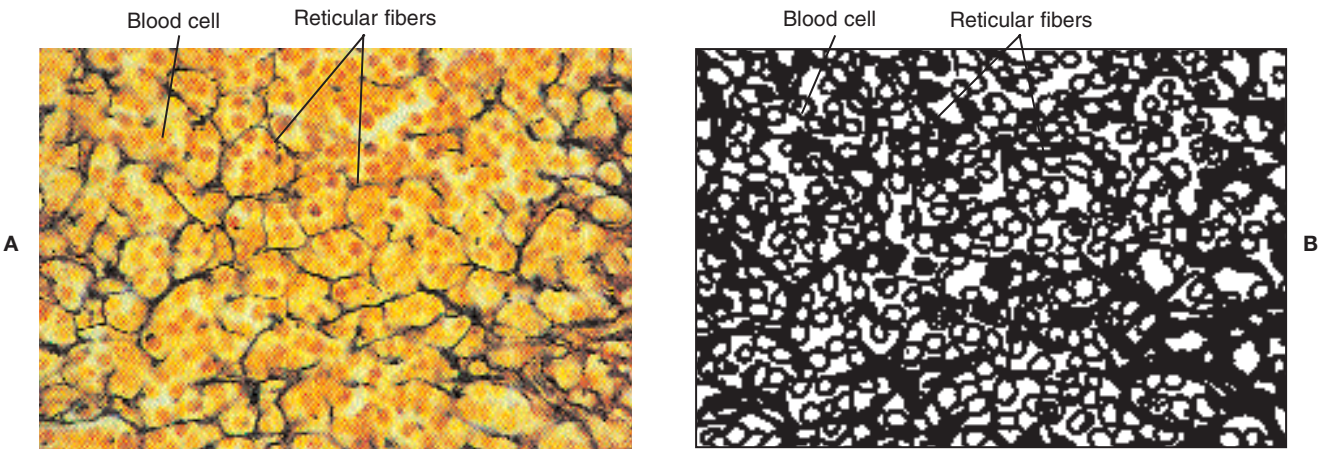


Figure 5-16 **Reticular connective tissue.** **A**, The supporting framework of reticular fibers are stained black in this section of spleen tissue. **B**, Sketch of photomicrograph.

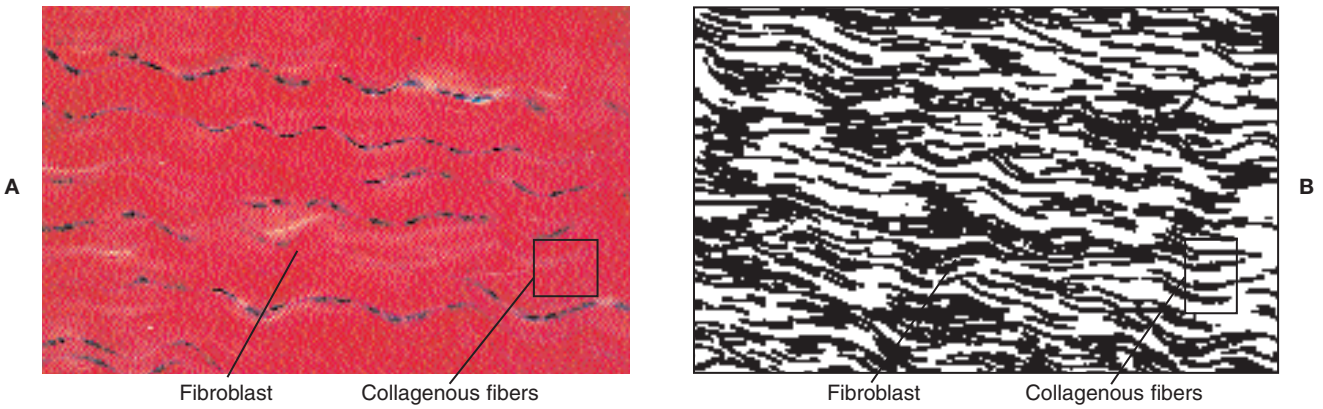


Figure 5-17 **Dense fibrous (regular) connective tissue.** **A**, Photomicrograph of tissue in a tendon. **B**, Sketch of photomicrograph. Note the multiple (regular) bundles of collagenous fibers arranged in parallel rows.

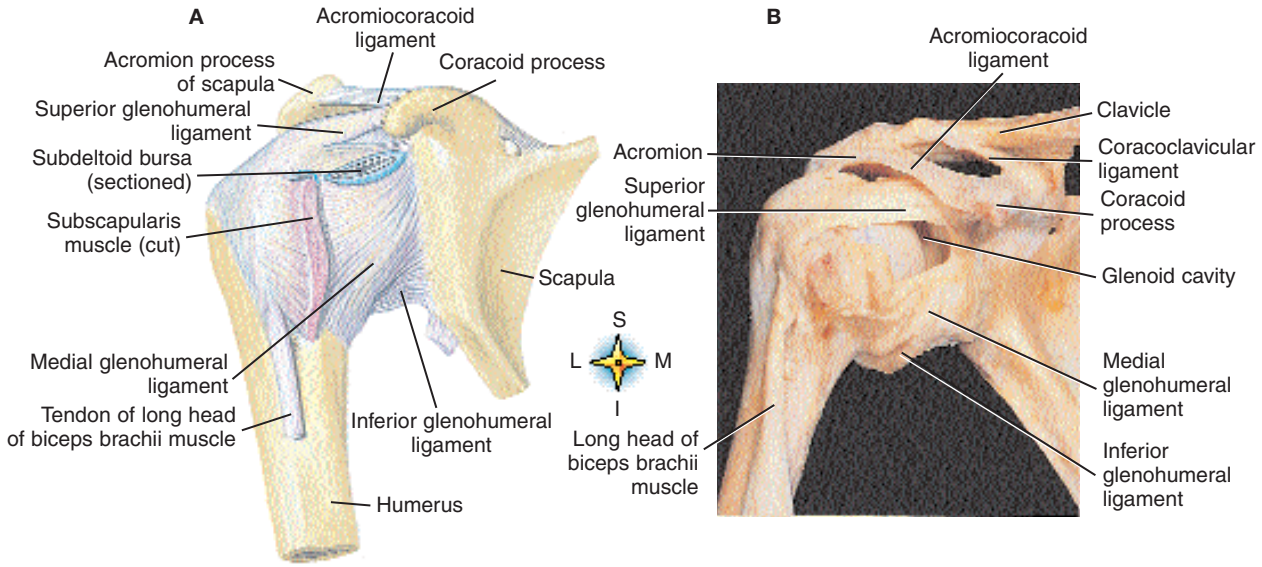


Figure 5-18 **Tendons and ligaments.** **A**, Tendons and ligaments of the shoulder are examples of dense fibrous connective tissue. **B**, Photo of cadaver dissection. Note the many strong connections needed to keep this important joint functioning properly.

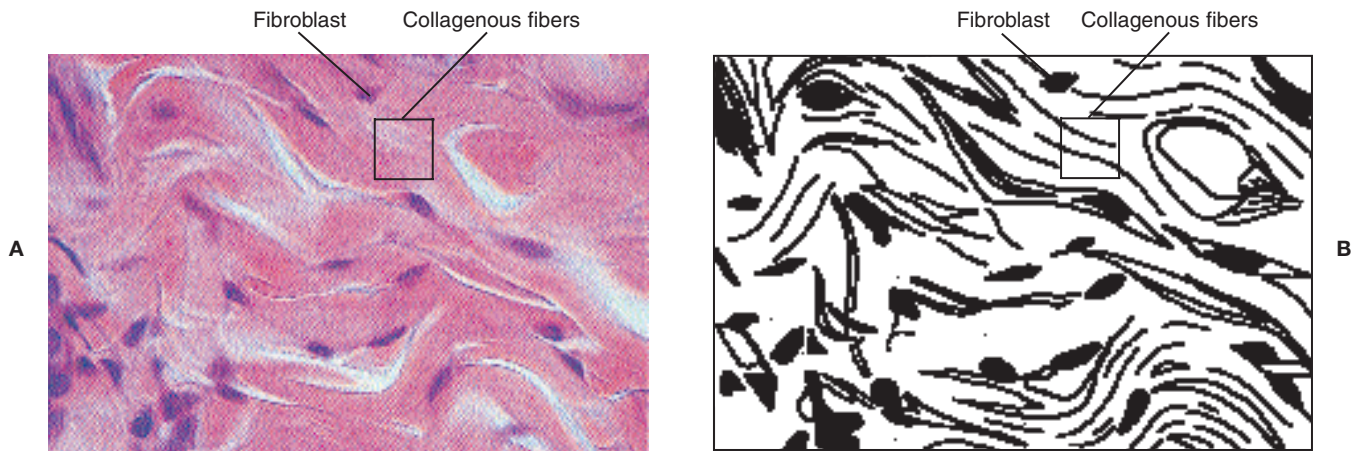


Figure 5-19 **Dense fibrous (irregular) connective tissue.** **A**, Section of skin (dermis) showing arrangements of collagenous fibers (pink) and purple-staining fibroblast cell nuclei. **B**, Sketch of photomicrograph.

total matrix material and is responsible for the hardness of bone.

Bones are the organs of the skeletal system. They provide support and protection for the body and serve as points of attachment for muscles. In addition, the calcified matrix of bones serves as a mineral reservoir for the body.

The basic organizational or structural unit of bone is the microscopic **osteon** or *Haversian system* (Figure 5-20). Osteocytes, or bone cells, are located in small spaces, or **lacunae,** which are arranged in concentric layers of bone matrix called **lamellae.** Small canals called **canaliculi** connect each lacuna and osteocyte with nutrient blood vessels found in the central Haversian canal.

Mature osteocytes actually are trapped in hard bone matrix. At one time they were active, bone-forming cells called **osteoblasts.** However, as they surround themselves with bone, they become trapped and cease making new bone matrix. Another type of bone cell, the **osteoclast,** or bone-destroying cell, may dissolve the bone away from the mature osteocyte and release it to again become an active osteoblast. Mature bone can thus grow and be reshaped by the simultaneous activity of osteoclasts breaking down and remove existing bone tissue as the osteoblasts lay down new bone.

Certain bones called **membrane bones** (e.g., flat bones of the skull) are formed within membranous tissue, whereas others (e.g., long bones such as the humerus) are formed indirectly through replacement of cartilage in a process called **endochondral ossification.** The details of bone formation are presented in Chapter 7.

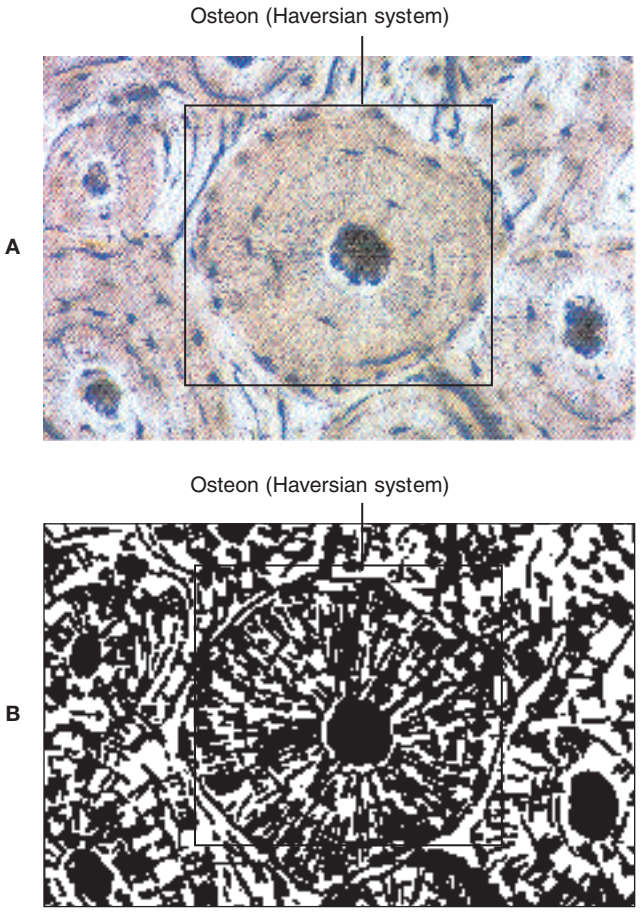


Figure 5-20 Bone tissue. *A,* Photomicrograph of dried, ground bone. **B,** Sketch of photomicrograph. Many wheel-like structural units of bone, known as *osteons* or *Haversian systems,* are apparent in this section.

Cartilage

Cartilage differs from other connective tissues in that only one cell type, the **chondrocyte,** is present. Chondrocytes produce the fibers and the tough, gristlelike ground substance of cartilage. Chondrocytes, like bone cells, are found in small openings called *lacunae*. Cartilage is avascular (lacking blood vessels), so nutrients must reach the cells by diffusion. Movement is through the matrix from blood vessels located in a specialized connective tissue membrane, called the **perichondrium,** which surrounds the cartilage mass. Injuries to cartilage heal slowly, if at all, because of this inefficient method of nutrient delivery.

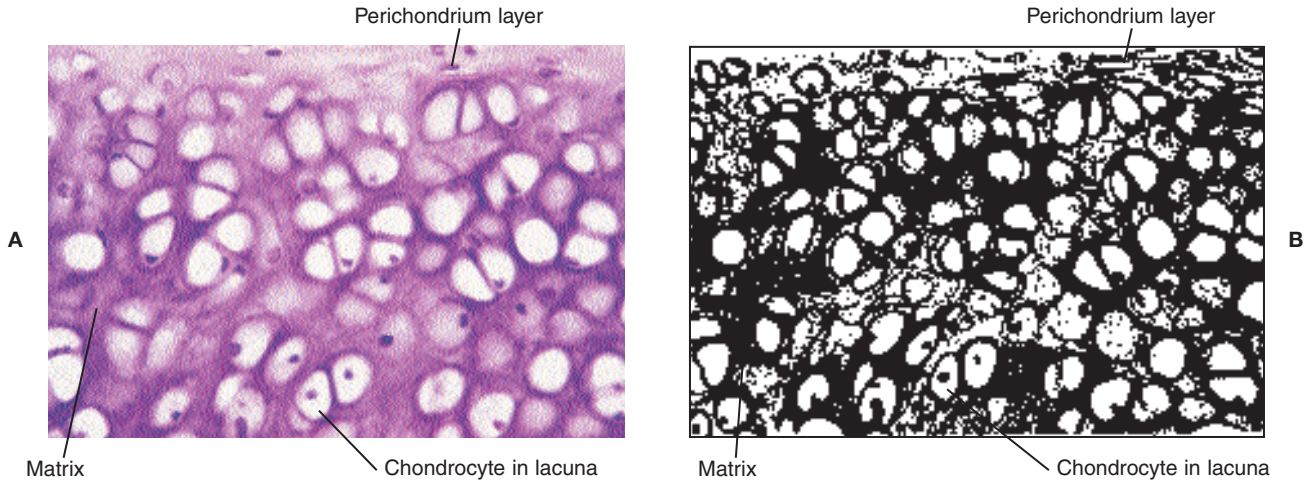


Figure 5-21 Hyaline cartilage. *A,* Photomicrograph of trachea. Note the many spaces, or lacunae, in the gel-like matrix. **B,** Sketch of photomicrograph.

Hyaline cartilage takes its name from the Greek word *hyalos* or "glass." The name is appropriate because the low amount of collagen in the matrix gives hyaline cartilage a shiny and translucent appearance. This is the most prevalent type of cartilage and is found in the support rings of the respiratory tubes and covering the ends of bones that articulate at joints (Figure 5-21).

Fibrocartilage is the strongest and most durable type of cartilage (Figure 5-22). The matrix is rigid and is filled with a dense packing of strong white collagen fibers. Fibrocartilage disks serve as shock absorbers between adjacent vertebrae (intervertebral disks) and in the knee joint. Damage to the fibrocartilage pads or joint menisci (curved pads) in the knee occurs frequently as a result of sport-related injuries.

Elastic cartilage contains few collagen fibers but large numbers of very fine elastic fibers that give the matrix material a high degree of flexibility (Figure 5-23). This type of cartilage is found in the external ear and in the voice box, or larynx.

Blood

Blood is perhaps the most unusual connective tissue, because it exists in a liquid state and contains neither ground substance nor fibers (Figure 5-24).

Whole blood is often divided into a matrix, or **liquid fraction,** called **plasma** and **formed elements** or blood cells. Blood cells may be divided into three classes: red blood cells, or **erythrocytes;** white blood cells, or **leukocytes;** and **thrombocytes,** or platelets. The liquid fraction makes up about 55% of whole blood, and the formed elements compose about 45%.

Blood performs many body transport functions, including movement of respiratory gases (oxygen and carbon dioxide), nutrients, and waste products. In addition, blood plays a critical role in maintaining a constant body temperature and in regulating the pH of body fluids. The white blood cells function in destroying harmful microorganisms.

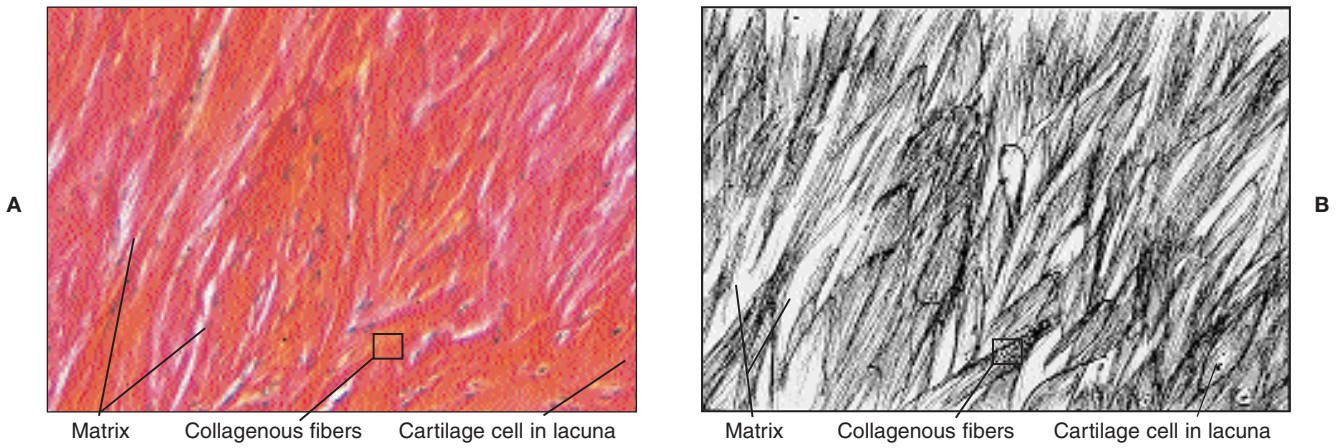


Figure 5-22 **Fibrocartilage.** **A**, Photomicrograph of pubic symphysis joint. The strong dense fibers that fill the matrix convey shock-absorbing qualities. **B**, Sketch of photomicrograph.

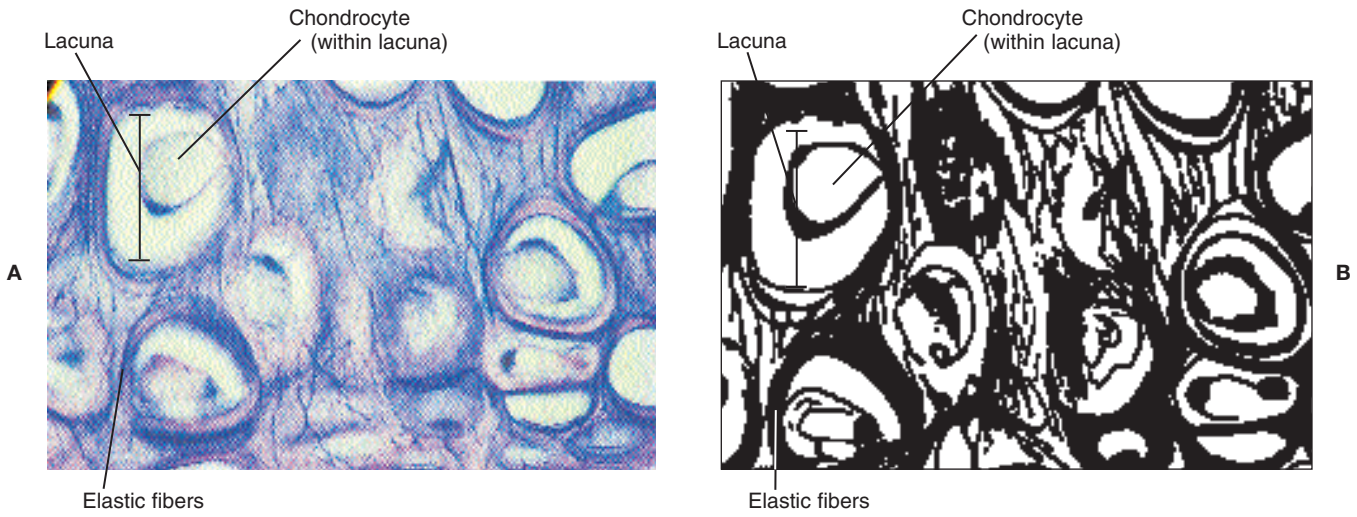


Figure 5-23 **Elastic cartilage.** **A**, Note the cartilage cells in the lacunae surrounded by matrix and dark-staining elastic fibers. **B**, Sketch of photomicrograph.

Box 5-3

Inflammation

The terms ***inflammation*** or **inflammatory response** are used to describe the complex way in which cells and tissues react to injury. Many of the events, which are now identified as steps in the inflammatory response, are so dramatic that for centuries they were often thought to be a primary disease. It was in the first century AD that the Roman physician Celsus first established inflammation as an entity by describing its four cardinal signs: **rubor** (redness), **calor** (heat), **tumor** (swelling), and **dolor** (pain). His accurate and detailed description of the visible signs that signal the body's response to injury is considered a classic in the annals of medicine.

The inflammatory response can best be described as a series of sequenced events that occur as a result of an inflammatory stimulus or "insult." Heat, physical pressure, caustic chemicals, toxins released by harmful bacteria, or any other type of noxious stimulus initiate an inflammatory response. Early studies with rabbits, using a device known as a **transparent ear chamber**, permitted scientists to view for prolonged periods changes in living tissue after an injury. Skin over an animal's external ear was subjected to very slight injury and then viewed through the chamber under a microscope.

Immediately after an injury occurs, there is a very brief constriction of surrounding blood vessels that lasts but a moment. Then, almost immediately, blood vessels dilate, or open, and blood flow increases.

Injured tissues release a number of chemicals that affect blood vessels. These chemicals include **histamine**, **serotonin**, and a group of chemically related compounds called **kinins**. All of these substances result in vasodilation and an increase in the permeability of blood vessels so that components that would normally be retained in the blood are permitted to leak out into the tissue spaces.

In the absence of injury, blood flow through a small vessel is such that the cells tend to pass in large measure within the central two thirds of the lumen with a thin layer of plasma flowing closest to the outer walls. This is called **axial flow**. After an injury, blood cells no longer pass in a central stream. Microscopic examination of vessels near an injured site shows that white cells begin to accumulate in the vessel near the point of injury and then stick, or **marginate**, to the wall. This **margination of leukocytes** continues until the endothelial surface of the vessel is covered with adherent white cells. Within minutes these cells begin to pass through the endothelial lining and out of the vessels into the interstitial spaces near the injury. One of the important functions of many white blood cells is **phagocytosis**—the process of engulfing and destroying bacteria. Movement of white cells into the area of injury or infection is called **diapedesis**. The term **chemotaxis** describes the attraction of leukocytes, especially neutrophils, into the interstitial spaces. The attractive force is produced by the release of kinins and other chemicals by injured tissue. **Leukocytosis** means an increase in the number of leukocytes in the blood. A substance called **leukocytosis-promoting (LP) factor** is also released by injured tissue. It stimulates the release of white cells from storage areas and increases the number of circulating white blood cells.

The accumulation of dead leukocytes and tissue debris may lead to the formation of **pus** at the focal point of infection. Should this occur, an **abscess**, or cavity, formed by the disintegration of tissues, may fill with pus and require surgical drainage.

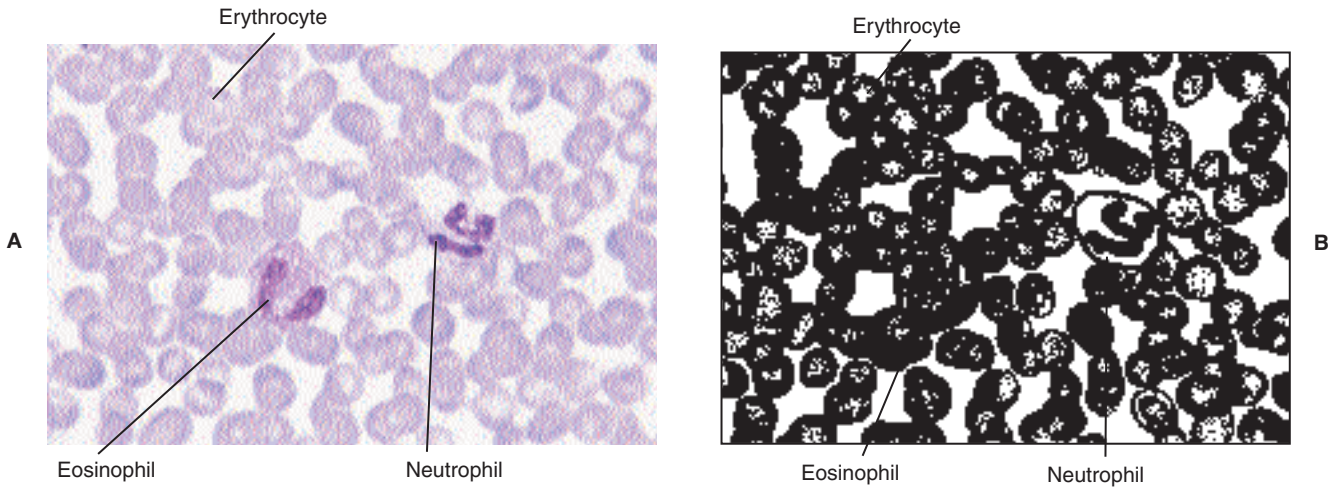


Figure 5-24 **Blood. A**, Photomicrograph of human blood smear shows two white blood cells, or leukocytes, surrounded by numerous smaller red blood cells. **B**, Sketch of photomicrograph.

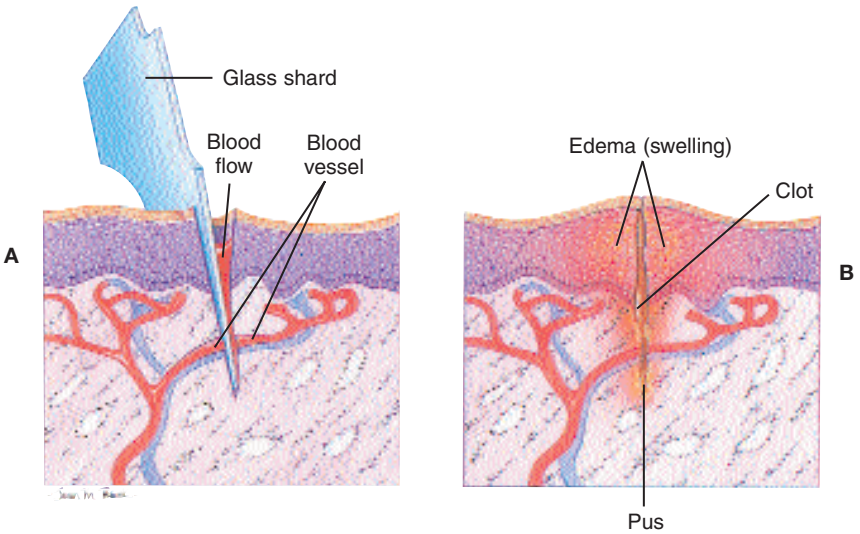
Box 5-3

Inflammation—cont'd

Increased permeability of blood vessels, increased blood flow, and the migration and accumulation of white blood cells all contribute to the formation of **inflammatory exudate**, which accumulates in the interstitial spaces in the area of injury. The result is often swelling, or **edema**, and pain. In addition to white blood cells and tissue debris, inflammatory exudate contains the "leaked" substances normally retained in the blood but allowed to escape into the interstitial spaces because of increased capillary permeability. One such substance is a soluble protein that is soon converted into **fibrin** in the interstitial spaces. Fibrin formation results in development of a clot, which helps to seal off the infected area and decrease the spread of bacteria or other infectious material.

The cardinal signs of inflammation "make sense" when examined in the light of our understanding of the process.

- The redness (rubor) is also caused by increased blood flow and pooling of blood following injury.
- The heat (calor) is largely the result of increased blood flow to the area of injury.
- Swelling (tumor) results because of edema and accumulation of inflammatory exudate and clot formation in the affected tissue spaces.
- Pain (dolor) is caused by chemicals such as the kinins (especially **bradykinin**) and other chemical mediators that are released following tissue injury and cellular death.



Inflammation in a section of traumatized skin. **A**, Injury or insult to tissue resulting in dilation of blood vessels and increase in blood flow. **B**, Inflammatory response—the body attempts to seal off an area of insult to limit bacterial invasion.

Circulating blood tissue is formed in the *red marrow* of bones and in other tissues by a process of differentiation called *hematopoiesis*. This blood-forming tissue is sometimes given the status of a separate connective tissue type: **hematopoietic tissue.**

Blood and its formation are described in detail in Chapter 17.

Quick Check

1. Name three kinds of fibers that may be present in a connective tissue matrix. Of what are they made?
2. Name three types of fibrous connective tissue and briefly describe each.
3. What makes bone tissue hard?
4. What is unique about the matrix of blood tissue?

MUSCLE TISSUE

Three types of ***muscle tissue*** are present in the body—skeletal muscle, smooth muscle, and cardiac muscle. Their names suggest their locations. **Skeletal muscle tissue** (Figure 5-25) composes muscles attached to bones; these are the organs that we think of as our muscles. **Smooth muscle tissue,** also sometimes called *visceral muscle tissue* (Figure 5-26), is found in the walls of the viscera (hollow internal organs—e.g., the stomach, intestines, and blood vessels; Figure 5-27). **Cardiac muscle tissue** makes up the wall of the heart (Figure 5-28). Another name for skeletal muscle is *striated voluntary* muscle. The term *striated* refers to cross striations (stripes) visible in microscopic slides of the tissue. The term *voluntary* indicates that voluntary or

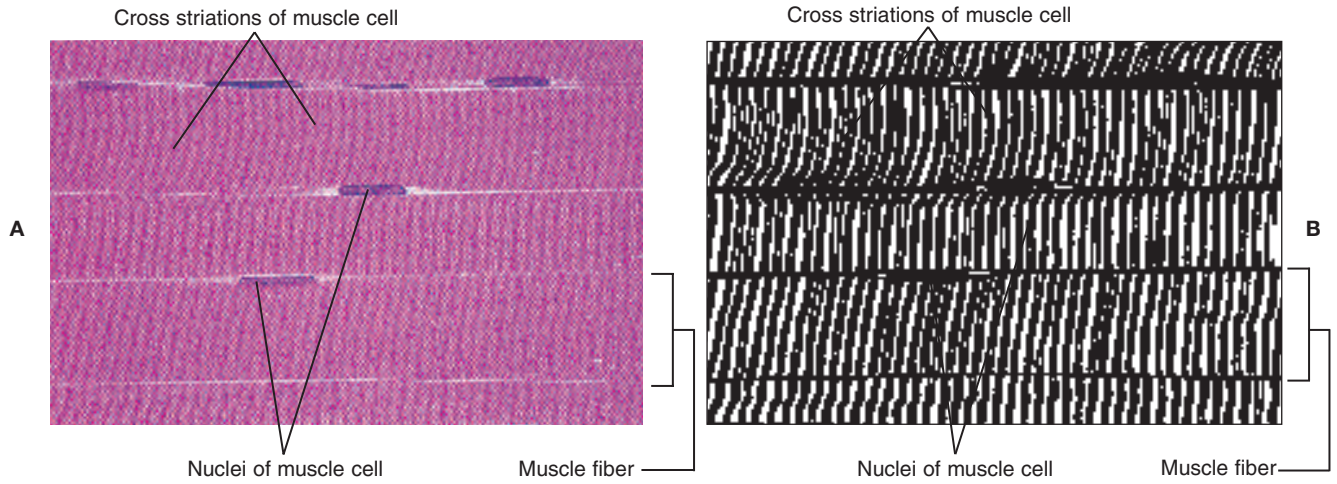


Figure 5-25 **Skeletal muscle.** **A**, Photomicrograph. **B**, Sketch of photomicrograph. Note the striations of the muscle cell fibers in longitudinal section.

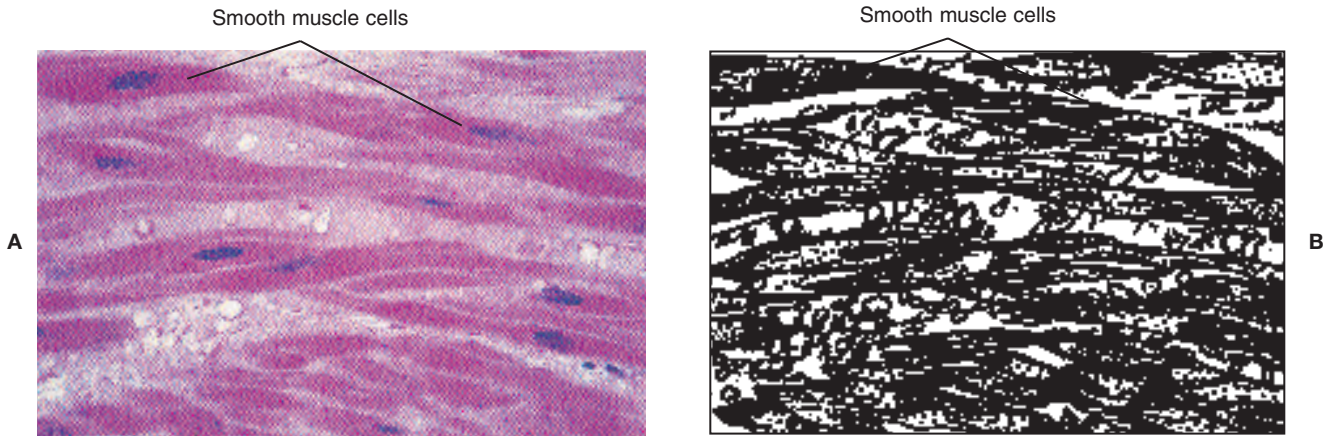


Figure 5-26 **Smooth muscle.** **A**, Photomicrograph, longitudinal section. **B**, Sketch of photomicrograph. Note the central placement of nuclei in the spindle-shaped smooth muscle fibers.

willed control of skeletal muscle contractions is possible. Another name for smooth muscle is *nonstriated involuntary.* Smooth muscle has no cross striations and cannot ordinarily be controlled by the will. Another name for cardiac muscle is *striated involuntary* muscle. Like skeletal muscle, cardiac muscle has cross striations, and, like smooth muscle, its contractions cannot ordinarily be controlled by will.

Look now at Figure 5-25 and observe the following structural characteristics of skeletal muscle cells: many cross striations, many nuclei per cell, and long, narrow, threadlike shape of the cells. Skeletal muscle cells may have a length of more than 3.75 cm, but they have diameters of only 10 to 100 μm. Because this gives them a threadlike appearance, muscle cells are often called muscle fibers. Chapter 11 gives more detailed information about the structure of skeletal muscle tissue.

Smooth muscle cells are also long, narrow fibers but not nearly as long as striated fibers. One can see the full length of a smooth muscle fiber in a microscopic field but only a small part of a striated fiber. According to one estimate, the longest smooth muscle fibers measure about 500 μm and the longest striated fibers about 40,000 μm. As Figure 5-26 shows, smooth muscle fibers have only one nucleus per fiber and are nonstriated or smooth in appearance.

Under the light microscope, cardiac muscle fibers (see Figure 5-28) have cross striations and unique dark bands (intercalated disks). They also seem to be incomplete cells that branch into each other to form a big continuous mass of cytoplasm (a syncytium). The electron microscope, however, reveals that the intercalated disks are actually places where the plasma membranes of two cardiac fibers abut. Cardiac fibers branch in and out, but a complete plasma membrane encloses each cardiac fiber—around its end (at intercalated disks) and its sides.

Muscle cells are the movement specialists of the body. Because their cytoskeletons include bundles of microfilaments specialized for movement, they have a higher degree of contractility (ability to shorten or contract) than cells of any other tissue.

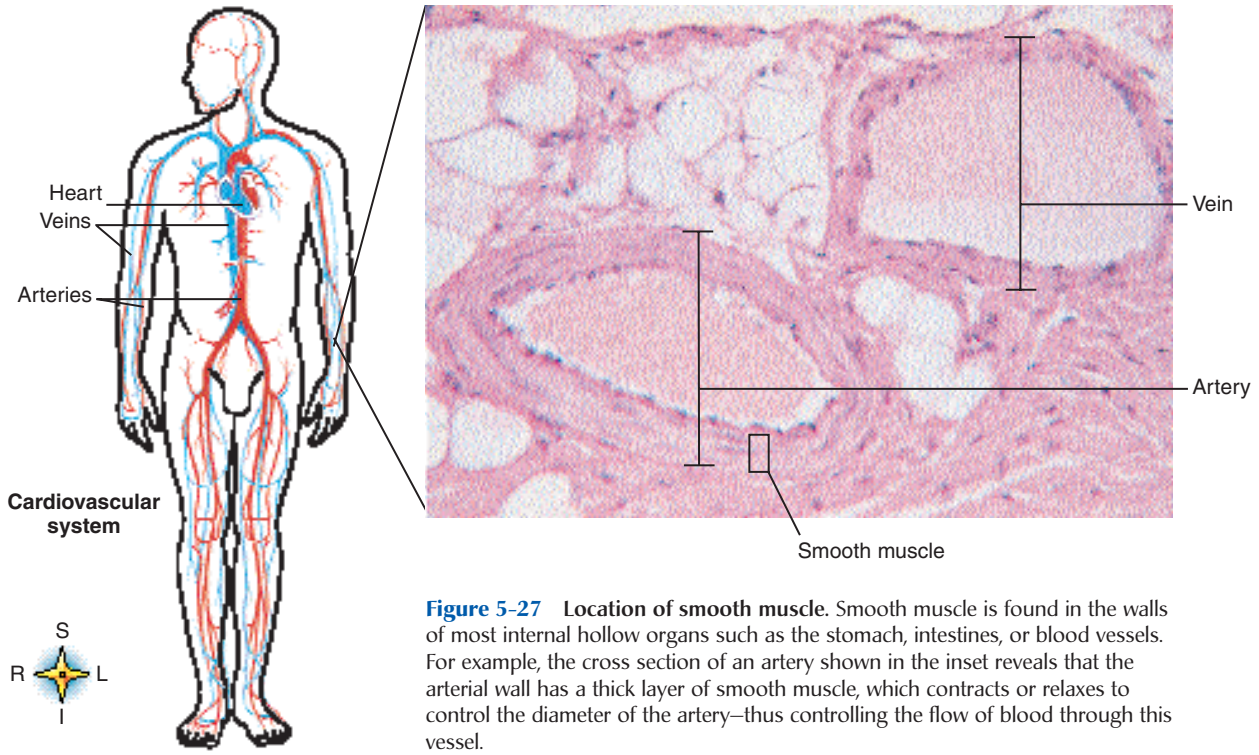


Figure 5-27 Location of smooth muscle. Smooth muscle is found in the walls of most internal hollow organs such as the stomach, intestines, or blood vessels. For example, the cross section of an artery shown in the inset reveals that the arterial wall has a thick layer of smooth muscle, which contracts or relaxes to control the diameter of the artery—thus controlling the flow of blood through this vessel.

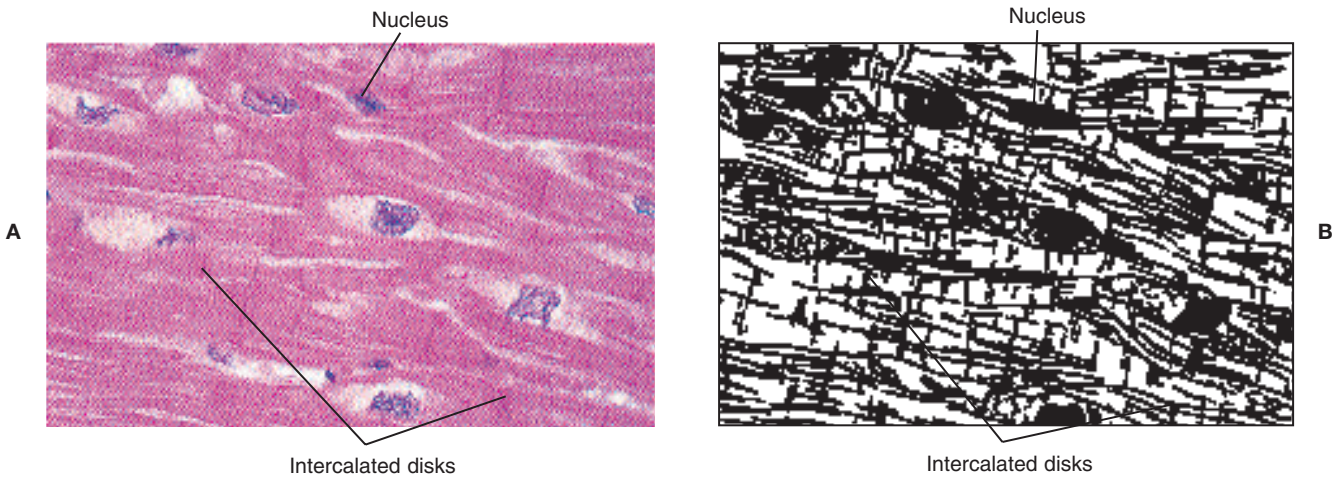


Figure 5-28 Cardiac muscle. A, Photomicrograph. **B**, Sketch of photomicrograph. The dark bands, called *intercalated disks,* which are characteristic of cardiac muscle, are easily identified in this tissue section.

NERVOUS TISSUE

The basic function of the nervous system is to rapidly regulate, and thereby integrate, the activities of the different parts of the body. Functionally, rapid communication is possible because ***nervous tissue*** has much more developed excitability and conductivity characteristics than any other type of tissue.

The organs of the nervous system are the brain, the spinal cord, and the nerves. Actual **nerve tissue** is ectodermal in origin and consists of two basic kinds of cells: nerve cells, or **neurons,** which are the conducting units of the system, and special connecting and supporting cells called **neuroglia** (Figure 5-29).

All neurons are characterized by a cell body called the soma and, generally, at least two processes: one **axon,** which transmits nerve impulses away from the cell body, and one or more **dendrites,** which carry nerve signals toward the axon. Most neurons are located within the organs of the central nervous system.

The anatomy and physiology of the nervous system are presented in Chapters 12 through 14.

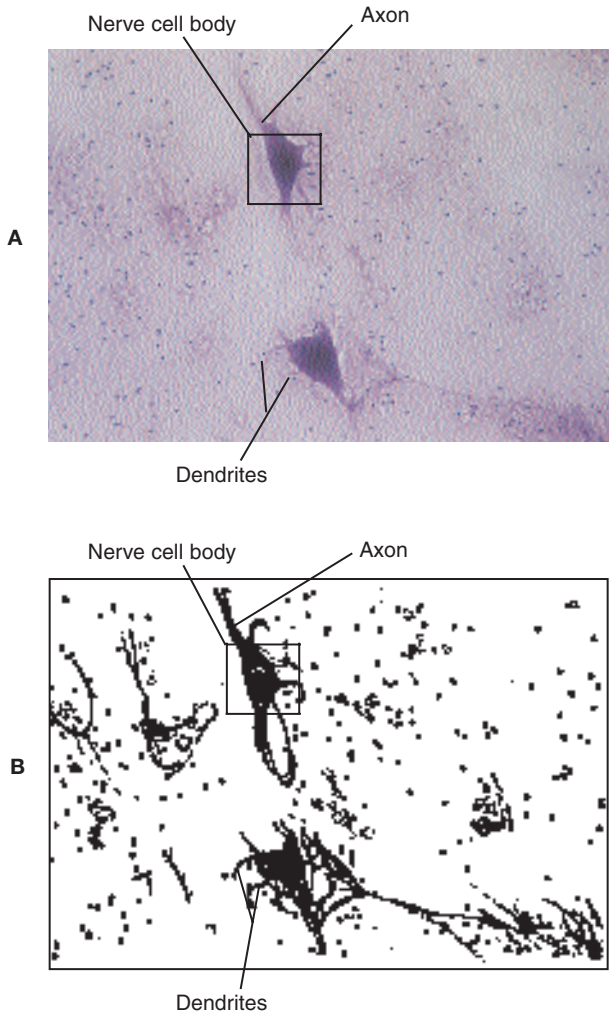


Figure 5-29 **Nervous tissue.** *A*, Photomicrograph. Multipolar neurons in smear of spinal cord. Both neurons in this slide show characteristic soma or cell bodies and multiple cell processes. **B**, Sketch of photomicrograph.

1. Name the two types of involuntary muscle. Where is each found in the body?
2. What are the two principal types of cell in nervous tissue? What is the function of each?

TISSUE REPAIR

When damaged by mechanical or other injuries, tissues have varying capacity to repair themselves. Damaged tissue regenerates or is replaced by tissue we know as scars. Tissues usually repair themselves by allowing the phagocytic cells to remove dead or injured cells, then filling in the gaps that are left. This growth of functional new tissue is called ***regeneration.***

Epithelial and connective tissues have the greatest capacity to regenerate (Figure 5-30). When a break in an epithelial membrane occurs, as in a cut, cells quickly divide to form daughter cells that fill the wound. In connective tissues, cells that form collagen fibers become active after an injury and fill in a gap with an unusually dense mass of fibrous connective tissue. If this dense mass of fibrous tissue is small, it may be replaced by normal tissue later. If the mass is deep or large, or if cell damage was extensive, it may remain as a dense fibrous mass, called a **scar.** An unusually thick scar that develops in the lower layer of the skin, such as that shown in Figure 5-31, is called a **keloid.**

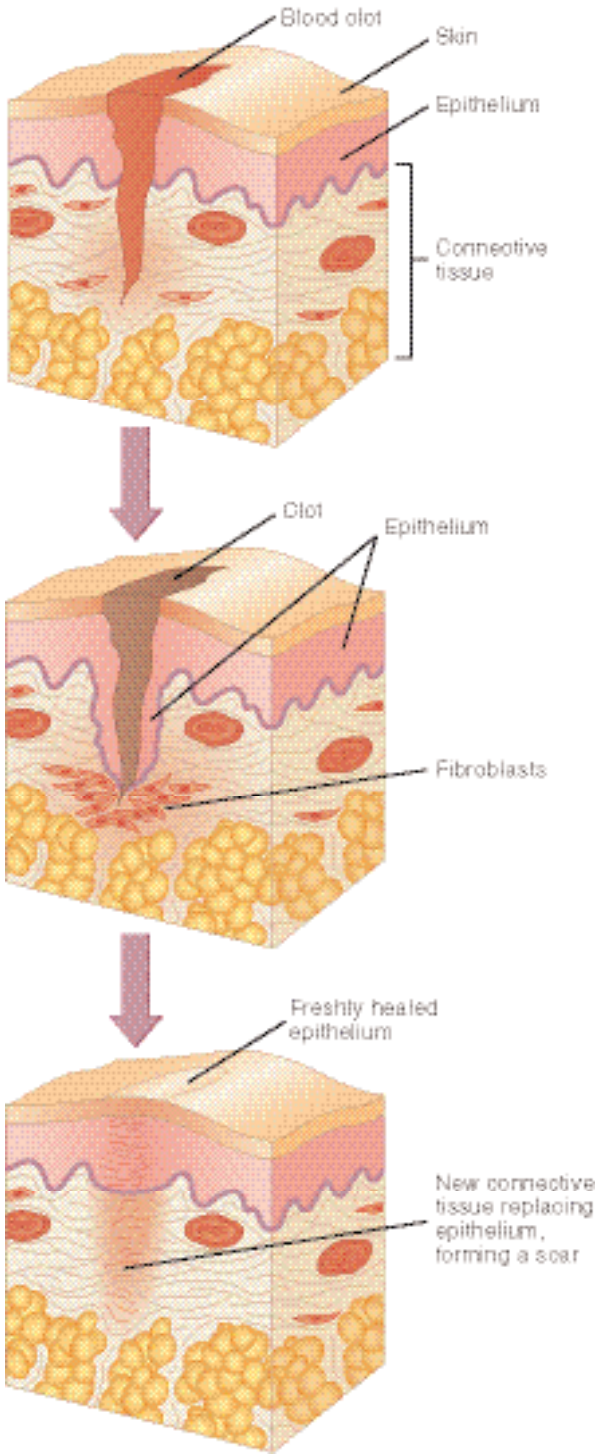


Figure 5-30 **Healing of a minor wound.** When a minor injury damages a layer of epithelium and the underlying connective tissue (as in a minor skin cut), the epithelial tissue and the connective tissue can self-repair.

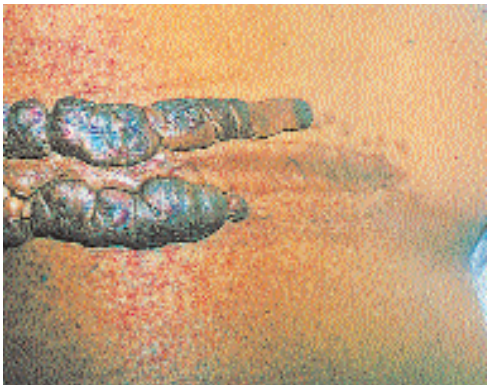


Figure 5-31 **Keloid**. Keloids are thick scars that form in the lower layer of the skin in predisposed individuals. This photograph shows keloids that formed at suture marks after surgery.

Muscle tissue, on the other hand, has a limited capacity to regenerate and thus heal itself. Damaged muscle is often replaced with fibrous connective tissue instead of muscle tissue. When this happens, the organ involved loses some or all of its ability to function.

Like muscle tissue, nerve tissue also has a limited capacity to regenerate. Neurons outside the brain and spinal cord can sometimes regenerate, but very slowly, and only if certain neuroglia are present to "pave the way." In the normal adult brain and spinal cord, neurons do not usually grow back when injured. Thus brain and spinal cord injuries nearly always result in permanent damage. Fortunately, the discovery of *nerve growth factors* produced by neuroglia offers the promise of treating brain damage by stimulating release of these factors.

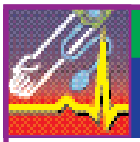
BODY MEMBRANES

The term **membrane** refers to a thin, sheetlike structure that may have many important functions in the body. Membranes cover and protect the body surface, line body cavities, and cover the inner surfaces of the hollow organs such as the digestive, reproductive, and respiratory passageways. Some membranes anchor organs to each other or to bones, and others cover the internal organs. In certain areas of the body, membranes secrete lubricating fluids that reduce friction during organ movements such as the beating of the heart or lung expansion and contraction. Membrane lubricants also decrease friction between bones and joints. Two major categories, or types, of body membranes exist (Figure 5-32):

1. **Epithelial membranes,** composed of epithelial tissue and an underlying layer of specialized connective tissue
2. **Connective tissue membranes,** composed exclusively of various types of connective tissue; no epithelial cells are present in this type of membrane

EPITHELIAL MEMBRANES

There are three types of epithelial tissue membranes in the body: (1) cutaneous membrane, (2) serous membranes, and (3) mucous membranes.



Box 5-4 HEALTH MATTERS

Inflammation of Serous Membranes

Pleurisy (PLOOR-i-see) (also called *pleuritis*) is a very painful pathological condition characterized by inflammation of the serous membranes (pleurae) that line the chest cavity and cover the lungs. Pain is caused by irritation and friction as the lungs rub against the walls of the chest cavity. In severe cases the inflamed surfaces of the pleura fuse, and permanent damage may develop. The term **peritonitis** (pair-i-toe-NYE-tis) is used to describe inflammation of the serous membranes in the abdominal cavity. Peritonitis is sometimes a serious complication of an infected appendix.

Cutaneous Membranes

The **cutaneous membrane** covers body surfaces that are exposed to the external environment. The cutaneous membrane, or **skin,** is the primary organ of the integumentary system. It is one of the most important and certainly one of the largest and most visible organs of the body. In most individuals the skin composes approximately 16% of the body weight. It fulfills the requirements necessary for an epithelial tissue membrane in that it has a superficial layer of epithelial cells and an underlying layer of supportive connective tissue. Its structure is uniquely suited to its many functions. The skin is discussed in depth in Chapter 6.

Serous Membranes

Serous membrane lines cavities that are not open to the external environment and covers many of the organs inside these cavities. Like all epithelial membranes, a serous membrane is composed of two distinct layers of tissue. One of the layers, the epithelial sheet, is a thin layer of simple squamous epithelium. The other layer, the connective tissue layer, forms a very thin sheet that holds and supports the epithelial cells.

The serous membrane that lines body cavities and covers the surfaces of organs in those cavities is in reality a single, continuous sheet covering two different surfaces. The *parietal membrane* is the portion that lines the wall of the cavity like wallpaper; the *visceral membrane* covers the surface of the viscera (organs within the cavity). Two important serous membranes are identified in Figure 5-32: the *pleura,* which surrounds a lung and lines the thoracic cavity, and the *peritoneum,* which covers the abdominal viscera and lines the abdominal cavity. Another example is the *pericardium,* which surrounds the heart.

Serous membranes secrete a thin, watery fluid that lubricates organs as they rub against one another and against the walls of cavities.

Mucous Membranes

Mucous membranes are epithelial membranes that line body surfaces opening directly to the exterior. Examples of mucous membranes include those lining the respiratory,

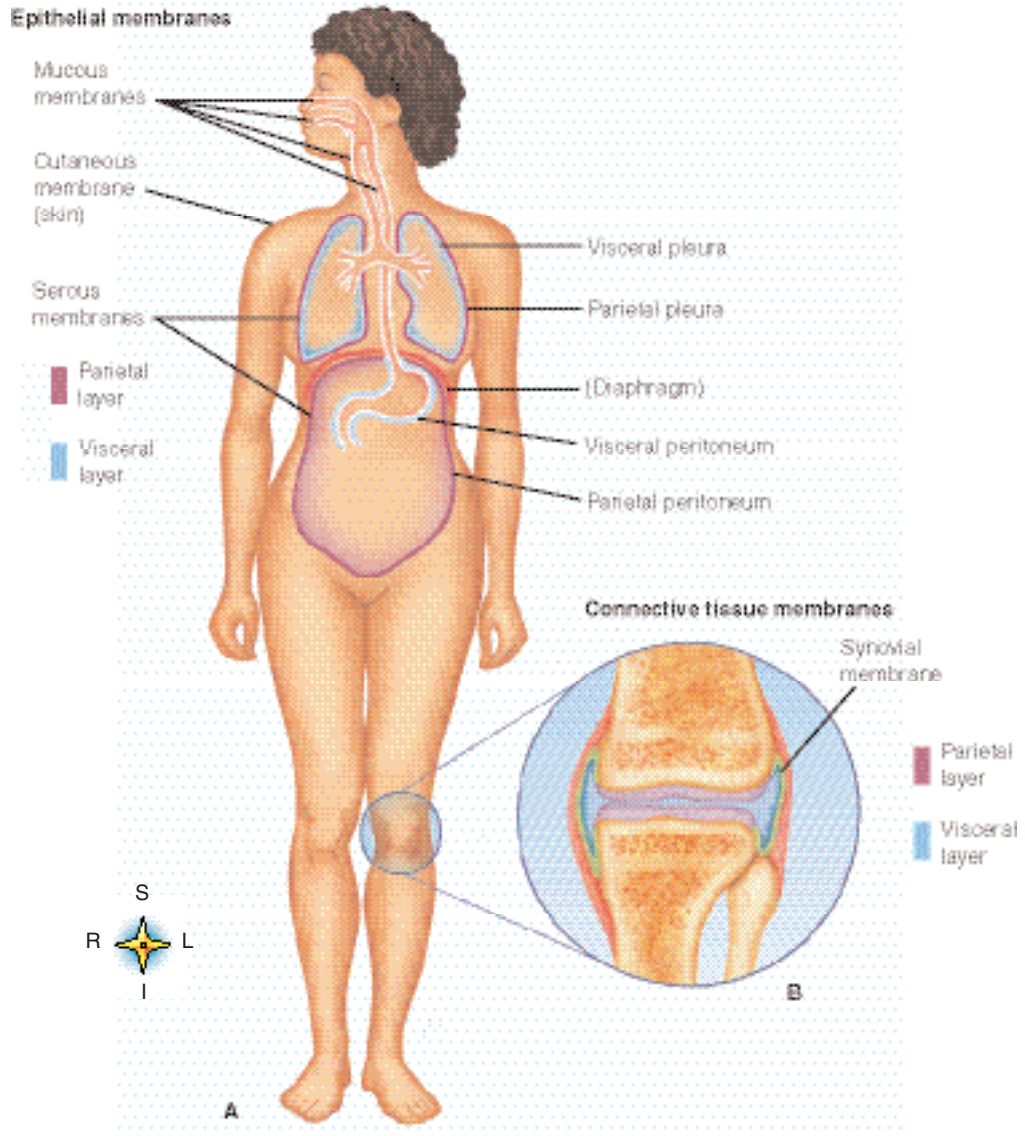


Figure 5-32 **Types of body membranes.** **A**, Epithelial membranes, including cutaneous membrane (skin), serous membranes (parietal and visceral pleura and peritoneum), and mucous membranes. **B**, Connective tissue membranes, including synovial membranes. See text for explanation.

digestive, urinary, and reproductive tracts. The epithelial component of the mucous membrane varies, depending on its location and function. In the esophagus, for example, a tough, abrasion-resistant stratified squamous epithelium is found. A thin layer of simple columnar epithelium covers the walls of the lower segments of the digestive tract.

Mucous membranes get their name from the fact that they produce a film of mucus that coats and protects the underlying cells. Besides protection, mucus also serves other purposes. For example, mucus acts as a lubricant for food as it moves along the digestive tract. In the respiratory tract, it serves as a sticky trap for contaminants.

CONNECTIVE TISSUE MEMBRANES

Unlike cutaneous, serous, and mucous membranes, connective tissue membranes do not contain epithelial components. The **synovial membranes** lining the spaces between bones and joints that move are classified as connective tissue membranes. These membranes are smooth and slick and secrete a thick and colorless lubricating fluid called **synovial fluid.** The membrane itself, with its specialized fluid, helps reduce friction between the opposing surfaces of bones in movable joints. Synovial membranes also line the small, cushionlike sacs called *bursae* found between some moving body parts.

1. Which two of the four major tissue types have the greatest capacity to regenerate after an injury?
2. Name the four principal types of body membranes. Which are epithelial membranes?

THE BIG PICTURE

Tissues, Membranes, and the Whole Body

Tissues and body membranes are sometimes called "the fabric of the body." Like the pieces of fabric in a garment, tissues and body membranes are portions of a larger integrated structure. Just as each type of fabric in a complex garment has a different functional role determined by its structural characteristics, so does each type of tissue within the body. One of the ultimate functional goals of most tissues and membranes is maintenance of relative constancy in the body: homeostasis.

How do the major tissue types help maintain homeostasis? Epithelial tissues promote constancy of the body's internal environment in several ways. They form membranes that contain and protect the internal fluid environment; they absorb nutrients and other substances needed to maintain an optimum concentration in the body; and they secrete various products that regulate body functions involved in homeostasis. Connective tissues hold organs and systems together to form a whole, connected body. They also form structures that support the body and permit movement, such as the components of the skeleton. Some connective tissues, such as blood, transport nutrients, wastes, and other substances within the internal environment. Some blood cells help protect the internal environment by participating in the body's immune system. Muscle tissues work in conjunction with connective tissues (bones, tendons, etc.) to permit movement (a function needed to avoid injury); communicate; and to find food, shelter, and other requirements. Nervous tissue works with glandular epithelial tissue to regulate various body functions in a way that maintains homeostatic balance.

Now that you have a basic knowledge of the various types of body "fabric"—the tissues and body membranes—you are ready to study the structure and function of specific organs and systems. As you take this next step in your studies, pay close attention to the tissue types that make up each organ. If you do, you will find it easier to understand the characteristics of a particular organ, and you will also improve your understanding of the integrated nature of the whole body.

MECHANISMS OF DISEASE

Tumors and Cancer

Neoplasms

The term **neoplasm** literally means "new matter" and refers to any abnormal growth of cells. Also called **tumors,** neoplasms can be distinct lumps of abnormal cells or, in blood tissue, can be diffuse. Neoplasms often are classified as **benign** or **malignant.** Benign tumors are called that because they do not spread to other tissues, and they usually grow very slowly. Their cells are often well differentiated, unlike the undifferentiated cells typical of malignant tumors. Cells in a benign tumor tend to stay together, and they often are surrounded by a capsule of dense tissue. Benign tumors are usually not life-threatening but can be if they disrupt the normal function of a vital organ. Malignant tumors, or **cancers,** on the other hand, are not encapsulated and tend to spread to other regions of the body. For example, cells from malignant breast tumors usually form new (secondary) tumors in bone, brain, and lung tissues. The cells migrate by way of lymphatic or blood vessels. This manner of spreading is called **metastasis.** Cells that do not metastasize can spread another way: they grow rapidly and extend the tumor into nearby tissues (Figure 5-33). Malignant tumors may replace part of a vital organ with abnormal, undifferentiated tissue—a life-threatening situation.

Neoplasms are classified further into subgroups, depending on the tissue in which they originate. Both benign and malignant tumors can be divided into three types: epithelial tumors, connective tissue tumors, and miscellaneous tumors. Benign tumor types that arise from epithelial tissues include *papilloma* (a fingerlike projection), *adenoma* (glandular tumor), and *nevus* (small, pigmented skin tumors). Benign tumor types that arise from connective tissues include *lipoma* (adipose tumor), *osteoma* (bone tumor), and *chondroma* (cartilage tumor). Malignant tumors that arise from epithelial tissues are generally called **carcinomas.** Examples include *melanoma* (cancer of skin pigment cells) and *adenocarcinoma* (glandular cancer). Malignant tumors that arise from connective tissues are generally called **sarcomas.** Examples include *lymphoma* (lymphatic cancer), *osteosarcoma* (bone cancer), and *fibrosarcoma* (cancer of fibrous connective tissue). Miscellaneous tumors are those that do not fit either of the previous categories. For example, an *adenofibroma* is a benign neoplasm formed by epithelial and connective tissues. Another example is *neuroblastoma,* a malignant tumor that arises from nerve tissue.

The etiologies (origins) of various forms of cancer puzzle medical science no less today than a hundred years ago. We do know that cancer involves uncontrolled cell division: **hyperplasia** (too many cells) and/or **anaplasia** (abnormal, undifferentiated cells). Thus the mechanism of all cancers is a mistake or problem in cell division. What we are uncertain of is the cause of the abnormal cell division. Currently, several factors are known to play a role:

Genetic factors. Many forms of cancer are known to be inherited directly, perhaps involving abnormal "cancer genes" called **oncogenes.** Another type of gene, called a **tumor suppressor gene,** may fail to operate, allowing cancer to develop. Exactly how these genes work is still being investigated. Presumably many cancers involve a

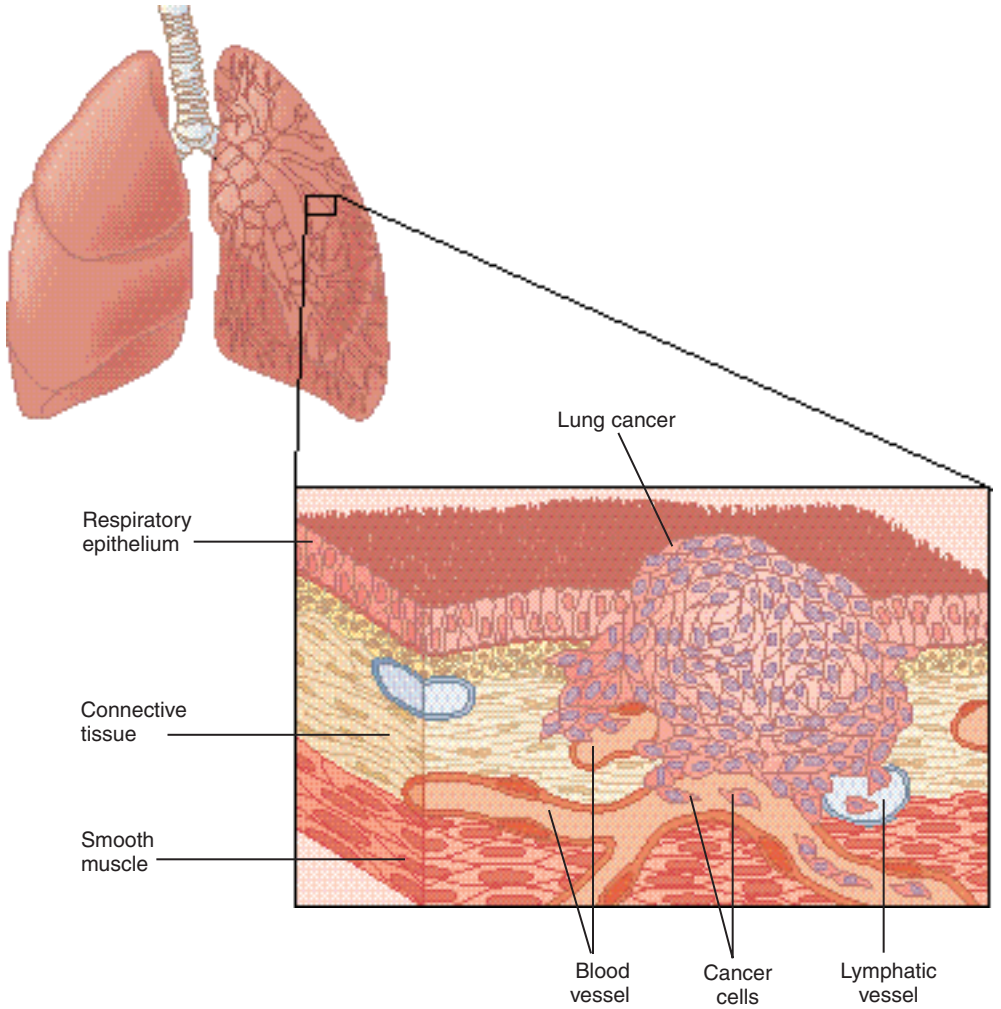


Figure 5-33 **Cancer.** This abnormal mass of proliferating cells in the lining of lung airways is a malignant tumor—lung cancer. Notice how some cancer cells are leaving the tumor and entering the blood and lymph vessels.

genetic predisposition (risk factor) coupled with other cancer-causing mechanisms. Cancers with known genetic risk factors include basal cell carcinoma (a type of skin cancer), breast cancer, and neuroblastoma (a cancer of nerve tissue).

Carcinogens. Carcinogens (cancer makers) are agents that affect genetic activity in some way, causing abnormal cell reproduction. Some carcinogens are **mutagens** (mutation makers) that cause changes or mutations in a cell's DNA structure. Although many industrial products are known to be carcinogens, various natural mineral, vegetable, and animal materials are also carcinogenic. Exposure to damaging types of radiation or other physical injuries can be carcinogenic. For example, sunburns or chronic exposure to sunlight can cause skin cancer. Even viruses have been known to cause cancer, perhaps by altering the genetic code of cells during an infection or by damaging the body's ability to suppress cancer. Papilloma (wart) viruses have been blamed for some cases of cervical cancer in women.

Age. Certain cancers are found primarily in young people (e.g., leukemia) and others primarily in older adults (e.g., colon cancer). The age factor may result from changes in the genetic activity of cells over time or from accumulated effects of cell damage.

Detection and Treatment of Cancer

Signs of cancer are those one would expect of a malignant neoplasm: the appearance of abnormal, rapidly growing tissue. Cancer specialists, or *oncologists,* have stressed that early detection of cancer is important because it is in the early stages of development of primary tumors, before metastasis and the development of secondary tumors have begun, that cancer is most treatable. Some methods currently used to detect the presence of cancer include the following:

Self-examination for the early signs of cancer previously described is one method for detection of cancer. For example, women are encouraged to perform a monthly breast self-examination. Likewise, males are encour-

aged to perform a monthly testicular self-examination. If an abnormality is found, it can be further investigated with one of the following described methods.

Medical imaging techniques that visualize deep tissues for medical study are often used to detect cancers (see pp. 17 and 18). Radiography (x-ray photography) often is used to detect the presence of tumors. *Mammography,* x-ray photography of a breast, is considered an important detection tool for this type of cancer. *Computed tomography (CT)* (x-ray scanning), *magnetic resonance imaging (MRI)* (electromagnetic scanning), and *ultrasonography* (ultrasound scanning) produce cross-sectional images of body regions suspected of having tumors.

Blood tests to determine the concentration of ions, enzymes, or other blood components are useful in detecting cancer when the results show abnormalities associated with particular forms of cancer. Cancer cells also may produce or trigger the production of substances often referred to as *tumor markers.* For example, tests for a prostate cancer marker are now being used in conjunction with other diagnostic tests.

Biopsy is the removal and examination of living tissue. Microscopic examination of tumor tissue removed surgically or through a needle sometimes reveals whether it is malignant or benign.

The information gained from these techniques can be used to *stage* and *grade* malignant tumors. Staging involves classifying a tumor based on its size and the extent of its spread. Grading is an assessment of what the tumor is likely to do based on the degree of abnormality of the cells—a useful basis for making a prognosis (statement of probable outcome).

Without treatment, cancer usually results in death. The progress of a particular type of cancer depends on the type of cancer and its location. Many cancer patients suffer from *cachexia,* a syndrome involving loss of appetite, weight loss, and general weakness. Various anatomical or functional abnormalities may arise as a result of damage to particular organs. The ultimate causes of death in cancer patients include secondary infection by pathogenic microorganisms, organ failure, hemorrhage (blood loss), and, in some cases, undetermined factors.

Of course, once cancer has been identified, every effort is made to treat it and thus prevent or delay its development. Surgical removal of cancerous tumors is sometimes performed, but the probability that malignant cells have been left behind must be addressed. **Chemotherapy,** or "chemical therapy," using *cytotoxic* (cell-killing) compounds, or antineoplastic drugs, can be used after surgery to destroy remaining malignant cells. **Radiation therapy,** also called *radiotherapy,* using destructive x-ray or gamma radiation may be used alone or with chemotherapy to destroy remaining cancer cells. **Laser therapy,** in which an intense beam of light destroys a tumor, also is sometimes coupled with chemotherapy or radiation therapy. **Immunotherapy,** a newer type of cancer treatment, bolsters the body's own defenses against cancer cells. Because viruses cause some types of cancer, oncologists hope that vaccines against certain forms of cancer will be developed.

Perhaps the most promising new research area in the battle against cancer is *molecular oncology.* This rapidly growing medical specialty attempts to use advances in molecular biology and genetics to develop so called *rational drugs* that, unlike conventional chemotherapy agents, target only those specific molecules, enzymes, receptors or other features unique to cancer cells or tumor growth. Ideally, such treatments would affect only the cancer and spare normal cells and body functions, thus increasing efficiency and reducing side effects. Three of the most promising new classes of "rational" drugs used to treat various types of cancer include the following:

Monoclonal antibodies (see p. 656), for example, Herceptin for breast cancer and Cetuximal or IMC225 for colorectal cancer

Antiangiogenesis (anti-blood-vessel-formation) *agents*, for example, VEGF for various solid tumors

Tyrosine kinase inhibitors (enzyme inhibitors), for example, Gleevec or ST1571 for chronic myeloid leukemia

Some oncologists believe that future advances in rational drug design could mean for cancer what antibiotics meant for infectious diseases.

CASE STUDY

Antonio Garza, age 64 years, is brought to the rural health clinic by his granddaughter. Mr. Garza has had non–insulin-dependent diabetes for the past 10 years. He is currently taking hypoglycemic medication, Micronase (glyburide) 5 mg twice a day, and following a diabetic diet to help control his disease process. Additionally, Mr. Garza is taking Lotensin (benazepril) 10 mg daily for hypertension. Forty-eight hours ago, Mr. Garza sustained a burn on his right foot from burning trash. The area is blistered, swollen, hot, and tender to the touch. The area surrounding the burn has an increased redness. Vital signs reflect a low-grade fever of 100.4° F (38° C), with other vital signs and blood sugar level being within normal limits.

1. Based on the structure and function of types of tissue, what type of injury do you suspect Mr. Garza has sustained?
   - **A.** Epithelial
   - **B.** Connective
   - **C.** Muscle tissue
   - **D.** Nervous tissue
2. Which one of the functions of this tissue type is most affected by this injury?
   - **A.** Secretion and absorption
   - **B.** Protection and sensory
   - **C.** Protection and secretion
   - **D.** Digestion and absorption
3. Which one of the following might you expect to be elevated in Mr. Garza's blood cell count?
   - **A.** Erythrocytes
   - **B.** Platelets
   - **C.** Thrombocytes
   - **D.** Leukocytes
4. Because the basement membrane was not completely destroyed in Mr. Garza's injury, what type of tissue repair would you expect to occur?
   - **A.** Nonregeneration of scar tissue
   - **B.** Keloid formation
   - **C.** Replacement by fibrous connective tissue
   - **D.** Regeneration
5. Immediately after Mr. Garza's injury, an inflammatory response occurred in response to the injury. Which of the following is the correct description of this expected response?
   - **A.** Constriction of blood vessels surrounding the injury, increase in red blood cell production, vasodilation, and resulting phagocytosis by the red blood cells
   - **B.** Short-term immediate vasoconstriction, quickly followed by blood vessel dilation, and release of chemicals by injured tissues to cause vasodilation and increased permeability of blood vessels
   - **C.** Chemical release of histamine, serotonin, and kinins to assist in vasoconstriction and maintenance of intracellular fluids.
   - **D.** Axial flow, or increased blood flow, through the small vessels toward the central two thirds of the lumen to maintain equal osmotic pressures

CHAPTER SUMMARY

INTRODUCTION

A. Tissue—group of similar cells that perform a common function
B. Matrix—nonliving intercellular material

PRINCIPAL TYPES OF TISSUE

A. Epithelial tissue
B. Connective tissue
C. Muscle tissue
D. Nervous tissue

EMBRYONIC DEVELOPMENT OF TISSUES

A. Primary germ layers (Figure 5-1)
   1. Endoderm
   2. Mesoderm
   3. Ectoderm
B. Gastrulation—process of cell movement and differentiation, which results in development of primary germ layers
C. Histogenesis—the process of the primary germ layers differentiating into different kinds of tissue

EPITHELIAL TISSUE

A. Types and locations
   1. Epithelium is divided into two types:
      a. Membranous (covering or lining) epithelium
      b. Glandular epithelium
   2. Locations
      a. Membranous epithelium—covers the body and some of its parts; lines the serous cavities, blood and lymphatic vessels, and respiratory, digestive, and genitourinary tracts
      b. Glandular epithelium—secretory units of endocrine and exocrine glands
B. Functions
   1. Protection
   2. Sensory functions
   3. Secretion

4. Absorption
5. Excretion

C. Generalizations about epithelial tissue
1. Limited amount of matrix material
2. Membranous type attached to a basement membrane
3. Avascular
4. Cells are in close proximity, with many desmosomes and tight junctions
5. Capable of reproduction

D. Classification of epithelial tissue
1. Membranous (covering or lining) epithelium
a. Classification based on cell shape (Figure 5-2)
(1) Squamous
(2) Cuboidal
(3) Columnar
(4) Pseudostratified columnar
b. Classifications based on layers of cells (Table 5-1)
(1) Simple epithelium
(a) Simple squamous epithelium (Figures 5-3 and 5-4)
(i) One-cell layer of flat cells
(ii) Permeable to many substances
(iii) Examples: endothelium—lines blood vessels; mesothelium—pleura
(b) Simple cuboidal epithelium (Figure 5-5)
(i) One-cell layer of cuboidal-shaped cells
(ii) Found in many glands and ducts
(c) Simple columnar epithelium (Figure 5-6)
(i) Single layer of tall, column-shaped cells
(ii) Cells often modified for specialized functions such as goblet cells (secretion), cilia (movement), microvilli (absorption)
(iii) Often lines hollow visceral structures
(d) Pseudostratified columnar epithelium (Figure 5-7)
(i) Columnar cells of differing heights
(ii) All cells rest on basement membrane but may not reach the free surface above
(iii) Cell nuclei at odd and irregular levels
(iv) Found lining air passages and segments of male reproductive system
(v) Motile cilia and mucus are important modifications
(2) Stratified epithelium
(a) Stratified squamous (keratinized) epithelium
(i) Multiple layers of flat, squamous cells (Figure 5-8)
(ii) Cells filled with keratin
(iii) Covering outer skin on body surface
(b) Stratified squamous (nonkeratinized) epithelium (Figure 5-9)
(i) Lining vagina, mouth, and esophagus
(ii) Free surface is moist
(iii) Primary function is protection
(c) Stratified cuboidal epithelium
(i) Two or more rows of cells are typical
(ii) Basement membrane is indistinct
(iii) Located in sweat gland ducts and pharynx
(d) Stratified columnar epithelium
(i) Multiple layers of columnar cells
(ii) Only most superficial cells are typical in shape
(iii) Rare
(iv) Located in segments of male urethra and near anus
(e) Stratified transitional epithelium (Figure 5-10)
(i) Located in lining of hollow viscera subjected to stress (e.g., urinary bladder)
(ii) Often 10 or more layers thick
(iii) Protects organ walls from tearing
2. Glandular epithelium
a. Specialized for secretory activity
b. Exocrine glands—discharge secretions into ducts
c. Endocrine glands—"ductless" glands; discharge secretions directly into the blood or interstitial fluid
d. Structural classification of exocrine glands (Figure 5-11; Table 5-2)
(1) Multicellular exocrine glands are classified by the shape of their ducts and the complexity of their duct system
(2) Shapes include tubular and alveolar
(3) Simple exocrine glands—only one duct leads to the surface
(4) Compound exocrine glands—have two or more ducts
e. Functional classification of exocrine glands (Figure 5-12)
(1) Apocrine glands
(a) Secretory products collect near apex of cell and are secreted by pinching off the distended end
(b) Secretion process results in some damage to cell wall and some loss of cytoplasm
(c) Mammary glands are good examples of this secretory type
(2) Holocrine glands
(a) Secretion products, when released, cause rupture and death of the cell
(b) Sebaceous glands are holocrine
(3) Merocrine glands
(a) Secrete directly through cell membrane
(b) Secretion proceeds with no damage to cell wall and no loss of cytoplasm
(c) Most numerous gland type

CONNECTIVE TISSUE

A. Functions, characteristics, and types
   1. General function—connects, supports, transports, and protects
   2. General characteristics—matrix predominates in most connective tissues and determines its physical characteristics; consists of fluid, gel, or solid matrix, with or without extracellular fibers (collagenous, reticular, and elastic) and proteoglycans or other compounds that thicken and hold together the tissue
   3. Four main types (Table 5-3)
      a. Fibrous
         (1) Loose, ordinary (areolar)
         (2) Adipose
         (3) Reticular
         (4) Dense
      b. Bone
      c. Cartilage
         (1) Hyaline
         (2) Fibrocartilage
         (3) Elastic
      d. Blood

B. Fibrous connective tissue
   1. Loose (areolar) connective tissue (Figure 5-13)
      a. One of the most widely distributed of all tissues
      b. Intercellular substance is prominent and consists of collagenous and elastic fibers loosely interwoven and embedded in soft viscous ground substance
      c. Several kinds of cells present, notably, fibroblasts and macrophages, also mast cells, plasma cells, fat cells, and some white blood cells
      d. Function—connection
   2. Adipose tissue (Figures 5-14 and 5-15)
      a. Similar to loose connective tissue but contains mainly fat cells
      b. Functions—protection, insulation, support, and food reserve
   3. Reticular tissue (Figure 5-16)
      a. Forms framework of spleen, lymph nodes, and bone marrow
      b. Consists of network of branching reticular fibers with reticular cells overlying them
      c. Functions—defense against microorganisms and other injurious substances; reticular meshwork filters out injurious particles and reticular cells phagocytose them
   4. Dense fibrous tissue (Figures 5-17 to 5-19)
      a. Matrix consists mainly of fibers packed densely and relatively few fibroblast cells
         (1) Regular—bundles of fibers are arranged in regular parallel rows
         (2) Irregular—fibers intertwine to form a thick mat
      b. Locations—composes structures that need great tensile strength, such as tendons and ligaments; also dermis and the outer capsule of kidney and spleen
      c. Function—furnishes flexible but strong connection

C. Bone tissue
   1. Highly specialized connective tissue type (Figure 5-20)
      a. Cells—osteocytes—embedded in a calcified matrix
      b. Inorganic component of matrix accounts for 65% of total bone tissue
   2. Functions
      a. Support
      b. Protection
      c. Point of attachment for muscles
      d. Reservoir for minerals
   3. Osteon (Haversian system)
      a. Structural unity of bone
      b. Spaces for osteocytes called lacunae
      c. Matrix present in concentric rings called lamellae
      d. Canaliculi are canals that join lacunae with the central Haversian canal
   4. Cell types
      a. Osteocyte—mature, inactive bone cell
      b. Osteoblast—active bone-forming cell
      c. Osteoclast—bone-destroying cell
   5. Formation (ossification)
      a. In membranes—e.g., flat bones of skull
      b. From cartilage (endochondral)—e.g., long bones, such as the humerus

D. Cartilage
   1. Chondrocyte is only cell type present
   2. Lacunae house cells as in bone
   3. Avascular—therefore nutrition of cells depends on diffusion of nutrients through matrix
   4. Heals slowly after injury because of slow nutrient transfer to the cells
   5. Perichondrium is membrane that surrounds cartilage
   6. Types
      a. Hyaline (Figure 5-21)
         (1) Appearance is shiny and translucent
         (2) Most prevalent type of cartilage
         (3) Located on the ends of articulating bones
      b. Fibrocartilage (Figure 5-22)
         (1) Strongest and most durable type of cartilage
         (2) Matrix is semirigid and filled with strong white fibers
         (3) Found in intervertebral disks and pubic symphysis
         (4) Serves as shock-absorbing material between bones at the knee (menisci)
      c. Elastic (Figure 5-23)
         (1) Contains many fine elastic fibers
         (2) Provides strength and flexibility
         (3) Located in external ear and larynx

E. Blood
   1. A liquid tissue (Figure 5-24)
   2. Contains neither ground substance nor fibers

3. Composition of whole blood
   a. Liquid fraction (plasma) is the matrix—55% of total blood volume
   b. Formed elements contribute 45% of total blood volume
      (1) Red blood cells, erythrocytes
      (2) White blood cells, leukocytes
      (3) Platelets, thrombocytes
4. Functions
   a. Transportation
   b. Regulation of body temperature
   c. Regulation of body pH
   d. White blood cells destroy bacteria
5. Circulating blood tissue is formed in the red bone marrow by a process called *hematopoiesis*; the blood-forming tissue is sometimes called *hematopoietic tissue*

MUSCLE TISSUE

A. Types
   1. Skeletal, or striated voluntary (Figure 5-25)
   2. Smooth, or nonstriated involuntary, or visceral (Figures 5-26 and 5-27)
   3. Cardiac, or striated involuntary (Figure 5-28)
B. Microscopic characteristics
   1. Skeletal muscle—threadlike cells with many cross striations and many nuclei per cell
   2. Smooth muscle—elongated narrow cells, no cross striations, one nucleus per cell
   3. Cardiac muscle—branching cells with intercalated disks (formed by abutment of plasma membranes of two cells)

NERVOUS TISSUE

A. Functions—rapid regulation and integration of body activities
B. Specialized characteristics
   1. Excitability
   2. Conductivity
C. Organs
   1. Brain
   2. Spinal cord
   3. Nerves
D. Cell types
   1. Neuron—conducting unit of system (Figure 5-29)
      a. Cell body, or soma
      b. Processes
         (1) Axon (single process)—transmits nerve impulse away from the cell body
         (2) Dendrites (one or more)—transmits nerve impulse toward the cell body
   2. Neuroglia—special connecting and supporting cells

TISSUE REPAIR

A. Tissues have a varying capacity to repair themselves; damaged tissue regenerates or is replaced by scar tissue
B. Regeneration—growth of new tissue (Figure 5-30)
C. Scar—dense fibrous mass; unusually thick scar is a keloid (Figure 5-31)
D. Epithelial and connective tissues have the greatest ability to regenerate
E. Muscle and nervous tissues have a limited capacity to regenerate

BODY MEMBRANES

A. Thin tissue layers that cover surfaces, line cavities, and divide spaces or organs (Figure 5-32)
B. Epithelial membranes are most common type
   1. Cutaneous membrane (skin)
      a. Primary organ of integumentary system
      b. One of the most important organs
      c. Composes approximately 16% of body weight
   2. Serous membrane
      a. Parietal membranes—line closed body cavities
      b. Visceral membranes—cover visceral organs
      c. Pleura—surrounds a lung and lines the thoracic cavity
      d. Peritoneum—covers the abdominal viscera and lines the abdominal cavity
   3. Mucous membrane
      a. Lines and protects organs that open to the exterior of the body
      b. Found lining ducts and passageways of respiratory and digestive tracts
C. Connective tissue membranes
   1. Do not contain epithelial components
   2. Synovial membranes—line the spaces between bone in joints
   3. Have smooth and slick membranes that secrete synovial fluid
   4. Help reduce friction between opposing surfaces in a moveable joint
   5. Synovial membranes also line bursae

THE BIG PICTURE: TISSUES, MEMBRANES, AND THE WHOLE BODY

A. Tissues and membranes maintain homeostasis
   1. Epithelial tissues
      a. Form membranes that contain and protect the internal fluid environment
      b. Absorb nutrients
      c. Secrete products that regulate functions involved in homeostasis
   2. Connective tissues
      a. Hold organs and systems together
      b. Form structures that support the body and permit movement
   3. Muscle tissues
      a. Work with connective tissues to permit movement
   4. Nervous tissues
      a. Work with glandular epithelial tissue to regulate body function

REVIEW QUESTIONS

1. Define the term *tissue* and identify the four principal tissue types.
2. List at least three structures derived from each of the primary germ layers.
3. What are the five most important functions of epithelial tissue?
4. Which of the following best describes the number of blood vessels in epithelial tissue: none, very few, very numerous?
5. Explain how the shape of epithelial cells is used for classification purposes. Identify the four types of epithelium described in this classification process.
6. Classify epithelium according to the layers of cells present.
7. List the types of simple and stratified epithelium and give examples of each.
8. What is glandular epithelium? Give examples.
9. Discuss the structural classification of exocrine glands. Give examples of each type.
10. Describe loose connective tissue.
11. Discuss and compare the microscopic anatomy of bone and cartilage tissue.
12. Compare the structure of the three major types of cartilage tissue. Locate and give an example of each type.
13. List the components of whole blood and discuss the basic function of each fraction or cell type.
14. List the three major types of muscle tissue.
15. Identify the two basic types of cells in nervous tissue.
16. What are the four cardinal signs of inflammation? What causes each?
17. Describe the regenerative capacity of muscle and nerve tissues.
18. Name the two major categories or types of body membranes. Give examples of each.
19. What is a neoplasm?

CRITICAL THINKING QUESTIONS

1. A baby was born with congenital problems in the skeleton and muscle system. From what primary germ layers do these systems arise? What is the earliest possible developmental stage during which a problem could have affected just one primary germ layer?
2. Summarize the structural characteristics of epithelial tissues enable them to perform their specific functions.
3. Does the production of saliva, milk, or oil cause the most damage to the cell that produces it? Explain.
4. Describe the role of the fiber types in the classification of connective tissue. What examples can you find of these various types?
5. People with arthritis sometimes find relief from their condition by taking a dietary supplement of glucosamine and chondroitin. What do you know about the cartilage and ligaments in joints that might help explain this?
6. Many athletes work to reduce their body fat to the lowest possible percent. What would happen if too little body fat were present?
7. If a tendon is badly damaged, it may need to be replaced surgically. Based on what you know about the structural and functional differences, explain why a tendon rather than a ligament must replace it.
8. Develop a flow chart or other diagram to describe the process by which tissues respond to injury.
9. If a small but deep cut involving skin and muscle occurs, predict which tissue will probably heal first and which will heal more completely. Explain your answer.
10. When a joint swells, sometimes it is necessary to remove a thick colorless liquid from the joint. What is it, where did it come from, and what is its normal function?

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CAREER CHOICES

Emergency Clinical Nurse Specialist

As an Emergency Clinical Nurse Specialist at Dartmouth Hitchcock Medical Center in Lebanon, NH, my responsibilities involve the nursing care delivered to emergency patients. I teach classes, orient new nurses, evaluate supplies and equipment, trouble shoot patient care problems, set up systems to enhance care delivery, and help take care of patients.

I've wanted to be a nurse since I was 4 or 5 years old. I was drawn to the emergency care setting because I like action and variety. We see it all, cradle to grave, benign to life-threatening. I've delivered babies in the parking lot; I've reassured parents that their child's "blue" hands are related to a new pair of jeans. I've seen teenagers with "lesions" that turned out to be pimples; I've held the hands of the dying as I administered blood to try to save their lives.

Change is a current trend in my field; new medications, new equipment, and new therapies are constantly being introduced. The reassuring thing about change in the twenty-first century is that it is more likely to be evidence based than in the past. In other words, we have scientific data to support doing things differently. We're questioning things we've always done and evaluating them in terms of their impact on the patient's outcome.

When I'm taking care of patients, the rewards are obvious: relief of pain and suffering (physical and emotional), saving lives, and helping people return to an optimum state of health. When I'm teaching other nurses, the reward is in promoting improved knowledge and skills so that the professional practice of the nurse is enhanced and the care that she or he delivers to patients is improved.

I use anatomy specifically for accurate and concise descriptions of my physical examination findings. Physiology is interwoven into the patient's overall care. In assessment, I relate the signs, symptoms, and laboratory results to potential underlying physiologic causes. When implementing interventions such as medication administration or positioning, I must consider their intended affect on the patient and potential adverse affects. To evaluate the effectiveness of interventions, I rely on my understanding of physiology to gauge outcome. For example, if I am giving IV fluid to a patient in shock, I know that glomerular filtration rate reflects perfusion to vital organs, so urine output is a valuable parameter to monitor.

One professor I had always emphasized that nurses needed to know anatomy because some day we might be the only one available who could identify something. I found an anatomy coloring book to be a great study aid. Mnemonics were also a lifesaver; I still recite "On Old Olympus' Tiny Tops A Friendly Viking Grew Vines And Hops" when naming cranial nerves.