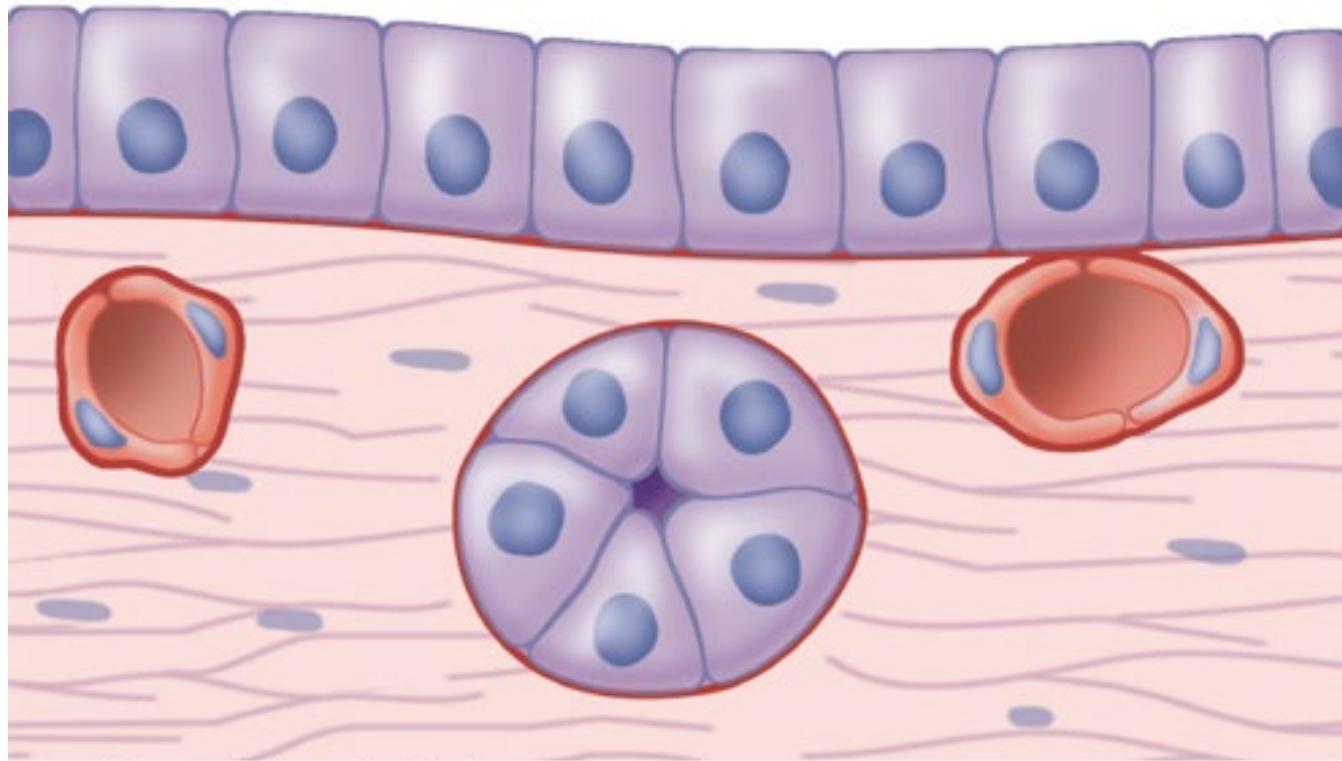


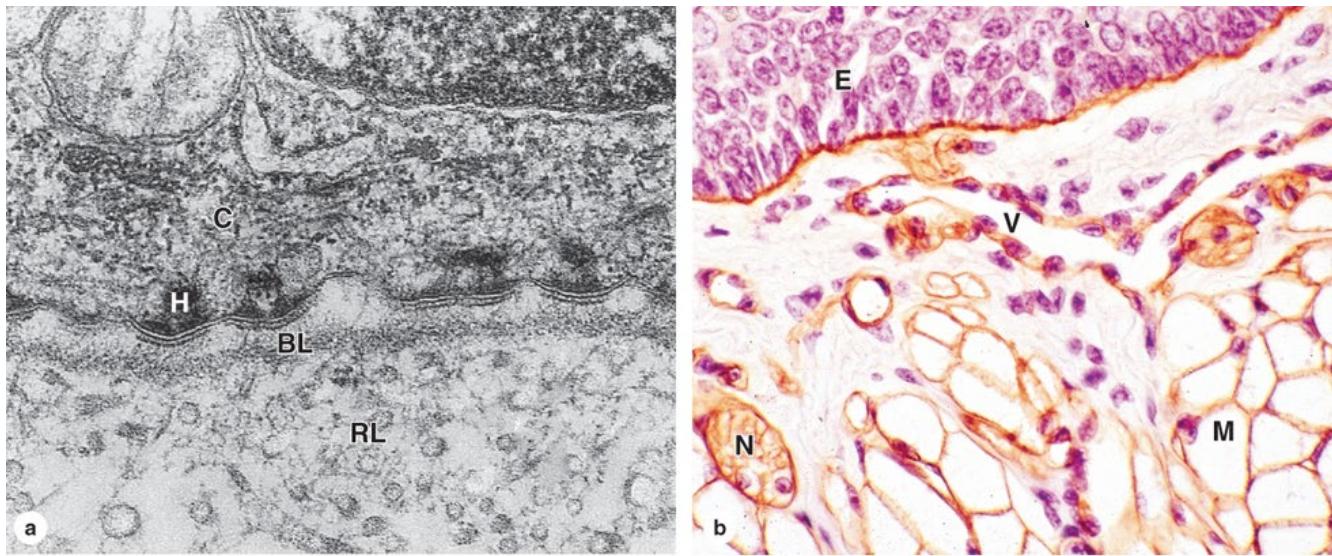
Epithelium



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Epithelia and adjacent connective tissue.

Cuboidal or pyramidal cells of epithelia generally have spherical nuclei, while nuclei of squamous epithelial cells are flattened. An extracellular basement membrane (red) always lies at the interface of epithelial cells and connective tissue. Nutrients for epithelial cells must diffuse across the basement membrane. Nerve fibers normally penetrate this structure, but small blood capillaries (being epithelial themselves) normally never enter epithelia.

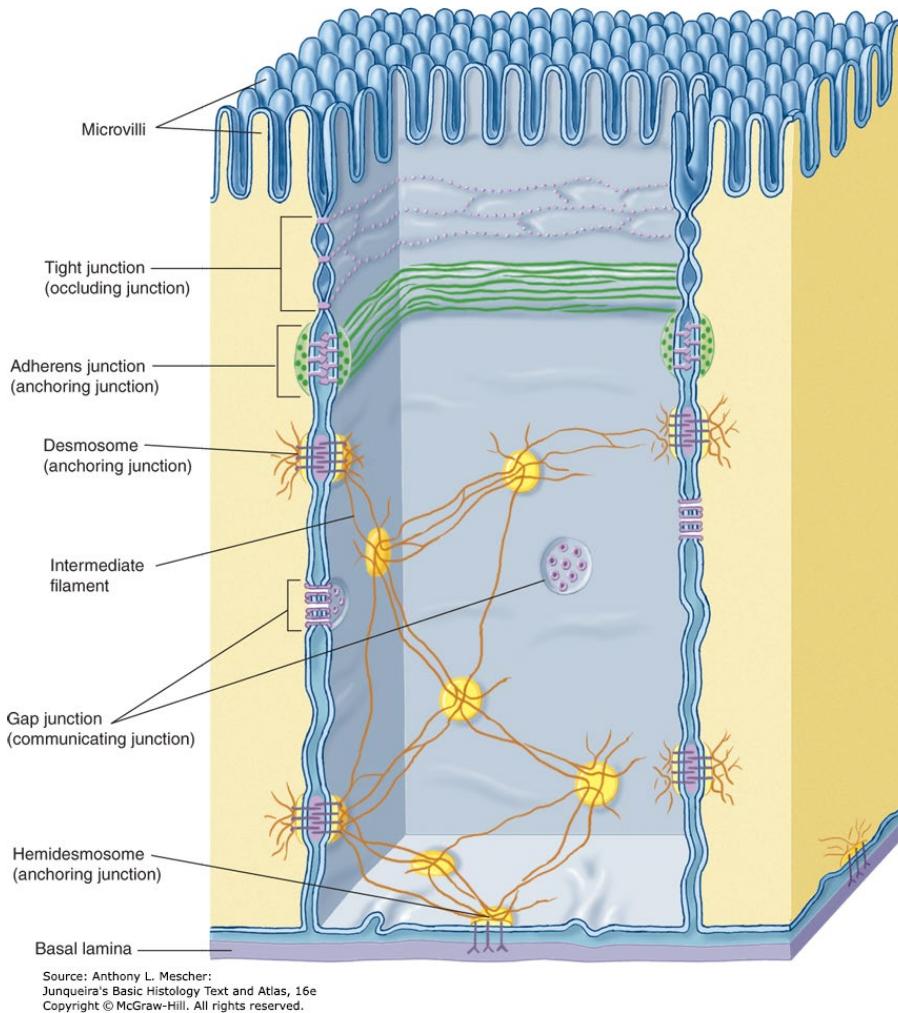


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Basal and reticular laminae of basement membranes.

(a) The ultrastructural components of the basement membrane are revealed by TEM. The dense basal lamina (BL), 20-100 nm thick, may appear with thin clear zones on each side and is anchored to a thicker, more diffuse reticular lamina (RL) containing collagen III fibers. Hemidesmosomes (H) bind the basal surface of the epithelial cell (C) to the basal lamina. (X54,000)

(b) Laminin, a major glycoprotein within basal laminae, is shown here by immunohistochemistry and identifies the basement membranes of the stratified epithelium (E) and the simple epithelium lining a small blood vessel (V). Laminin also occurs in the external laminae surrounding nerves (N) and muscle (M) fibers, seen here in cross section. (X200)

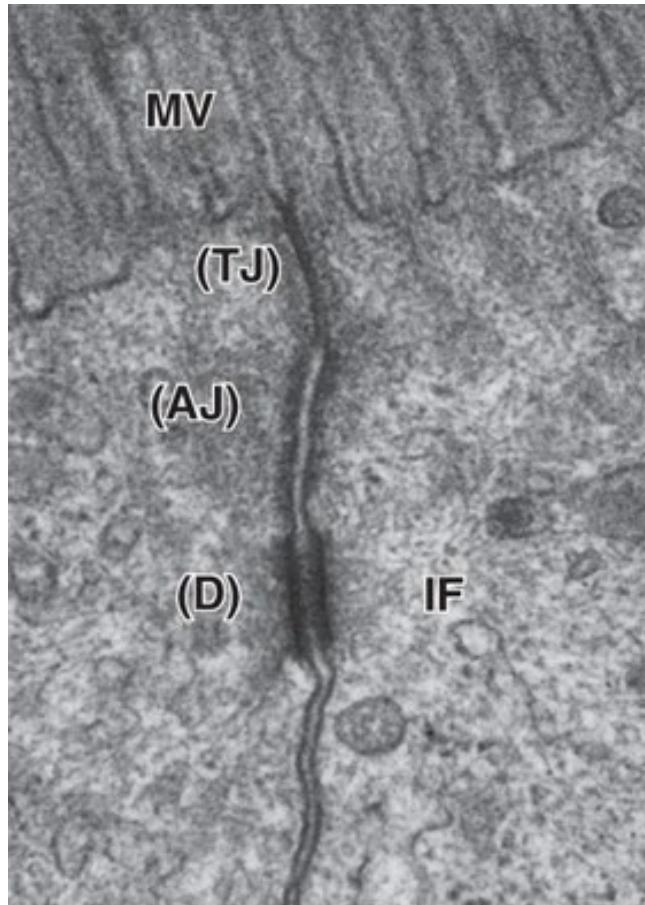


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Junctional complexes of epithelial cells.

Most cuboidal or columnar epithelial cells have intercellular junctional complexes with the different types of junctions shown schematically here. At the apical end, tight junctions (*zonulae occludens*) and adherent junctions (*zonulae adherens*) are typically close together and each forms a continuous band around the cell. Multiple ridges of the tight junction prevent passive flow of material between the cells but are not very strong; the adhering junctions immediately below them serve to stabilize and strengthen the circular occluding bands and help hold the cells together.

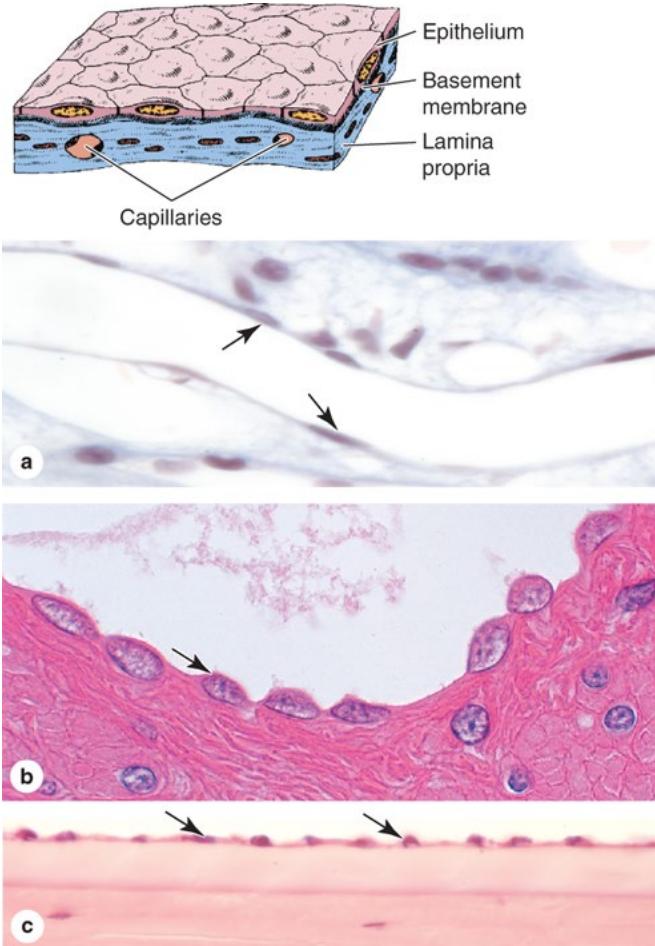
Both desmosomes and gap junctions are spot-like, not circular, structures between two cells. Bound to intermediate filaments inside the cells, desmosomes form very strong attachment points that supplement the *zonula adherens* and play a major role to maintain the integrity of an epithelium. Gap junctions, each a patch of many connexons in the adjacent cell membranes, have little strength but serve as intercellular channels for flow of molecules. All of these junctional types are also found in certain other cell types besides epithelia. Hemidesmosomes bind epithelial cells to the underlying basal lamina.



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Epithelial cell junctional complex.

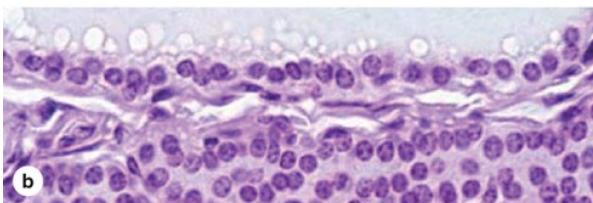
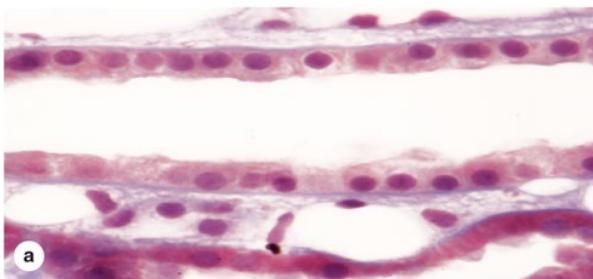
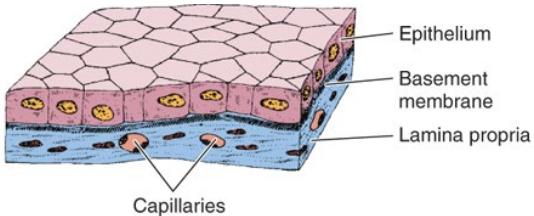
Ultrastructural View Of The Apical Region Near Microvilli (Mv) of two epithelial cells, revealing a junctional complex with a tight junction (TJ) or zonula occludens, an adherent junction (AJ) or zonula adherens, and a desmosome (D) associated with intermediate filaments (IF). (X195,000)



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Simple squamous epithelium.

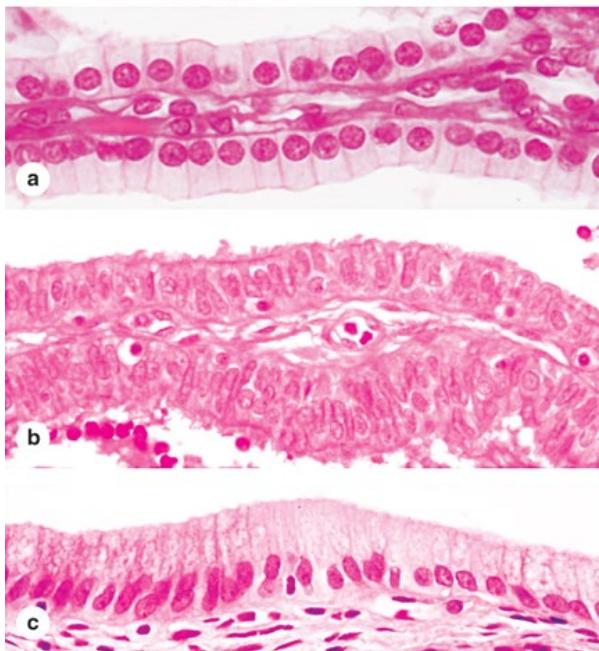
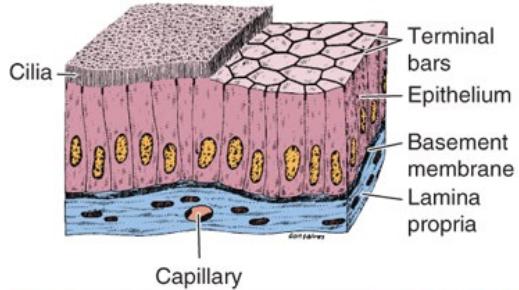
This is a single layer of thin cells, in which the cell nuclei (arrows) are the thickest and most visible structures. Simple epithelia are typically specialized as lining of vessels and cavities, where they regulate passage of substances into the underlying tissue. The thin cells often exhibit transcytosis. Examples shown here are those lining the thin renal loops of Henle (a), covering the outer wall of the intestine (b), and lining the inner surface of the cornea (c). The simple squamous epithelium lining the vasculature or the cornea is also called endothelium, while that lining large body cavities is called mesothelium and secretes a lubricant film called serous fluid. (a, c X400; b X600; H&E)



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Simple cuboidal epithelium.

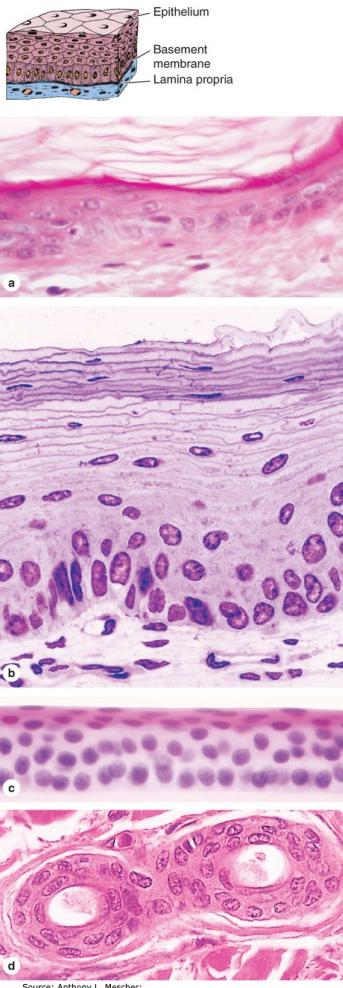
Cells here are roughly as tall as they are wide. Their greater thickness allows cytoplasm to be rich in mitochondria and other organelles for a high level of active transport across the epithelium and other functions. Examples shown here are from a renal collecting tubule (a), a large thyroid follicle (b), and the thick mesothelium covering an ovary (c). (All X400; H&E)



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Simple columnar epithelium.

Cells here are always taller than they are wide, with apical cilia or microvilli, and are often specialized for absorption. Complexes of tight and adherent junctions, sometimes called “terminal bars” in light microscopic images, are present at the apical ends of cells. The examples shown here are from a renal collecting duct (a), the oviduct lining, with both secretory and ciliated cells (b), and the lining of the gallbladder (c). (All X400; H&E)



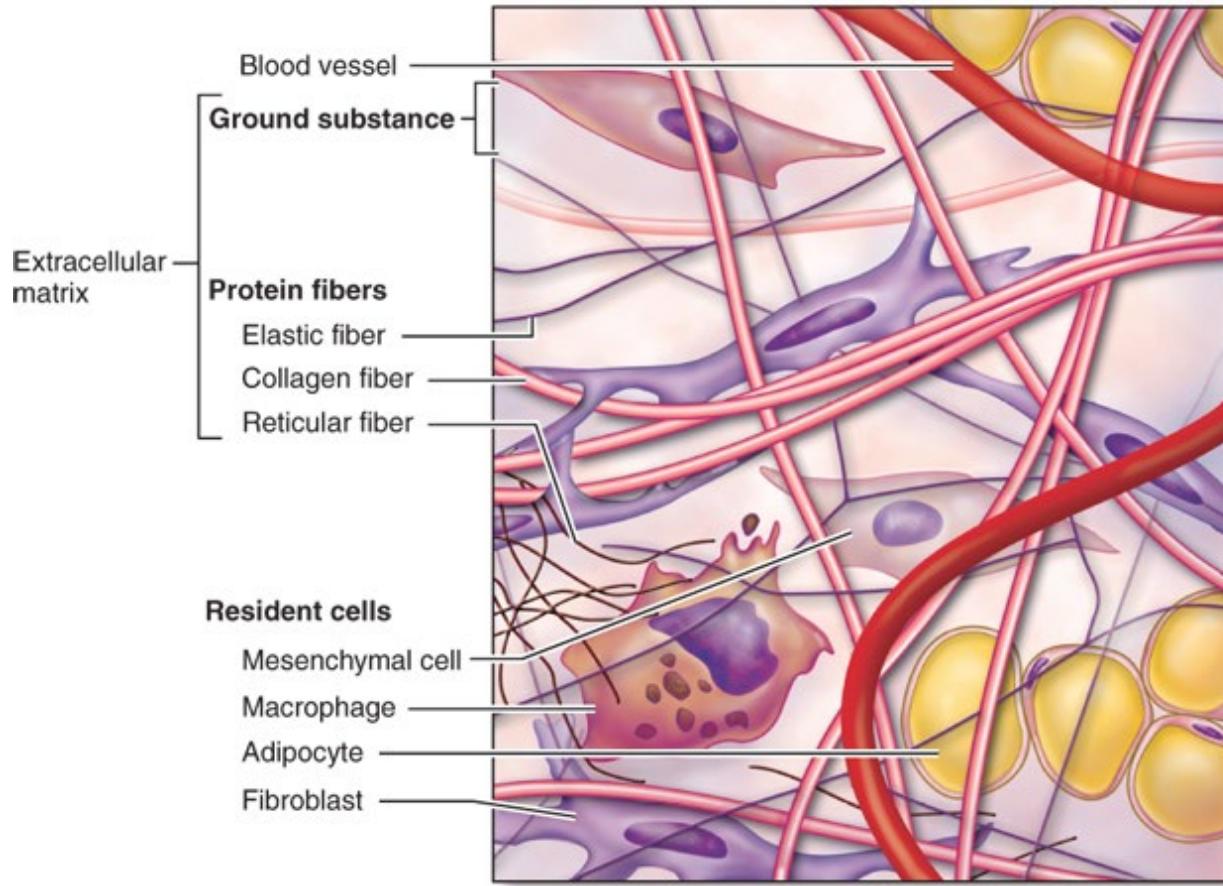
Stratified epithelium.

Stratified squamous epithelia usually have protective functions: protection against easy invasion of underlying tissue by microorganisms and protection against water loss. These functions are particularly important in the epidermis (a) in which differentiating cells become keratinized, that is, filled with keratin and other substances, eventually lose their nuclei and organelles, and form superficial layers of flattened squames that impede water loss. Keratinized cells are sloughed off and replaced by new cells from more basal layers, which are discussed fully with the skin in Chapter 18.

Nonkeratinized stratified squamous epithelia occur in many organs, such as the esophageal lining (b) or outer covering of the cornea (c). Here cells accumulate much less keratin and retain their nuclei but still provide protection against microorganisms.

Stratified cuboidal or columnar epithelia are fairly rare but occur in excretory ducts of certain glands, such as sweat glands (d) where the double layer of cells allows additional functions. All X400; (b) PT, (a, c, and d) H&E.

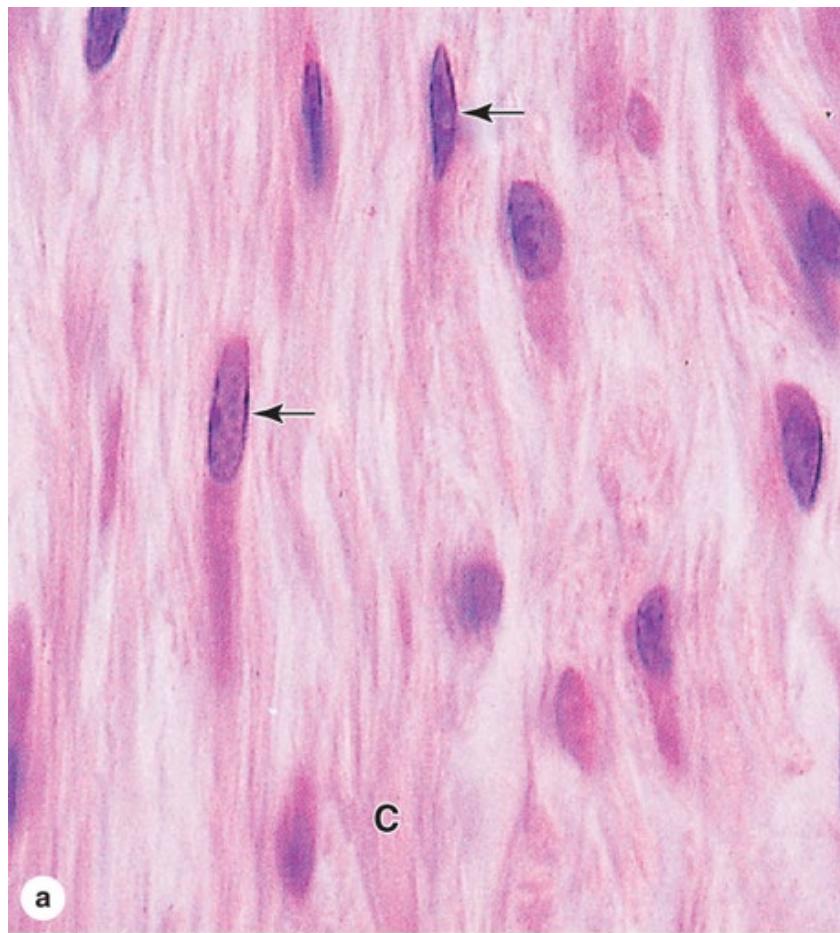
Connective Tissue



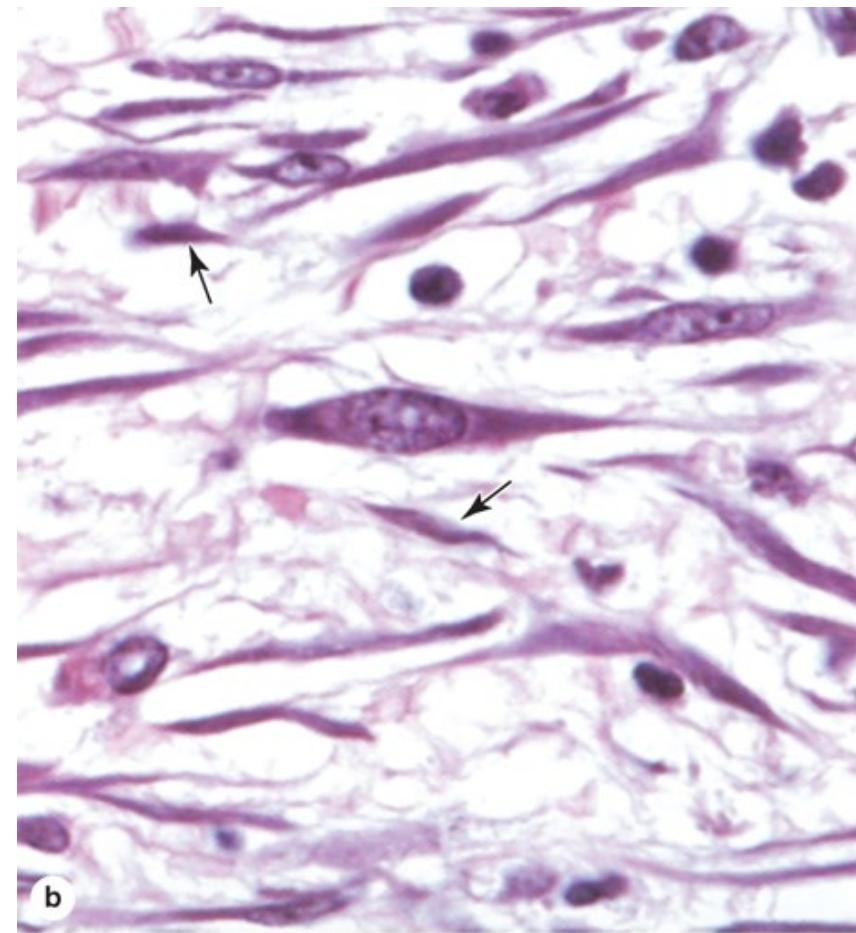
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Cellular and extracellular components of connective tissue.

Connective tissue is composed of fibroblasts and other cells and an ECM of various protein fibers, all of which are surrounded by watery ground substance. In all types of connective tissue, the extracellular volume exceeds that of the cells.



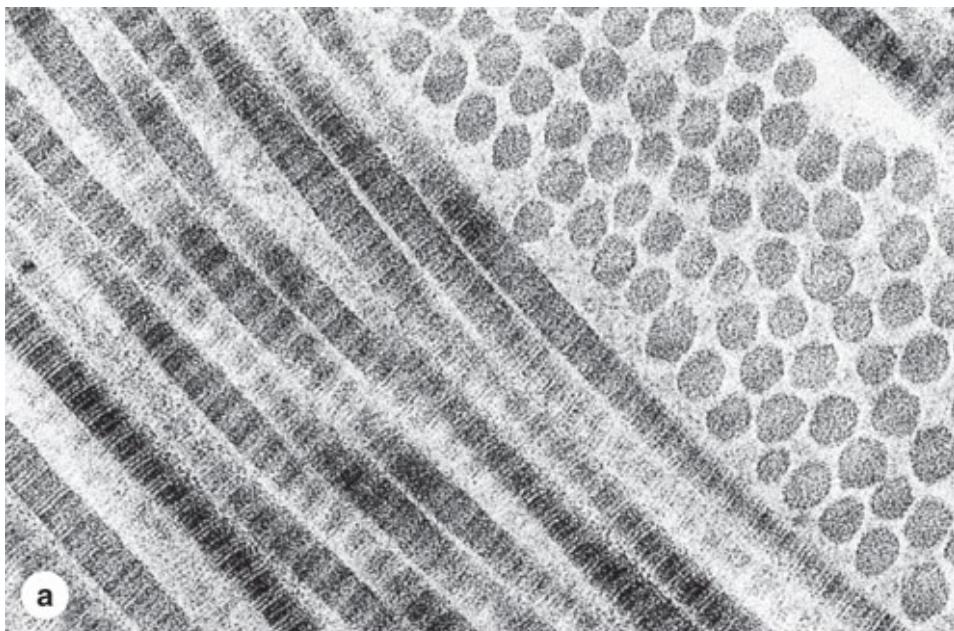
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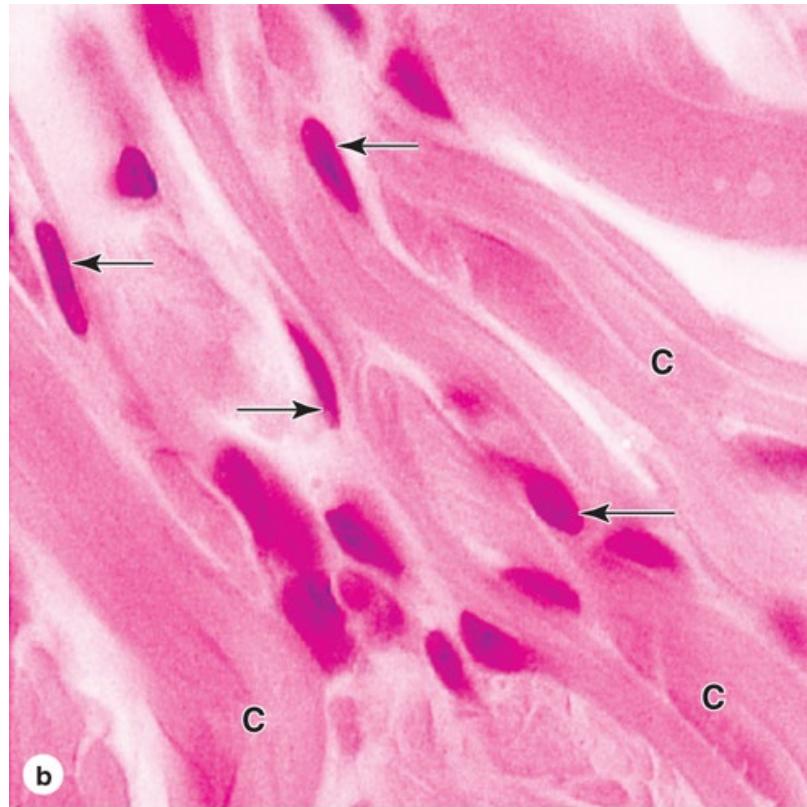
Fibroblasts.

- (a) Fibroblasts typically have large active nuclei and eosinophilic cytoplasm that tapers off in both directions along the axis of the nucleus, a morphology often referred to as “spindle-shaped.” Nuclei (arrows) are clearly seen, but the eosinophilic cytoplasmic processes resemble the collagen bundles (C) that fill the ECM and are difficult to distinguish in H&E-stained sections.
- (b) Both active and quiescent fibroblasts may sometimes be distinguished, as in this section of dermis. Active fibroblasts have large, euchromatic nuclei and basophilic cytoplasm, while inactive fibroblasts (or fibrocytes) are smaller with more heterochromatic nuclei (arrows). The round, very basophilic round cells are in leukocytes. (Both X400; H&E)



a

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b

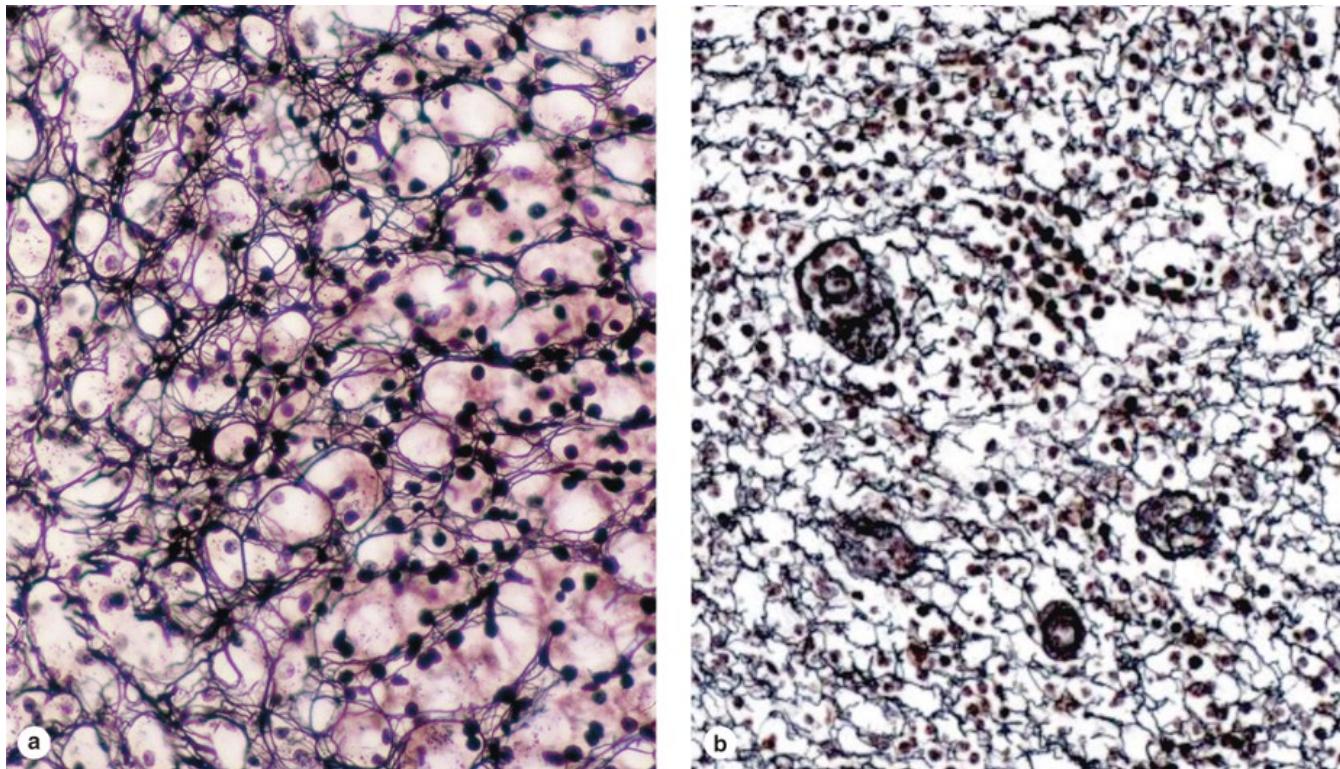
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Type I collagen.

Subunits of type I collagen, the most abundant collagen, assemble to form extremely strong fibrils, which are then bundled together further by other collagens into much larger structures called collagen fibers.

(a) TEM shows fibrils cut longitudinally and transversely. In longitudinal sections, fibrils display alternating dark and light bands; in cross section, the cut ends of individual collagen molecules appear as dots. Ground substance completely surrounds the fibrils. (X100,000)

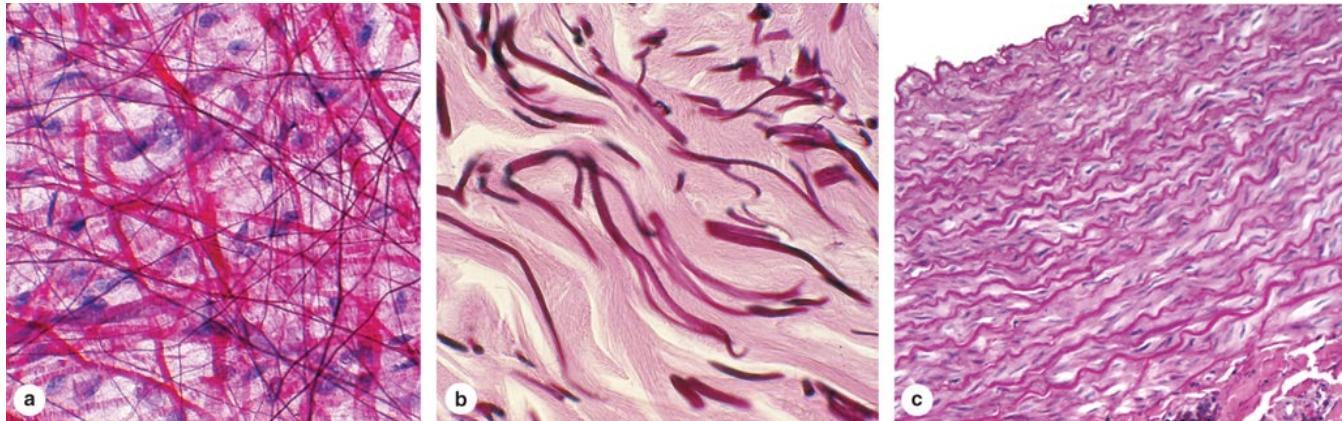
(b) The large bundles of type I collagen fibrils (C) appear as acidophilic collagen fibers in connective tissues, where they may fill the extracellular space. Subunits for these fibers were secreted by the fibroblasts (arrows) associated with them. (X400; H&E)



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Reticular fibers.

In these silver-stained sections of adrenal cortex (a) and lymph node (b), networks of delicate, black reticular fibers are prominent. These fibers serve as a supportive stroma in most lymphoid and hematopoietic organs and many endocrine glands. The fibers consist of type III collagen that is heavily glycosylated, producing the black argyrophilia. Cell nuclei are also dark, but cytoplasm is unstained. (X100) Fibroblasts specialized for reticular fiber production in hematopoietic and lymphoid organs are often called reticular cells.

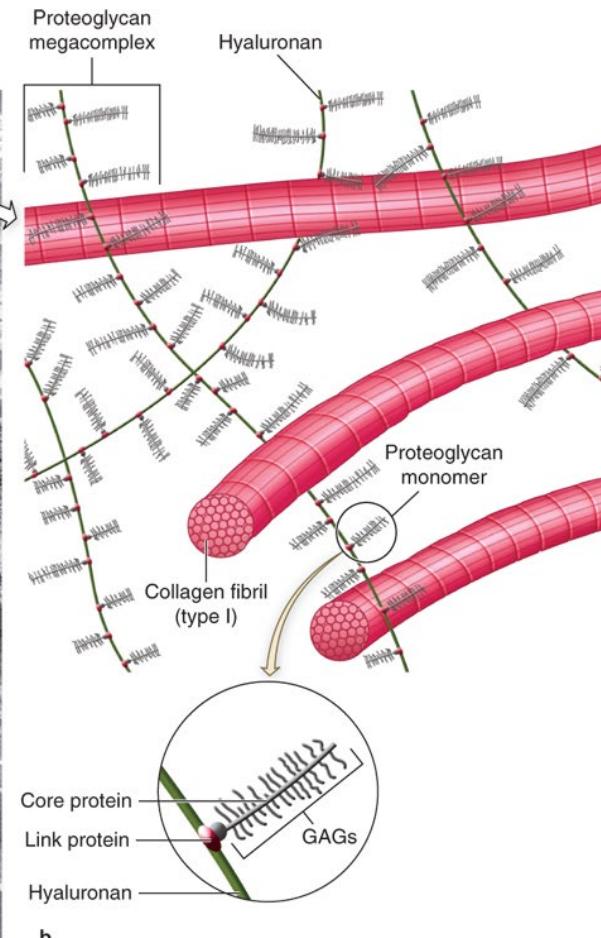
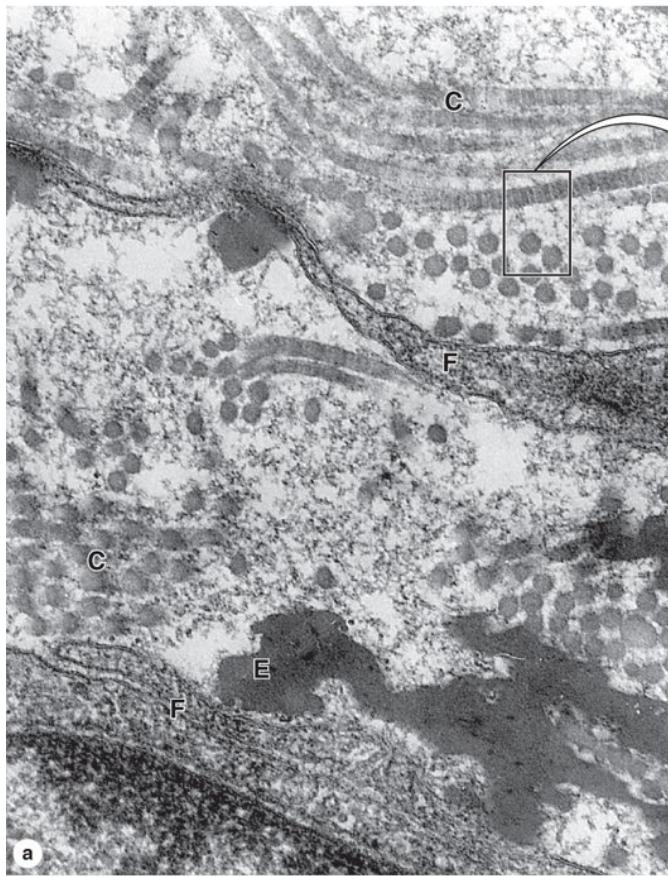


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Elastic fibers.

Elastic fibers or lamellae (sheets) add resiliency to connective tissue. Such fibers may be difficult to discern in H&E-stained tissue, but elastin has a distinct, darker-staining appearance with other staining procedures.

- (a) The length, diameter, distribution, and density of dark elastic fibers are easily seen in this spread preparation of nonstretched connective tissue in a mesentery. (X200; Hematoxylin and orcein)
- (b) In sectioned tissue at higher magnification, elastic fibers can be seen among the acidophilic collagen bundles of dermis. (X400; Aldehyde fuchsin)
- (c) Elastic lamellae in the wall of the aorta are more darkly stained, incomplete sheets of elastin between the layers of eosinophilic smooth muscle. (X80; H&E)

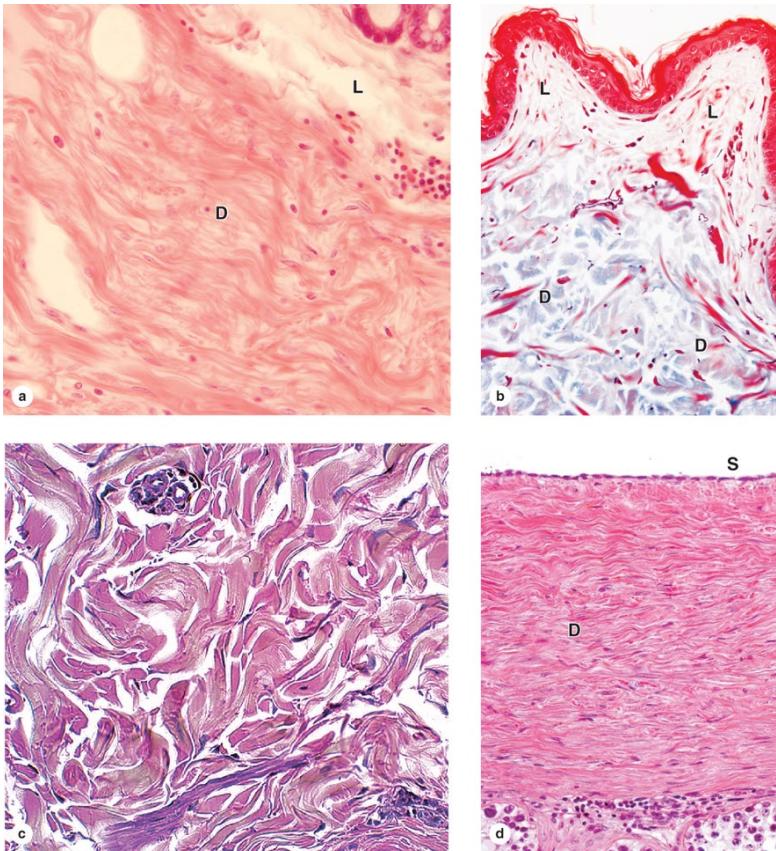


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Ground substance of the ECM.

(a) TEM of connective tissue ECM reveals ground substance as areas containing only fine granular material among the collagen (C) fibers, elastic (E) fibers, and fibroblast processes (F). X100,000.

(b) As shown here schematically, connective tissue ground substance contains a vast complex of proteoglycans linked to very long hyaluronan molecules. Each proteoglycan monomer has a core protein with a few or many side chains of the sulfated GAGs listed in Table 5–5. Synthesized in the RER and Golgi apparatus like glycoproteins, proteoglycan monomers are distinguished by often being more heavily glycosylated and by the addition and sulfation of GAGs, which vary significantly among proteoglycans in their number, length, and the degree to which the sugar polymers are modified. Aggrecan, the most abundant and important proteoglycan in the articular cartilage of joints (see Chapter 8), is a very large macromolecule with a 250 kDa core protein approximately 400 nm long with roughly 100 chondroitin sulfate side chains, each 20 kDa, and 30-60 keratan sulfate side chains, each 5-15 kDa.



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Loose connective tissue and dense irregular connective tissue.

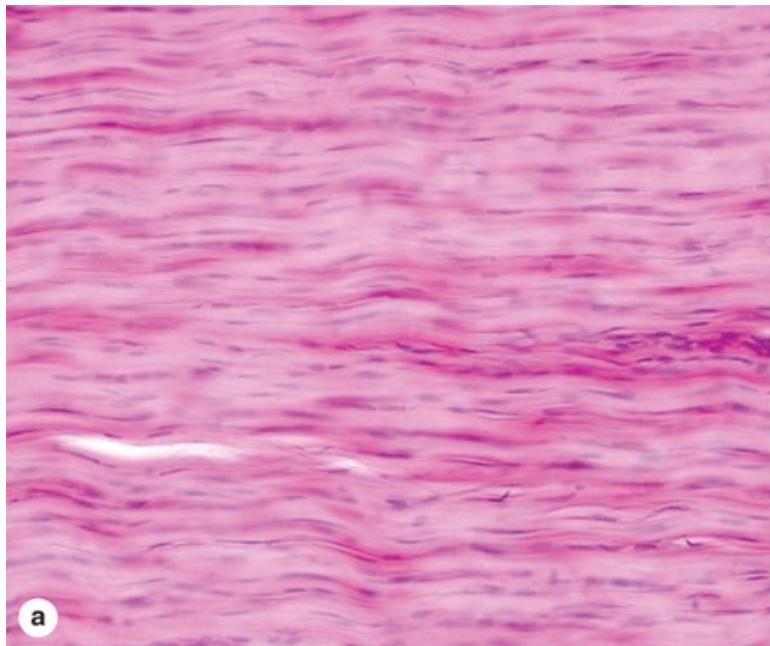
Examples of these connective tissue types shown here indicate the close association that often occurs between these two types.

(a) Loose connective tissue (L) of a gland contains faintly stained ground substance with fine fibers of collagen and frequently forms a thin layer near epithelia, while dense irregular connective tissue (D) forms a thicker layer and is invariably much richer in larger bundles of collagen. Scattered leukocytes can be seen in both connective tissues, along with the large irregular spaces of lymphatic vessels (left). (X100; H&E)

(b) Trichrome staining of a section from skin demonstrates the blue staining of collagen with this method and its relative density in loose (L) and dense irregular (D) connective tissue. (X100; Mallory trichrome)

(c) Another example of dense irregular connective tissue, showing the randomly arranged large collagen bundles. The arrangement of collagen strengthens the tissues and resists tearing from all directions. (X150; H&E)

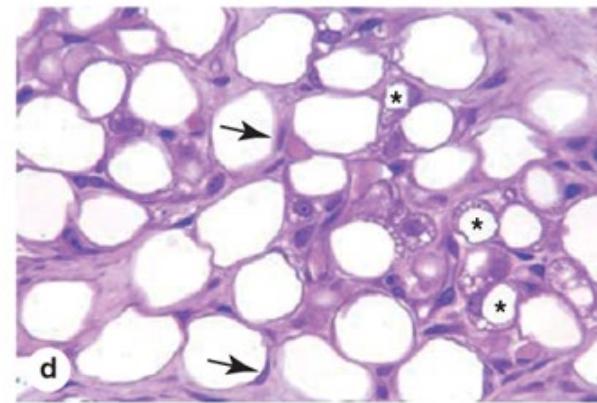
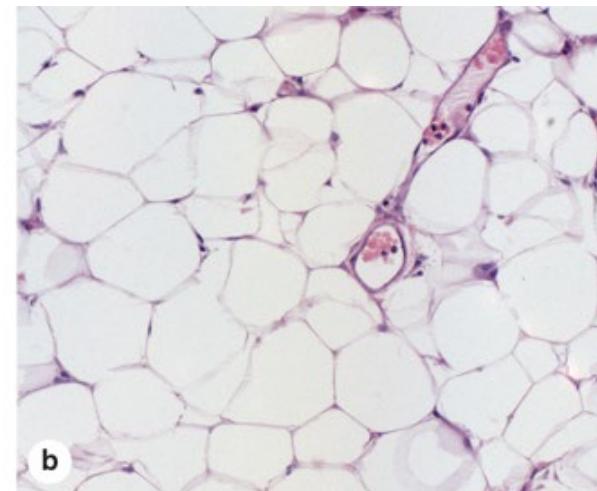
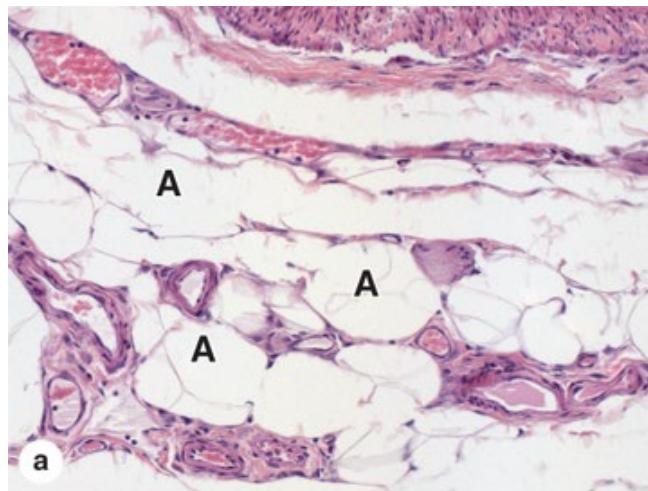
(d) Dense irregular connective tissue (D) forms a thick, protective capsule around many organs such as the testis shown here. Here the capsule is covered by a simple squamous epithelium of serous mesothelial cells (S), which produce a hyaluronate-rich lubricant around such organs. (X150; H&E)



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Dense regular connective tissue.

- (a) Micrograph shows a longitudinal section of dense regular connective tissue in a tendon. Long, parallel bundles of collagen fibers fill the spaces between the elongated nuclei of fibrocytes. (X100; H&E stain)
- (b) The electron micrograph shows one fibrocyte in a cross section of tendon, revealing that the sparse cytoplasm of the fibrocytes is divided into numerous thin cytoplasmic processes extending among adjacent collagen fibers. (X25,000)



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White adipose tissue.

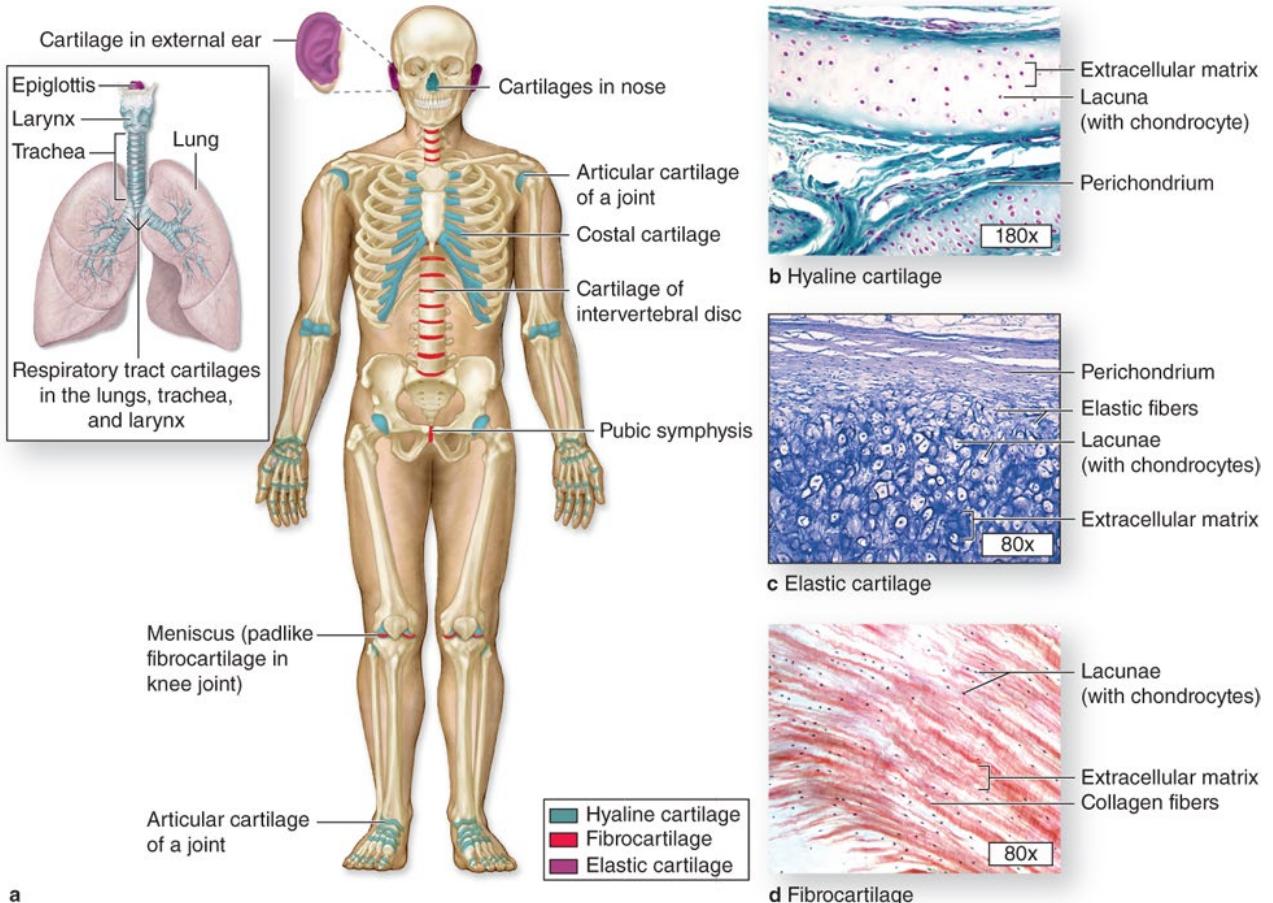
White or unilocular adipose tissue is commonly seen in sections of many human organs.

(a) Large white adipocytes (A) are seen in the connective tissue associated with small blood vessels. The fat cells are empty because lipid was dissolved away in slide preparation. Nuclei at the cell membranes are visible in some of the fat cells. (X100; H&E)

(b) Large (empty) adipocytes predominate in this typical white adipose tissue, which shows only a small portion of microvasculature. In a single histologic section, nuclei of most very large adipocytes are not included. (X100; H&E)

(c) Tissue was fixed here with osmium tetroxide, which preserves lipid (L) and stains it black. Many adipocytes in this slide retain at least part of their large lipid droplets. (X440; Osmium tetroxide)

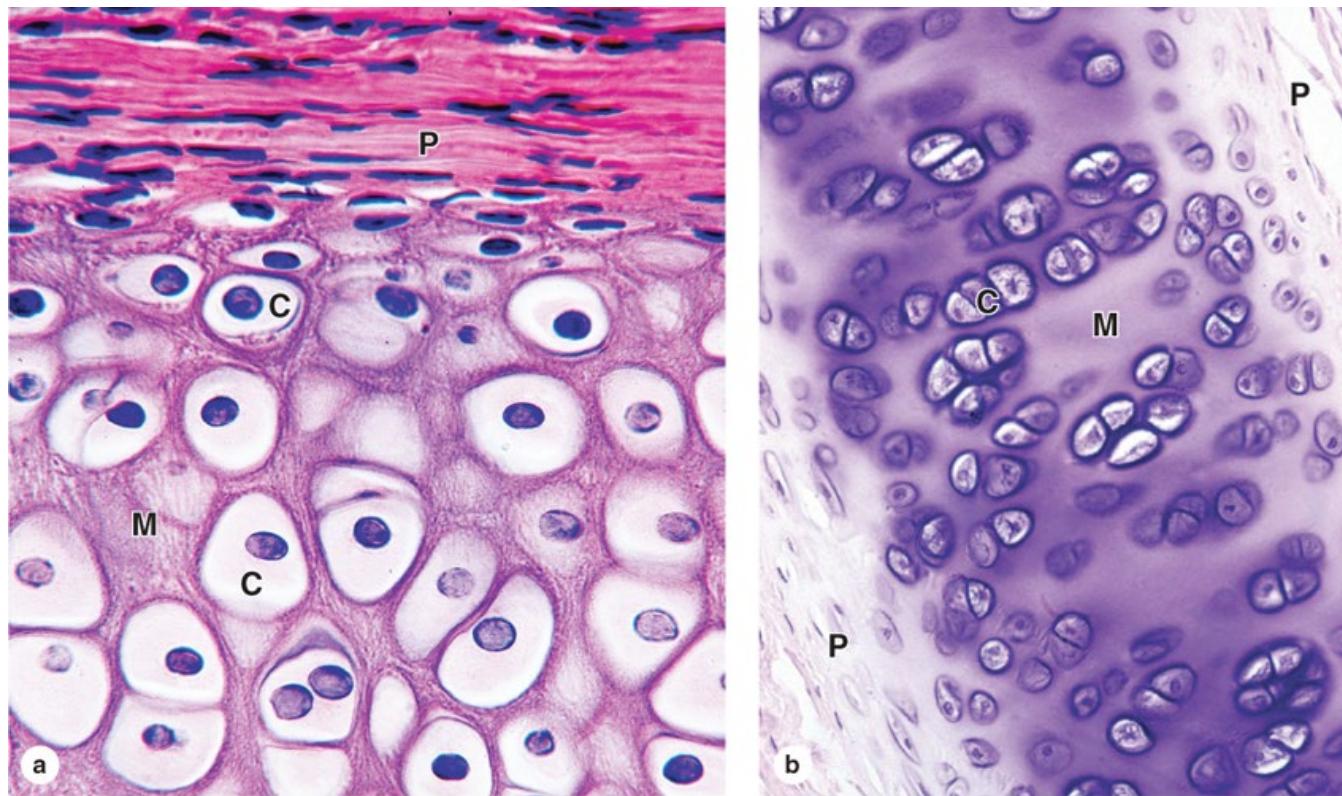
(d) In this specimen from a young mammal the smaller adipocytes marked with asterisks are not unilocular, having many lipid droplets of various sizes. Such cells in white fat represent those in which differentiation is incomplete as well as a small subpopulation of beige cells with brown fat-forming potential. The eccentric nuclei of the unilocular cells are indicated by arrowheads. (X200; PT)



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Distribution of cartilage in adults.

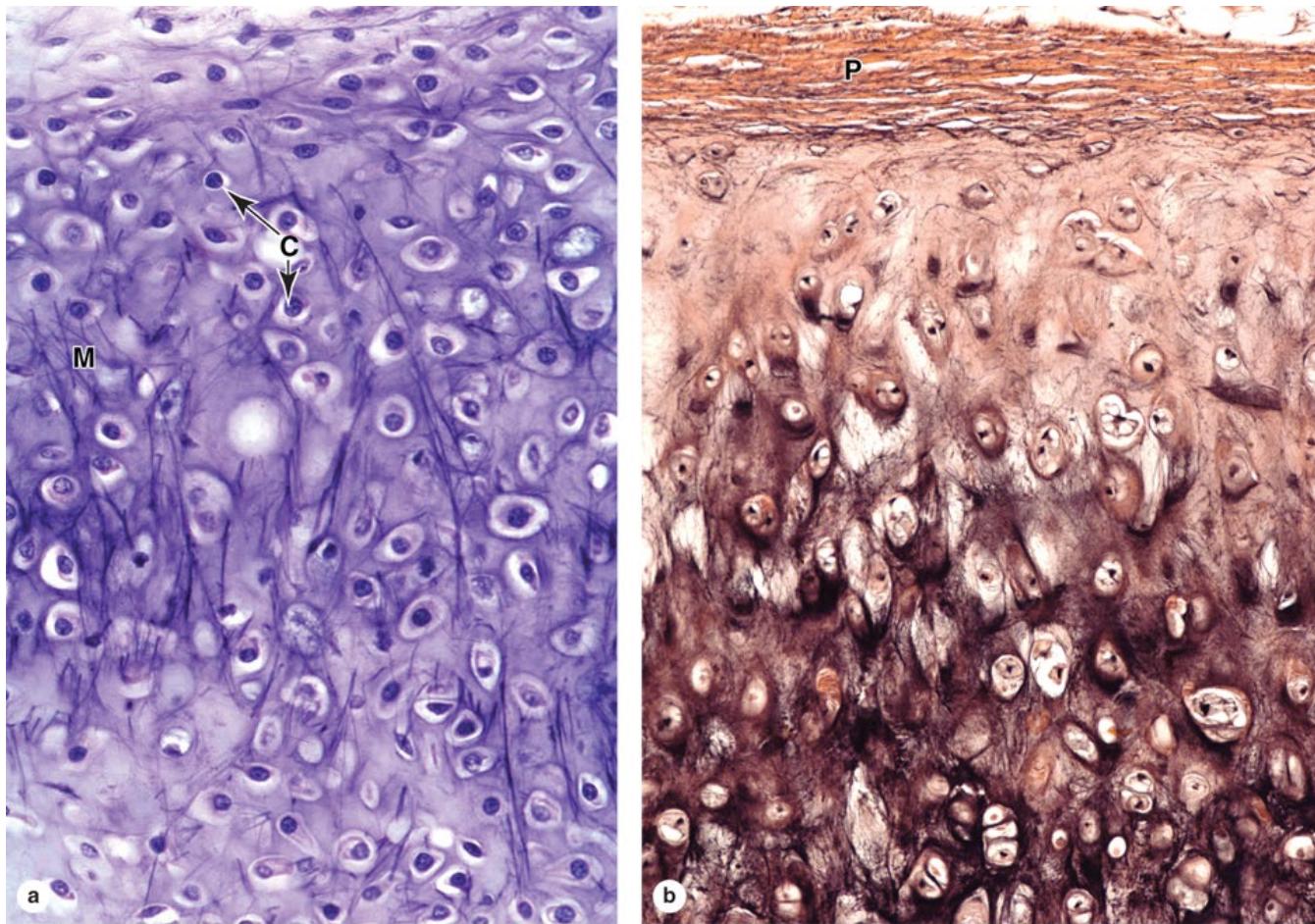
(a) There are three types of adult cartilage distributed in many areas of the skeleton, particularly in joints and where pliable support is useful, as in the ribs, ears, and nose. Cartilage support of other tissues throughout the respiratory tract is also prominent. The photomicrographs show the main features of (b) hyaline cartilage, (c) elastic cartilage, and (d) fibrocartilage. Dense connective tissue of perichondrium is shown here with hyaline and elastic cartilage.



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Hyaline cartilage.

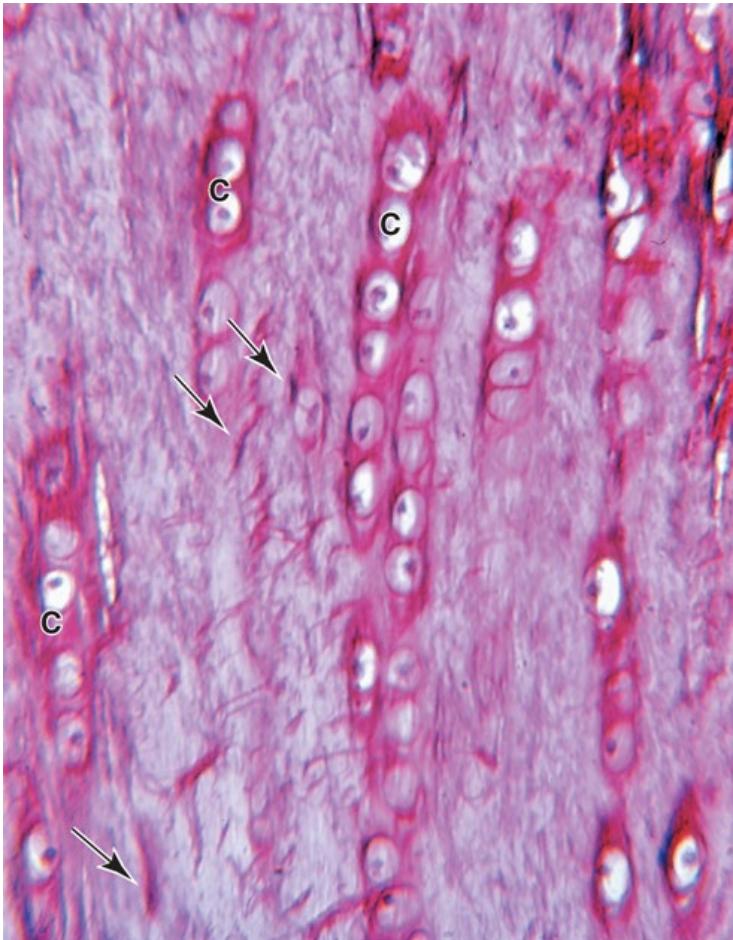
- (a) The upper part of the photo shows the perichondrium (P), an example of dense connective tissue consisting largely of type I collagen. Among the fibroblastic cells of the perichondrium are indistinguishable mesenchymal stem cells. There is a gradual transition and differentiation of cells from the perichondrium to the cartilage, with some elongated fibroblast-like cells becoming larger and more rounded as chondroblasts and chondrocytes (C). These are located within lacunae surrounded by the matrix (M) which these cells secreted. (X200; H&E)
- (b) The thin region of hyaline cartilage shown here has perichondrium (P) on both sides and shows larger lacunae containing isogenous groups of chondrocytes (C) within the matrix (M). Such groups of two, four, or more cells are produced by mitosis; the cells will separate into individual lacunae as they begin to secrete matrix. Territorial matrix immediately around the chondrocytes is more basophilic than interterritorial matrix farther from the cells. (X160; H&E)



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Elastic cartilage.

The chondrocytes (C) and overall organization of elastic cartilage are similar to those of hyaline cartilage, but the matrix (M) also contains elastic fibers that can be seen as darker components with proper staining. The abundant elastic fibers provide greater flexibility to this type of cartilage. The section in part b includes perichondrium (P) that is also similar to that of hyaline cartilage. (a) X160; Hematoxylin and orcein. (b) X180; Weigert resorcin and van Gieson.

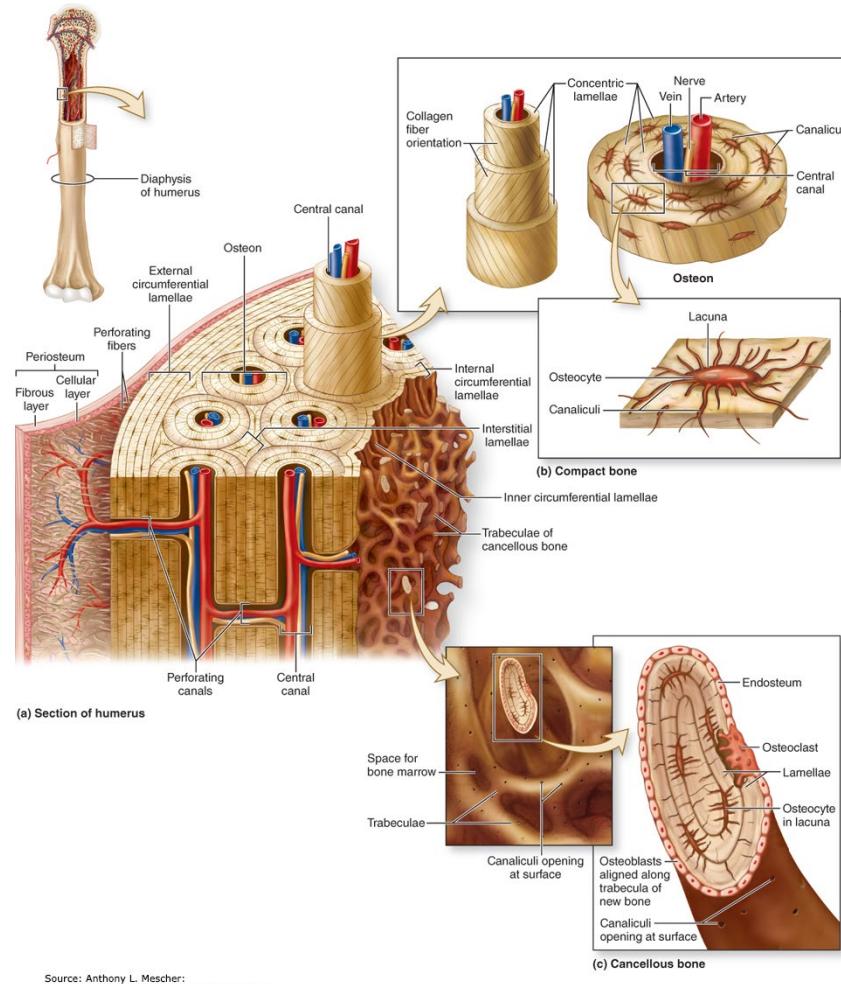


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Fibrocartilage.

Fibrocartilage varies histologically in different structures, but is always essentially a mixture of hyaline cartilage and dense connective tissue.

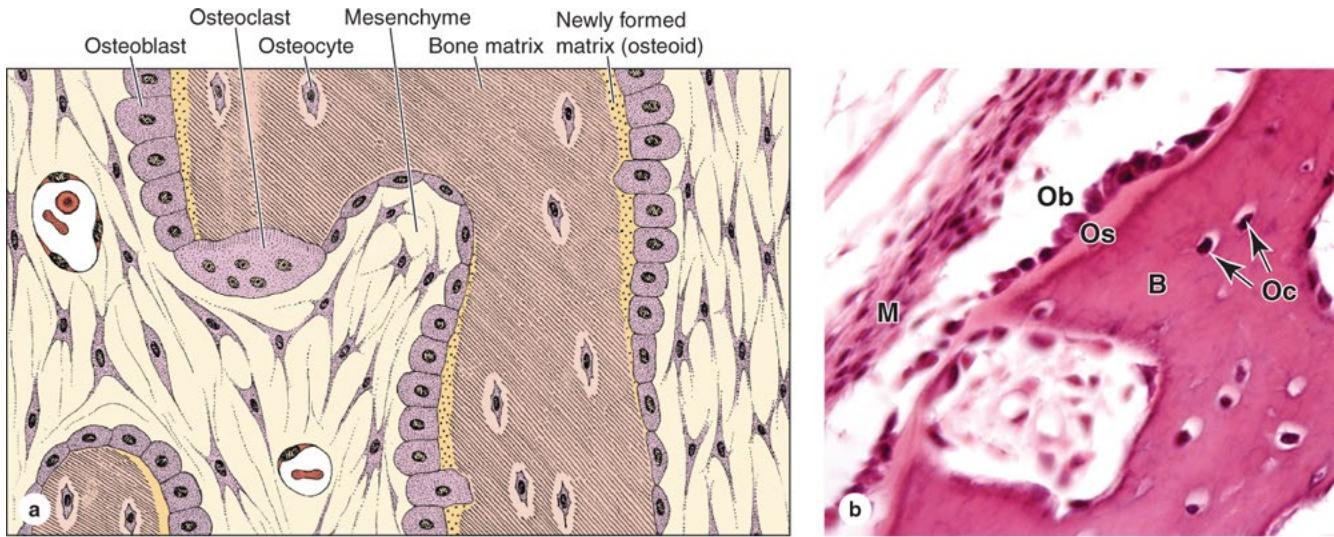
In a small region of intervertebral disc, the axially arranged aggregates of chondrocytes (C) are seen to be surrounded by small amounts of matrix and separated by larger regions with dense collagen and scattered fibroblasts with elongated nuclei (arrows). (X250; Picosirius-hematoxylin)



Components of bone.

A schematic overview of the basic features of bone, including the three key cell types: osteocytes, osteoblasts, and osteoclasts; their usual locations; and the typical lamellar organization of bone. Osteoblasts secrete the matrix that then hardens by calcification, trapping the differentiating cells now called osteocytes in individual lacunae. Osteocytes maintain the calcified matrix and receive nutrients from microvasculature in the central canals of the osteons via very small channels called canaliculi that interconnect the lacunae. Osteoclasts are monocyte-derived cells in bone required for bone remodeling.

The periosteum consists of dense connective tissue, with a primarily fibrous layer covering a more cellular layer. Bone is vascularized by small vessels that penetrate the matrix from the periosteum. Endosteum covers all trabeculae around the marrow cavities.

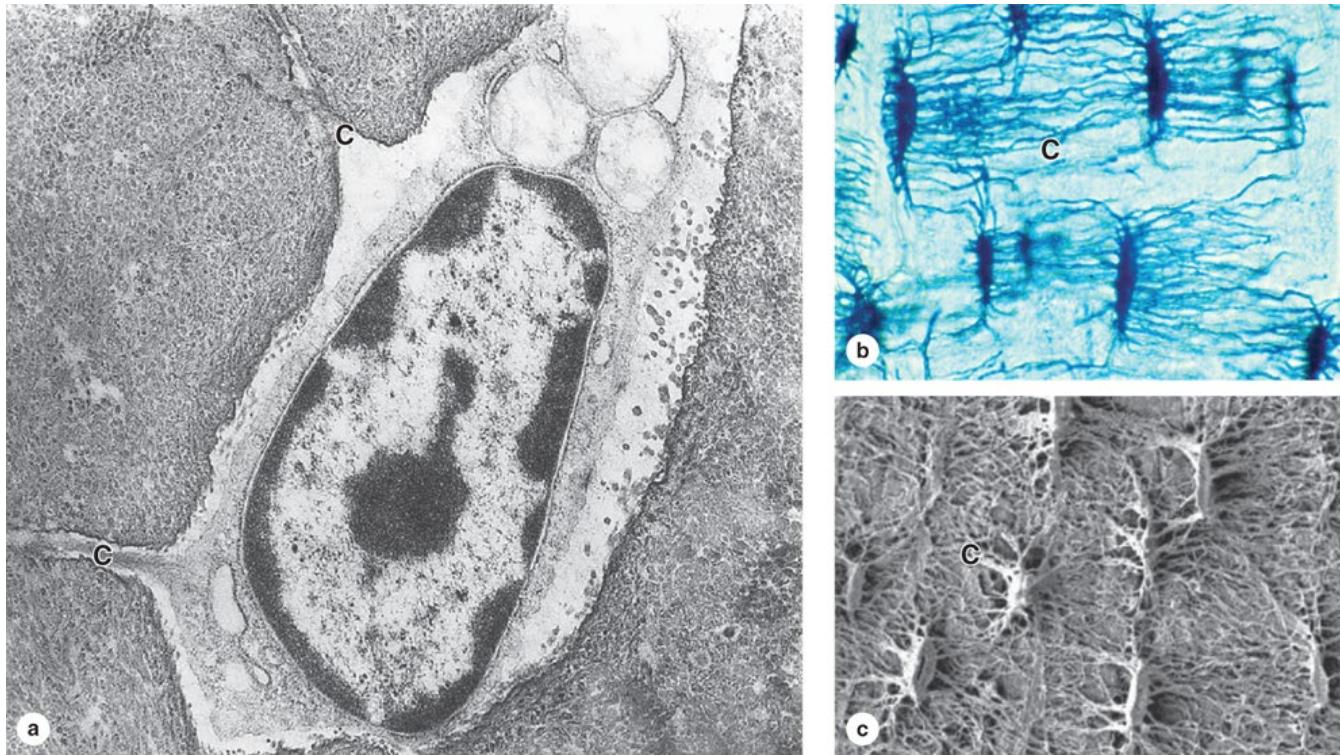


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Osteoblasts, osteocytes, and osteoclasts.

(a) Diagram showing the relationship of osteoblasts to the newly formed matrix called "osteoid," bone matrix, and osteocytes. Osteoblasts and most of the larger osteoclasts are part of the endosteum covering the bony trabeculae.

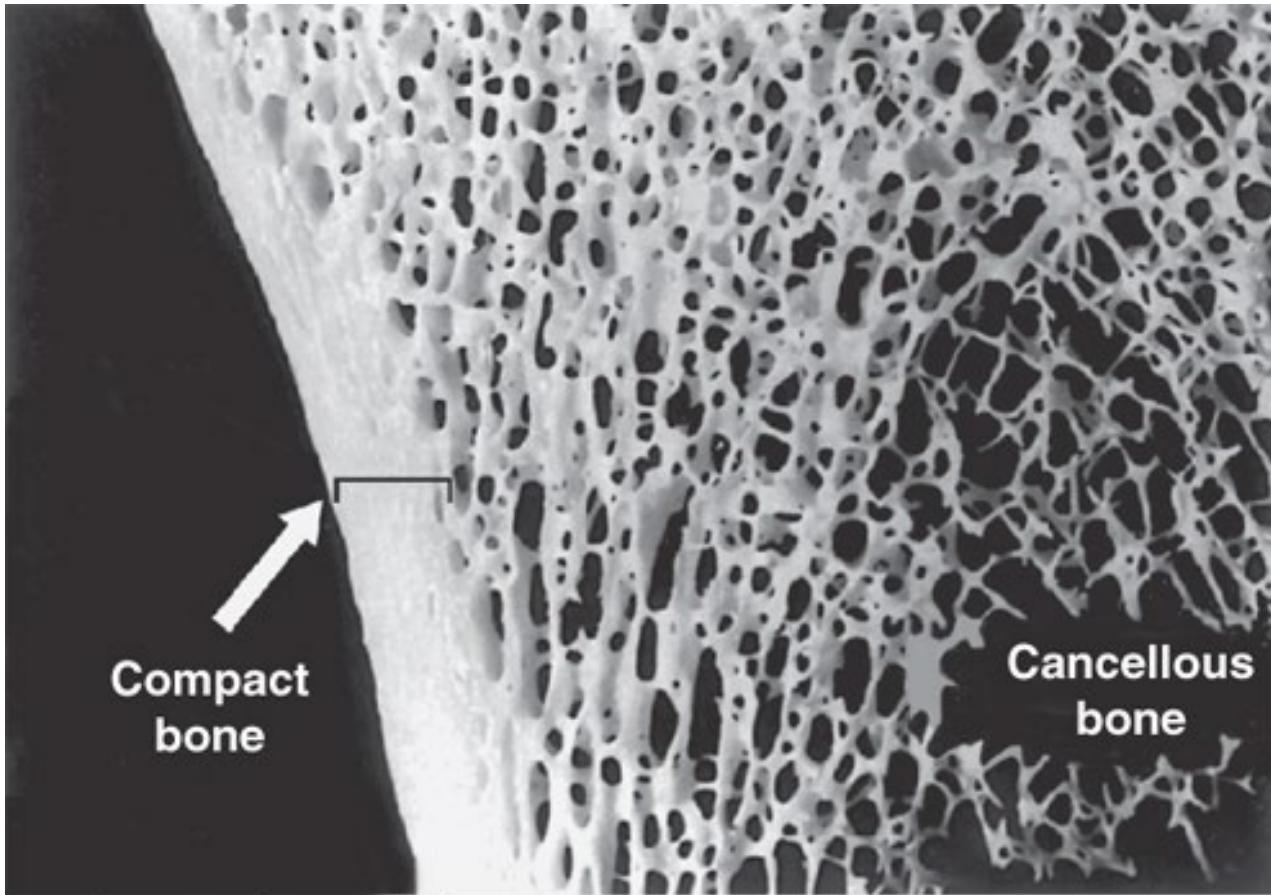
(b) The photomicrograph of developing bone shows the location and morphologic differences between active osteoblasts (Ob) and osteocytes (Oc). Rounded osteoblasts, derived from progenitor cells in the adjacent mesenchyme (M), cover a thin layer of lightly stained osteoid (Os) on the surface of the more heavily stained bony matrix (B). Most osteoblasts that are no longer actively secreting osteoid will undergo apoptosis; others differentiate either as flattened bone lining cells on the trabeculae of bony matrix or as osteocytes located within lacunae surrounded by bony matrix. (X300; H&E)



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Osteocytes in lacunae.

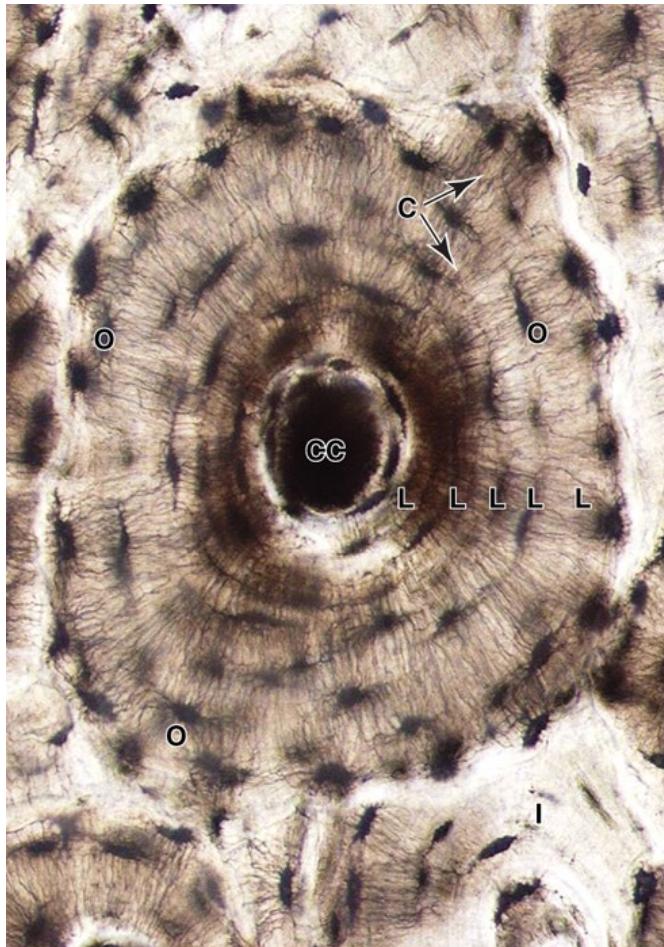
- (a) TEM showing an osteocyte in a lacuna and two dendritic processes in canaliculi (C) surrounded by bony matrix. Many such processes are extended from each cell as osteoid is being secreted; this material then undergoes calcification around the processes, giving rise to canaliculi. (X30,000)
- (b) Photomicrograph of bone, not decalcified or sectioned, but ground very thin to demonstrate lacunae and canaliculi. The lacunae and canaliculi (C) appear dark and show the communication between these structures through which nutrients derived from blood vessels diffuse and are passed from cell to cell in living bone. (X400; Ground bone)
- (c) SEM of nondecalcified, sectioned, and acid-etched bone showing lacunae and canaliculi (C). (X400)
(Figure 8–5c, used with permission from Dr Matt Allen, Indiana University School of Medicine, Indianapolis.)



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Compact and cancellous bone.

Macroscopic photo of a thick section of bone showing the cortical compact bone and the lattice of trabeculae in cancellous bone at the bone's interior. The small trabeculae that make up highly porous cancellous bone serve as supportive struts, collectively providing considerable strength, without greatly increasing the bone's weight. The compact bone is normally covered externally with periosteum and all trabecular surfaces of the cancellous bone are covered with endosteum. (X10)

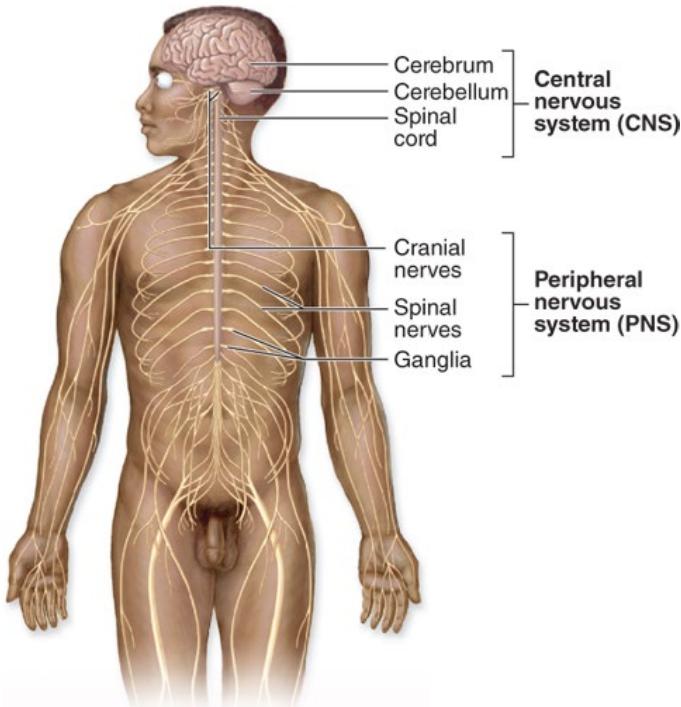


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An osteon.

Osteons (Haversian systems) constitute most of the compact bone. Shown here is an osteon with four to five concentric lamellae (L) surrounding the central canal (CC). Osteocytes (O) in lacunae are in communication with each other and with the central canal and periphery of the osteon via through hundreds of dendritic processes located within fine canaliculi (C). Also shown are the partial, interstitial lamellae (I) of an osteon that was eroded when the intact osteon was formed. (Ground bone; X500)

Nervous Tissue



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The general organization of the nervous system.

Anatomically the nervous system is divided into the CNS and PNS, which have the major components shown in the diagram.

Functionally the nervous system consists of the following: Sensory division (afferent)

Somatic—sensory input perceived consciously (eg, from eyes ears, skin, and musculoskeletal structures)

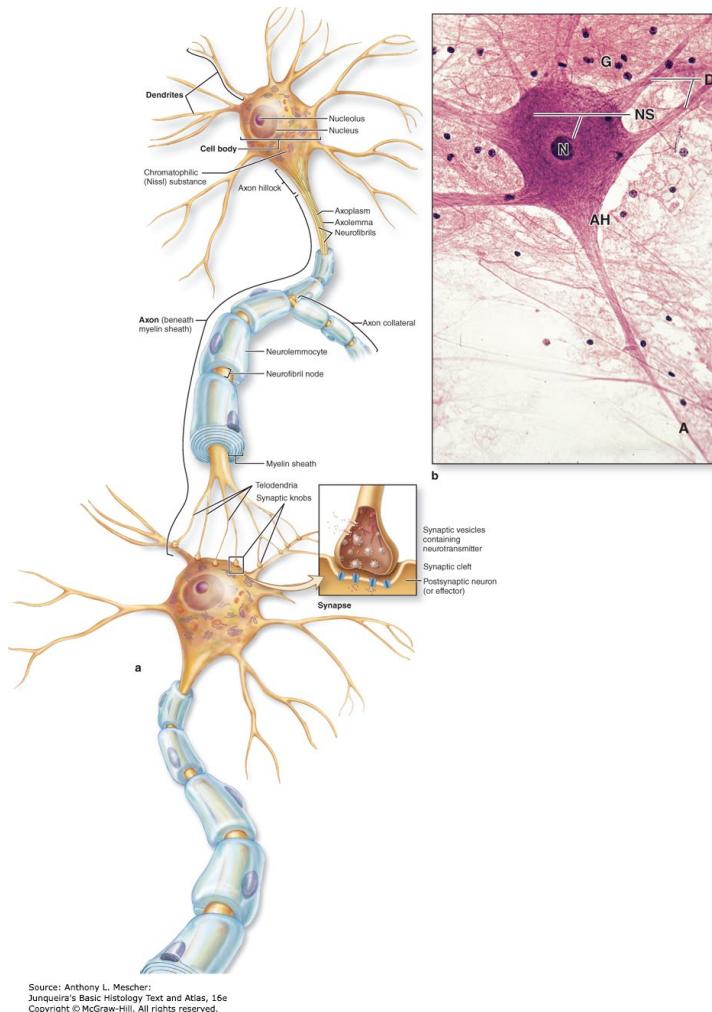
Visceral—sensory input not perceived consciously (eg, from internal organs and cardiovascular structures)

Motor division (efferent)

Somatic—motor output controlled consciously or voluntarily (eg, by skeletal muscle effectors)

Autonomic—motor output not controlled consciously (eg, by heart or gland effectors)

The autonomic motor nerves, comprising what is often called the autonomic nervous system (ANS), all have pathways involving two neurons: a preganglionic neuron with the cell body in the CNS and a postganglionic neuron with the cell body in a ganglion. The ANS has two divisions: (1) The parasympathetic division, with its ganglia within or near the effector organs, maintains normal body homeostasis. (2) The sympathetic division has its ganglia close to the CNS and controls the body's responses during emergencies and excitement. ANS components located in the wall of the digestive tract are sometimes referred to as the enteric nervous system.



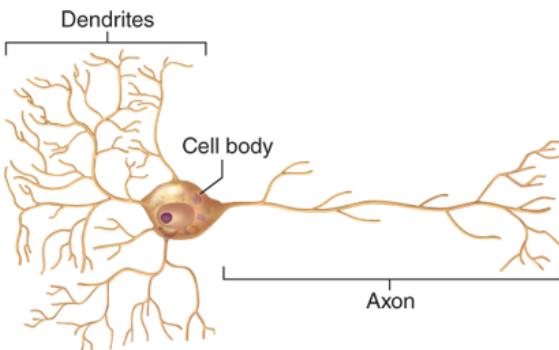
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Structures of a typical neuron.

Axons may also receive information from other neurons, information that mainly modifies the transmission of action potentials to those neurons.

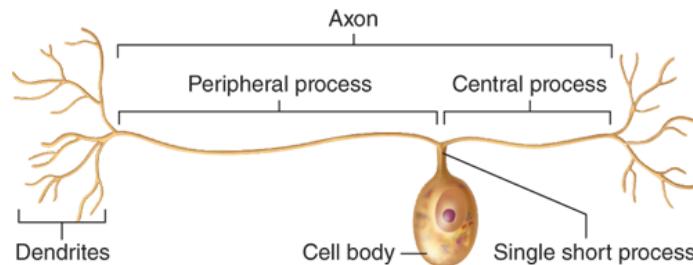
(a) A "typical" neuron has three major parts: (1) The cell body (also called the perikaryon or soma) is often large, with a large, euchromatic nucleus and well-developed nucleolus. The cytoplasmic contains basophilic Nissl substance or Nissl bodies, which are large masses of free polysomes and RER indicating the cell's high rate of protein synthesis. (2) Numerous short dendrites extend from the perikaryon, receiving input from other neurons. (3) A long axon carries impulses from the cell body and is covered by a myelin sheath composed of other cells. The ends of axons usually have many small branches (telodendria), each of which ends in a knob-like structure that forms part of a functional connection (synapse) with another neuron or other cell.

(b) Micrograph of a large motor neuron showing the large cell body and nucleus (N), a long axon (A) emerging from an axon hillock (AH), and several dendrites (D). Nissl substance (NS) can be seen throughout the cell body and cytoskeletal elements can be detected in the processes. Nuclei of scattered glial cells (G) are seen among the surrounding tissue. (X100; H&E)



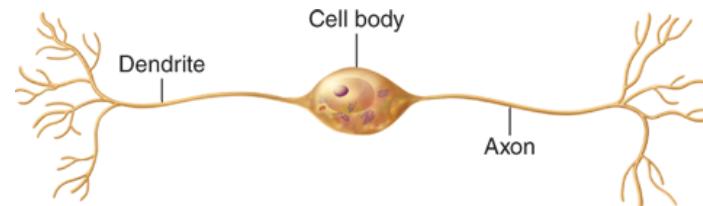
(a) Multipolar neuron

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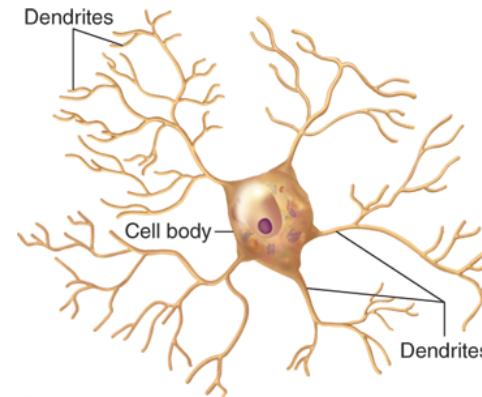
(c) Unipolar neuron

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(b) Bipolar neuron

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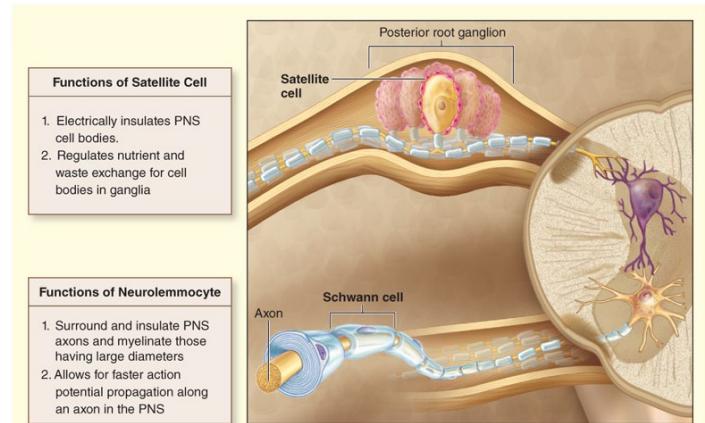
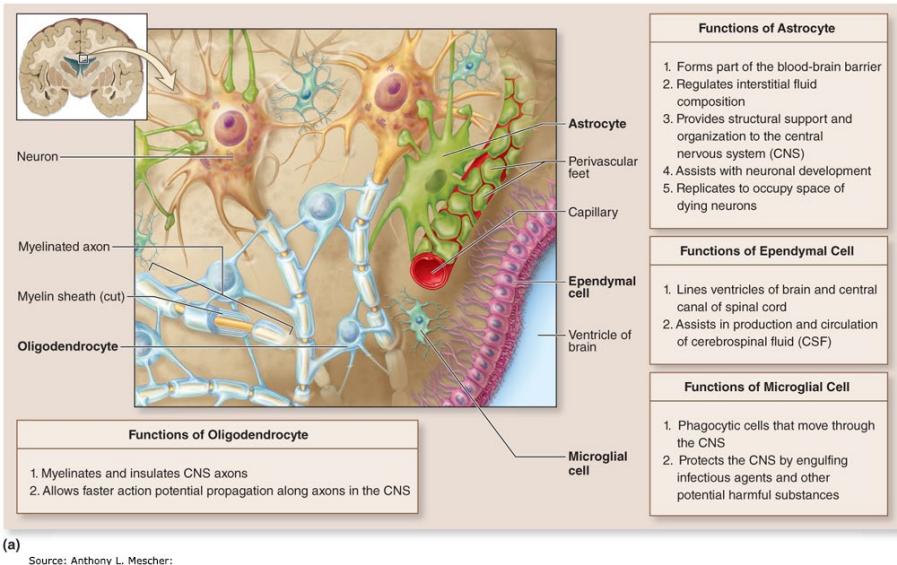


(d) Anaxonic neuron

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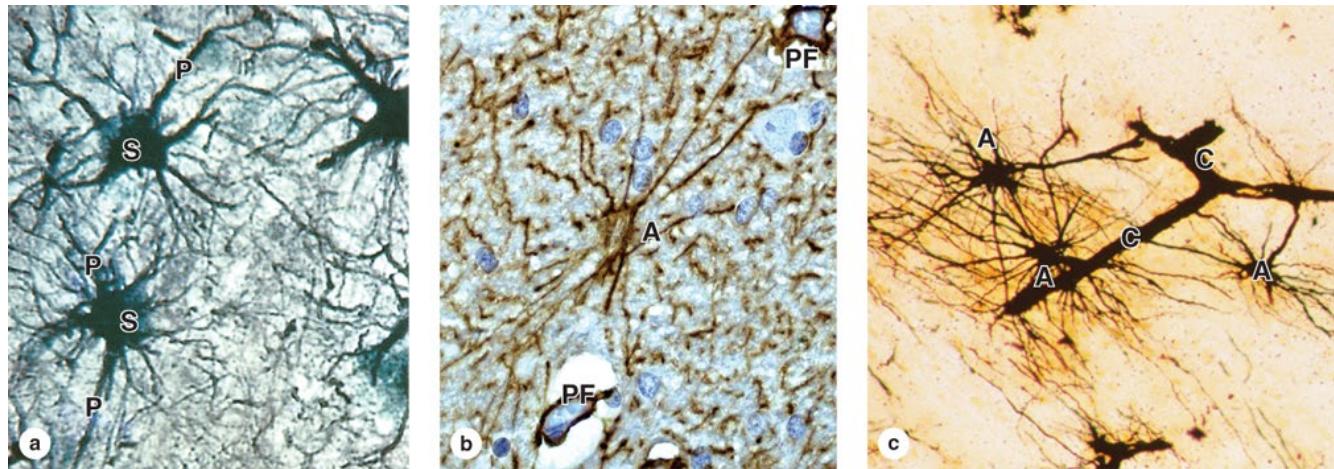
Structural classes of neurons.

Shown are the four main types of neurons, with short descriptions. (a) Most neurons, including all motor neurons and most CNS interneurons, are multipolar. (b) Bipolar neurons include sensory neurons of the retina, olfactory mucosa, and inner ear. (c) All other sensory neurons are unipolar or pseudounipolar. (d) The anaxonic configuration, found only in certain CNS interneurons, lack true axons and do not produce action potentials, but regulate local electrical changes of adjacent neurons.



Glial cells of the CNS and PNS.

- (a) There are four major kinds of glial cells in the CNS: oligodendrocytes, astrocytes, ependymal cells, and microglial cells. The interrelationships and major functions of these cells are shown diagrammatically here.
- (b) Two glial cells occur in the PNS: Schwann cells (sometimes called neurolemmocytes), which surround peripheral nerve fibers, and satellite cells, which surround the nerve cell bodies and are thus found only in ganglia. Major functions of these cells are indicated.



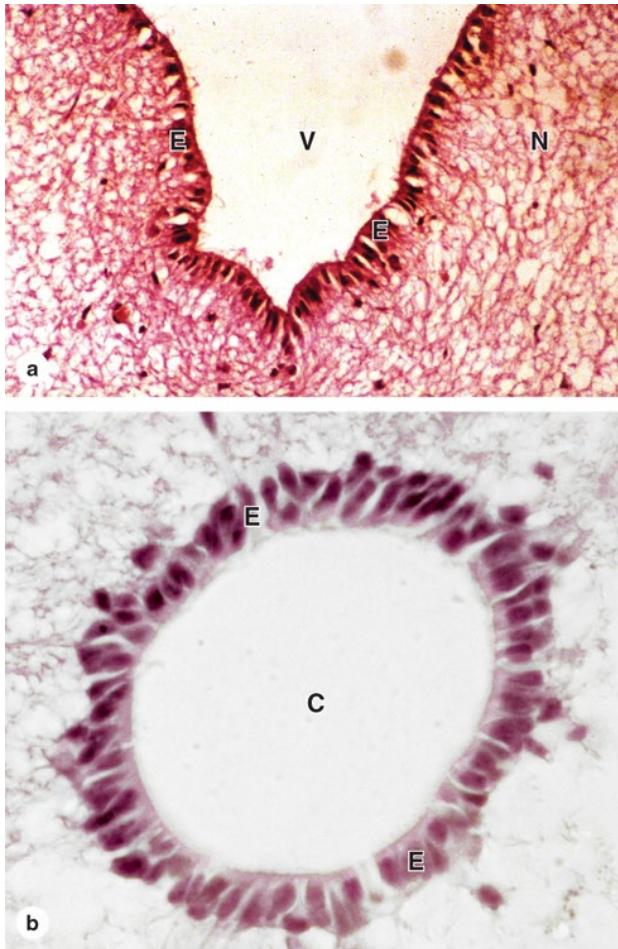
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Astrocytes.

(a) Astrocytes are the most abundant glial cells of the CNS and are characterized by numerous cytoplasmic processes (P) radiating from the glial cell body or soma (S). Astrocytic processes are not seen with routine light microscope staining but are easily seen after gold staining. Morphology of the processes allows astrocytes to be classified as fibrous (relatively few and straight processes) or protoplasmic (numerous branching processes), but functional differences between these types are not clear. (X500; Gold chloride)

(b) All astrocytic processes contain intermediate filaments of GFAP, and antibodies against this protein provide a simple method to stain these cells, as seen here in a fibrous astrocyte (A) and its processes. The small pieces of other GFAP-positive processes in the neuropil around this cell give an idea of the density of this glial cell and its processes in the CNS. Astrocytes form part of the blood-brain barrier (BBB) and help regulate entry of molecules and ions from blood into CNS tissue. Capillaries at the extreme upper right and lower left corners are enclosed by GFAP-positive perivascular feet (PF) at the ends of numerous astrocytic processes. (X500; Anti-GFAP immunoperoxidase and hematoxylin counterstain)

(c) A length of capillary (C) is shown here completely covered by silver-stained terminal processes extending from astrocytes (A). (X400; Rio Hortega silver)



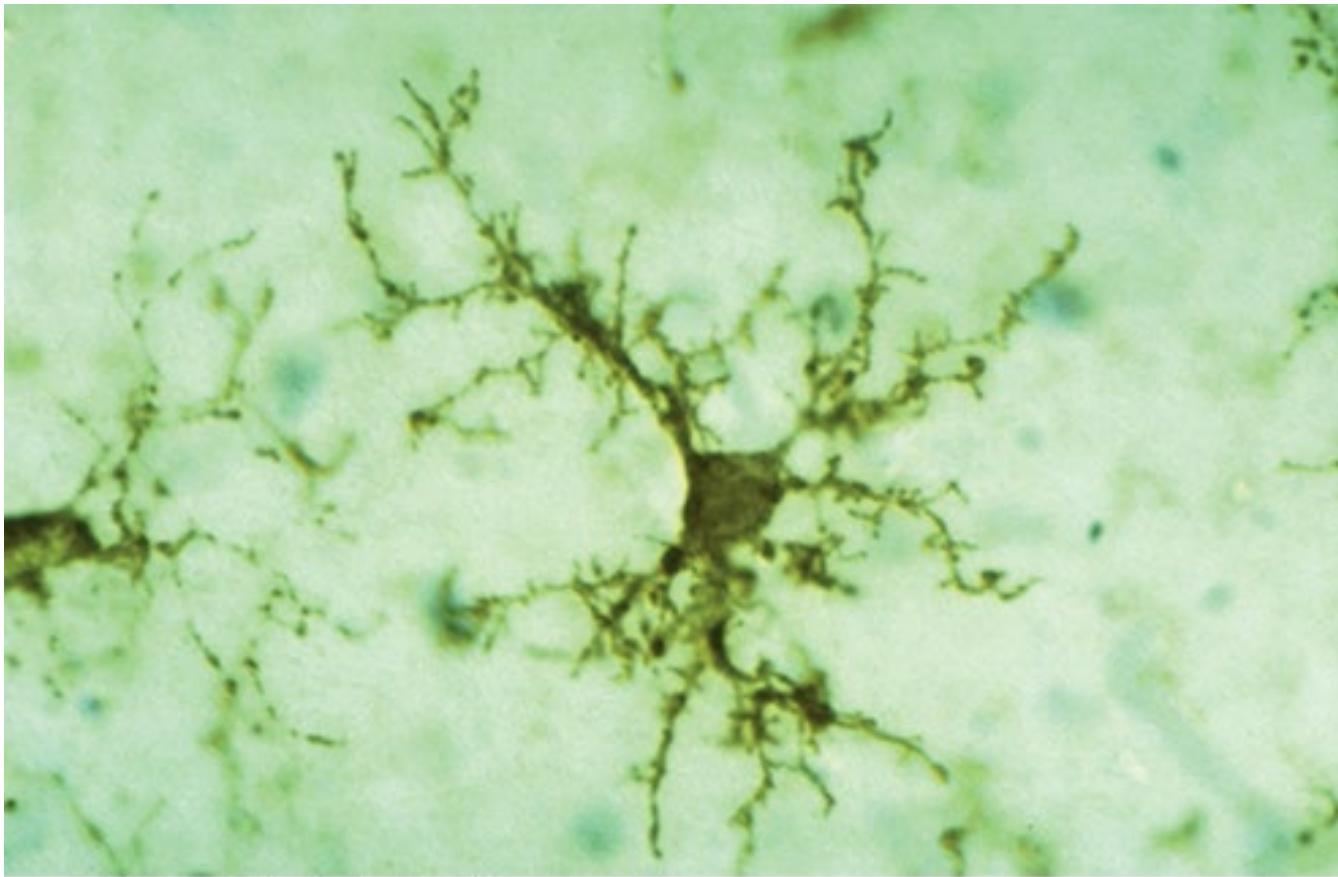
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Ependymal cells.

Ependymal cells are epithelial-like cells that form a single layer lining the fluid-filled ventricles and central canal of the CNS.

(a) Lining the ventricles of the cerebrum, columnar ependymal cells (E) extend cilia and microvilli from the apical surfaces into the ventricle (V). These modifications help circulate the CSF and monitor its contents. Ependymal cells have junctional complexes at their apical ends like those of epithelial cells but lack a basal lamina. The cells' basal ends are tapered, extending processes that branch and penetrate some distance into the adjacent neuropil (N). Other areas of ependyma are responsible for production of CSF. (X100; H&E)

(b) Ependymal cells (E) lining the central canal (C) of the spinal cord help move CSF in that CNS region. (X200; H&E)

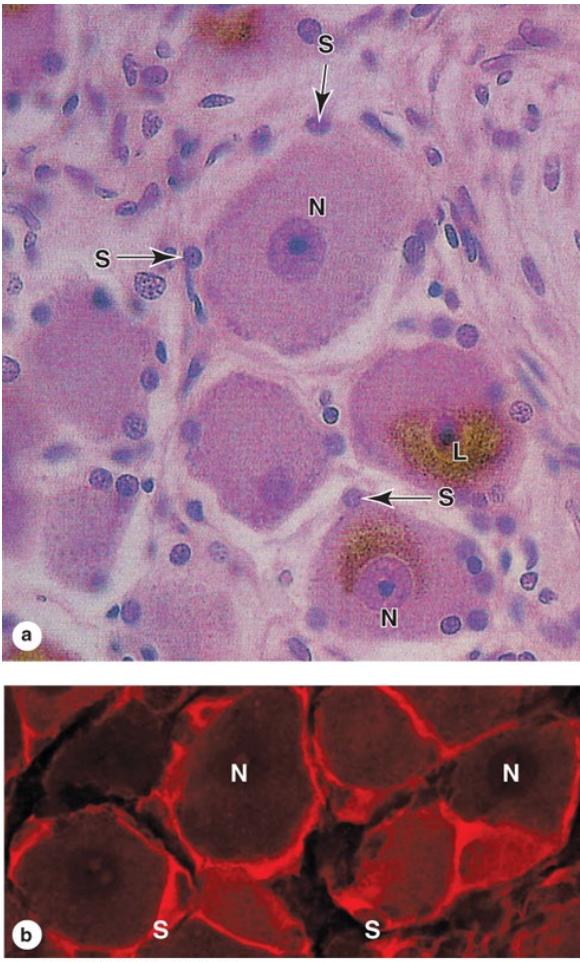


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Microglial cells.

Microglia are monocyte-derived, antigen-presenting cells of the CNS, less numerous than astrocytes but nearly as common as neurons and evenly distributed in both gray and white matter. By immunohistochemistry, here using a monoclonal antibody against human leukocyte antigens (HLA) of immune-related cells, the short branching processes of microglia can be seen. Routine staining demonstrates only the small dark nuclei of the cells. Unlike other glia of the CNS, microglia are not interconnected; they are motile cells, constantly used in immune surveillance of CNS tissues. When activated by products of cell damage or by invading microorganisms, the cells retract their processes, begin phagocytosing the damage- or danger-related material, and behave as antigen-presenting cells. (X500; Antibody against HLA-DR and peroxidase)

(Used with permission from Wolfgang Streit, Department of Neuroscience, University of Florida College of Medicine, Gainesville.)

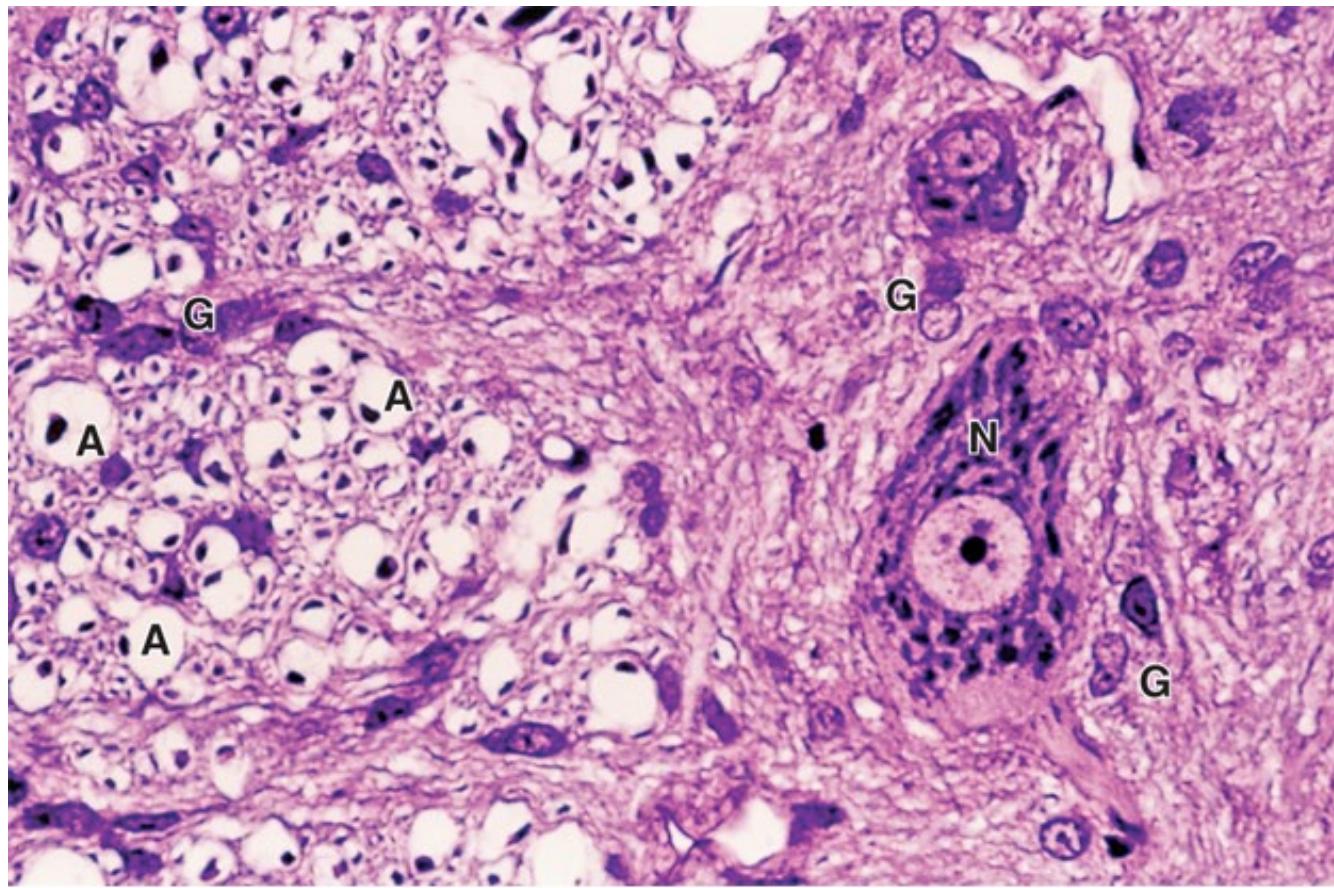


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Satellite cells around neurons of ganglia in the PNS.

- Satellite cells are very closely associated with neuronal cell bodies in sensory and autonomic ganglia of the PNS and support these cells in various ways.
- (a) Nuclei of the many satellite cells (S) surrounding the perikarya of neurons (N) in an autonomic ganglion can be seen by light microscopy, but their cytoplasmic extensions are too thin to see with H&E staining. These long-lived neurons commonly accumulate brown lipofuscin (L). (X560; H&E)
 - (b) Immunofluorescent staining of satellite cells (S) reveals the cytoplasmic sheets extending from these cells and surrounding the neuronal cell bodies (N). The layer of satellite cells around each soma is continuous with the myelin sheath around the axon. Like the effect of Schwann cells on axons, satellite glial cells insulate, nourish, and regulate the microenvironment of the neuronal cell bodies. (X600; Rhodamine red-labeled antibody against glutamine synthetase)

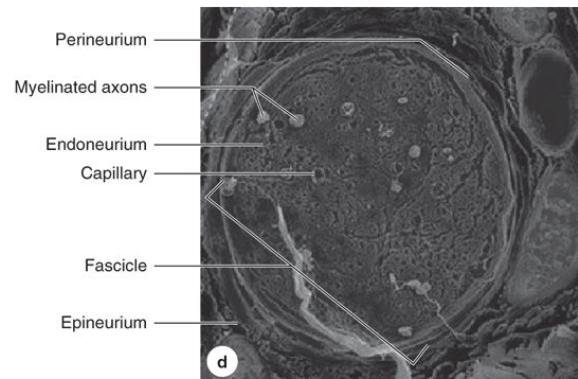
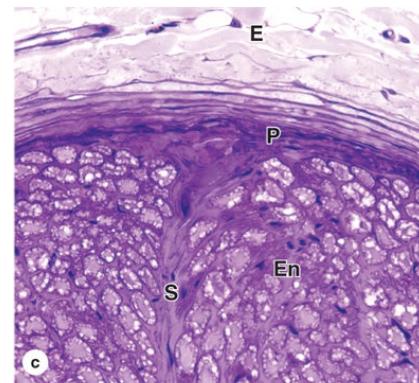
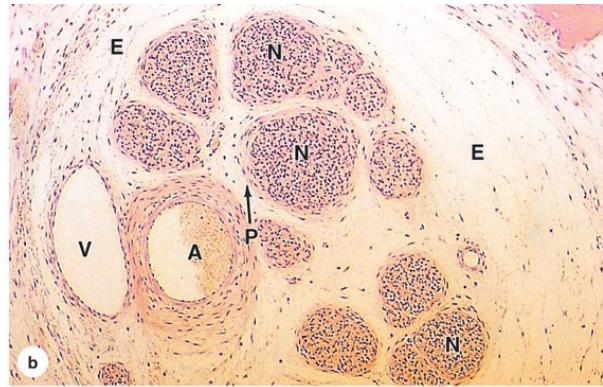
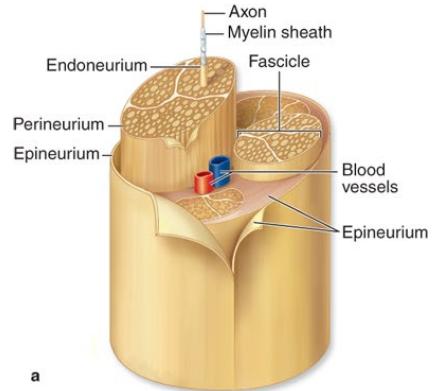
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White versus gray matter.

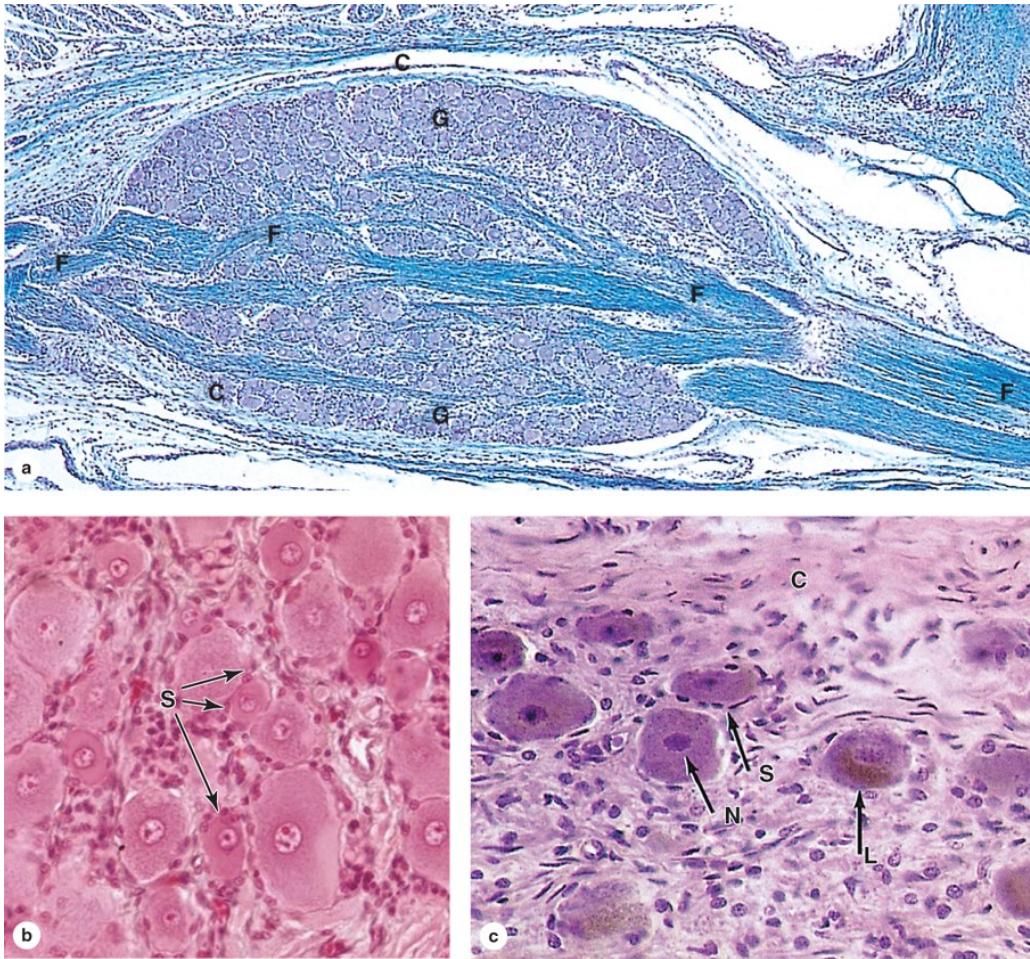
A cross section of H&E-stained spinal cord shows the transition between white matter (left region) and gray matter (right). The gray matter has many glial cells (G), neuronal cell bodies (N), and neuropil; white matter also contains glia (G) but consists mainly of axons (A) whose myelin sheaths were lost during preparation, leaving the round empty spaces shown. Each such space surrounds a dark-stained spot that is a small section of the axon. (X400)



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Peripheral nerve connective tissue: Epi-, peri-, and endoneurium.

- (a) The diagram shows the relationship among these three connective tissue layers in large peripheral nerves. The epineurium (E) consists of a dense superficial region and a looser deep region that contains the larger blood vessels.
- (b) The micrograph shows a small vein (V) and artery (A) in the deep epineurium (E). Nerve fibers (N) are bundled in fascicles. Each fascicle is surrounded by the perineurium (P), consisting of a few layers of unusual squamous fibroblastic cells that are all joined at the peripheries by tight junctions. The resulting blood-nerve barrier helps regulate the microenvironment inside the fascicle. Axons and Schwann cells are in turn surrounded by a thin layer of endoneurium. (X140; H&E)
- (c) As shown here and in the diagram, septa (S) of connective tissue often extend from the perineurium into larger fascicles. The endoneurium (En) and lamellar nature of the perineurium (P) are also shown at this magnification, along with some adjacent epineurium (E). (X200; PT)
- (d) SEM of small, transversely cut nerve showing a single fascicle surrounded by distinct perineurium and packed with delicate endoneurium in which are located a few axons with myelin sheaths and many unmyelinated axons, all shown at higher magnification in the next figure. Endoneurium also contains sparse capillaries with tightly joined cells, another part of the blood-nerve barrier controlling release of substances from plasma into the axonal microenvironment. Dense, irregular connective tissue of the epineurium surrounds the perineurium and larger blood vessels (on far right of photo). A fragment of epineurium lies across the cut fascicle here. (X400)



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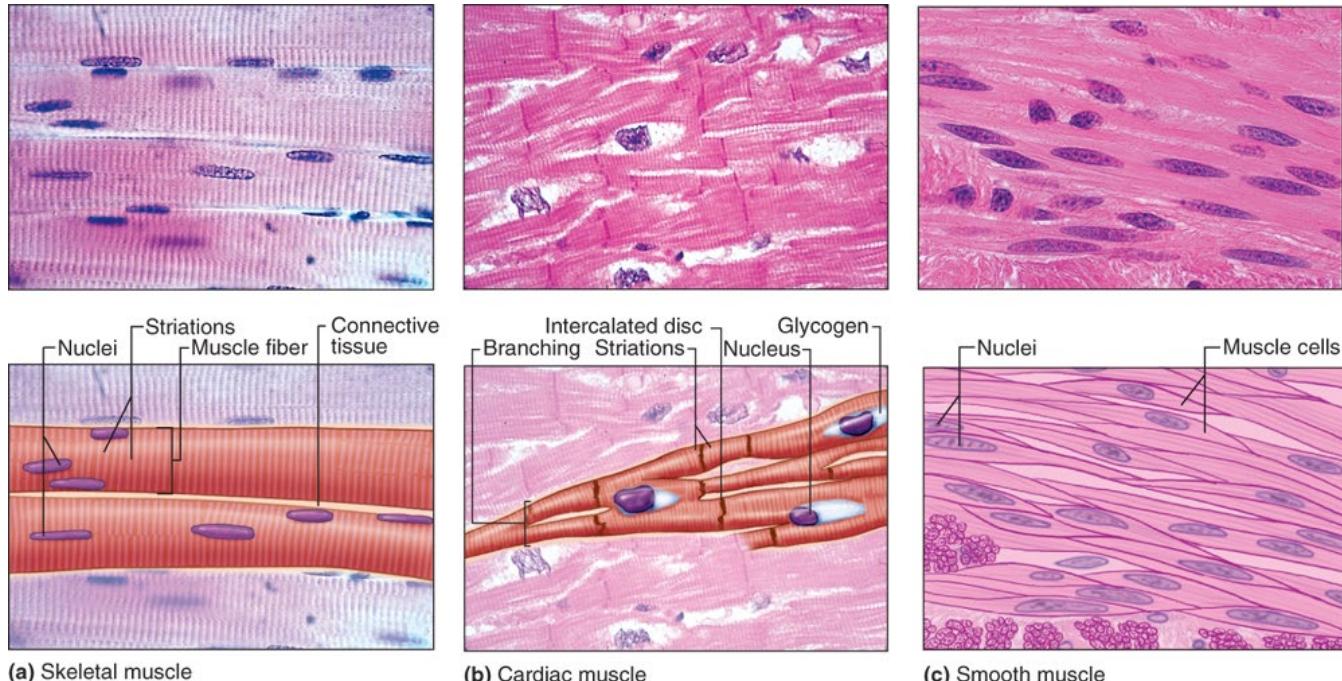
Ganglia.

(a) A sensory ganglion (G) has a distinct connective tissue capsule (C) and internal framework continuous with the epineurium and other components of peripheral nerves, except that no perineurium is present and that there is no blood-nerve barrier function. Fascicles of nerve fibers (F) enter and leave these ganglia. (X56; Kluver-Barrera stain)

(b) Higher magnification shows the small, rounded nuclei of glia cells called satellite cells (S) which produce thin, sheetlike cytoplasmic extensions that completely envelop each large neuronal perikaryon. (X400; H&E)

(c) Sympathetic ganglia are smaller than most sensory ganglia but similar in having large neuronal cell bodies (N), some containing lipofuscin (L). Sheets from satellite cells (S) enclose each neuronal cell body with morphology slightly different from that of sensory ganglia. Autonomic ganglia generally have less well-developed connective tissue capsules (C) than sensory ganglia. (X400; H&E)

Muscle



(a) Skeletal muscle

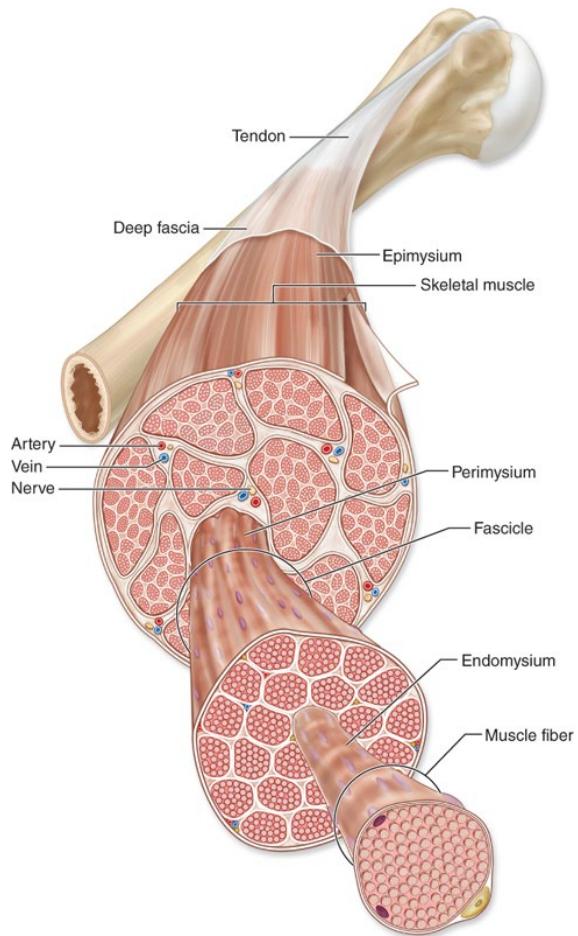
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(b) Cardiac muscle

(c) Smooth muscle

Three types of muscle.

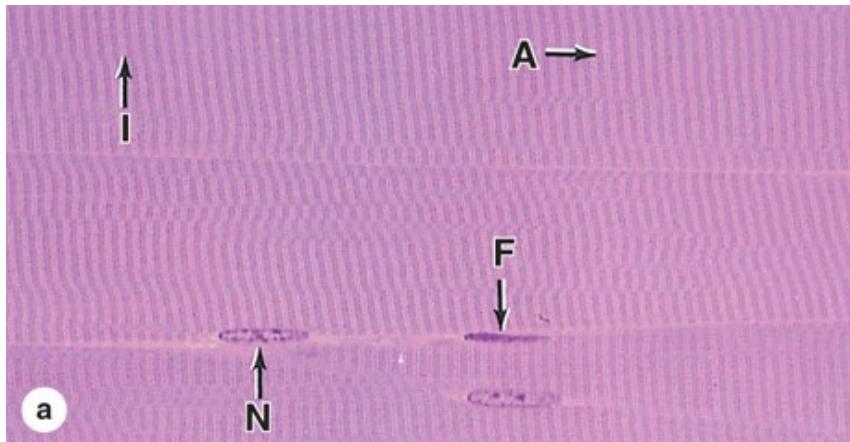
Light micrographs of each type, accompanied by labeled drawings. (a) Skeletal muscle is composed of large, elongated, multinucleated fibers that show strong, quick, voluntary contractions. (b) Cardiac muscle is composed of irregular branched cells bound together longitudinally by intercalated discs and shows strong, involuntary contractions. (c) Smooth muscle is composed of grouped, fusiform cells with weak, involuntary contractions. The density of intercellular packing seen reflects the small amount of extracellular connective tissue present. (a, b: X200; c: X300; All H&E)



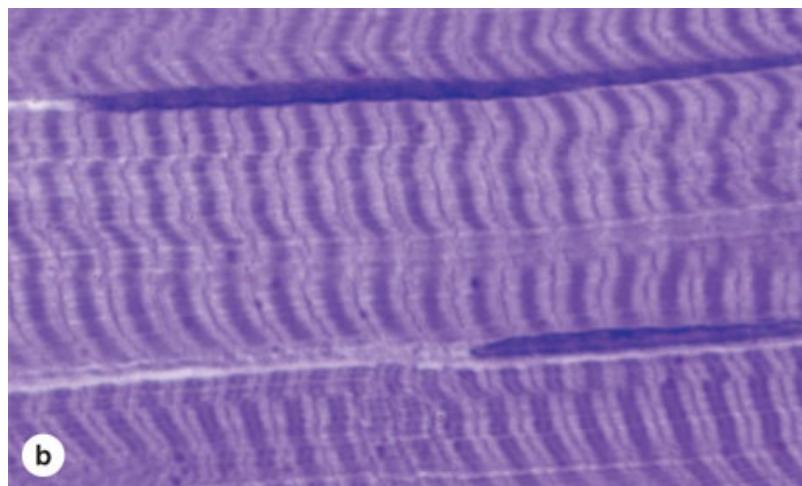
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Organization of skeletal muscle.

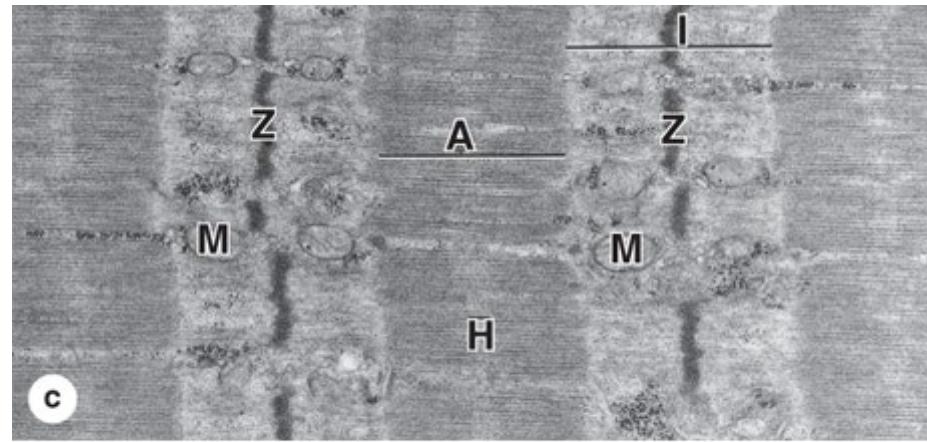
An entire skeletal muscle is enclosed within a thick layer of dense connective tissue called the epimysium that is continuous with fascia and the tendon binding muscle to bone. Large muscles contain several fascicles of muscle tissue, each wrapped in a thin but dense connective tissue layer called the perimysium. Within fascicles individual muscle fibers (elongated multinuclear cells) are surrounded by a delicate connective tissue layer, the endomysium.



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Striated skeletal muscle in longitudinal section.

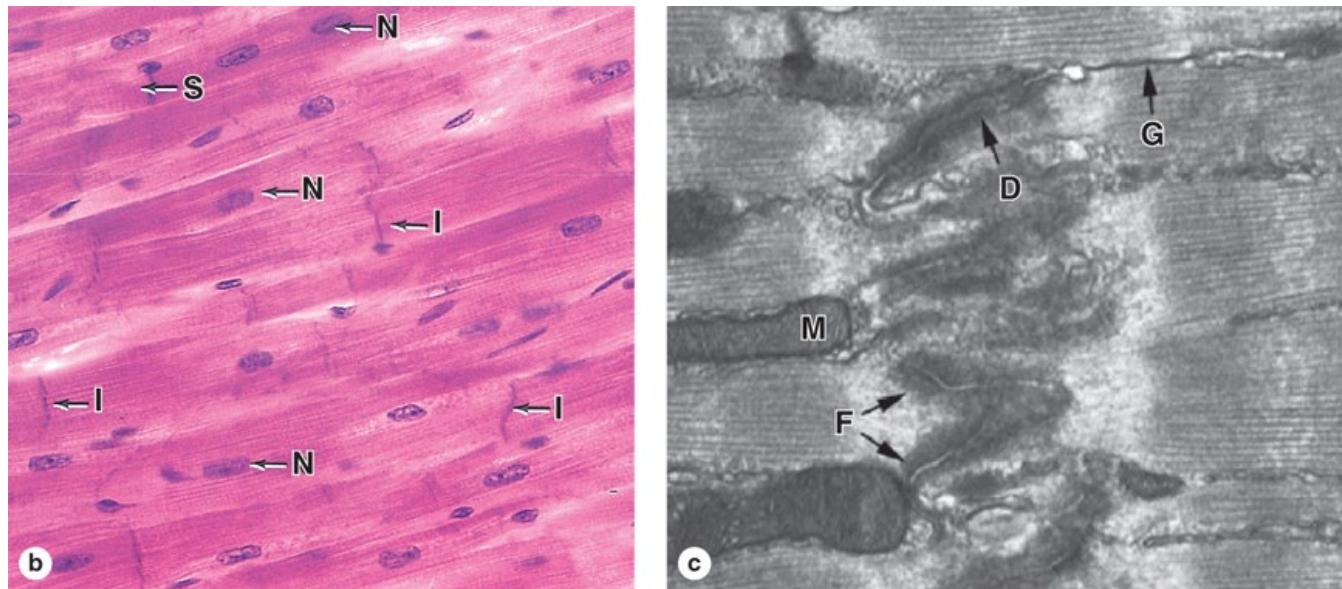
Longitudinal sections reveal the striations characteristic of skeletal muscle.

(a) Parts of three muscle fibers are separated by very thin endomysium that includes one fibroblast nucleus (F). Muscle nuclei (N) are found against the sarcolemma. Along each fiber thousands of dark-staining A bands alternate with lighter I bands. (X200; H&E)

(b) At higher magnification, each fiber can be seen to have three or four myofibrils, here with their striations slightly out of alignment with one another. Myofibrils are cylindrical bundles of thick and thin myofilaments which fill most of each muscle fiber. (X500; Giemsa)

(c) TEM showing one contractile unit (sarcomere) in the long series that comprises a myofibril. In its middle is an electron-dense A band bisected by a narrow, less dense region called the H zone. On each side of the A band are the lighter-stained I bands, each bisected by a dense Z disc which marks one end of the sarcomere. Mitochondria (M), glycogen granules, and small cisternae of SER occur around the Z disc. (X24,000)

(Figure 10–6c, used with permission from Dr. Mikel H. Snow.)



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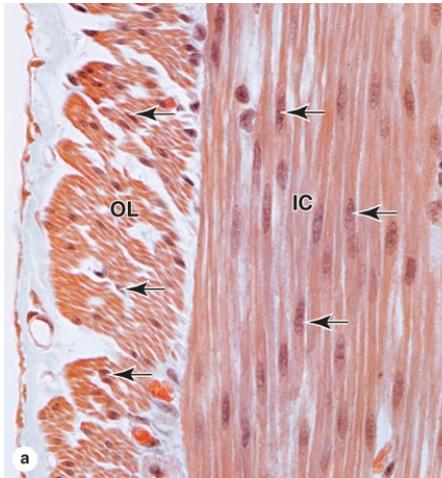
Cardiac muscle.

(a) The diagram of cardiac muscle cells indicates their characteristic features. The fibers consist of separate cells in a series joined at interdigitating regions called the intercalated discs, which cross an entire fiber between two cells. The transverse regions of the steplike intercalated disc have abundant desmosomes and other adherent junctions for firm adhesion, while longitudinal regions of the discs are filled with gap junctions.

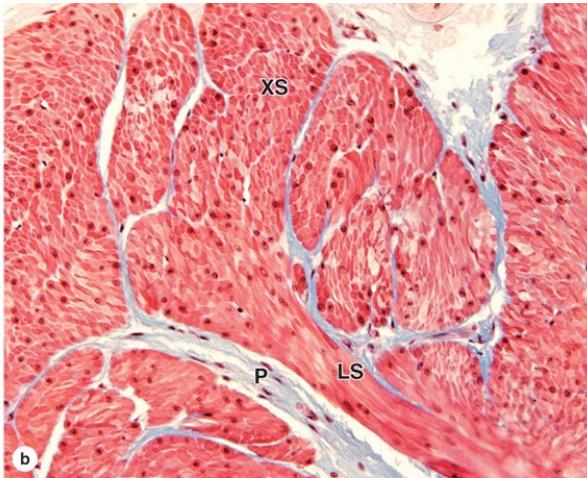
Cardiac muscle cells have central nuclei and myofibrils which are usually sparser and less well-organized than those of skeletal muscle. Also, the cells are often branched, allowing the muscle fibers to interweave in a more complicated arrangement within fascicles which helps produce an efficient contraction mechanism for emptying the heart.

(b) Light microscopy of cardiac muscle in longitudinal section show nuclei (N) in the center of the muscle fibers and widely spaced intercalated discs (I) that cross the fibers. These irregular intercalated discs should not be confused with the repetitive, much more closely spaced striations (S), which are similar to those of skeletal muscle but less well-organized. Nuclei of fibroblasts in endomysium are also present. (X200; H&E)

(c) TEM showing an electron-dense intercalated disc with a steplike structure along the short interdigitating processes of adjacent cardiac muscle cells. As shown here transverse disc regions have many desmosomes (D) and adherent junctions called fascia adherentes(F) which join the cells firmly. Gap junctions (G) joining the cells physiologically are abundant in other regions of the disc. The sarcoplasm has numerous mitochondria (M) and myofibrillar structures like those of skeletal muscle but slightly less organized. (X65,000)



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Smooth muscle.

Cells or fibers of smooth muscle are long, tapering structures with elongated nuclei centrally located at the cell's widest part.

- (a) In most of the digestive tract and certain similar structures smooth muscle is organized into two layers which contract in a coordinated manner to produce a wave that moves the tract's contents in a process termed peristalsis. In smooth muscle of the small intestine wall cut in cross section, cells of the inner circular (IC) layer are cut lengthwise and cells of the outer longitudinal layer (OL) are cut transversely. Only some nuclei (arrows) of the latter cells are in the plane of section so that many cells appear to be devoid of nuclei. (X140; H&E)
- (b) Section of smooth muscle in bladder shows interwoven bundles of muscle fibers in cross section (XS) and longitudinal section (LS) with the same fascicle. There is much collagen in the branching perimysium (P), but the endomysium can barely be seen by routine staining. (X140; Mallory trichrome)
- (c) Section stained only for reticulin reveals the thin endomysium around each fiber, with more reticulin in the connective tissue of small arteries (A). Reticulin fibers associated with the basal laminae of smooth muscle cells help hold the cells together as a functional unit during the slow, rhythmic contractions of this tissue. (X200; Silver)