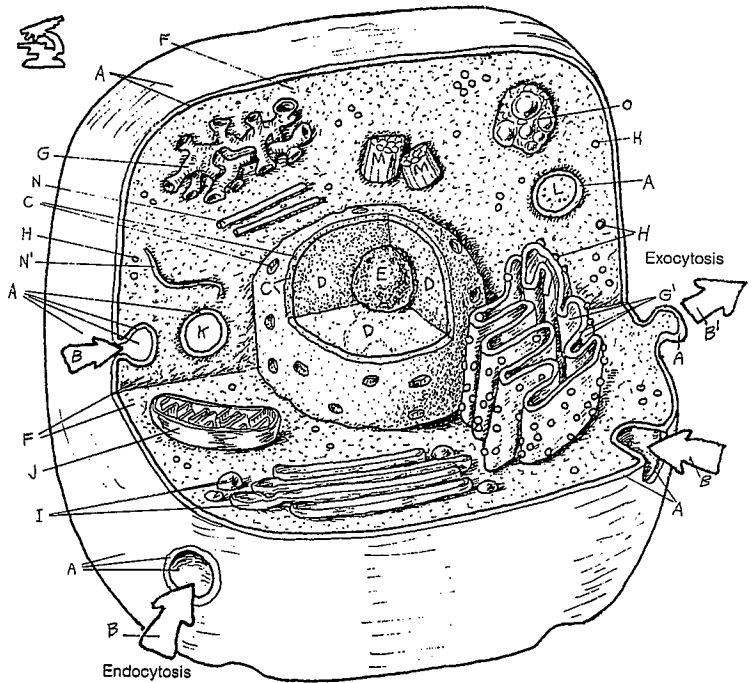
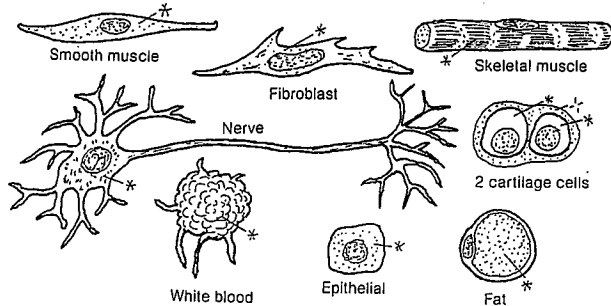


THE GENERALIZED CELL

CN: Color gray the variety of cell shapes at upper left. Use lightest colors for A, C, D, F and G. (1) Small circles representing ribosomes (H) are found throughout the cytoplasm (F) and on the rough endoplasmic reticulum (G'); color those larger areas, including the ribosomes, first, and then color over the ribosomes again with a darker color. Each organelle shown is just one of many found in the living cell.

CELL SHAPES*



ORGANELLES+

- CELL MEMBRANE_A
- ENDOCYTOSIS_B; EXOCYTOSIS_{B'}
- NUCLEAR MEMBRANE_C
- NUCLEOPLASM_D
- NUCLEOLUS_E
- CYTOPLASM_F
- ENDOPLASMIC RETICULUM
- SMOOTH_G; ROUGH_{G'}
- RIBOSOME_H
- GOLGI COMPLEX_I
- MITOCHONDRION_J
- VACUOLE_K
- LYSOSOME_L
- CENTRIOLE_M
- MICROTUBULE_N
- MICROFILAMENT_{N'}
- CELL INCLUSION_O

Cell membrane: the limiting lipoprotein membrane of the cell; retains internal structure; permits exportation and importation of materials. Infolding/outfolding of the cell membrane permits the introduction of material into the cell (endocytosis) or its expulsion (exocytosis) from the cell.

Nuclear membrane: porous, limiting, lipoprotein membrane; regulates passage of molecules.

Nucleoplasm: the nuclear substance containing chromatin (chromosomes during cell division) and RNA.

Nucleolus: a mass of largely RNA, it forms ribosomal RNA (rRNA) that passes into cytoplasm and becomes the site of protein synthesis.

Cytoplasm: the ground substance of the cell less the nucleus. Contains organelles and inclusions listed below.

Smooth/rough endoplasmic reticulum (ER): membrane-lined tubules to which ribosomes may be attached (rough ER; flattened tubules) or not (smooth ER; rounded tubules). Rough ER is concerned with transport of protein synthesized at the ribosomes. Smooth ER synthesizes complex molecules called steroids in some cells; stores calcium ions in muscle; breaks down toxins in liver.

Ribosome: the site of protein synthesis where amino acids are strung in sequence as directed by messenger RNA from the nucleus.

Golgi complex: flattened membrane-lined sacs that bud off small vesicles from the edges; collect secretory products and package them for export or cell use, e.g., lysosomes.

Mitochondrion: membranous, oblong structure in which the inner membrane is convoluted like a maze. Energy for cell operations is generated here through a complex series of reactions between oxygen and products of digestion (oxidative reactions).

Vacuoles: membrane-lined containers that can merge with one another or other membrane-lined structure, such as the cell membrane. They function as transport vehicles.

Lysosome: membrane-lined container of enzymes with great capacity to break down structure, e.g., microorganisms, damaged cell parts, and ingested nutrients.

Centriole: bundle of microtubules in the shape of a short barrel; usually seen paired, perpendicular to one another. They give rise to spindles used by migrating chromatids during cell division.

Microtubules: formed of protein; provide structural support for the cell and/or its parts.

Microfilaments: are support structures formed of protein different from that of microtubules. In skeletal muscle, the proteins actin and myosin are examples of thin and thick microfilaments.

Cell inclusion: aggregation of material within the cell that is not a functional part (organelle) of the cell—e.g., glycogen, lipid.

The cell is the basic structural and functional unit of all living things. Living things are characterized by the ability to reproduce and grow, metabolize (transform or produce/consume of energy), and adapt to limited changes in their internal and external environment. Body structure lacking these characteristics, such as connective tissue fibers, is not considered to be "alive." Body structure more complex than a cell consists of a collection of cells and their products.

The activities of cells constitute the life process; they include ingestion, assimilation, and digestion of nutrients and excretion of the residue; respiration; synthesis and degradation of materials; movement; and excitability or response to stimuli. The impairment or cessation of these activities in normal cells, whether caused by trauma, infection, tumors, degeneration, or congenital defects, is the basis of a disordered or disease process.

By volume, the generalized cell is 80% water; by weight, it is composed of proteins (about 15%), lipids (3%), carbohydrates (1%), and nucleic acids and minerals (1%). These materials may be integrated into structural working units (organelles), form a more mobile functional unit (e.g., messenger RNA, globular protein-based enzymes), or form products of the cell. The basic function of a cell is to produce protein, which is essential to the acquisition and use of cell energy, formation and repair of structure, and cell activities (e.g., synthesis, secretion, absorption, contraction).

TISSUES: FIBROUS CONNECTIVE TISSUES

CN: Use yellow for C and C¹, and red for J. (1) Begin with the illustration at middle left and the related titles (A through K). The titles and borders of the microscopic sections of dense regular/irregular c.t. (F¹, F²) receive the color of collagen (F), as that is the dominant structure in both tissues. (2) Do not color the matrix.

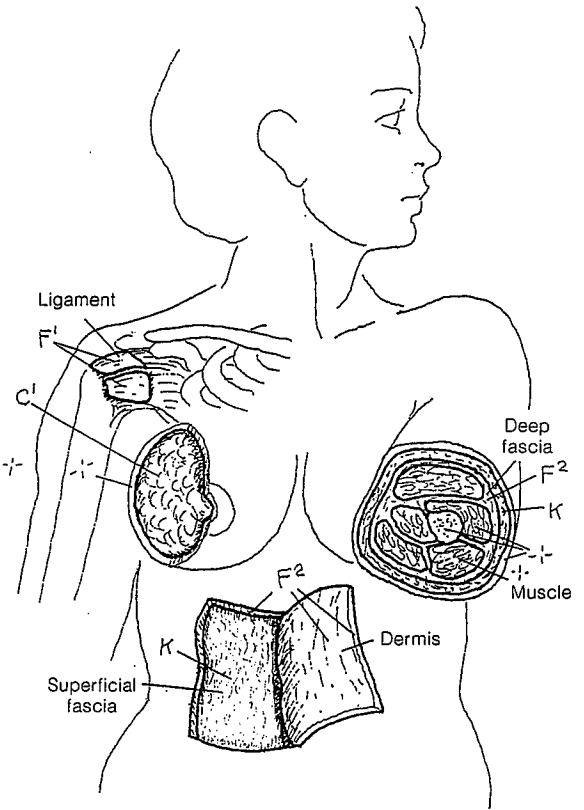
CELLS:

- FIBROBLAST_A
- MACROPHAGE_B
- FAT CELL_C
- PLASMA CELL_D
- MAST CELL_E

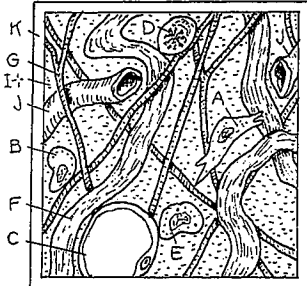
FIBERS:

- COLLAGEN_F
- ELASTIC_G
- RETICULAR_H
- MATRIX,
GROUND SUBSTANCE_{I, J}
- CAPILLARY_K

The connective tissues (c.t.) connect, bind, and support body structure. They consist of variable numbers of cells, fibers, and ground substance (fluid, viscous sol/gel, or mineralized). At the microscopic level (here illustrated at about 600x magnification), connective tissues range from blood (cells/fluid), through the fibrous tissues (cells/fibers/variable matrix) to the more stiff supporting tissues (cells/fibers/dense matrix) of cartilage and mineralized bone. Connective tissue can be seen at visible levels of body organization as well, in fascial layers of the body wall, tendons, ligaments, bone, and so on. This plate introduces the fibrous connective tissues (c.t. proper).



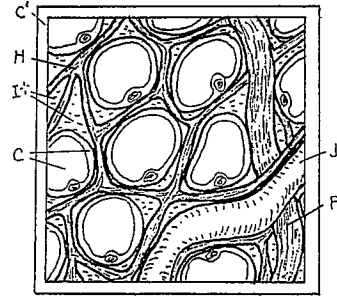
LOOSE, AREOLAR C.T. K



Loose, areolar connective tissue is characterized by many cells, a loose, irregular arrangement of fibers, and a moderately viscous fluid matrix. *Fibroblasts* secrete the fibers and ground substance of this tissue. Mobile *macrophages* engulf cell debris, foreign matter, and microorganisms. *Fat cells*, storing lipids, may be seen in small numbers or large (adipose tissue). *Plasma cells* secrete antibodies in response to infection. *Mast cells* contain heparin and other secretory products, some of which initiate allergic reactions when released. Numerous other cells may transit the loose

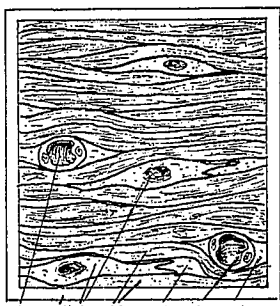
fibrous tissues, including white blood cells (leukocytes). *Collagen* (linkages of protein exhibiting great tensile strength) and *elastic fibers* (made of the protein elastin) are the fibrous support elements in this tissue. *Reticular tissue* is a smaller form of collagen, forming supporting networks around cell groups of the blood-forming tissues, the lymphoid tissues, and adipose tissue. The *matrix* (consisting largely of water with glycoproteins and glycosaminoglycans in solution) is the intercellular ground substance in which all of the above function; it is fluid-like in the fibrous tissue. Numerous *capillaries* roam throughout this tissue. Loose connective tissue found deep to the skin is called superficial fascia, subcutaneous tissue, or hypodermis. It is found deep to the epithelial tissues of mucous and serous membranes of hollow organs.

ADIPOSE C.T. C



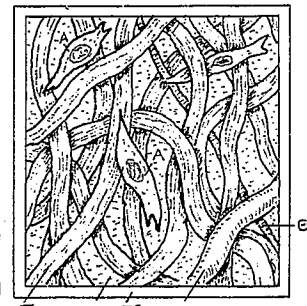
Adipose tissue is an aggregation of *fat cells*, supported by reticular and collagenous fibers and closely associated with both blood and lymph capillaries. The storage/release of fat in/from adipose tissue is regulated by hormones (including nutritional factors) and nervous stimuli. It serves as a source of fuel, an insulator, and mechanical padding and stores fat-soluble vitamins. Adipose tissue is located primarily in the superficial fasciae (largely breast, buttock, anterior abdominal wall, arm, and thigh), yellow marrow, and the surface of serous membranes.

DENSE REGULAR C.T. F1



Dense, parallel-arranged, masses of collagenous/elastic fibers form ligaments and tendons that are powerfully resistant to axially loaded tension forces, yet permit some stretch. Tendons/ligaments contain few cells, largely fibroblasts. Elastic, dense regular ligaments are found in the posterior neck and between vertebrae; the tendocalcaneus is the largest elastic structure (tendon or ligament) in the body, storing energy used in gait.

DENSE IRREGULAR C.T. F2



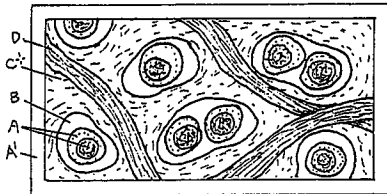
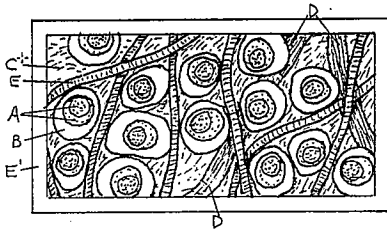
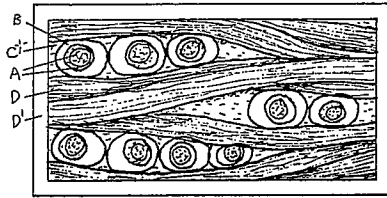
Dense, irregularly arranged masses of interwoven collagenous (and some elastic) fibers in a viscous matrix form capsules of joints, envelop muscle tissue (deep fasciae), encapsulate certain visceral organs (liver, spleen, and others), and largely make up the dermis of the skin. The tissue is impact resistant (bearing stress omnidirectionally), contains few cells, and is minimally vascularized.

TISSUES: SUPPORTING CONNECTIVE TISSUES

CN: Use the same colors as used on the previous plate for collagen (D) and elastic (E) fibers. Use a light tan or yellow for F and red for L. Use light colors for A, B, G, I, and M. Complete the upper material before coloring the bone section.

CARTILAGE

- CHONDROCYTE_A
- LACUNA_B
- MATRIX_{C¹}
- COLLAGEN FIBER_D
- ELASTIC FIBER_E



Microscopic sections of cartilage tissue reveal cells (chondrocytes) in small cavities (lacunae) surrounded by a hard but flexible matrix of water bound to proteoglycans and collagen fibers. Avascular cartilage receives its nutrition by diffusion from vessels in the perichondrium. For that reason, cartilage does not repair well after injury, yet it is often a part of a temporary framework (callus) in the healing process of fractured bone. There are three types of cartilage.

Bone is unique for its mineralized matrix (65% mineral, 35% organic by weight). The skeleton is bone. Bone is a reservoir of calcium; it is an anchor for muscles, tendons, and ligaments; it harbors many viscera; it assists in the mechanism of respiration; its cavity in certain bones is a center of blood-forming activity (hematopoiesis); in other bones, its cavity is a storage site for lipid.

FIBROCARTILAGE_D

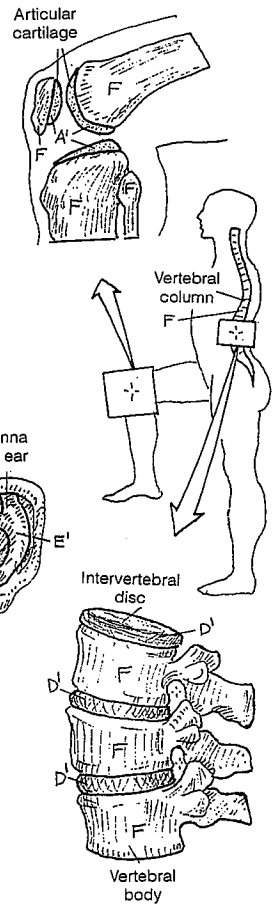
Fibrocartilage offers strength with flexibility, resisting both impact and tensile forces. The best example of this tissue is the intervertebral disc. It consists of dense fibrous tissue interspersed with cartilage cells and a relatively small amount of intercellular matrix.

ELASTIC CARTILAGE_E

This tissue is essentially hyaline cartilage with elastic fibers and some collagen. It supports the external ear and the epiglottis of the larynx. Feel its unique flexibility in your own external ear.

HYALINE CARTILAGE_A

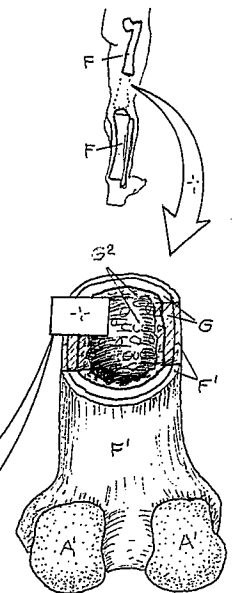
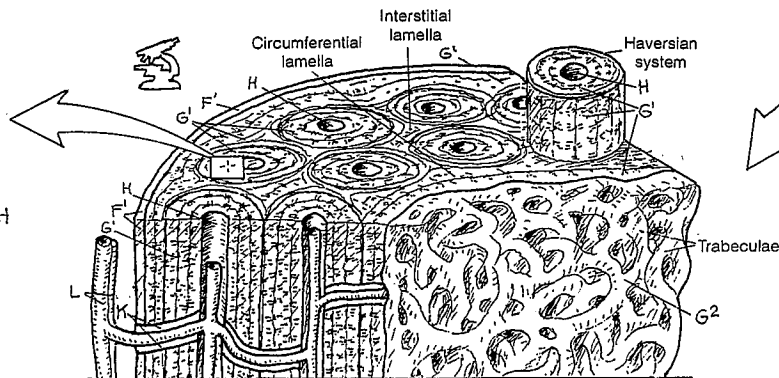
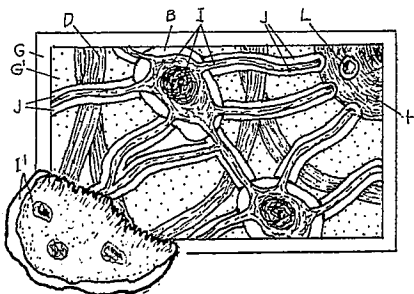
Well known as the covering at bone ends (articular cartilage), hyaline cartilage is avascular, insensitive, and compressible. It is porous, enhancing absorption of nutrients and oxygen. It supports the external nose (feel and compare with the elastic cartilage of the ear). It is the main structural support of the larynx and much of the lower respiratory tract. It forms the model for most early developing bone (Plate 168).



BONE_F

- PERIOSTEUM_F
- COMPACT BONE_G
- HAVERSIAN SYS_{G¹}
- HAV. CANAL_H
- LAMELLAE_{G¹}
- OSTEOCYTE_I
- OSTEOCLAST_{I'}
- LACUNA_B
- CANALICULI_J
- VOLKMANN CANAL_K
- BLOOD VESSEL_L
- SPONGY BONE_{G²}

As you read, check Plate 20. Bone has compact and cancellous forms. Compact bone is the impact-resistant, weight-bearing shell of bone lined by a sheath of life-supporting fibrous periosteum. Compact bone consists of columns called haversian systems or osteons: concentric layers (lamellae) of mineralized, collagenous matrix around a central (haversian) canal containing blood vessels. Volkmann's canals interconnect the haversian canals. Note the interstitial lamellae between columns and the circumferential lamellae enclosing the columns. Between lamellae are small cavities (lacunae) inter-connected by little canals (canaliculi). Bone cells (osteocytes) and their multiple extensions fill these spaces, which connect with the haversian canal. In areas of resorbing bone matrix, large, multinucleated, avidly phagocytic osteoclasts can be seen with multiple cytoplasmic projections facing the matrix they are destroying. Bone-forming cells (osteoblasts) can be seen in Plate 168. Cancellous bone is internal to compact bone and is especially well seen at the ends of long bones. It consists of irregularly-shaped, interwoven beams (trabeculae) of bone, lacking haversian systems.



TISSUES: MUSCLE

Muscle tissue, one of the four basic tissue types of the body, consists of muscle cells ("fibers") and their fibrous connective tissue coverings. There are three kinds of muscle tissues: skeletal, cardiac, and smooth. Muscle tissue shortens (contracts) in response to nerve, nerve-like, or hormonal stimulation. Depending on their attachments, skeletal muscles move bones at joints, constrict cavities, and move the skin; cardiac muscle compresses a heart cavity or orchestrates the sequence of cardiac muscle contraction; and smooth muscle moves the contents of cavities by rhythmic contractions, constricts vessels it surrounds, and moves hairs/closes pores of the skin. The surrounding *connective tissue* transfers the force of contraction from cell to cell and supports the muscle fibers and the many blood *capillaries* and nerves that supply them.

SKELETAL/STRIATED MUSCLE, _{1E} SARCOLEMMA _F CELL _{E'}

Skeletal muscle cells are long, striated, and *multinucleated*, formed of myofibrils, *mitochondria*, and other organelles within the cytoplasm (sarcoplasm). Each cell is enveloped in a cell membrane called *sarcolemma*. Collections of muscle cells make up the belly of a muscle. The highly vascularized skeletal muscles contribute greatly to the size and shape of the body. Skeletal muscles attach to bones or other muscles at their tendinous ends. Between bony attachments, muscles cross one or more joints, moving them. Muscles always pull; they never push. Skeletal muscle contractions consist of rapid, brief shortenings, often generating considerable force. Each contracting cell shortens maximally. Three kinds of skeletal muscle fibers are recognized: red (small, dark, long-acting, slow-contracting, postural muscle fibers with oxygen-rich myoglobin and many mitochondria), white (relatively large, pale, anaerobic, short-acting, fast-contracting muscle fibers with few mitochondria), and intermediate fibers. With exercise, fast fibers can convert to slow; slow fibers can convert to fast. Contraction of skeletal muscle requires nerves (innervation). Without a nerve supply (denervation), skeletal muscle cells cease to shorten; without reinnervation, the cells will die. A denervated portion of muscle loses its tone and becomes flaccid. In time, the entire muscle will become smaller (atrophy). Muscle contraction is generally under voluntary control, but the brain involuntarily maintains a degree of contraction among the body's skeletal muscles (muscle tone). After injury, skeletal muscle cells can regenerate from myoblasts with moderate functional significance; such regeneration may also occur in association with muscle cell hypertrophy in response to training/exercise.

GARDIAC/STRIATED MUSCLE, _{2G} INTERCALATED DISC _H CELL _{G'}

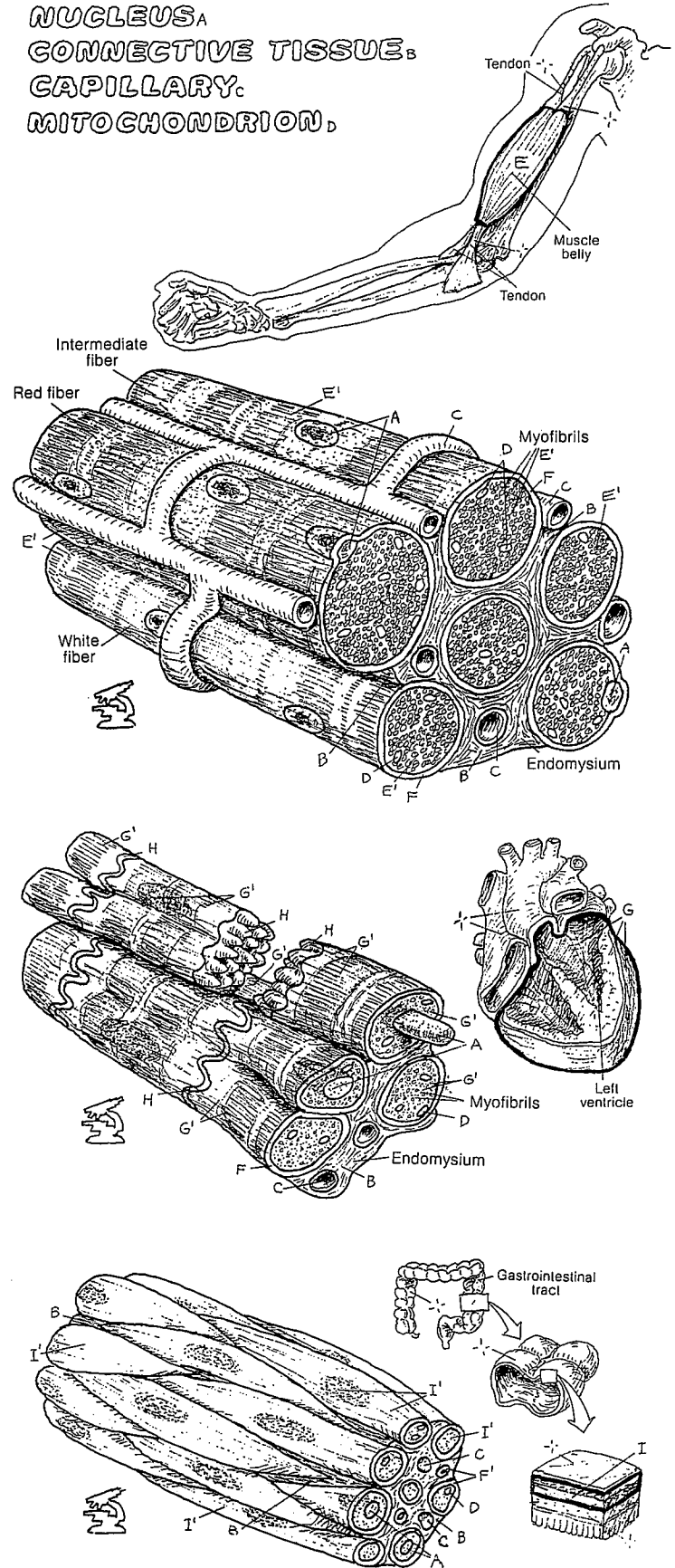
Cardiac muscle cells make up the heart muscle. They are branched, striated cells with one or two centrally located nuclei and a sarcolemma surrounding the sarcoplasm. They are connected to one another by junctional complexes called *intercalated discs*. Their structure is similar to skeletal muscle, but less organized. Cardiac muscle is highly vascularized; its contractions are rhythmic, strong, and well regulated by a special set of impulse-conducting muscle cells, not nerves. Rates of contraction of cardiac muscle are mediated by the autonomic (visceral) nervous system, the nerves of which increase/decrease heart rate. Cardiac muscle is probably not capable of regeneration.

VISCERAL/SMOOTH MUSCLE, _{3I} PLASMALEMMA _{F'} CELL _{I'}

Smooth muscle cells are long, tapered cells with centrally placed nuclei. Each cell is surrounded by a *plasmalemma* (cell membrane). These cells are smooth (nonstriated). Myofibrils are not seen; the myofilaments intersect with one another in a pattern less organized than that seen in skeletal muscle. Smooth muscle cells occupy the walls of organs with cavities (viscera) and serve to propel the contents along the length of those cavities by slow, sustained, often powerful rhythmic contractions (consider menstrual or intestinal cramps). Smooth muscle cells, oriented perpendicular to the flow of tubular contents, act as gates (sphincters) in specific sites, regulating the flow, as in delaying the flow of urine. Well-vascularized, smooth muscle fibers contract in response to both autonomic nerves and hormones. They are also capable of spontaneous contraction. Regeneration of smooth muscle, to some extent, is possible after injury.

CN: Use red for C and your lightest colors for B, E, G, and I. (1) The sarcolemma (F), which covers each skeletal and cardiac muscle cell, is colored only at the cut ends. The plasmalemma (F'), which covers each smooth muscle cell, is colored only at the cut ends. (2) The nuclei of cardiac and smooth muscle cells, located deep within the cells, are to be colored only at the cut ends (A). (3) One of the intercalated discs (H) of the cardiac cells has been separated to reveal its structure (schematically). (4) The cellular views are microscopic.

NUCLEUS _A
CONNECTIVE TISSUE _B
CAPILLARY _C
MITOCHONDRION _D



TISSUES: SKELETAL MUSCLE MICROSTRUCTURE

CN: Use the same colors used on Plate 13 for sarcolemma (A) and mitochondrion (D). Use the same color used on the skeletal muscle cell for the myofibril (E) here. Use light colors for G and J, a dark color for H, and very dark colors for F and K. The cell nucleus is not shown here. (1) Begin with the drawing of the arm. (2) Color the parts of the muscle cell in the central illustration; note the presence of mitochondria (D) between the myofibrils. (3) Color the parts of the exposed (lowest) myofibril and the color-related letters, bands, lines, zone. Note that the cut end of this myofibril receives the color E, for identification purposes, and is part of the A band of the sarcomere adjacent to the one to be colored. (4) Color the relaxed and contracted sarcomere, the filaments, and the mechanism for contraction, noting the color relationship with the myofibril and its parts.

A part of a skeletal muscle cell is shown with the *sarcolemma* opened to reveal some cellular contents. The most visible of the contents are the *myofibrils*, the contractile units of the cell. They are enveloped by a flat tubular *sarcoplasmic reticulum* (SR) that, in part, regulates the distribution of calcium ions (Ca⁺⁺) into the myofibrils. Inward tubular extensions of the sarcolemma, called the *transverse tubule system* (TTS), run transversely across the SR, at the level of the Z lines of the myofibrils. The TTS, containing stores of sodium ions (Na⁺) and calcium ions (Ca⁺⁺), conducts electrochemical excitation to the myofibrils from the sarcolemma. *Mitochondria* provide energy for the cell work.

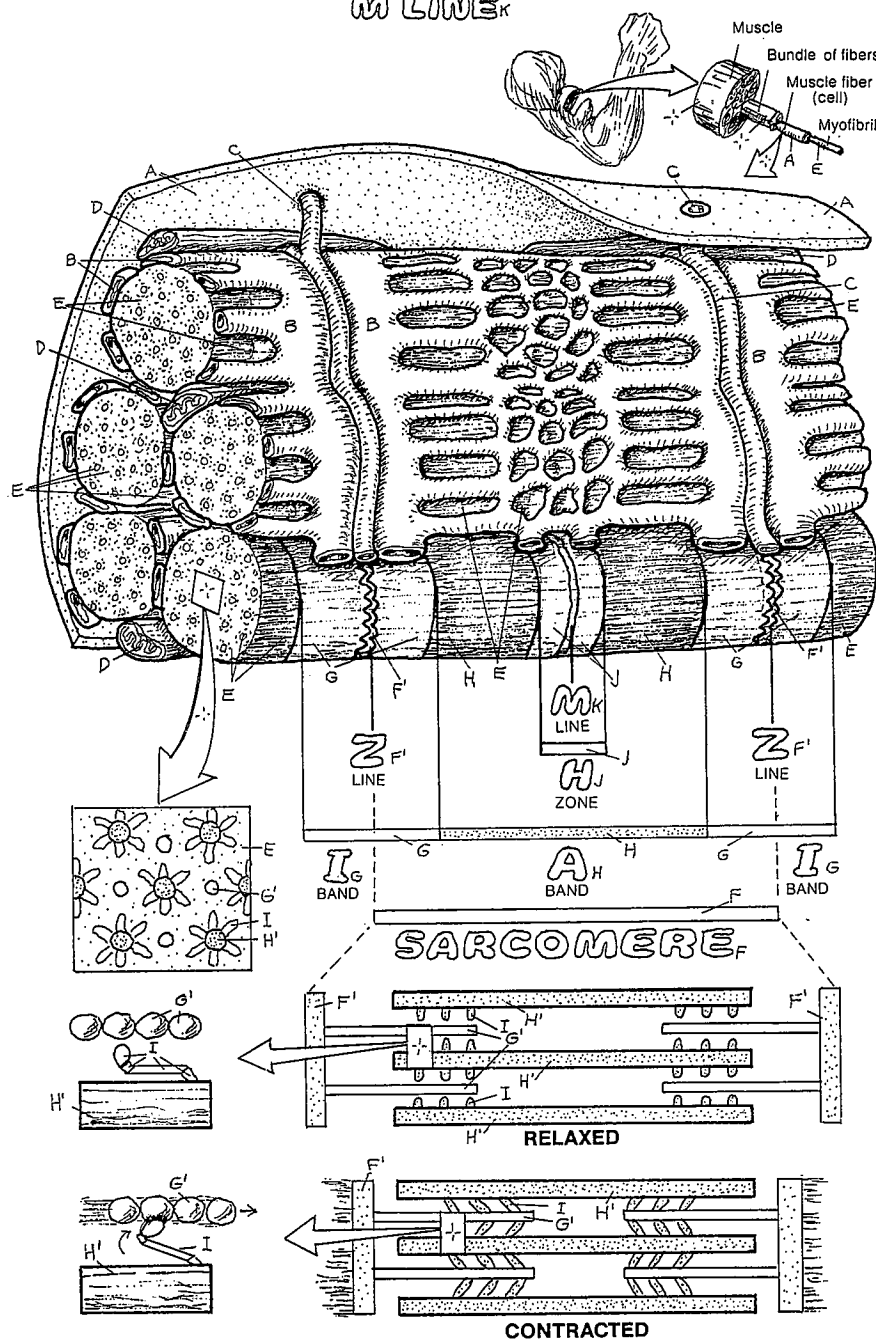
The myofibrils consist of myofilaments: *thick filaments* (largely myosin) with heads that project outward as *cross bridges*, and *thin filaments* (largely actin) composed of two interwoven strands. These two filament types are arranged into contractile units, each of which is called a *sarcomere*. Each myofibril consists of several radially arranged sarcomeres. At the end of each sarcomere, the thin filaments are permanently attached to the *Z line*, which separates one sarcomere from the next. The relative arrangement of the thick and thin filaments in the sarcomere creates *light (I, H) and dark (A) bands/zone* and the *M line*, all of which contribute to the appearance of cross-striations in skeletal (and cardiac) muscles.

Shortening of a myofibril occurs when the thin filaments slide toward the center (H zone), bringing the Z lines closer together in each sarcomere. The filaments do not shorten; the myosin filaments do not move. The close relationship of the TTS to the Z lines suggests that this site is the "trigger area" for induction of the sliding mechanism. This sliding motion is induced by *cross bridges* (heads of the immovable thick filaments) that are connected to the thin filaments. Activated by high-energy bonds from ATP, the paddle-like cross bridges swing in concert toward the H zone, drawing the thin filaments with them. The sarcomere shortens as the opposing thin filaments meet or even overlap at the M line.

Occurring simultaneously in all or most of the myofibrils of a muscle cell, shortening of sarcomeres translates to a variable shortening of the resting length of the muscle cell. Repeated in hundreds of thousands of conditioned muscle cells of a professional athlete, the resultant contractile force can pull a baseball bat through an arc sufficient to send a hardball a hundred meters or more through the air.

SKELETAL MUSCLE CELL

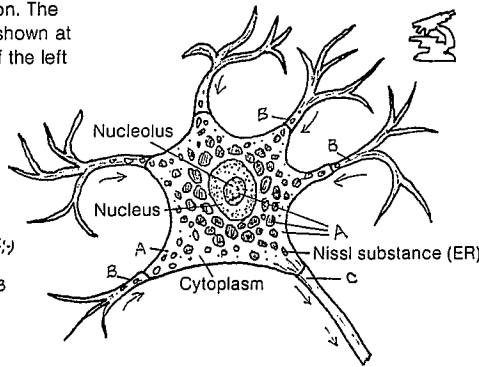
- SARCOLEMMA_A
- SARCOPLASMIC RETICULUM_B
- TRANSVERSE TUBULE SYS._C
- MITOCHONDRION_D
- MYOFIBRIL_E
- SARCOMERE_F
- I BAND_G
- THIN FILAMENT (ACTIN)_{G'}
- Z LINE_{F'}
- A BAND_H
- THICK FILAMENT (MYOSIN)_{H'}
- CROSS BRIDGE_I
- H ZONE_J
- M LINE_K



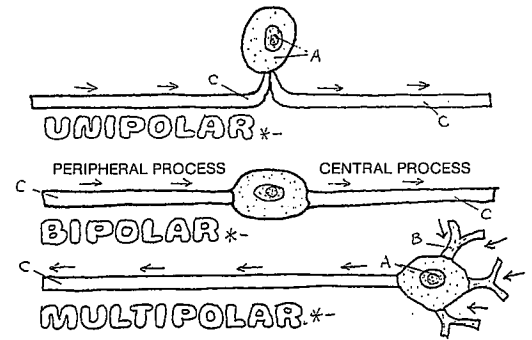
TISSUES: NERVOUS

CN: Use a light color for A. Note the small arrows that indicate direction of impulse conduction. The neurons of the peripheral nervous system shown at lower left are illustrated in the orientation of the left upper limb, although highly magnified.

NEURON +
CELL BODY A
PROCESSES(ES) (-)
DENDRITE B
AXON C



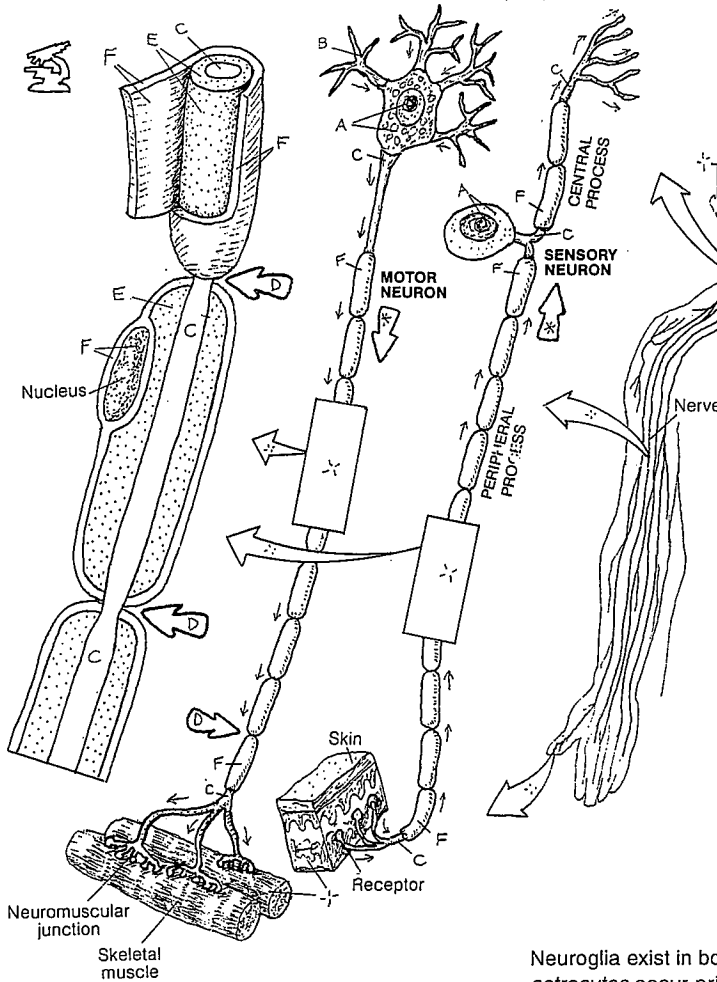
TYPES OF NEURONS



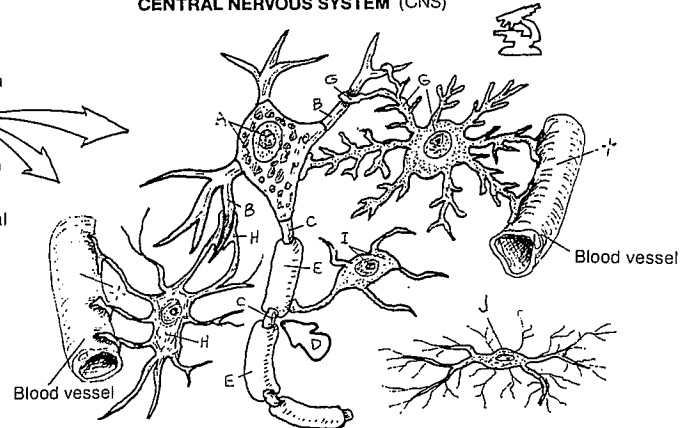
Nervous tissue consists of *neurons* (nerve cells) and *neuroglia*. Neurons generate and conduct electrochemical impulses by way of neuronal (cellular) *processes*. Neuroglia are the supporting, non-impulse-generating/ conducting cells of the nervous system. The main, nucleus-bearing part of the neuron is the *cell body*. Its cytoplasm contains the usual cell organelles. Uniquely, the endoplasmic reticulum occurs in clusters called Nissl substance. Neurons do not undergo mitosis after birth, compromising their ability to regenerate after injury. Neuronal growth consists of migration and arborization of processes. Neurons are the impulse-conducting cells of the brain and spinal cord (central nervous system, or CNS) and the spinal and cranial nerves (peripheral nervous system, or PNS).

Neurons fall into three structural categories based on numbers of processes ("poles"). Processes that are highly branched (arborized) and uncovered are called *dendrites*. Slender, long, minimally branched processes are called *axons*. Within each category, there is a great variety of shape and size of neurons. *Unipolar* neurons have or appear to have (pseudounipolar) one process that splits near its cell body into a central and peripheral process. Both processes conduct impulses in the same direction, and each is termed an axon (see the sensory neuron at lower left). *Bipolar* neurons have two (central and peripheral) processes, called axons, conducting impulses in the same direction (see Plate 71). *Multipolar* neurons have three or more processes, one of which is an axon (see PNS motor neuron at lower left and CNS neuron at lower right).

PERIPHERAL NERVOUS SYSTEM (PNS)



CENTRAL NERVOUS SYSTEM (CNS)



NEUROGLIA

- PROTOPLASMIC ASTROCYTE
- FIBROUS ASTROCYTE
- OLIGODENDROCYTE
- MICROGLIA

Most axons are enveloped in one or more (up to 200) layers of an insulating phospholipid (*myelin*) that enhances impulse conduction rates. Myelin is produced by *oligodendrocytes* in the CNS (lower right) and by Schwann cells in the PNS (lower left). All axons of the PNS are ensheathed by the cell membranes of Schwann cells (neurilemma) but not necessarily myelin. The gaps between Schwann cells are *nodes of Ranvier*, making possible rapid node-to-node impulse conduction. Schwann cells make possible axonal regeneration in the PNS. Significant axonal regeneration in the CNS has not been observed.

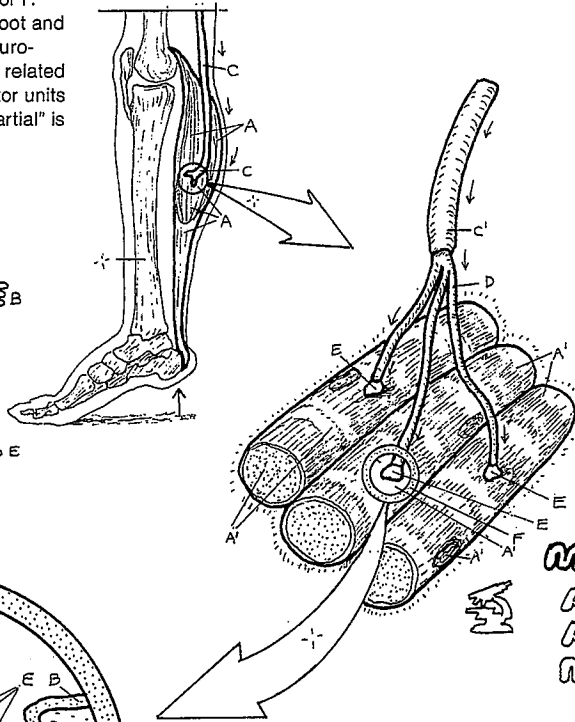
NODE OF RANVIER +
AXON COVERINGS +
MYELIN E
SCHWANN CELL F

Neuroglia exist in both the CNS and PNS (Schwann cells). *Protoplasmic astrocytes* occur primarily in gray matter (dendrites, cell bodies) of the CNS, *fibrous astrocytes* in the white matter (myelinated axons). Their processes attach to both neurons and blood vessels and may offer metabolic, nutritional, and physical support. They may play a role in the blood/brain barrier. Oligodendrocytes are smaller than astrocytes, have fewer processes, and are seen near neurons. *Microglia* are the small scavenger cells of the brain and spinal cord.

NEUROMUSCULAR INTEGRATION

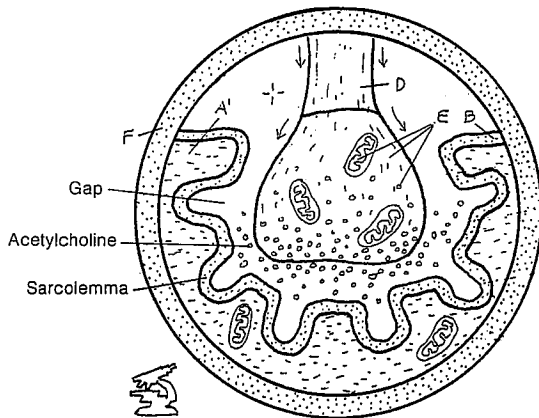
CN: Use very light colors for A and E, and a dark color for F.
 (1) Begin with the skeletal muscle lifting the heel of the foot and complete the motor unit and the enlarged view of the neuromuscular junction. (2) Color carefully the motor units and related titles at the bottom of the plate: only the discharging motor units (in dark outline) are to be colored. Note that the word "partial" is not colored under the example of partial contraction.

SKELETAL MUSCLE_A
MUSCLE FIBER_{A'}
MOTOR END PLATE_B
MOTOR NERVE_C
AXON_C
AXON BRANCH_D
AXON TERMINAL_E



MOTOR UNIT_F
AXON_C
AXON BRANCH_D
NEUROMUSCULAR JUNCTION_F
MUSCLE FIBER_{A'}

An axon of a single motor neuron, its axon branches, and the skeletal muscle fibers with which they form neuromuscular junctions constitute a *motor unit*. Within any given skeletal muscle, the number of muscle fibers innervated by a single motor neuron largely determines the specificity of contraction of that muscle; the fewer the number of muscle fibers in each motor unit, the more selective and refined the degree of contraction of that skeletal muscle.

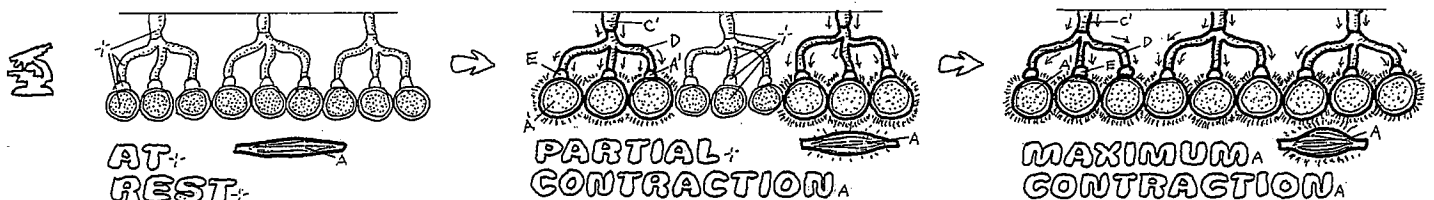


NEUROMUSCULAR JUNCTION_F
AXON TERMINAL_E
MOTOR END PLATE_B

Skeletal muscle consists of innumerable muscle fibers (cells). Skeletal muscle requires an intact nerve (innervation) to shorten (contract). Such a nerve, called a *motor nerve*, consists of numerous axons of motor neurons. A motor neuron (see Plate 15) is dedicated solely to stimulating muscle fibers to contract. Each single *muscle fiber* in a skeletal muscle is innervated by a *branch of an axon*. The microscopic site at which the axon branch attaches to the skeletal muscle fiber is called the *neuromuscular junction*. Each neuromuscular junction consists of an *axon terminal* closely applied to an area of convoluted muscle fiber sarcolemma called the *motor end plate*. There is a gap between the two surfaces. When a skeletal muscle fiber is about to be stimulated, a chemical neurotransmitter, called acetylcholine, is released by the axon terminal into the gap. The neurotransmitter induces a change in the permeability of the sarcolemma to sodium (Na^+), which initiates muscle fiber contraction. A muscle fiber can only contract maximally ("all or none" law).

GRADES OF CONTRACTION

Given the fact of "all or none" contraction by individual skeletal muscle fibers, grades of contraction of a skeletal muscle are made possible by activating a number of motor units and not activating others. A *resting muscle* activates no motor units. In a *partial contraction*, only some of the motor units are activated. In *maximal contraction* of a skeletal muscle, all motor units are activated. Gluteus maximus consists of skeletal muscle fibers having a nerve-to-muscle ratio of 1:1000 or more. There is no possibility of controlled, refined contractions from this muscle. The facial muscles, on the other hand, have a much lower nerve-to-muscle ratio, closer to 1:10. Here small numbers of muscle fibers can be contracted by implementing one or a few motor units, generating very fine control on the muscular effect (facial expression) desired.

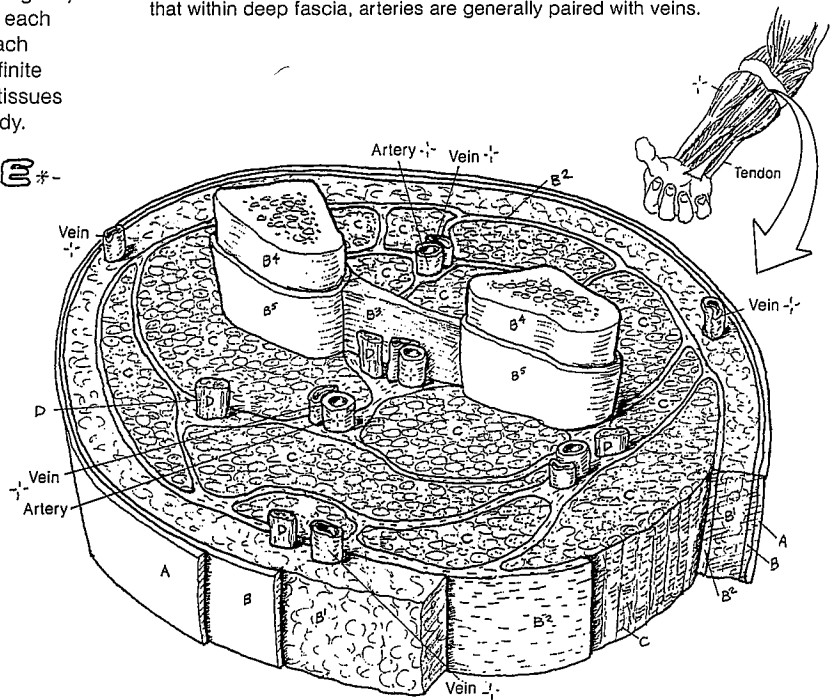


INTEGRATION OF TISSUES

This plate has one goal: to aid you in visually integrating the four basic tissues into somatic (body wall) and visceral (cavity-containing organs) structure. Concentrate on how the four tissues are arranged in each example of body structure. Consider the general function of each tissue in the overall function of the part/organ. There are an infinite number of functionally related variations in the way these four tissues form a discrete construction of the soma and viscera of the body.

SOMATIC STRUCTURE

- EPITHELIAL TISSUE
 - SKIN (OUTER LAYER)^A
- CONNECTIVE TISSUE
 - SKIN (DEEP LAYER)^B
 - SUPERFICIAL FASCIA^{B¹}
 - DEEP FASCIA^{B²}
 - LIGAMENT^{B³}
 - BONE^{B⁴}
 - PERIOSTEUM^{B⁵}
- MUSCLE TISSUE
 - SKELETAL MUSCLE.
- NERVOUS TISSUE
 - NERVE.



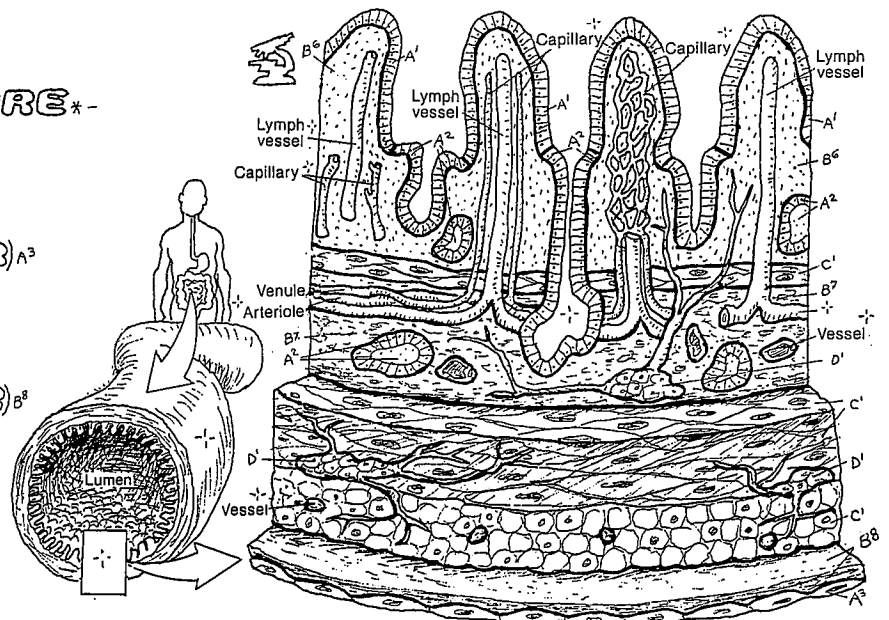
CN: Use yellow for D and light, contrasting colors for A and B, and a medium brown for C. The various vessels that are shown in these tissues—arteries and veins above, and arterioles, venules, capillaries, and lymph vessels below—are not to be colored, as they are made up of more than one basic tissue. Note that within deep fascia, arteries are generally paired with veins.

Somatic structure, making up the skin-covered musculoskeletal frame of the body, is concerned with stability, movement, and protection. Its construction reflects these functions. The outermost covering of the body wall everywhere is a protective keratinized *stratified squamous epithelial tissue*, constituting the *outer layer of skin* (epidermis). Other epithelial tissues in somatic structure are the inner layers of blood vessels, and the glands (not shown). Connective tissue layers of the body wall include the *deep layer of skin* (dermis), consisting of dense, irregular fibrous *connective tissue*; and the sub-adjacent, variously mobile, subcutaneous *superficial fascia*

(loose connective and adipose tissues), containing cutaneous nerves, small vessels, and occasional large veins. *Deep fascia* a more vascular, sensitive, dense, irregular fibrous tissue, ensheathes skeletal muscle (myofascial tissue) as well as the supporting nerves and vessels. *Ligaments* (dense regular connective tissue) bind *bone* to bone by way of *periosteum* (vascular, cellular, dense, irregular, fibrous tissue). *Skeletal muscles* and their *nerves* are packaged in groups, separated by slippery septa of deep fascia securing neurovascular structure. The fibrous investments of skeletal muscle converge to form tendons of the muscle.

VISCERAL STRUCTURE

- EPITHELIAL TISSUE
 - MUCOSAL LINING^{A¹}
 - GLAND^{A²}
 - SEROSA (OUTER LAYER)^{A³}
- CONNECTIVE TISSUE
 - LAMINA PROPIA^{B⁴}
 - SUBMUCOSA^{B⁵}
 - SEROSA (INNER LAYER)^{B⁶}
- MUSCLE TISSUE
 - SMOOTH MUSCLE^{C¹}
- NERVOUS TISSUE
 - NERVE CELLS^{D¹}



Visceral structure is generally concerned with absorbing, secreting, trapping, and/or moving food, air, secretions, and/or waste in its cavities. *Epithelial tissue* is the innermost layer (*mucosal lining*) of the thin and pliable visceral wall. It faces the lumen (cavity of the viscus); it is often a single layer of cells (esophagus, urinary tract, and reproductive tract excepted) and deals with the contents of the visceral cavity. *Glands*, unicellular or larger in the mucosa or submucosa, are epithelial, as are the inner layers of blood and lymph vessels. The mucosa includes a sub-epithelial layer of loose fibrous tissue (*lamina propria*), supporting mobile

cells, glands, vessels, and *nerves*. The deepest layer of the mucosa (when present) is a thin *smooth muscle* layer moving finger-like projections (villi) of the mucosal surface. Deep to the mucosa is a dense fibrous tissue (*submucosa*), replete with large vessels and small nerves/nerve cells (intramural ganglia) supplying the mucosa. Deeper yet, two or three layers of smooth muscle (*tunica muscularis*), innervated by local nerve cells, move the visceral wall in peristaltic contractions. The outermost layer of the gastrointestinal tract is the slippery serosa: an *outer* secretory simple squamous epithelial layer and an *inner* supporting layer of light fibrous tissue.