



Bone, Nervous, Muscle

BI 455 CHAPTER 8-10

Chapter 8 Bone Objectives

1. Cells and ECM: Osteoblasts, osteocytes, bone matrix
2. Mineralized extracellular matrix
3. General structure of bone tissue: lamellar bone, osteons, perforating canals, lacunae
4. Bone formation: membranous ossification, endochondral ossification
5. Bone growth, remodeling, and repair: interstitial and appositional growth
6. Calcium homeostasis

Functions of the Skeleton

- Support: holds up the body, supports muscles, mandible and maxilla support teeth
- Protection: brain, spinal cord, heart, lungs
- Movement: limb movements, breathing, action of muscle on bone
- Electrolyte balance: calcium and phosphate ions
- Acid–base balance: buffers blood against excessive pH changes
- Blood formation: red bone marrow is the chief producer of blood cells



Bone cells

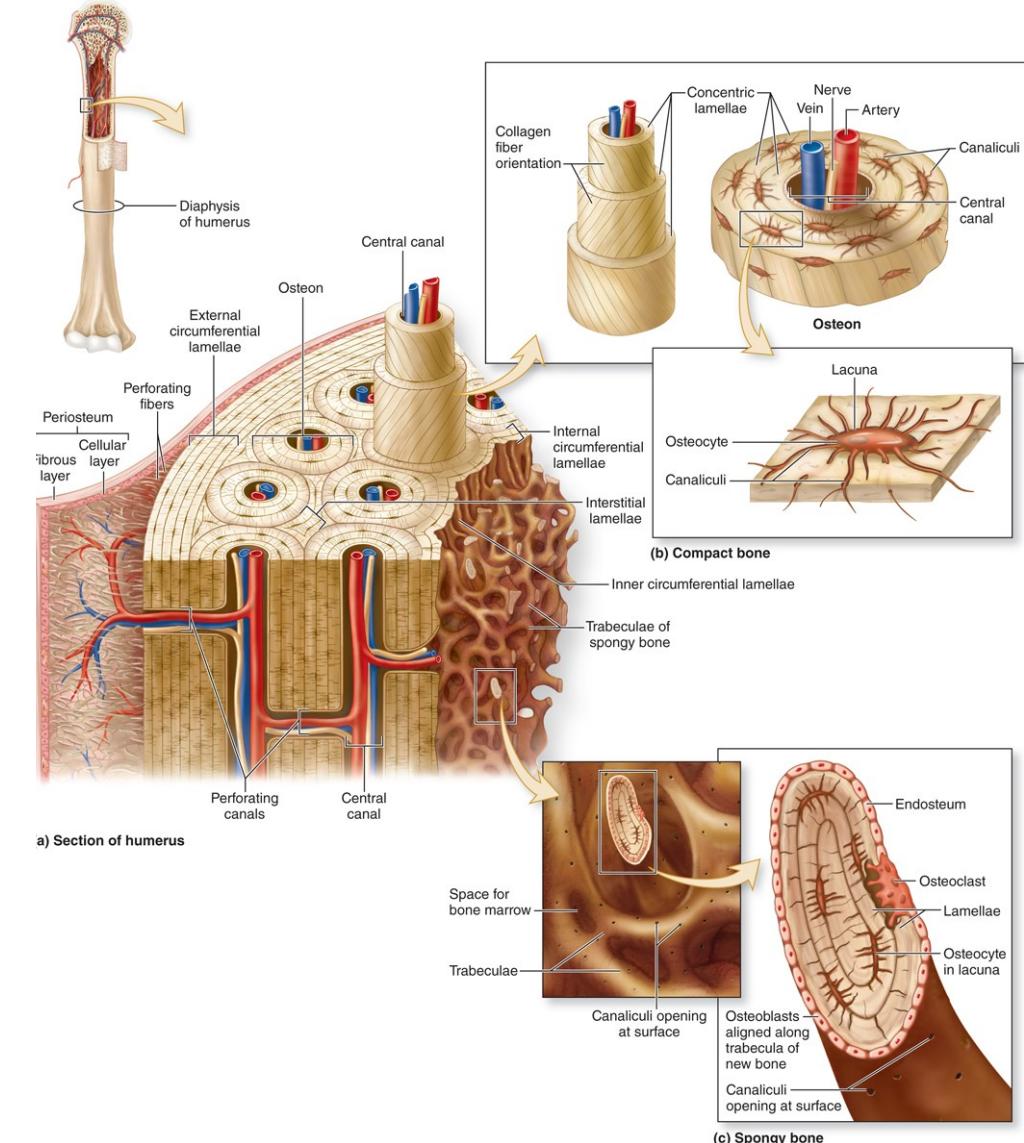
Bone Density Decreases in Space - What to Do? | Video: <https://www.youtube.com/watch?v=nHbj7kqYoVk>

Osteoprogenitor cells: derived from mesenchymal stem cells; give rise to osteoblasts.

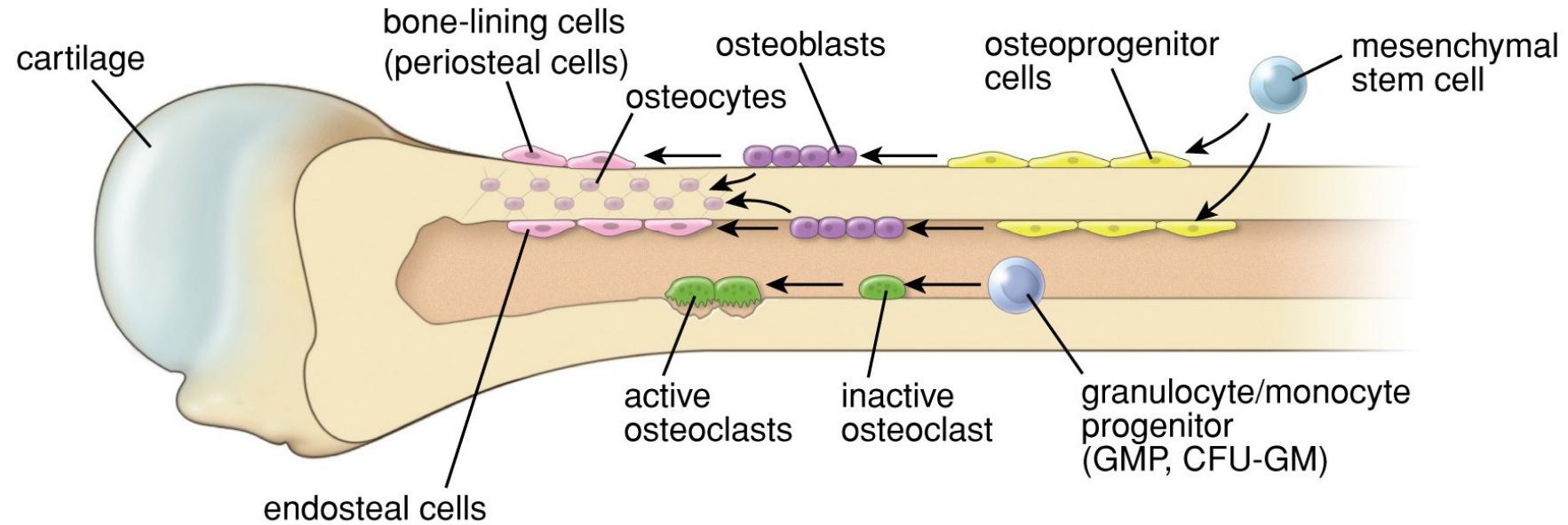
Osteoblasts: secrete the extracellular matrix of bone; becomes **osteocyte** once the cell is surrounded with its secreted matrix

Osteoclasts: bone-resorbing cells on bone surfaces, for remodeling and repair

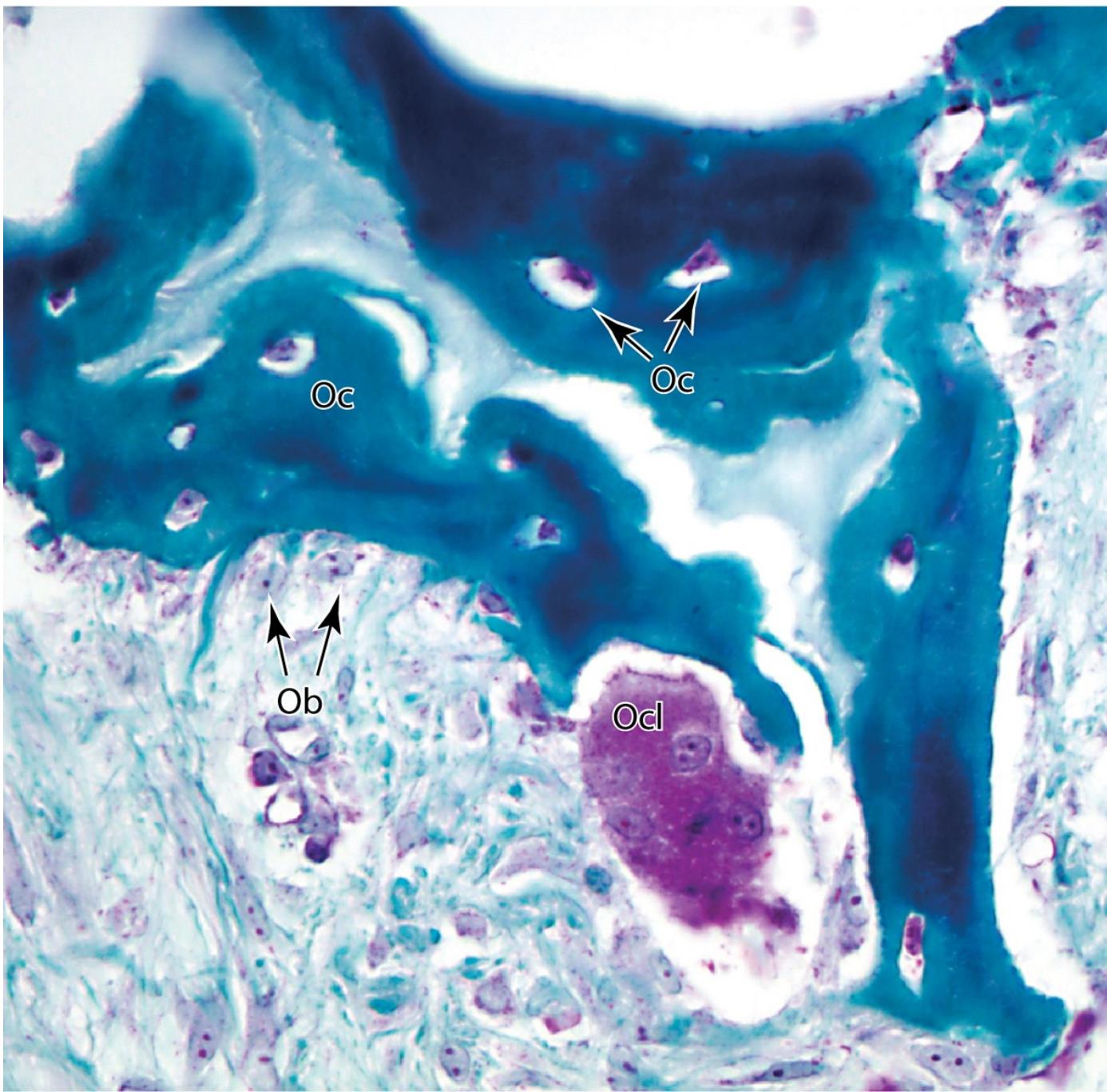
MEDICAL APPLICATION: dendritic processes of osteocytes detect load and maintain the matrix accordingly. Lack of exercise or the weightlessness experienced by astronauts leads to decreased bone density.



Bone Cells



MEDICAL APPLICATION: Osteoporosis, frequent in immobilized patients and postmenopausal women, is an imbalance where bone resorption exceeds bone formation. This leads to calcium loss and reduced bone mineral density (BMD).



Osteoblasts, osteocytes, and an osteoclast (400X Mallory trichrome)

- Bone-forming osteoblasts (**Ob**) differentiate from osteoprogenitor cells in the periosteum and endosteum.
- These cells differentiate further as osteocytes (**Oc**)
- The much less numerous large, multinuclear osteoclasts (**Ocl** reside on bony surfaces

Bones and Osseous Tissue

- **Bone (osseous tissue):** connective tissue with the matrix hardened by calcium phosphate and other minerals
- **Mineralization or calcification: the hardening process of bone**
 - Continually remodels itself and interacts physiologically with all of the other organ systems of the body
 - Permeated with nerves and blood vessels, which attests to its sensitivity and metabolic activity

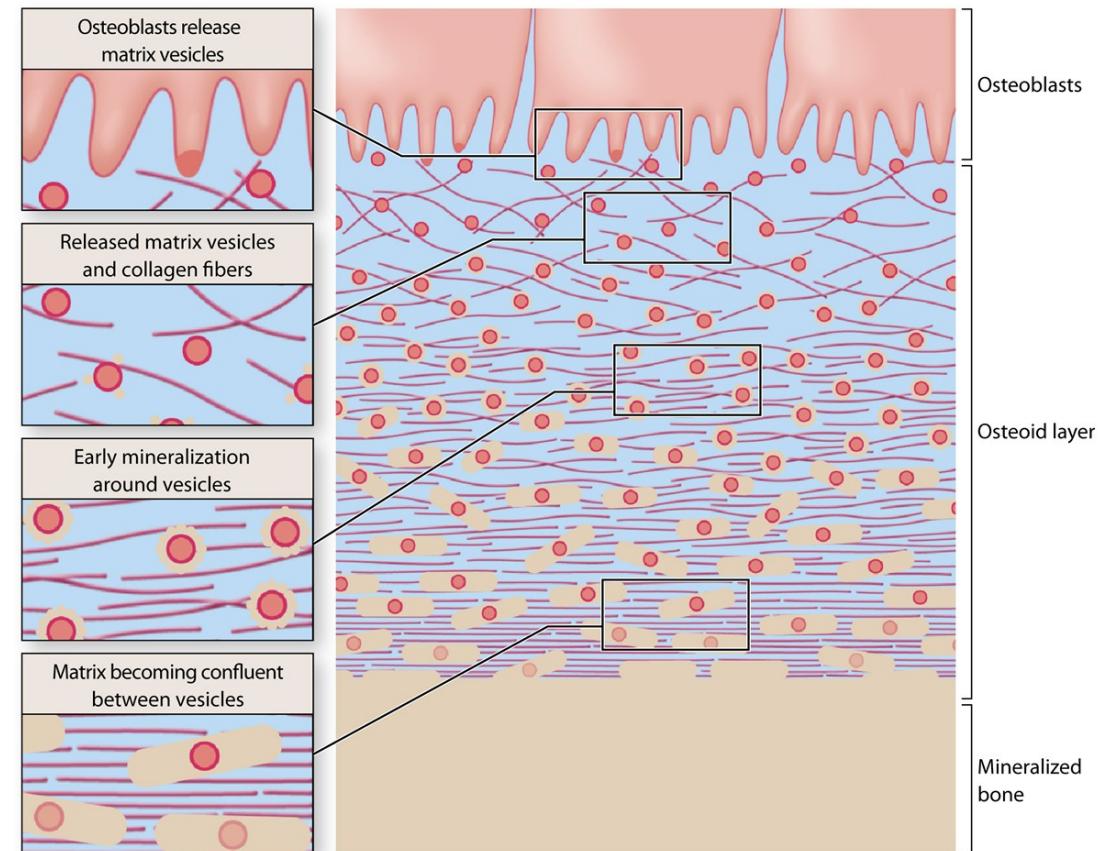
TEM: osteocyte surrounded by matrix, which calcifies around the processes, giving rise to canaliculi (**C**) in the bony matrix.



Bone matrix contains mainly type I collagen along with other matrix (noncollagenous) proteins.

Osteoblasts secrete type I collagen, several glycoproteins, and proteoglycans.

- Glycoproteins bind Ca^{2+} raising its local concentration of these ions.
- Osteoblasts also release very small membrane-enclosed **matrix vesicles**: filled with enzymes that hydrolyze PO_4^- ions from various macromolecules,
- Calcified nanocrystals of calcium hydroxyapatite $[\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2]$ surround the collagen fibers and form bony matrix



Osteogenesis imperfecta

Osteogenesis imperfecta, or “brittle bone disease,” refers to a group of related congenital disorders in which the osteoblasts produce deficient amounts of type I collagen or defective type I collagen due to genetic mutations. Such defects lead to a spectrum of disorders, all characterized by significant fragility of the bones. The fragility reflects the deficit in normal collagen, which normally reinforces and adds a degree of resiliency to the mineralized bone matrix.

Brittle bone disease

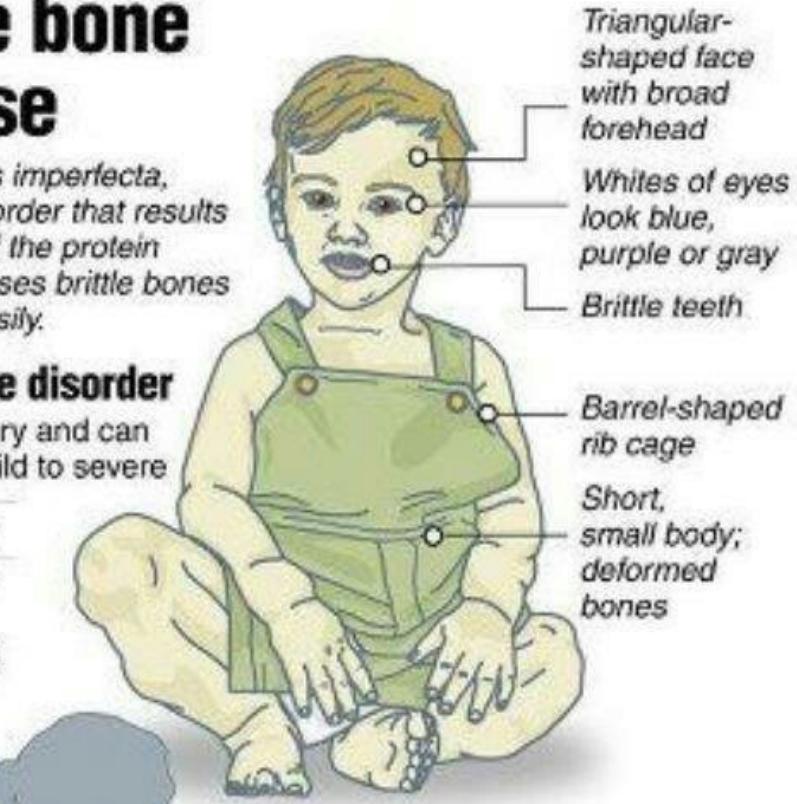
Osteogenesis imperfecta, a genetic disorder that results from a lack of the protein collagen, causes brittle bones that break easily.

Signs of the disorder

Symptoms vary and can range from mild to severe

Curved spine

Hearing loss
(often starts in 20s or 30s)



Bowing of the back

Can cause spinal curvature called kyphosis, which can lead to a hunchback



Kyphotic spine

Treatment

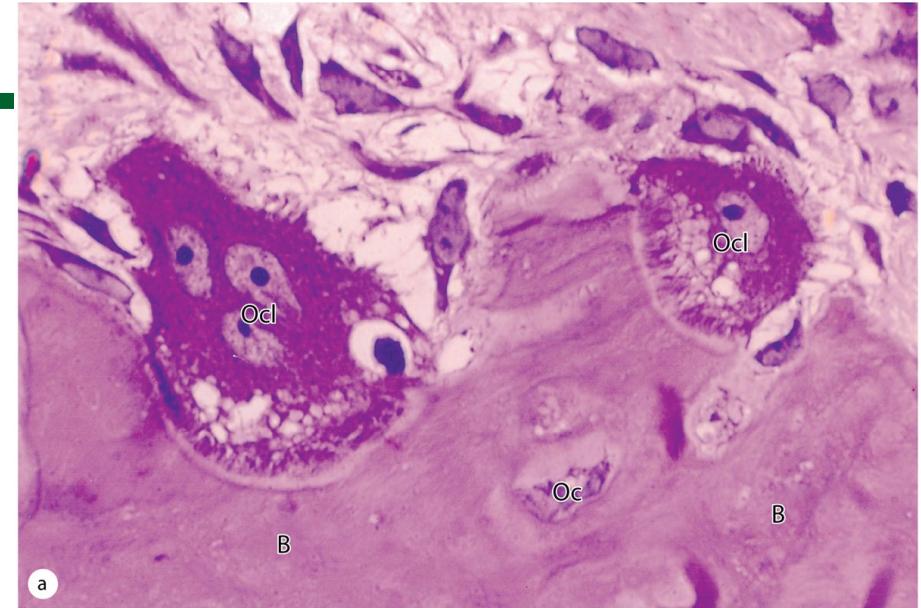
No cure; treatment involves managing symptoms

- Treating broken bones, brittle teeth
- Pain medications, physical therapy, use of assistive tools, such as braces, wheelchairs

Osteoclasts

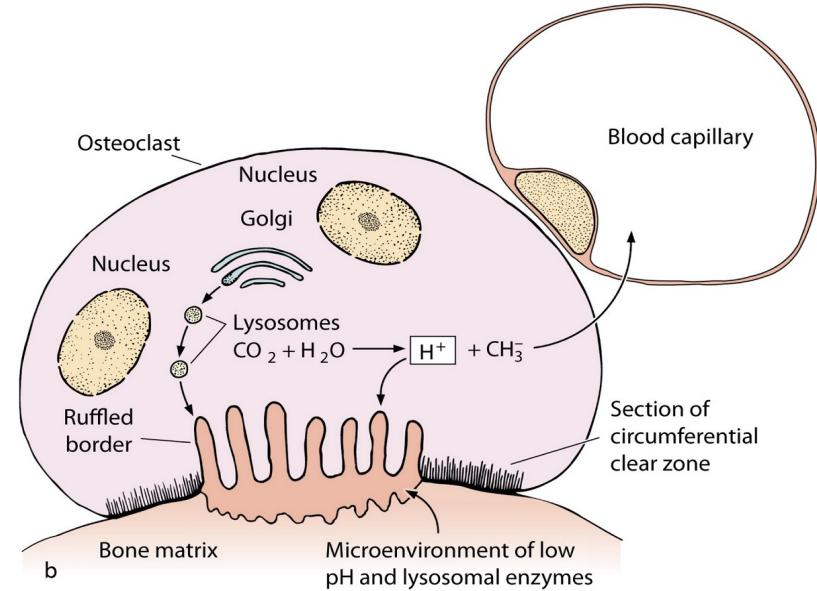
The osteoclast is a large cell with several nuclei derived by the fusion in bone of several blood-derived monocytes.

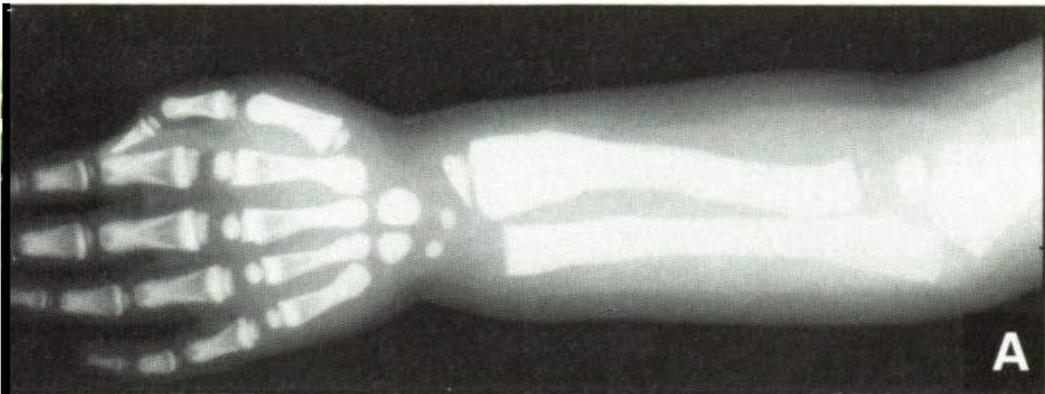
Osteoclasts (**Ocl**) digest bone matrix (**B**) in resorption cavities on the matrix surface.



Medical Application

Osteopetrosis: dense, heavy bones (“marble bones”). Osteoclasts lack ruffled borders and bone resorption is defective. Most patients with osteopetrosis have mutations in genes for the cells’ proton-ATPase pumps or chloride channels.





A



B

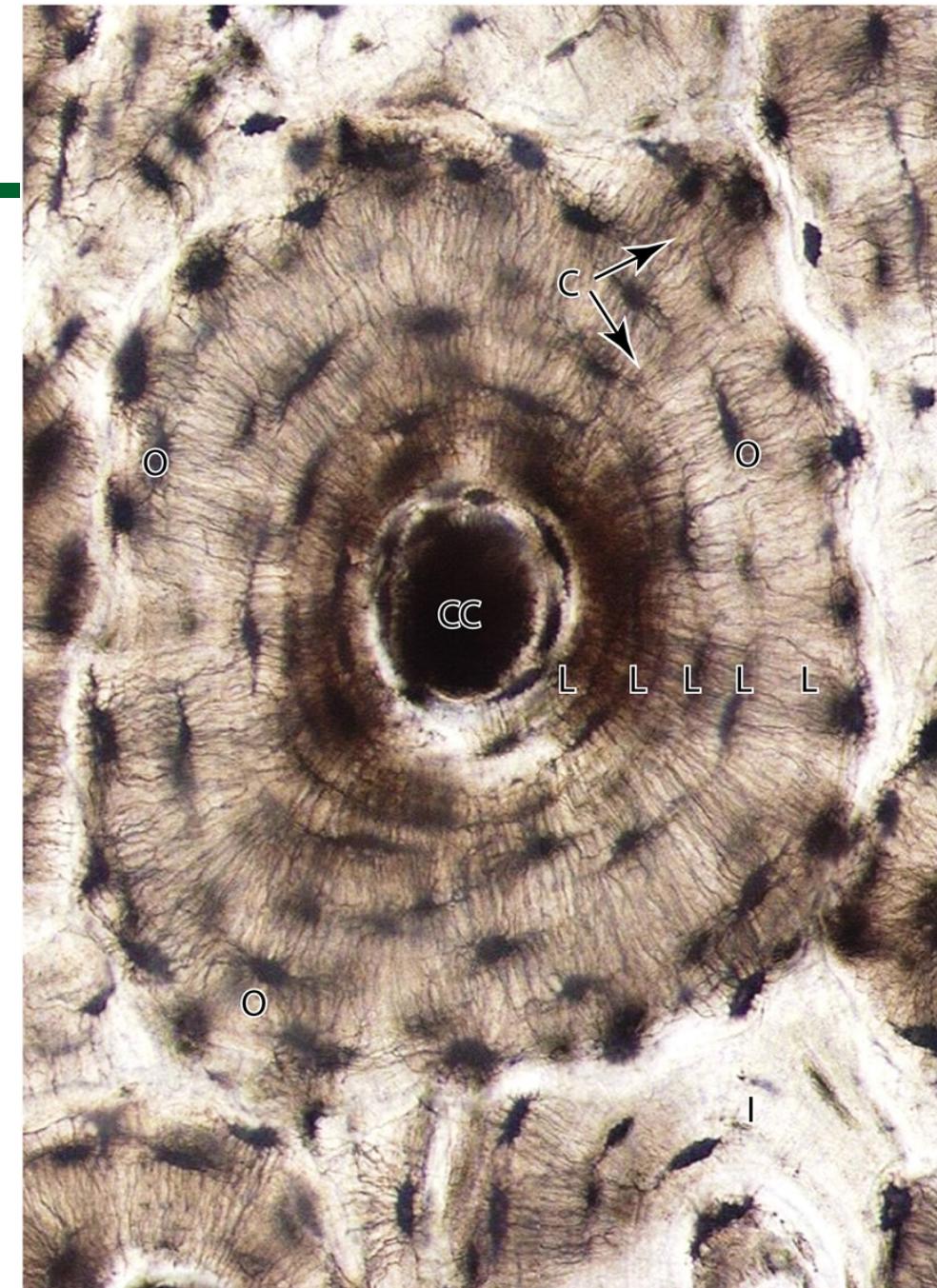
FIGURE 1: X-ray of arm prior to (A) and 6 months after (B) bone marrow transplantation. The high bone density, absent medullary

cavity, and abnormal epiphyseal plates of osteopetrosis have largely resolved following bone marrow transplantation.

An Osteon

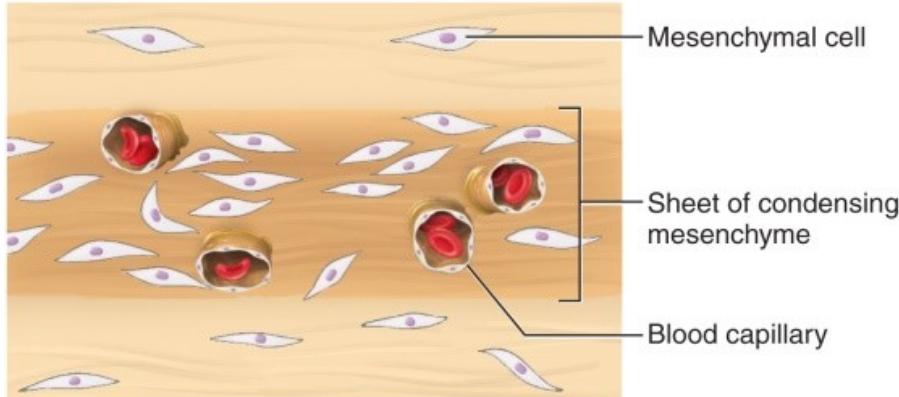
Osteons (Haversian systems) constitute most of the compact bone. Shown here is an osteon with four to five concentric lamellae (**L**) surrounding the central canal (**CC**). Osteocytes (**O**) in lacunae are in communication with each other and with the central canal and periphery of the osteon via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

http://highered.mheducation.com/sites/0072507470/student_view0/chapter_6/animation_bone_growth_in_width.html

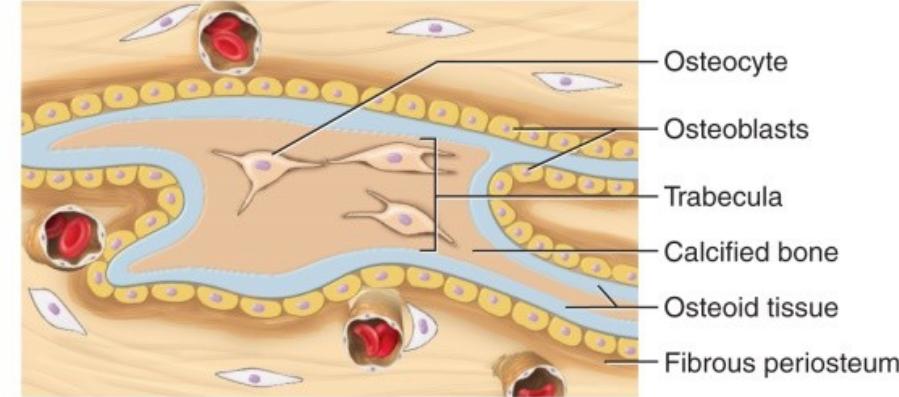


Intramembranous ossification produces flat bones of skull and clavicle from mesenchymal tissue

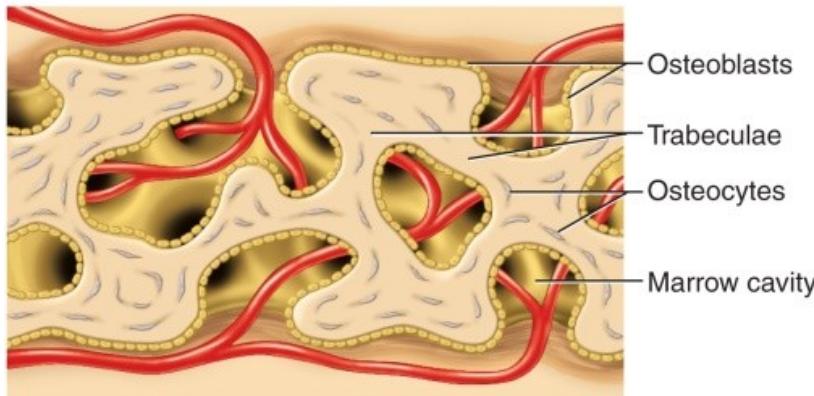
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



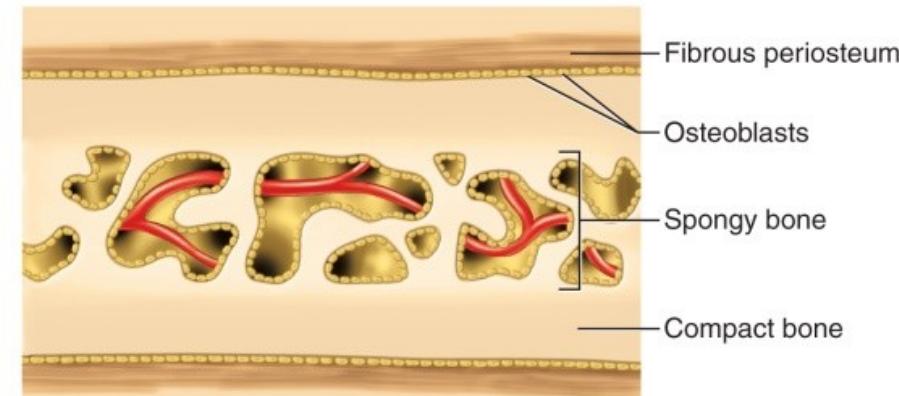
- ① Condensation of mesenchyme into soft sheet permeated with blood capillaries



- ② Deposition of osteoid tissue by osteoblasts on mesenchymal surface; entrapment of first osteocytes; formation of periosteum

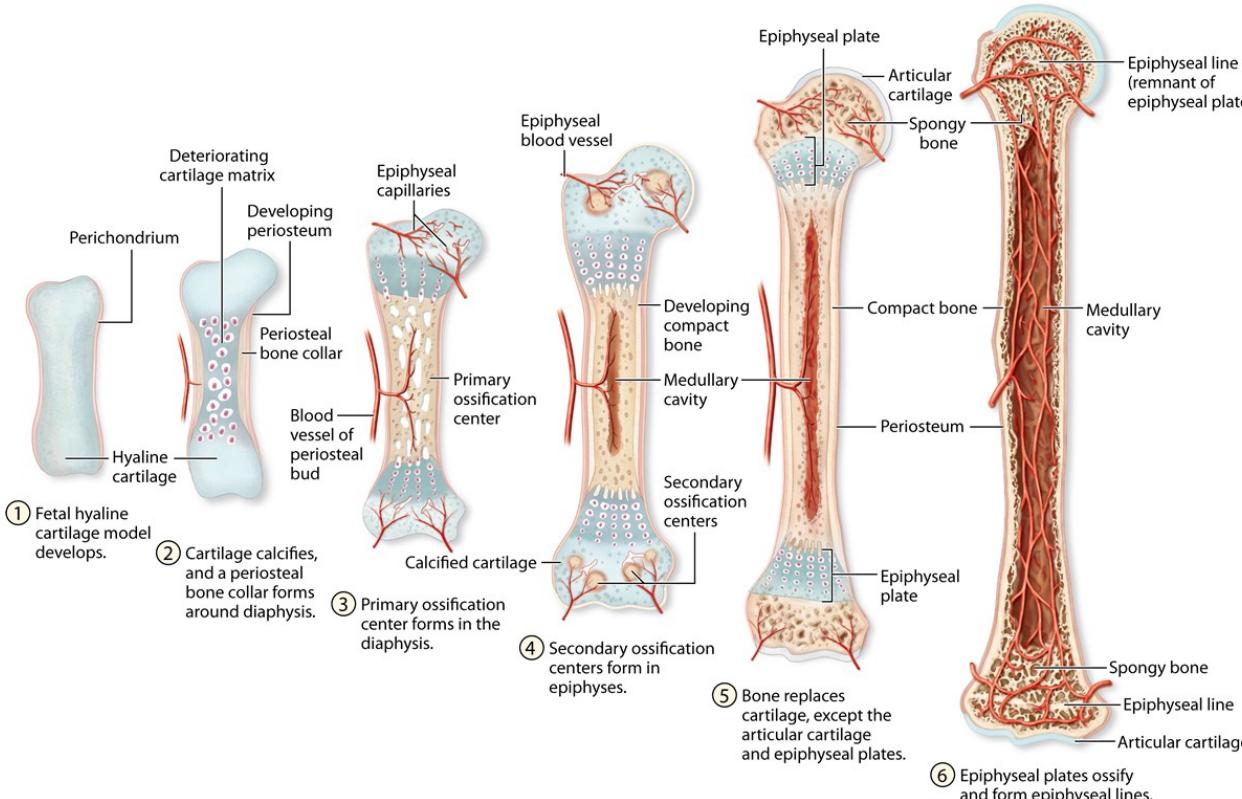


- ③ Honeycomb of bony trabeculae formed by continued mineral deposition; creation of spongy bone



- ④ Surface bone filled in by bone deposition, converting spongy bone to compact bone. Persistence of spongy bone in the middle layer.

Osteogenesis of long bones by endochondral ossification from hyaline cartilage



(1) Bone collar develops beneath the perichondrium
(2) Invasion of the degenerating cartilage by capillaries and osteoprogenitor cells to produce a **primary ossification center**
(3) Osteoid is deposited, calcified into woven bone, and is remodeled as compact bone.

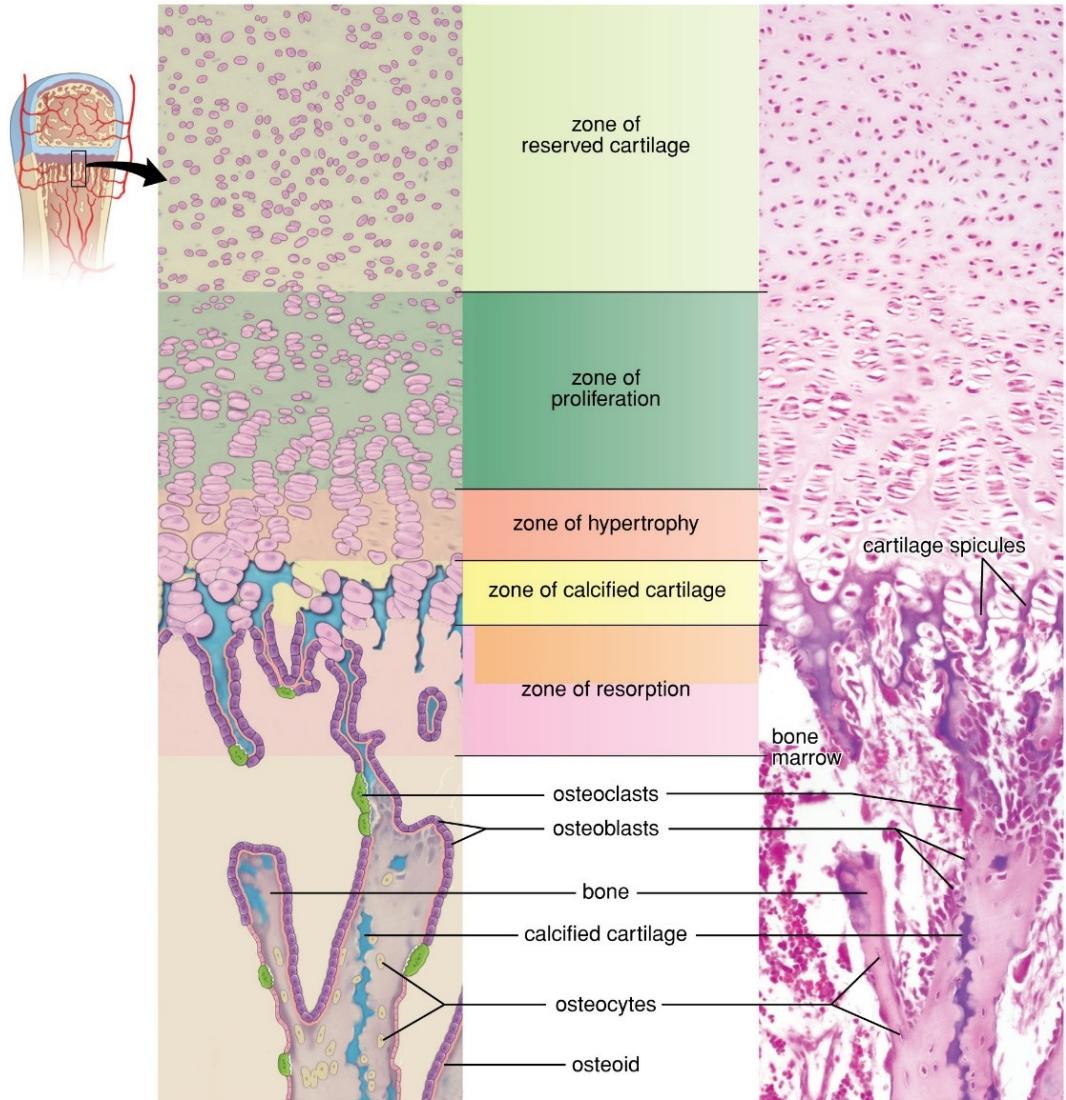
(4) **Secondary ossification centers** develop by a similar process in the epiphyses. Ossification centers gradually come to be separated only by the **epiphyseal plate**.

(5) Continued bone elongation. The two ossification centers do not merge until the epiphyseal plate disappears
(6) When full stature is achieved, osteoblasts of the periosteum provide for growth in the bone's diameter.

Development of Bone:

<https://www.youtube.com/watch?v=exXgZap0AvL0&nohtml5=false>

Zones in the Epiphyseal Cartilage



Zone of reserve cartilage exhibits no cellular proliferation or active matrix production.

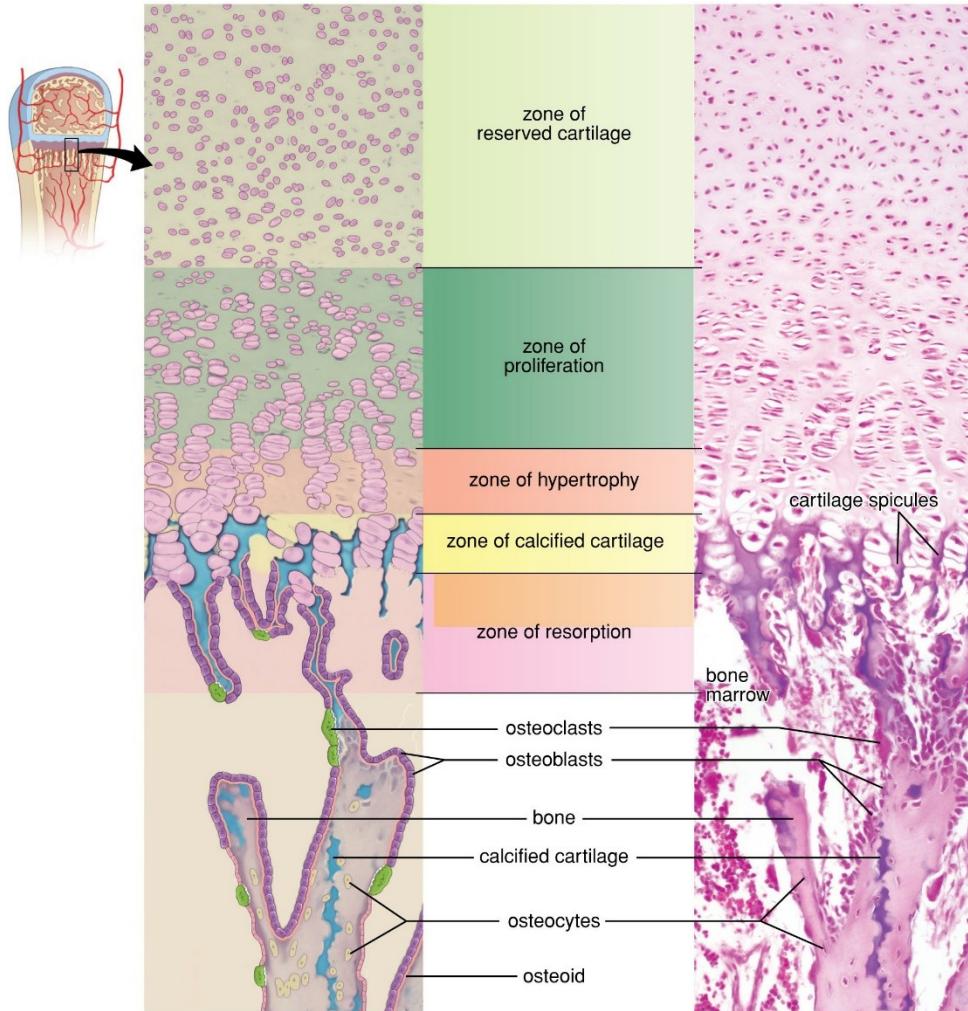
Zone of proliferation is adjacent to the zone of reserve cartilage in the direction of the diaphysis. In this zone, the cartilage cells undergo division and organize into distinct columns.

Zone of hypertrophy contains greatly enlarged (hypertrophic) cartilage cells.

Zone of calcified cartilage, the hypertrophied cells begin to degenerate and the cartilage matrix becomes calcified. The calcified cartilage then serves as an initial scaffold for deposition of new bone.

Zone of resorption is the zone nearest the diaphysis. The calcified cartilage here is in direct contact with the connective tissue of the marrow cavity.

Zones in the Epiphyseal Cartilage



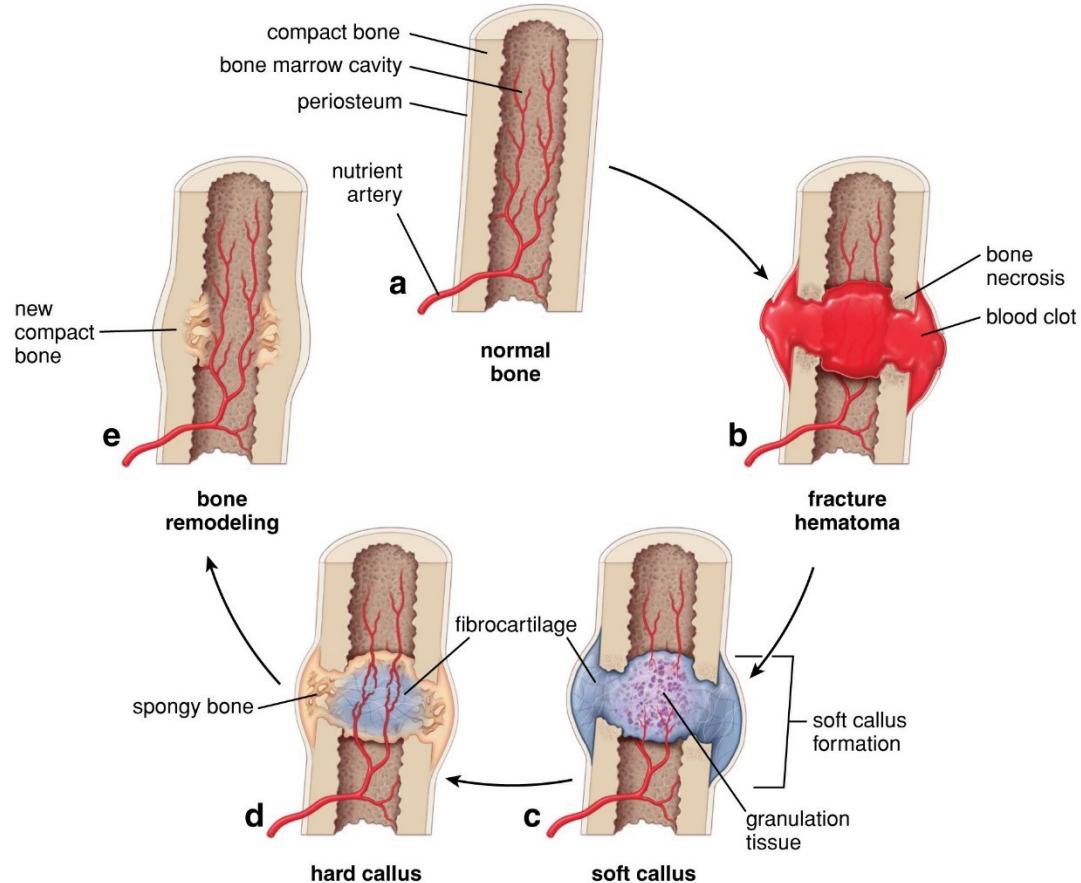
MEDICAL APPLICATION

Calcium deficiency in children can lead to rickets, a disease in which the bone matrix does not calcify normally and the epiphyseal plate can become distorted by the normal strains of body weight and muscular activity. Ossification processes are consequently impeded

http://highered.mheducation.com/sites/0072507470/student_view0/chapter_6/animation_osteoporosis.html

Bone fractures and the stages of the bone healing process

MEDICAL APPLICATION



Bone fractures are repaired by fibrocartilage formation and osteogenic activity of the major bone cells.

Bone fractures disrupt blood vessels, causing bone cells near the break to die.

The damaged blood vessels produce a localized hemorrhage or hematoma. Clotted blood is removed along with tissue debris by macrophages and the matrix of damaged, cell-free bone is

Chapter 9 Nerve Tissue & The Nervous System

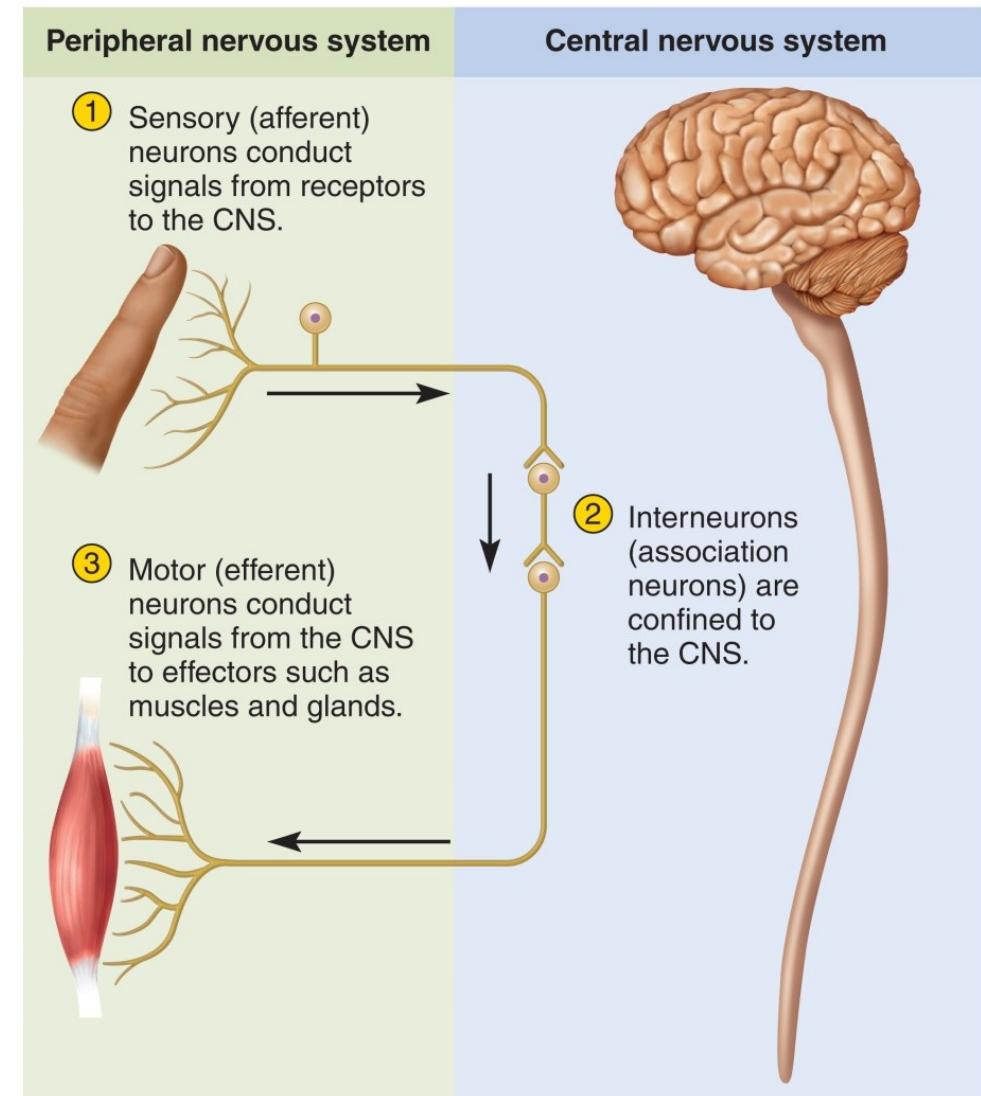
Objectives

- 1. Overview of Nervous System**
- 2. Neurons**
- 3. Nerves**
- 4. Glia**
- 5. Meninges**

Cells and Tissues of the Nervous System: Functions and Divisions

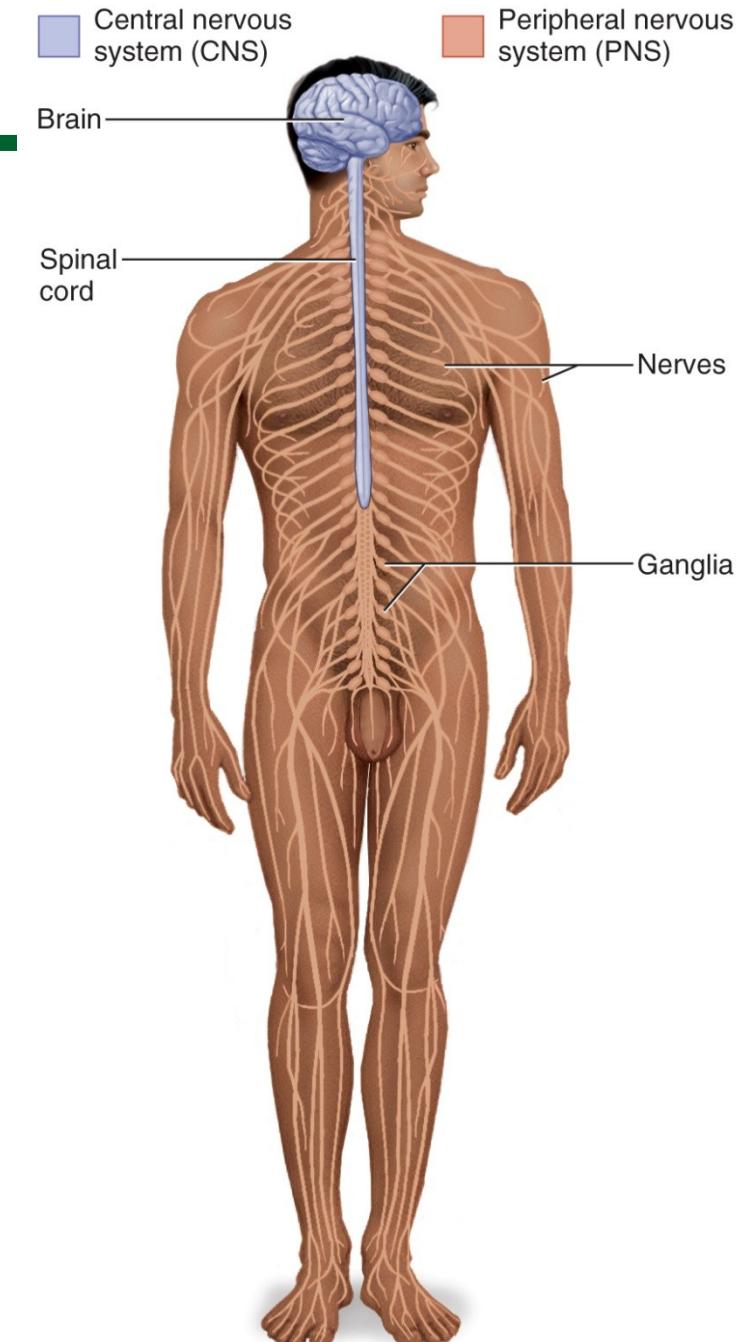
- **Sensory function:** Respond to stimuli
- **Integrative function:** Receive and process information
- **Motor function:** Issue outgoing signals

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



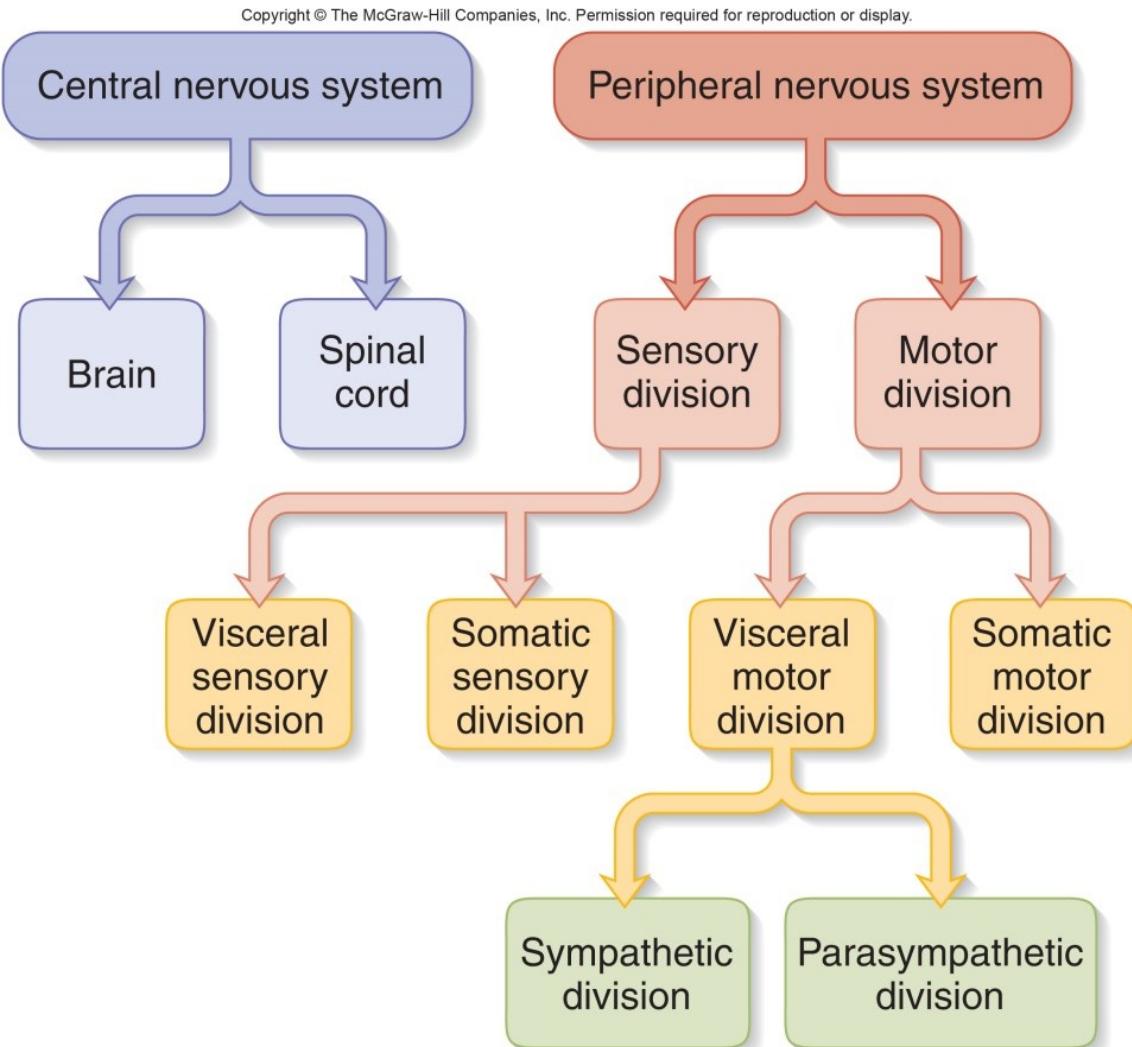
Two main anatomical subdivisions

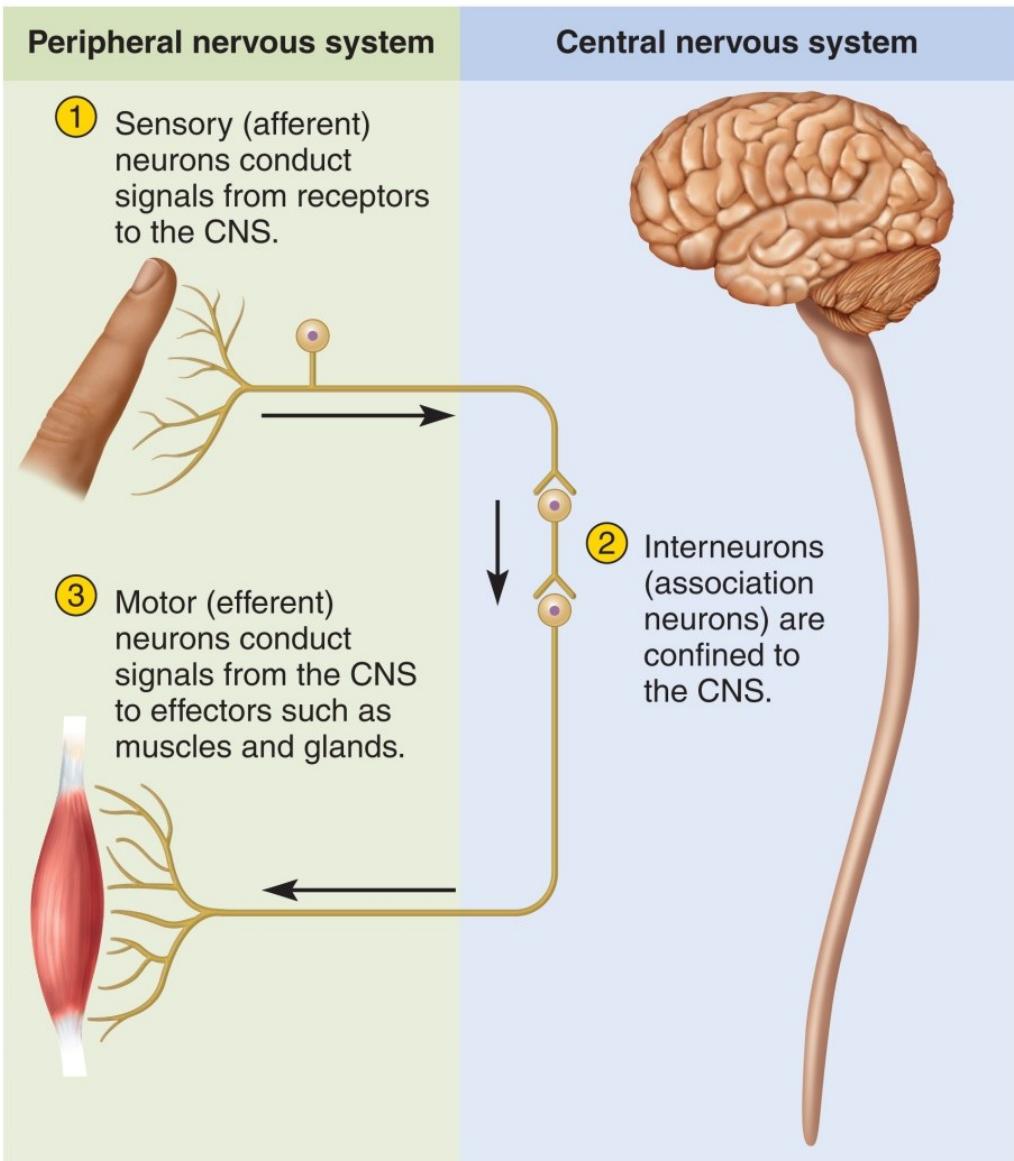
- **Central nervous system (CNS)**
 - Brain and spinal cord
 - Protected by cranium and vertebral column
 - Carries out integrative functions
- **Peripheral nervous system (PNS)**
 - Nerves leading to and from CNS
 - Provides pathway of signal input and output
 - Connects CNS to body's sense organs, muscles, and glands
 - Carries out sensory and motor functions



Overview of the Nervous System

- Peripheral nervous system has two major functional subdivisions
 - Sensory (afferent) division: carries sensory signals from various receptors to the CNS
 - Informs the CNS of stimuli within or around the body
 - Somatic sensory division: carries signals from receptors in the skin, muscles, bones, and joints
 - Visceral (Autonomic) sensory division: carries signals from the viscera of the thoracic and abdominal cavities
 - Heart, lungs, stomach, and urinary bladder





>> MEDICAL APPLICATION

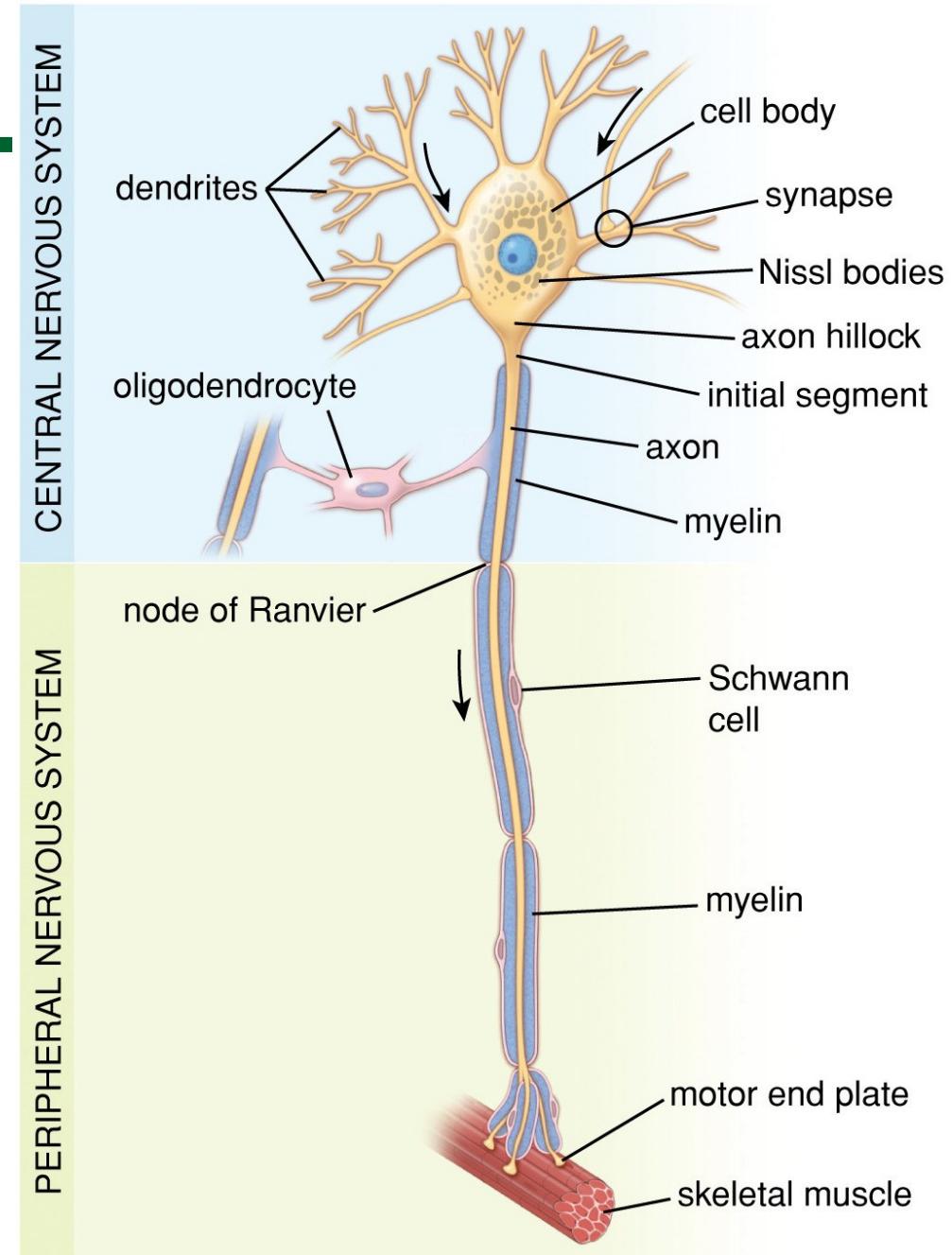
Parkinson disease is characterized by muscle tremors, reduced activity of the facial muscles, loss of balance, and postural stiffness.

It is caused by gradual loss by apoptosis of dopamine-producing neurons whose cell bodies lie within the nuclei of the CNS substantia nigra. Parkinson disease is treated with L-dopa (L-3,4-dihydroxyphenylalanine), a precursor of dopamine which augments the declining production of this neurotransmitter.

<http://abcnews.go.com/Health/video/dr-oliver-sacks-real-life-awakenings-29088197>

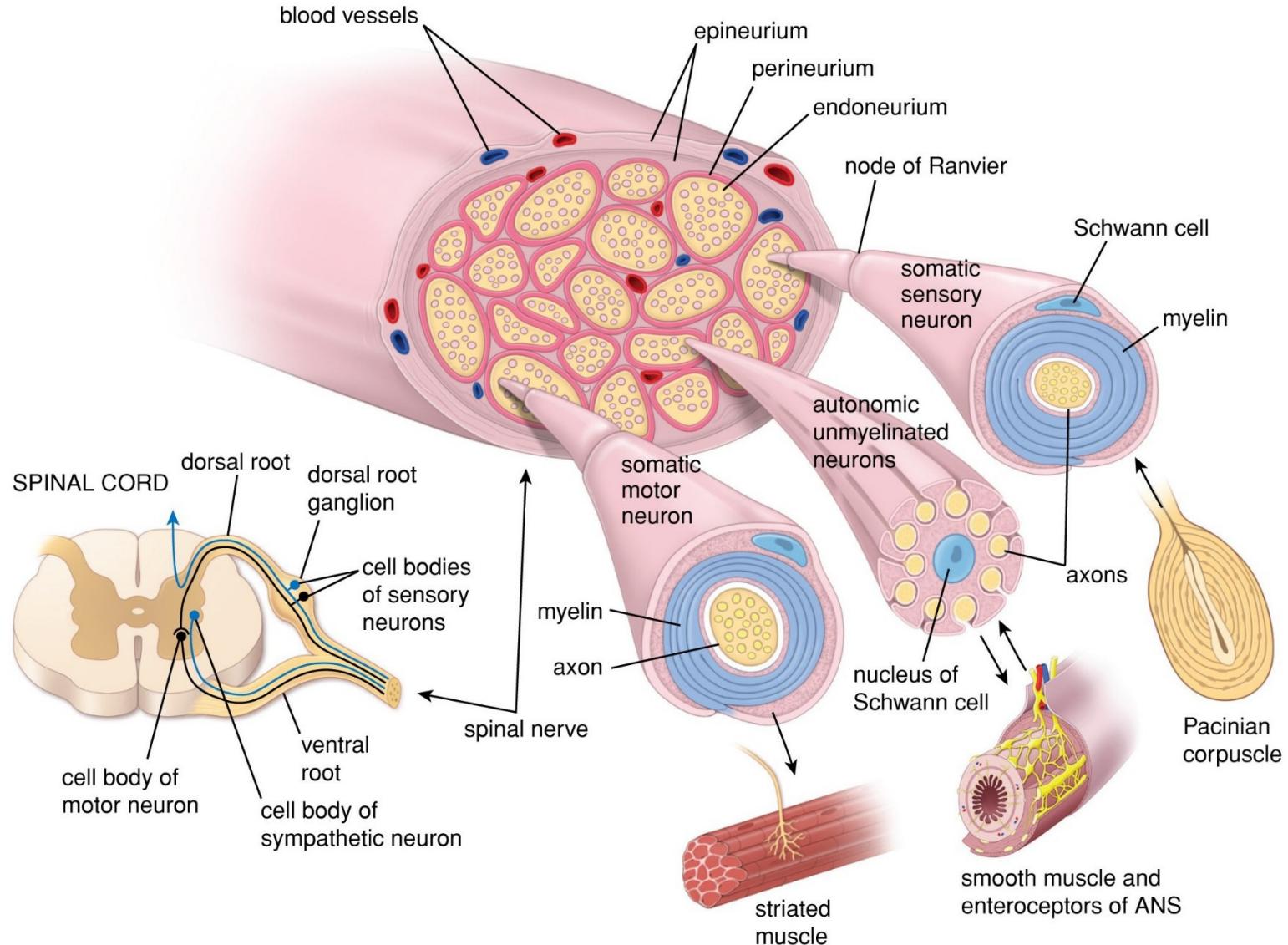
Neuron structure

- **Neurosoma (soma or cell body):** control center of neuron
- **Neurofibrils:** Cytoskeleton of protein bundles
- **Dendrites:** thick arms arising from soma, receives signals from other neurons
- **Axon (nerve fiber):** output pathway for signals to other cells not more than one, sometimes none
- **Synaptic knob:** bulb at terminus of axon
- **Axon hillock:** conical mound on soma side gives rise to axon
- **Axonal transport:** process of carrying substances to and from soma



Nerve: Bundle of nerve fibers and connective tissue wrappings with internal blood vessels

- **Endoneurium:** thin loose connective tissue covering nerve fiber
- **Perineurium:** epithelium-like cells, wrapped bundles of nerve cells, **fascicles**
- **Epineurium:** fibrous sleeve wrapping several fascicles
- **Ganglion:** Swelling, usually near end of nerve that contains cell bodies of peripheral neurons



Review of the Synapse

Presynaptic neuron: sends signal

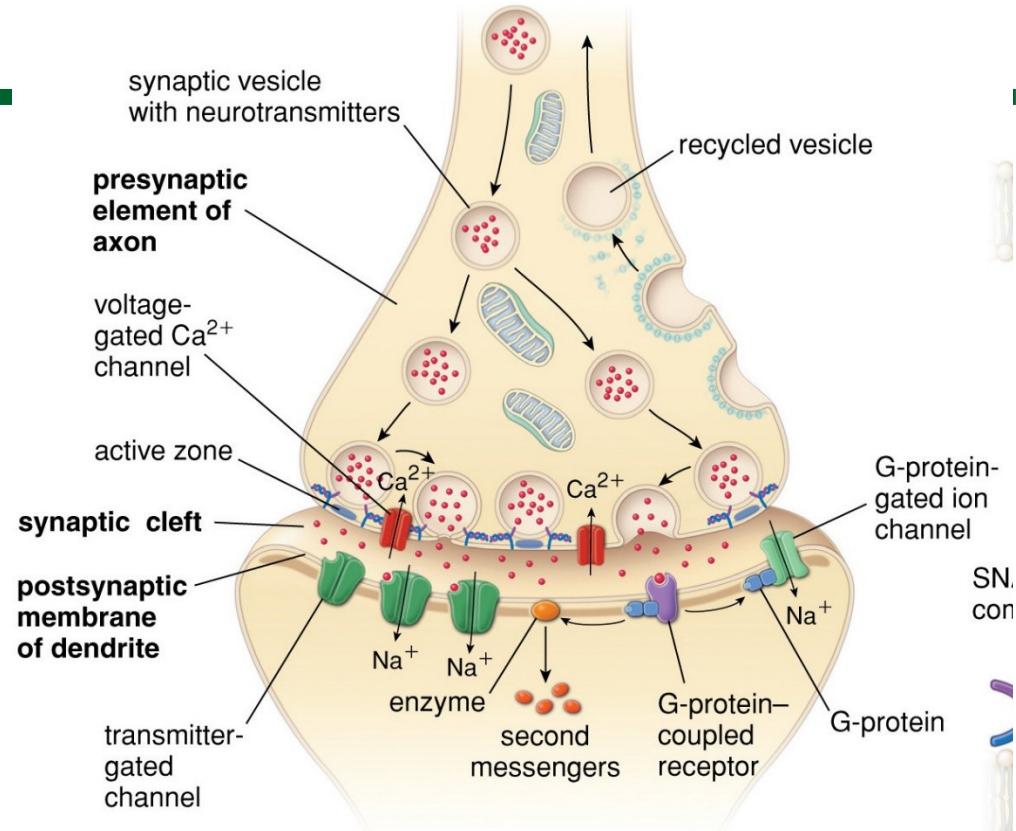
Postsynaptic neuron: stimulated neuron

Synaptic cleft: gap between two neurons

Synaptic knob: Dilated tip of presynaptic neuron

Synaptic vesicles: spherical vesicles with

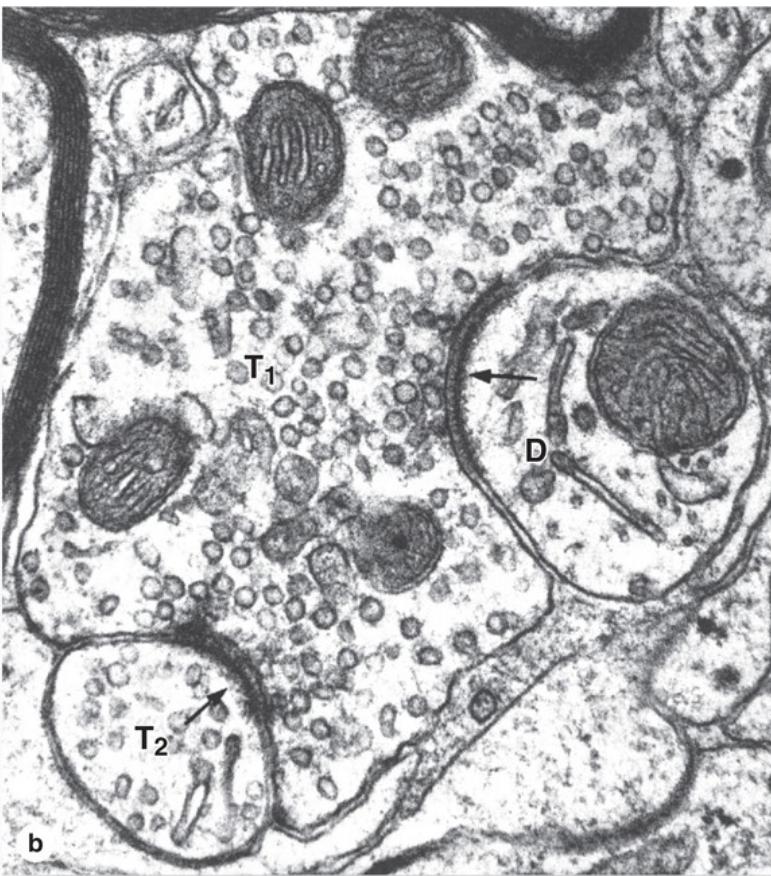
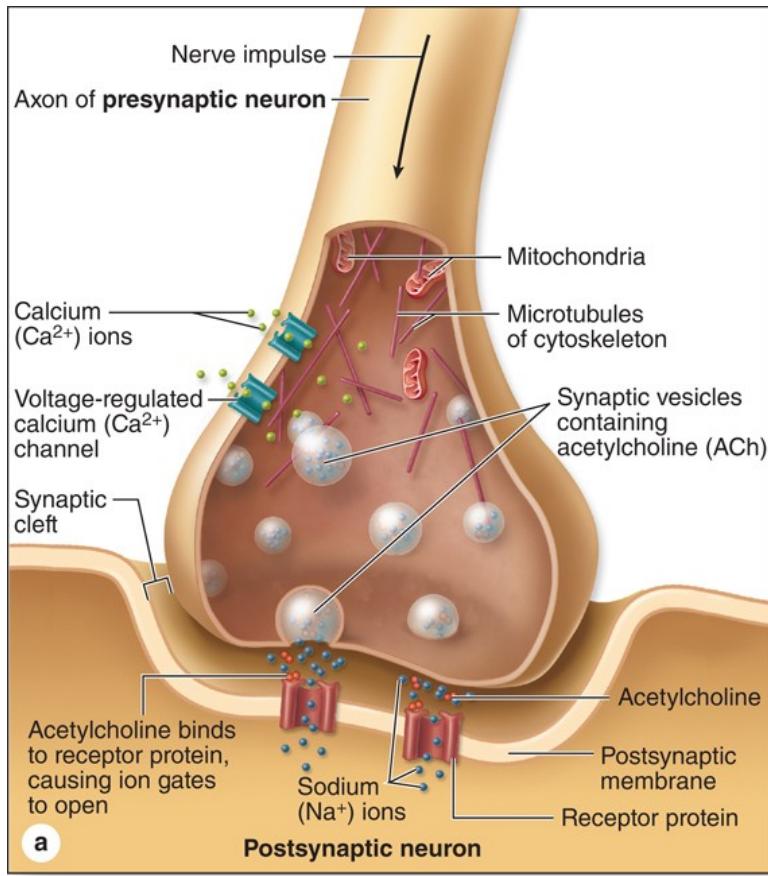
Neurotransmitters: chemical signals, undergo exocytosis with arrival of nerve signal



>> MEDICAL APPLICATION

Most local anesthetics are low-molecular-weight molecules that bind to the voltage-gated sodium channels of the axolemma, interfering with sodium ion influx and, consequently, inhibiting the action potential responsible for the nerve impulse.

http://highered.mheducation.com/sites/0072495855/student_view0/chapter14/animation_transmission_across_a_synapse.html



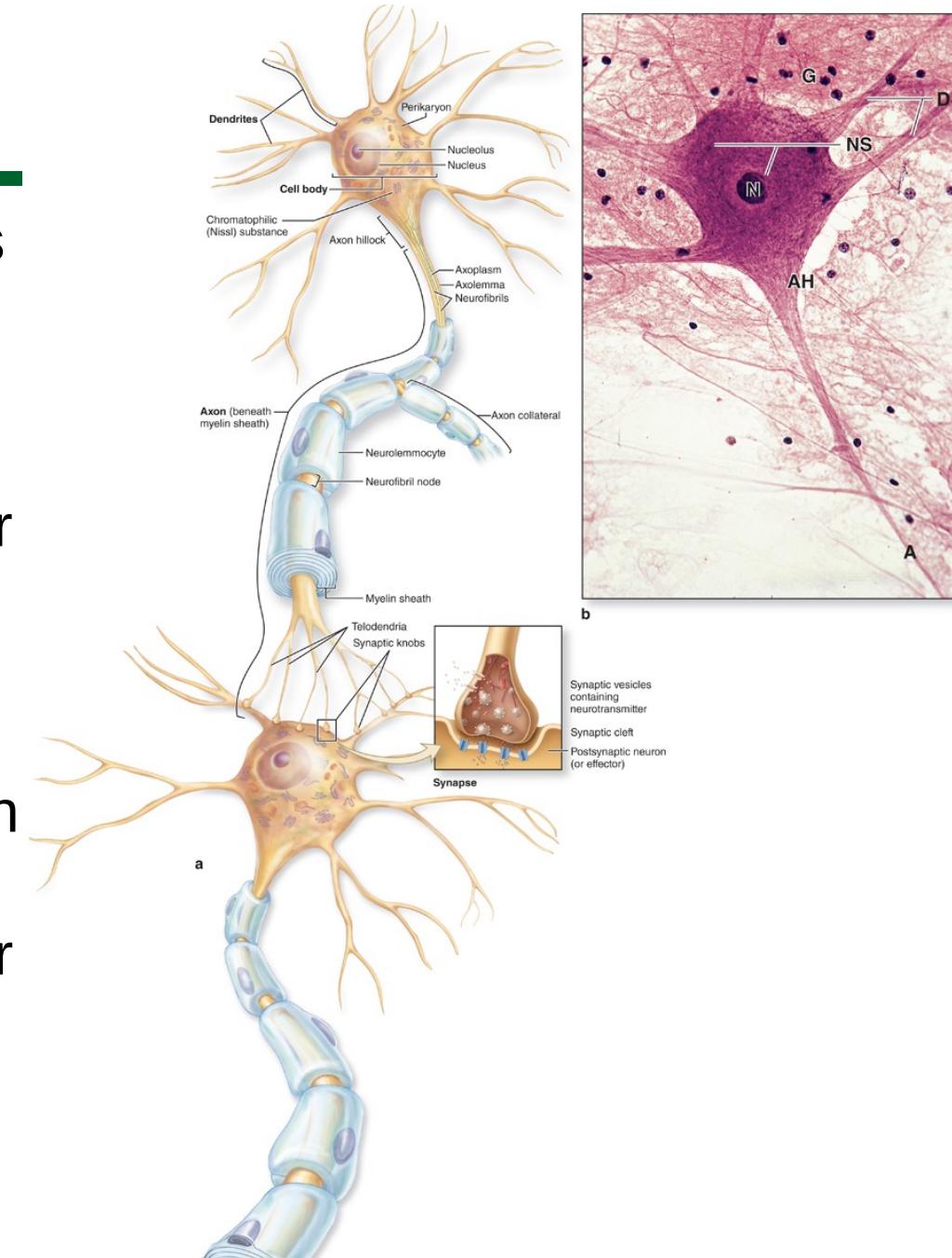
>> MEDICAL APPLICATION
 Alzheimer's disease, a common type of dementia in the elderly, affects both neuronal perikarya and synapses within the cerebrum. Functional defects are due to neurofibrillary tangles, which are accumulations of tau protein associated with microtubules of the neuronal perikaryon and axon hillock regions, and neuritic plaques, which are dense aggregates of β -amyloid protein that form around the outside of these neuronal regions.

>> MEDICAL APPLICATION

Levels of neurotransmitters in the synaptic cleft and available for binding postsynaptic receptors are normally regulated by several local mechanisms. Selective serotonin reuptake inhibitors (SSRIs), a widely used class of drugs for treatment of depression and anxiety disorders, were designed to augment levels of this neurotransmitter at the postsynaptic membrane of serotonergic CNS synapses by specifically inhibiting its reuptake at the presynaptic membrane.

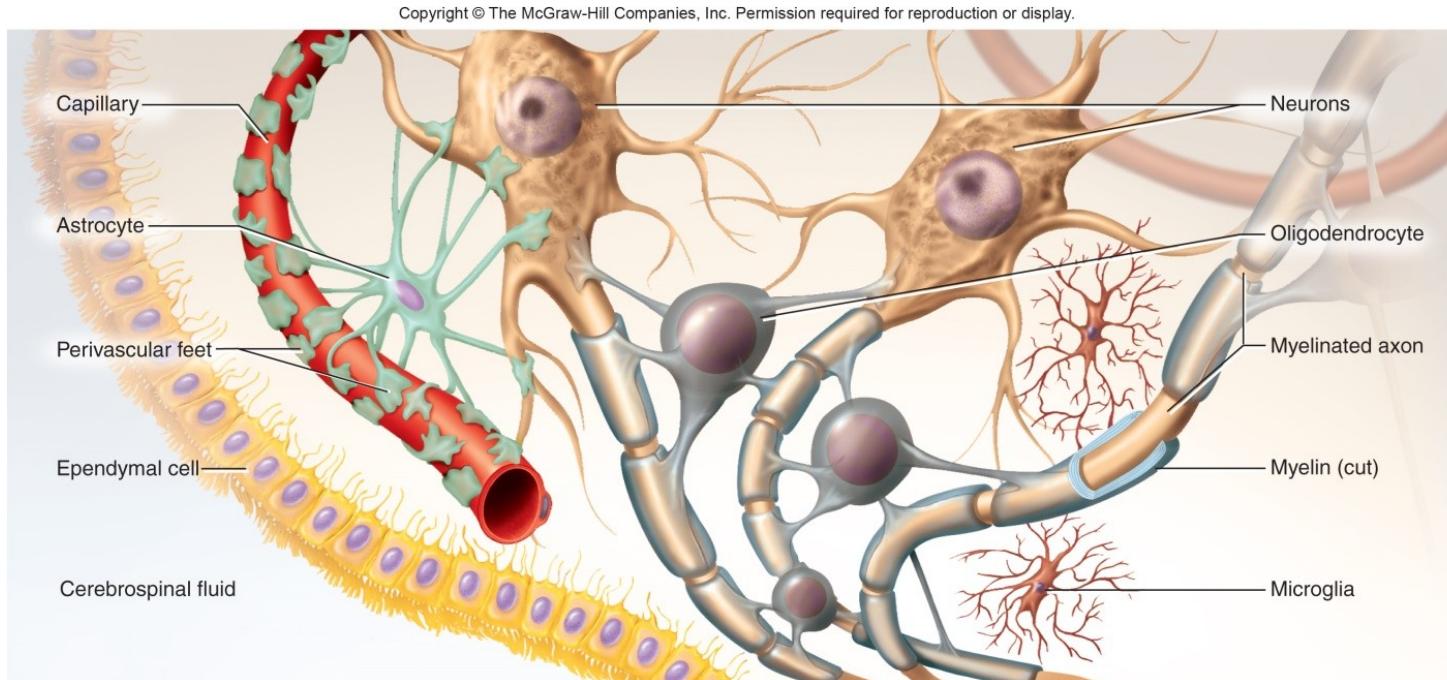
Supportive Cells (Neuroglia)

- Neuroglia outnumber the neurons by as much as 50 to 1
- Neuroglia or glial cells
 - Support and protect the neurons
 - Bind neurons together and form framework for nervous tissue
 - In fetus, guide migrating neurons to their destination
 - If mature neuron is not in synaptic contact with another neuron it is covered by glial cells
 - Prevents neurons from touching each other
 - Gives precision to conduction pathways



Types of Neuroglial Cells: CNS

- **Oligodendrocytes** form myelin sheaths in CNS: each wraps around many nerve fibers
- **Ependymal** cells line cavities and produce CSF
- **Microglia** (macrophages) formed from monocytes in areas of infection, trauma or stroke
- **Astrocytes:** contribute to BBB and regulate composition of brain tissue fluid



Types of Neuroglial Cells

PNS

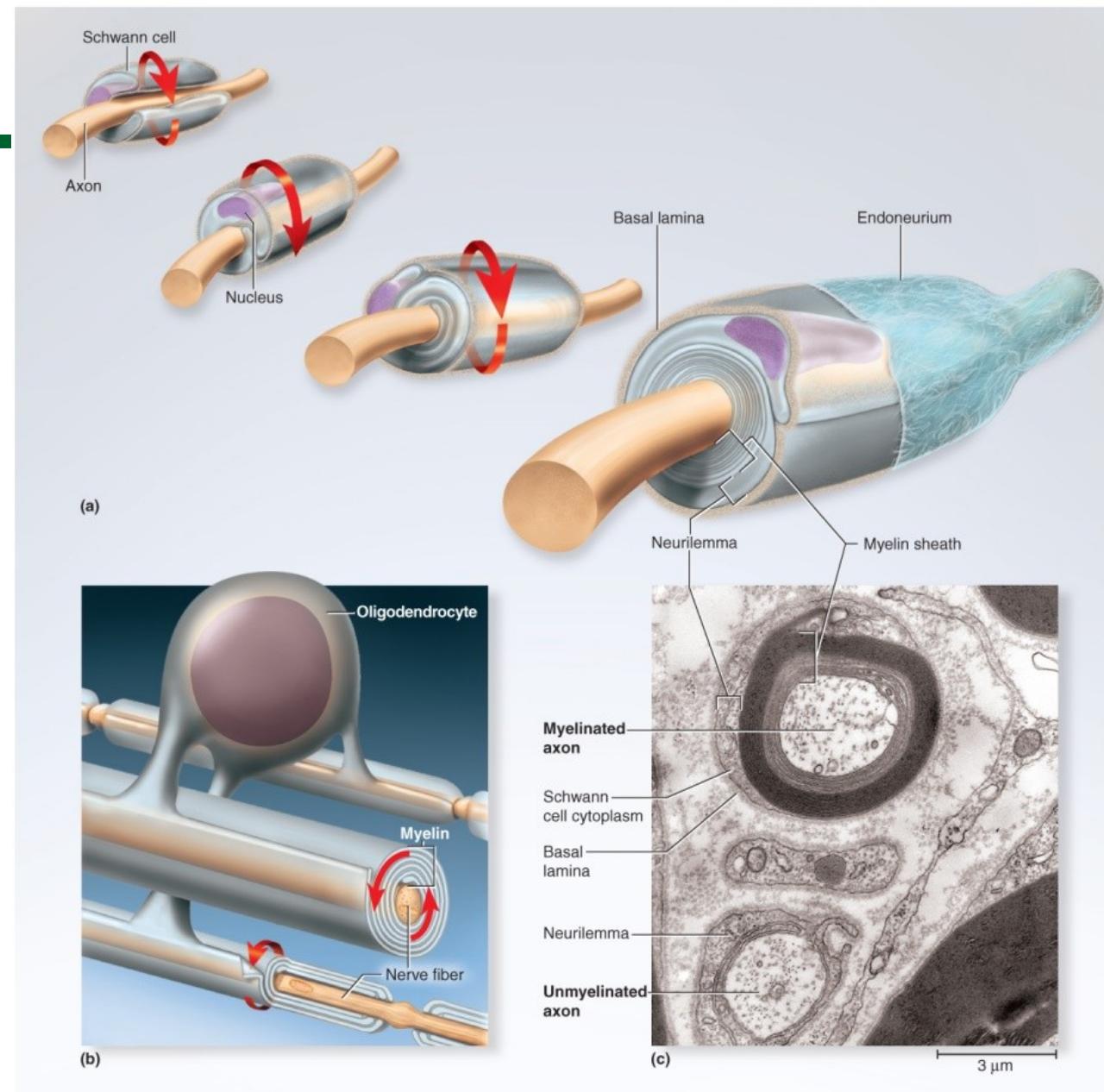
Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Schwann cells myelinate fibers of PNS
Satellite cells thought to have same function as astrocytes

»» MEDICAL APPLICATION

In multiple sclerosis (MS) myelin sheaths are damaged by an autoimmune mechanism. T lymphocytes and microglia degrade myelin.

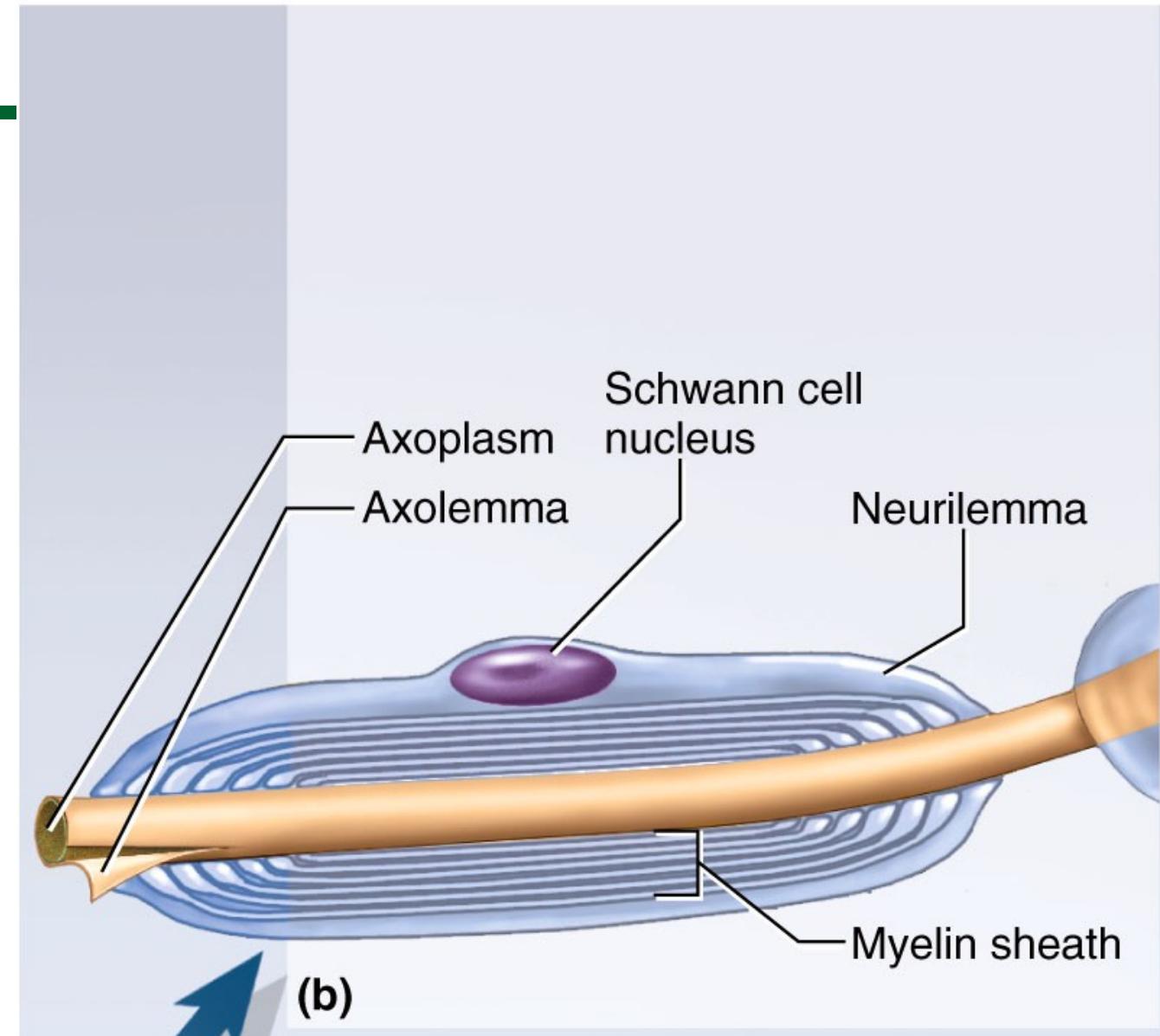
Introduction to Multiple Sclerosis - Medical Animation
Short: <https://www.youtube.com/watch?v=VloDr8ugbql>



c: © The McGraw-Hill Companies, Inc./Dr. Dennis Emery, Dept. of Zoology and Genetics, Iowa State University, photographer

The Myelin Sheath

- **Myelin sheath characteristics**
 - Layers wrapped around fiber, insulating it
 - like electrical tape around wire
 - Requires many cells to myelinate one nerve
 - **Nodes of Ranvier**
 - gaps between myelinated segments
 - Myelin covered segments termed **internodes**



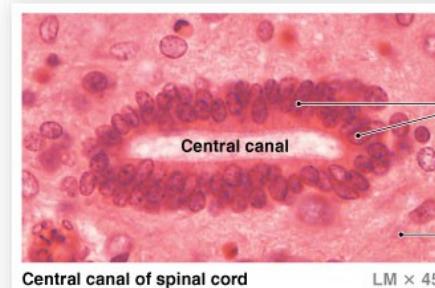
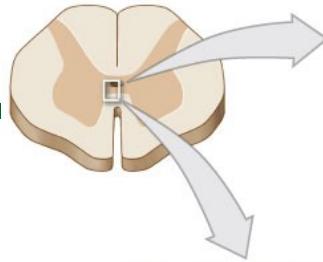
Myelination

White matter: Regions of CNS with many myelinated nerves

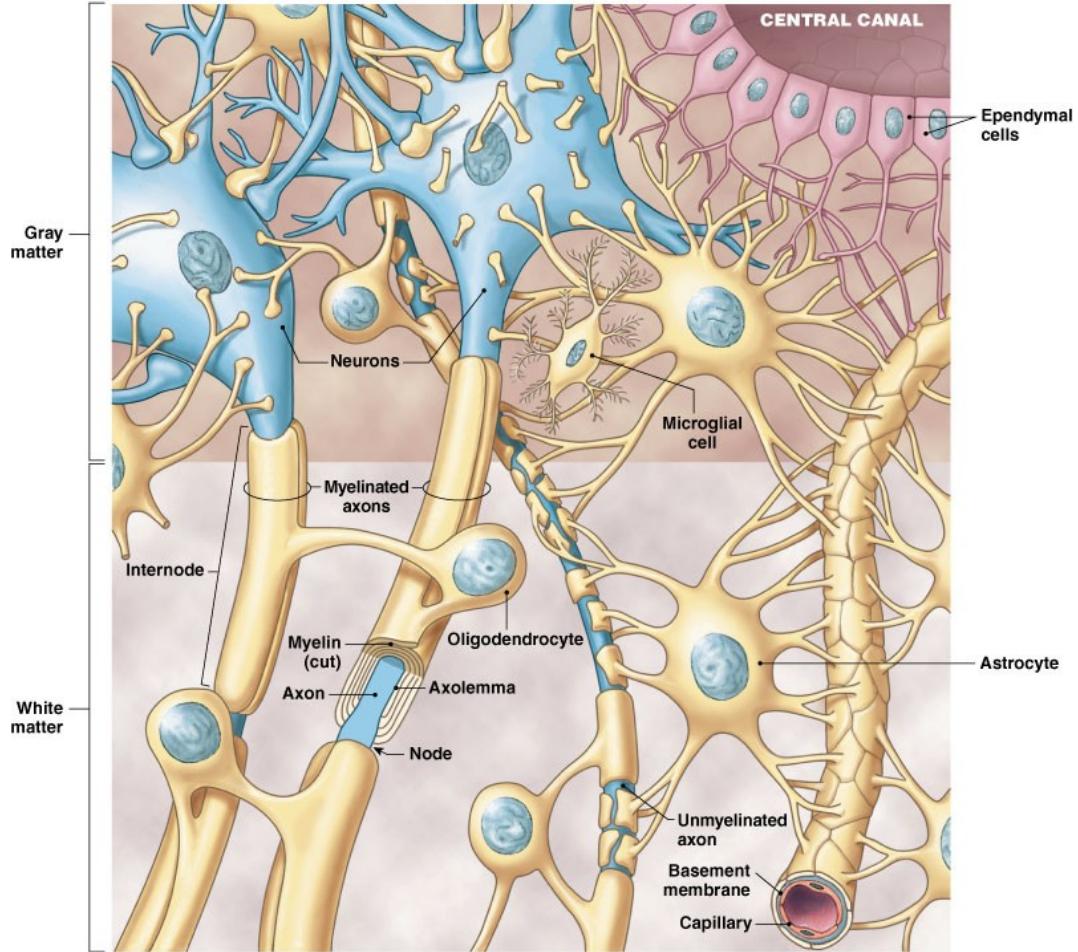
- Bundles of nerve fibers called tracts, each with similar origin, destination, and function
- Myelination giving white color

Gray matter: Unmyelinated areas of CNS where neurosomas, dendrites, and synapses are located

- Little myelin, so duller color
- Information-processing part of CNS



a Light micrograph showing the ependymal lining of the central canal of the spinal cord



b A diagrammatic view of neural tissue in the CNS, showing relationships between neuroglia and neurons

Meninges: Protective Membranes

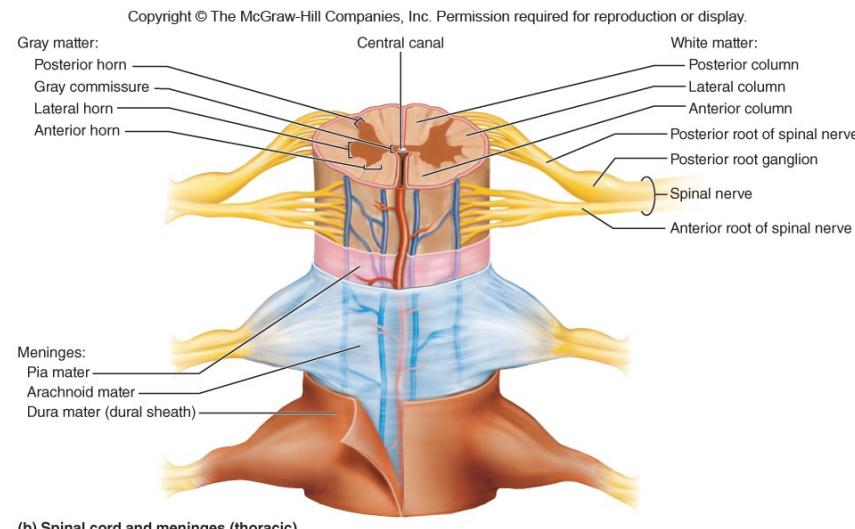
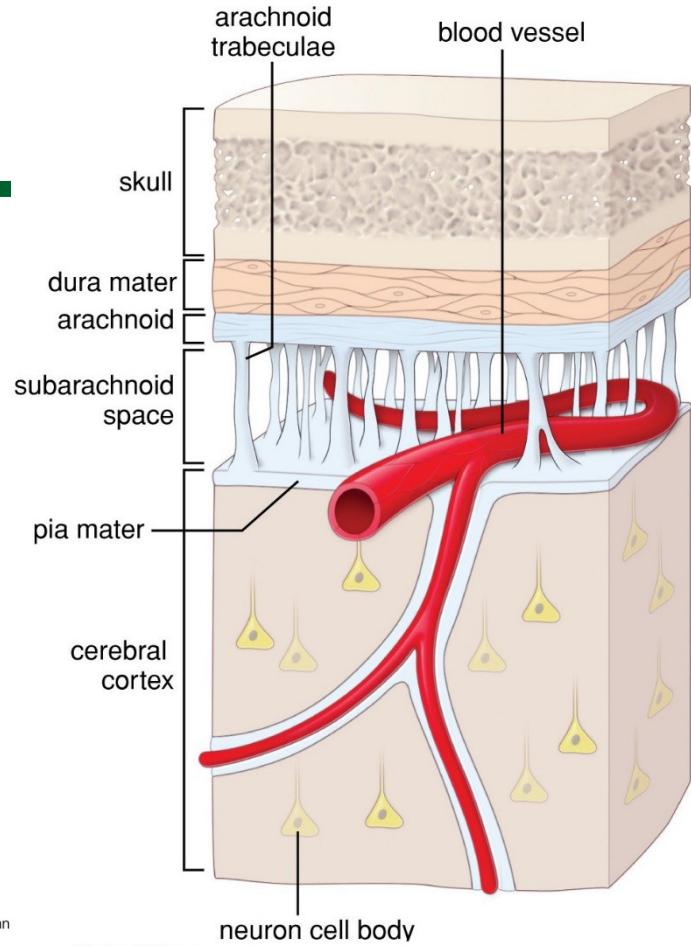
Meninges: Fibrous membranes between nervous tissue and bone

Dura mater: Tough collagenous outermost membrane

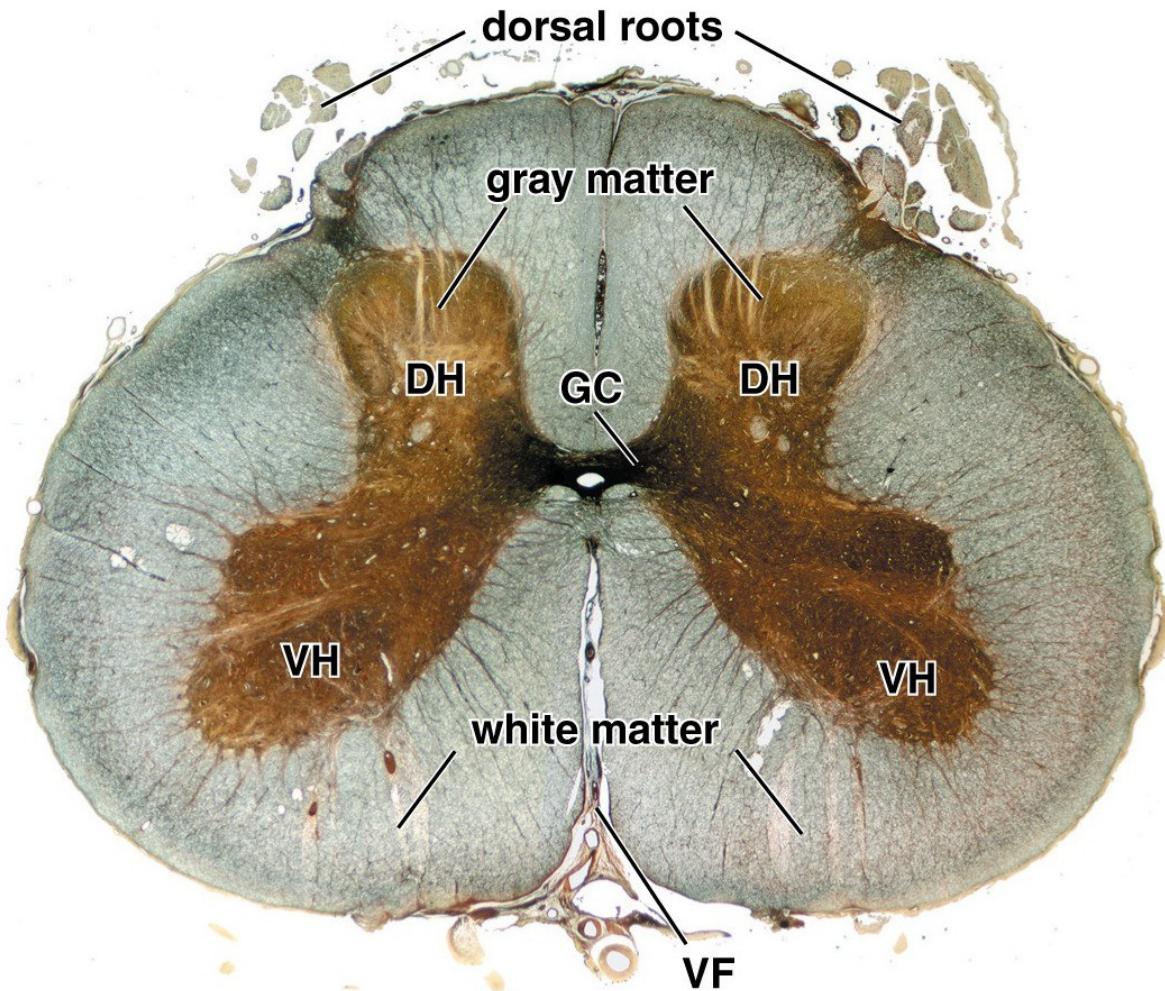
Separated from bone by epidural space, anesthetics often used here

Arachnoid mater: Delicate middle layer, Loose webby appearance

Pia mater: Innermost thin layer of connective tissue, follows contours of brain and spinal cord



Cross-section of the human spinal cord



The spinal cord is organized into an outer part, the white matter, and an inner part, the gray matter that contains nerve cell bodies and associated nerve fibers.

The gray matter of the spinal cord appears roughly in the form of a butterfly. The anterior and posterior prongs are referred to as ventral horns (VH) and dorsal horns (DH), respectively. They are connected by the gray commissure (GC).

The white matter contains nerve fibers that form ascending and descending tracts. The outer surface of the spinal cord is surrounded by the pia mater.

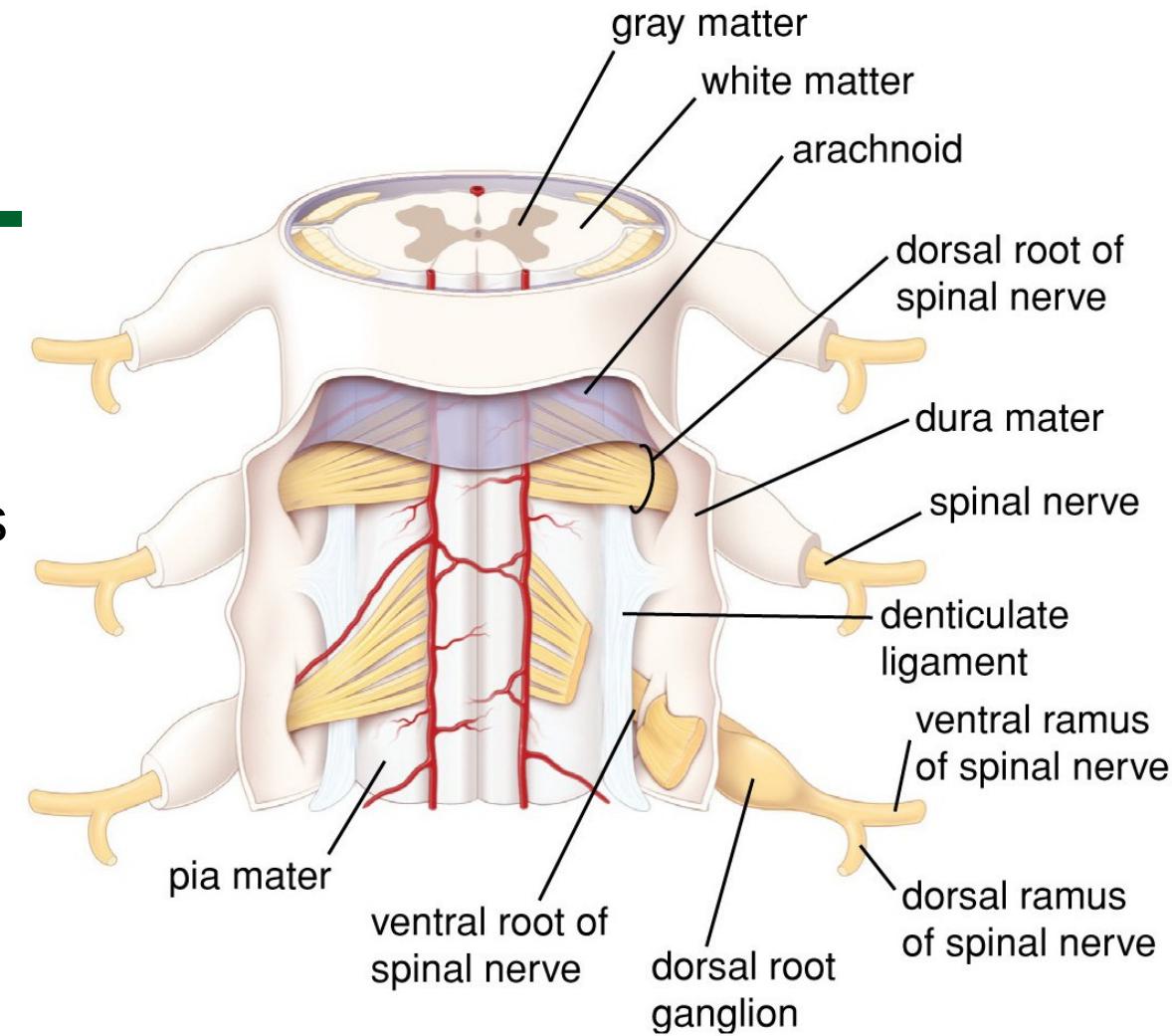
Cord cross section

Posterior (dorsal) horns: sensory reception

Anterior (ventral) horns: motor neurons give motor commands through axons/spinal nerve

Lateral horn: neurons of sympathetic nervous system

Gray commissure: connects right and left halves of cord. May have **central canal** filled with spinal fluid or closed



Copyright © 2016 Wolters Kluwer - All Rights Reserved

» **MEDICAL APPLICATION** regeneration of peripheral nerves is functionally efficient only when the fibers and the columns of Schwann cells are directed properly. In a mixed nerve, if regenerating sensory fibers grow into columns formerly occupied by motor fibers connected to motor end plates, the function of the muscle will not be reestablished.

Flow of information through the spinal cord

Somatic efferent (motor) system: one neuron conducts the impulses from the CNS to the effector (skeletal muscle).

Visceral (autonomic) efferent system: chain of two neurons conducts the impulses, a presynaptic neuron located within the CNS and a postsynaptic neuron located in the paravertebral or prevertebral ganglia.

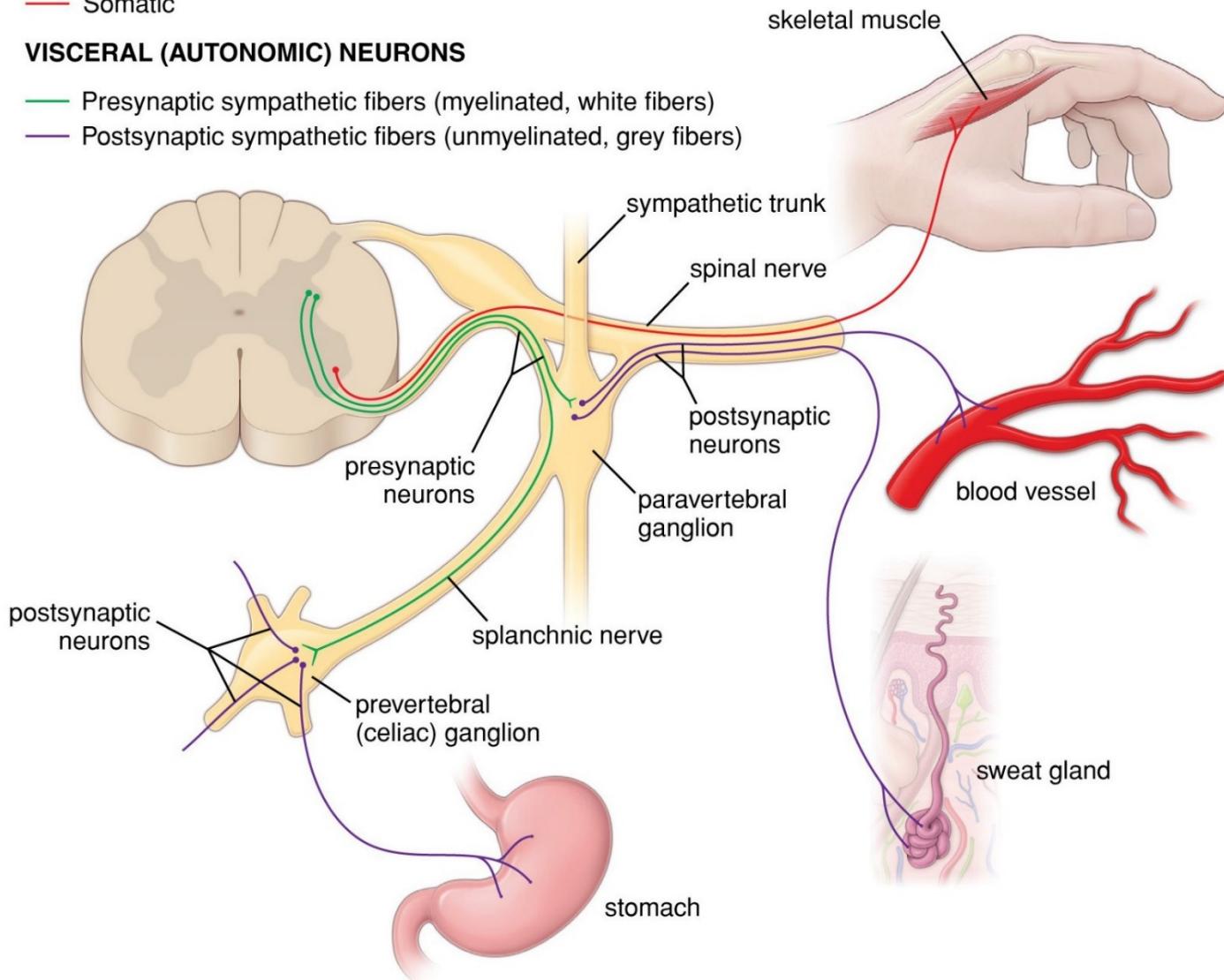
EFFERENT (MOTOR) NEURONS

— Somatic

VISCERAL (AUTONOMIC) NEURONS

— Presynaptic sympathetic fibers (myelinated, white fibers)

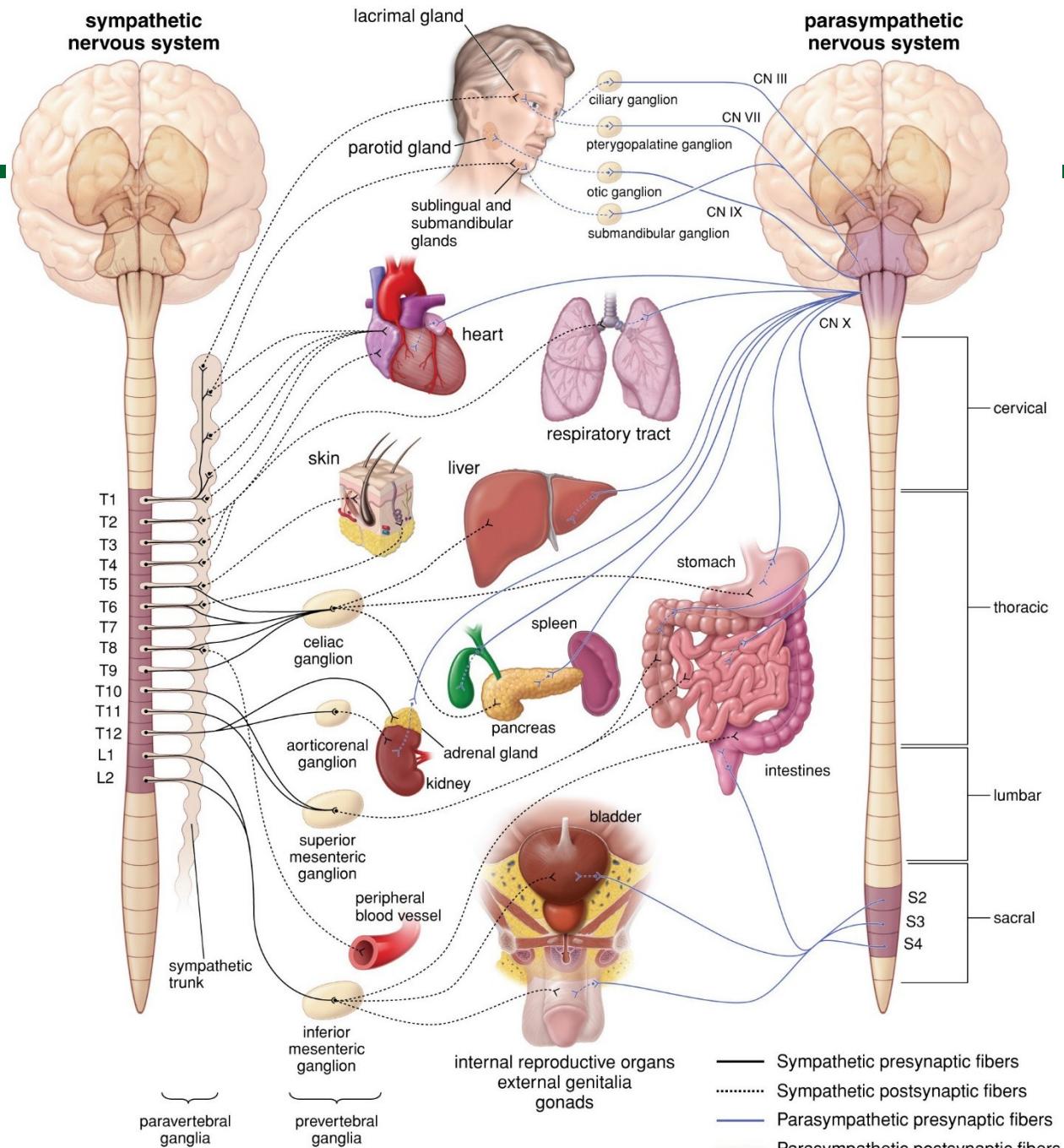
— Postsynaptic sympathetic fibers (unmyelinated, grey fibers)



Autonomic Nervous System

The sympathetic outflow is shown on the left, the parasympathetic on the right.

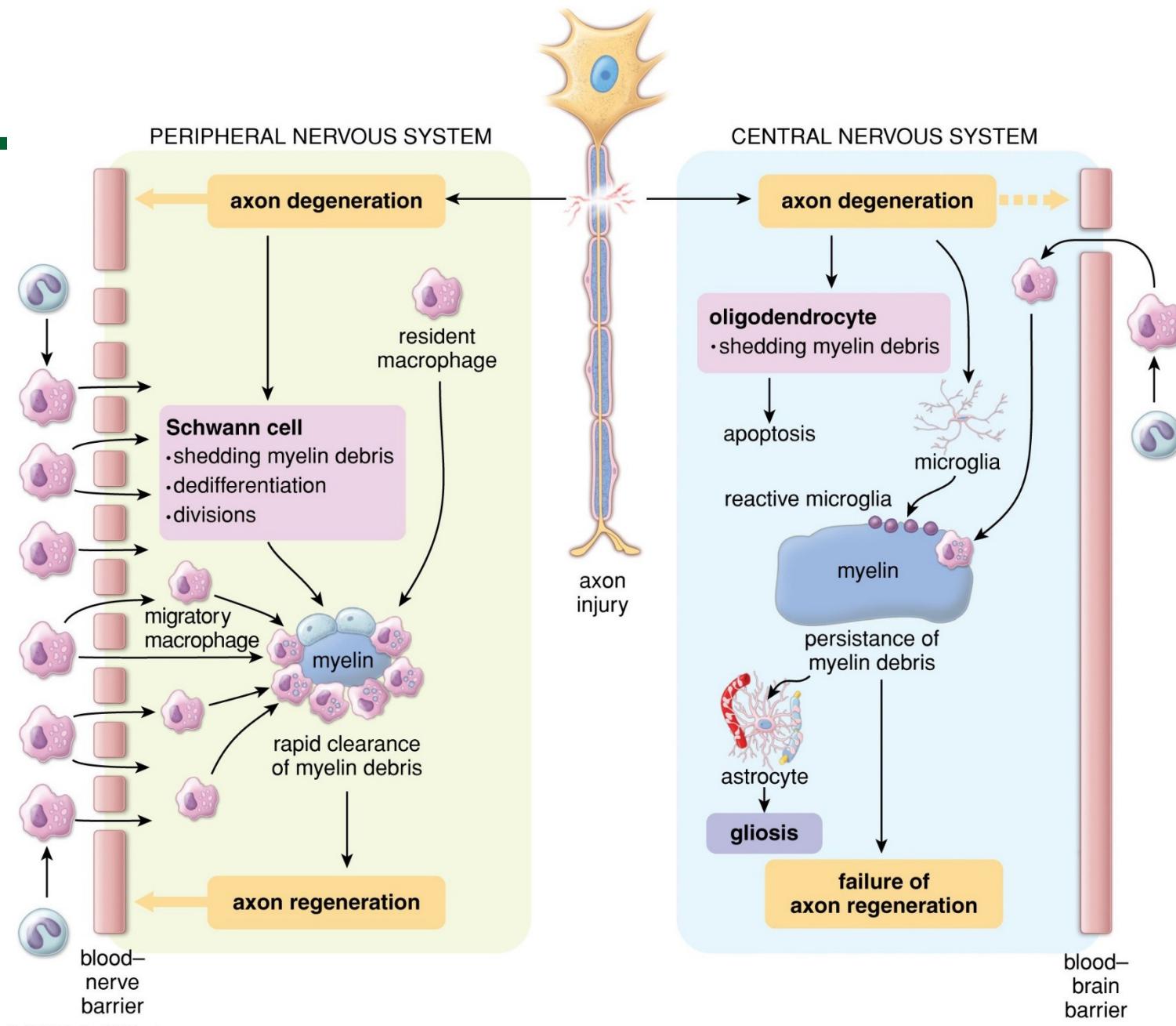
The sympathetic (thoracolumbar) outflow leaves the CNS from the thoracic and upper lumbar segments (T1 to L2) of the spinal cord.



Response to neuronal injury within peripheral and central nervous systems

Injuries induces axonal degeneration and neural regeneration.

Involves neurons, Schwann cells, oligodendrocytes, macrophages and microglia.



Chapter 10 Muscle Objectives

1. Skeletal muscle: Organization and physiology
2. Cardiac Muscle
3. Smooth Muscle

Functions of the Muscular system

Muscle is composed of elongated cells that contract

- Converts chemical energy of ATP into mechanical energy

Movement: Externally visible movements

- Also internal movements e.g., propulsion of digestive tract and expulsion of urine
- Important roles in communication: speech, writing, etc.

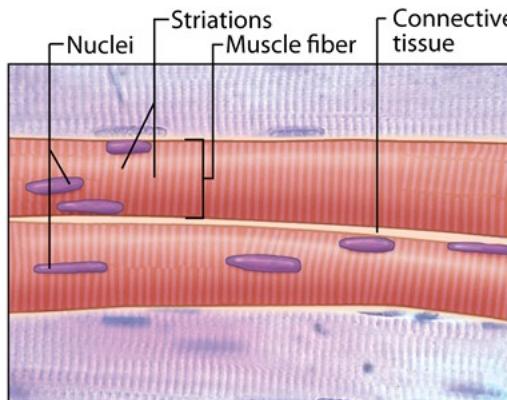
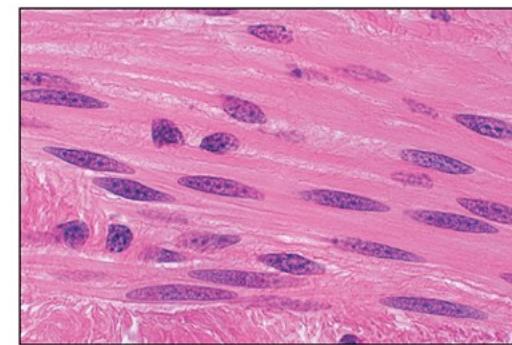
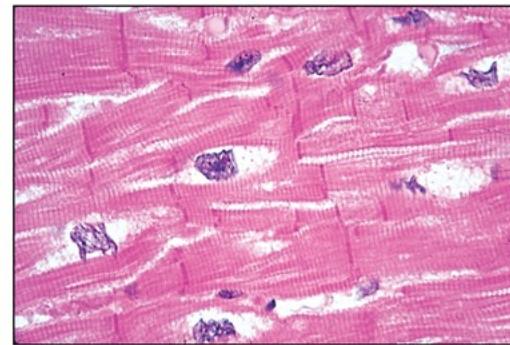
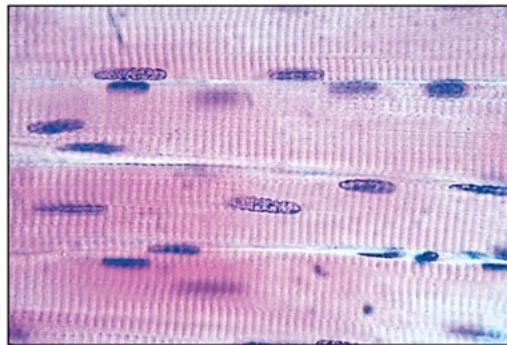
Stability: Prevent unwanted movement e.g., posture and holding bones in place

Control of body openings and passages E.g., sphincter muscles around eyelids, regulating waste elimination

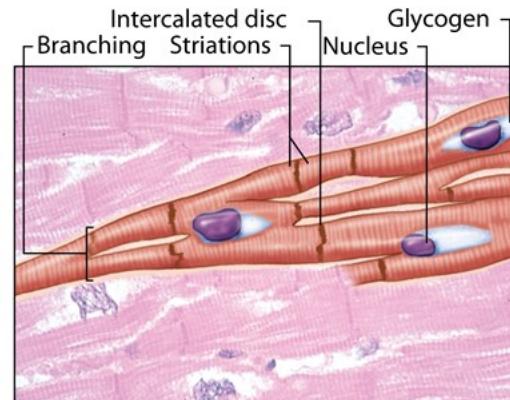
Heat generation: Muscles generating 20 to 30% of body heat at rest

Glycemic control: Aids regulation of blood glucose

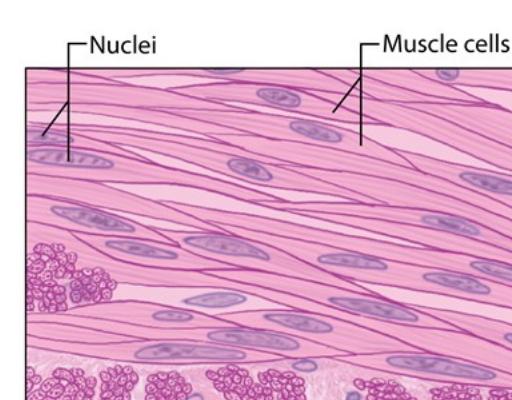




a Skeletal muscle



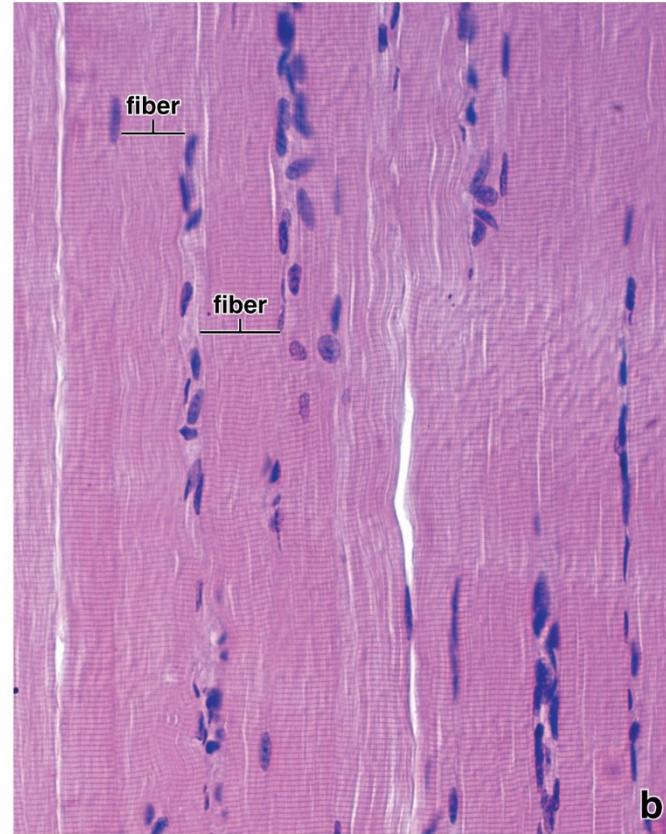
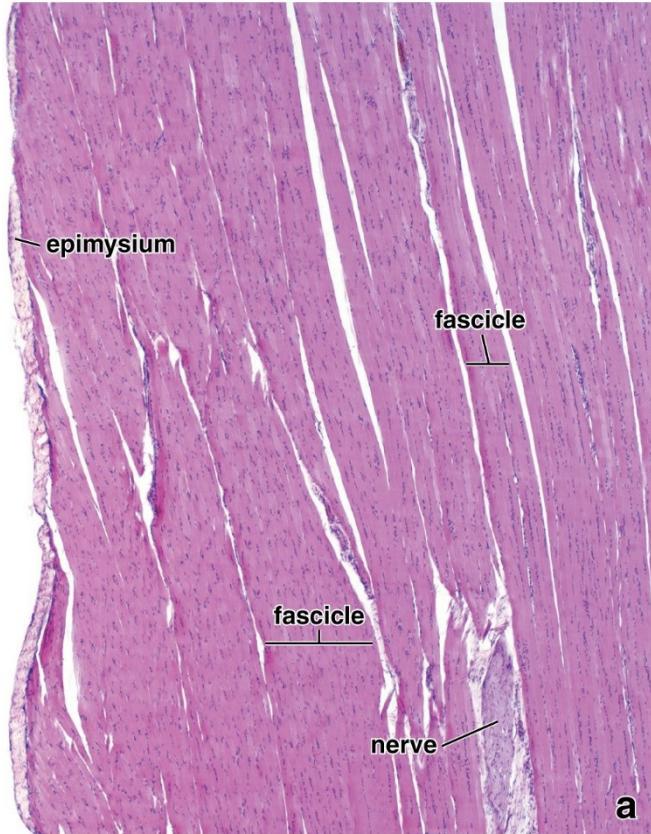
b Cardiac muscle



c Smooth muscle

- (a) **Skeletal muscle:** large, elongated, multinucleated fibers that show strong, quick, voluntary contractions.
- (b) **Cardiac muscle:** irregular branched cells bound together longitudinally by intercalated discs and shows strong, involuntary contractions.
- (c) **Smooth muscle:** grouped, fusiform cells with weak, involuntary contractions.

Skeletal Muscle Fibers



Voluntary: subject to conscious control

Striated: alternating light and dark bands, or **striations** reflect overlapping arrangement of internal proteins

Skeletal muscle cells:
multinucleate termed **muscle fibers** due to long slender shape

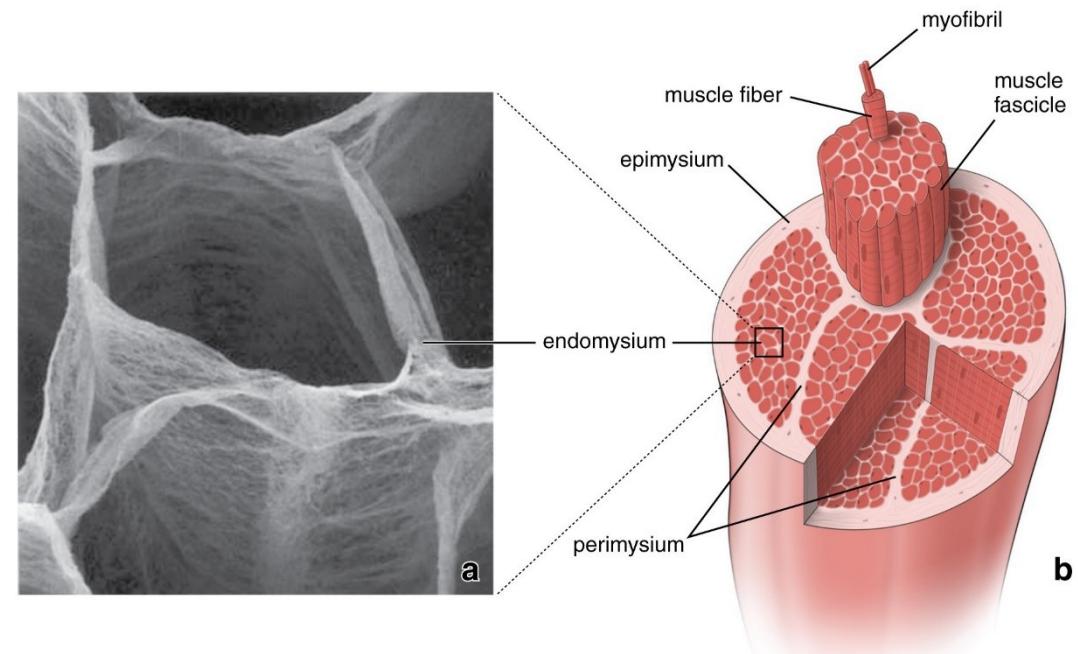
Endomysium: thin layer enclosing each muscle fiber, allows room for blood capillaries and nerve fibers. Reticular fibers.

Perimysium: layer of thicker connective tissue surrounds bundles of muscle fibers, **fascicles**

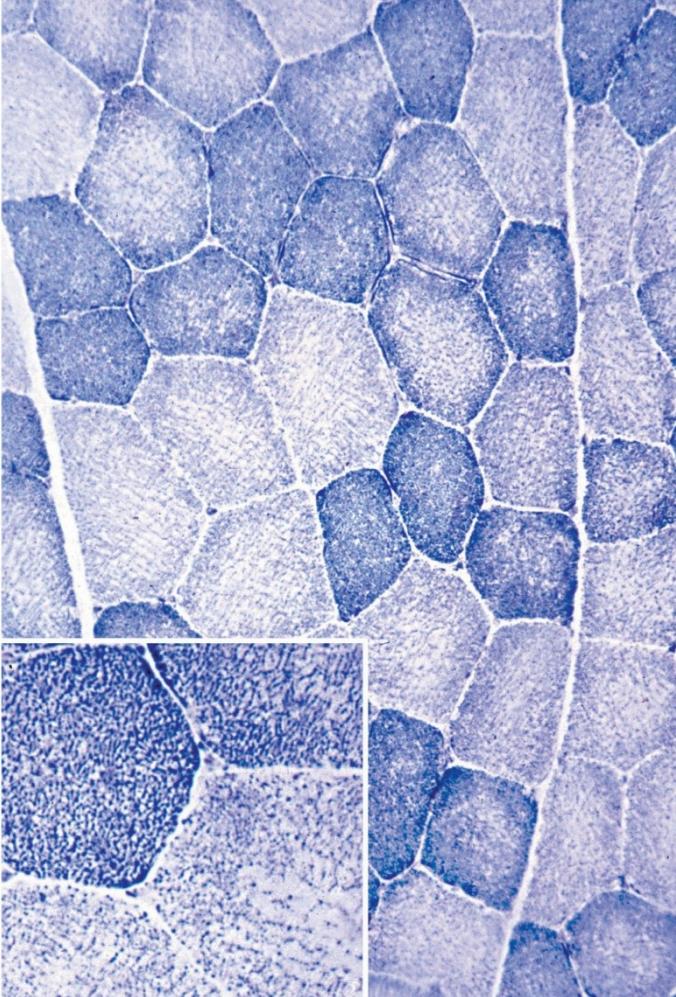
Epimysium: layer surrounding muscle as a whole, dense ct

Fasciae: fibrous sheets separating muscles from each other, may separate functionally related muscles into **compartments**. Contains nerves and vessels supplying muscle group

Connective tissue layers in skeletal muscle



Skeletal Muscle Fiber Types: High levels of mitochondrial oxidative enzymes → strong succinic dehydrogenase and NADH histochemical staining reactions



Type I fibers (slow oxidative): slow-twitch, fatigue-resistant motor units
small, many mitochondria. Postural muscles.

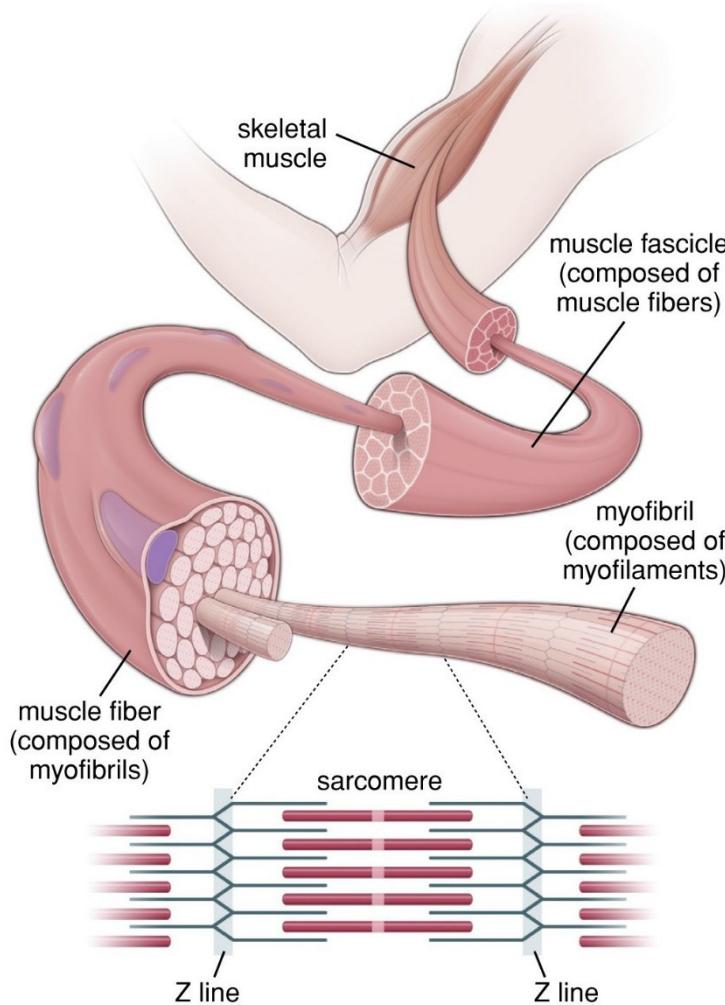
Type IIa fibers (fast oxidative glycolytic): fast-twitch, fatigue- resistant motor units that generate high peak muscle tension. 400-800m runners.

Type IIb fibers (fast glycolytic fibers): low level of oxidative enzymes, high anaerobic enzyme activity. Eyes and fingers.

»» MEDICAL APPLICATION

The variation in diameter of muscle fibers depends on factors such as the specific muscle, age, gender, nutritional status, and physical training of the individual. Exercise enlarges the skeletal musculature by stimulating formation of new myofibrils and growth in the diameter of individual muscle fibers. This process, characterized by increased cell volume, is called **hypertrophy** (gr. *hyper*, above + *trophe*, nourishment). Tissue growth by an increase in the number of cells is termed **hyperplasia** (hyper + gr. *plasis*, molding), which takes place very readily in smooth muscle, whose cells have not lost the capacity to divide by mitosis.

Organization of a skeletal muscle



Striations:

A bands: regions in which thick and thin filaments overlap. Middle part composed of myosin only

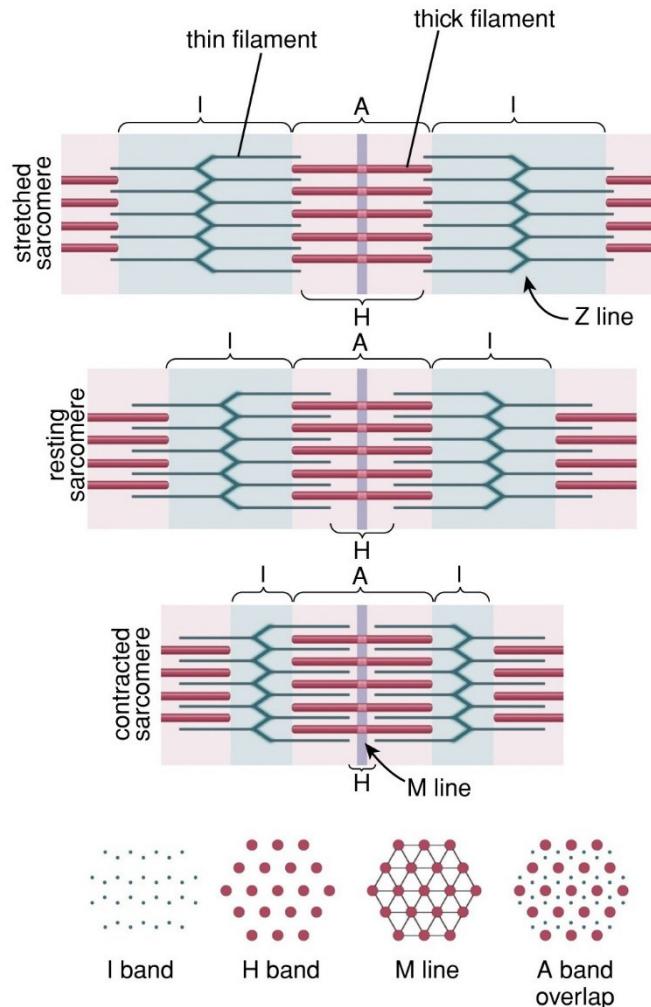
I bands: consists only of thin filaments bisected by thin dark line, **Z disc** (protein providing anchorage for thin filaments)

Sarcomere: Segment from one Z disc to the next, functional unit of muscle fiber

Muscle shortening due to sarcomeres shortening pull Z discs closer

http://highered.mheducation.com/sites/0072495855/student_view0/chapter_10/animation_sarcomere_contraction.html

The functional unit of the myofibril is the sarcomere, the segment of the myofibril between two adjacent Z lines

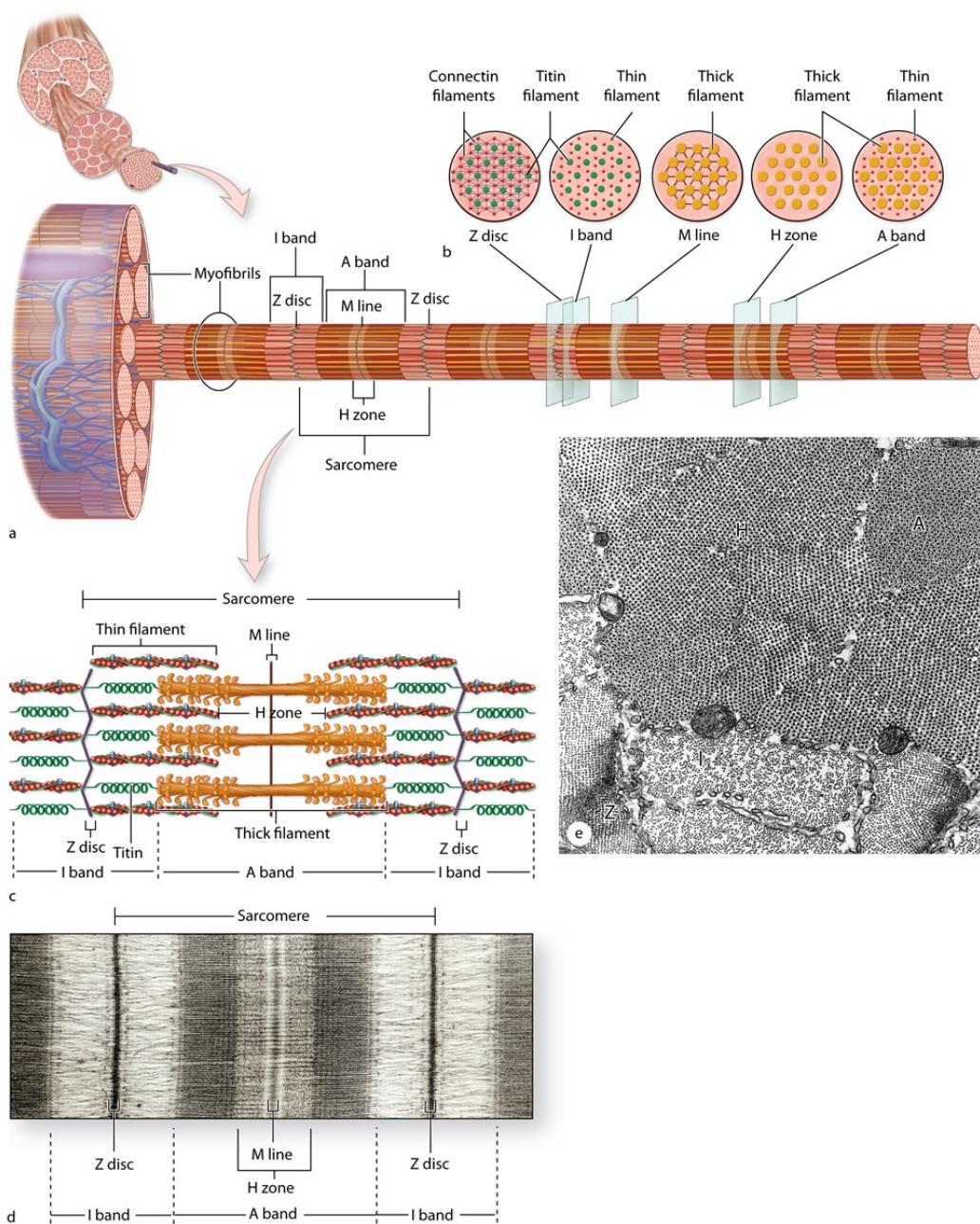


In the resting state (middle), interdigitation of thin (actin) and thick (myosin) filaments is not complete; the H and I bands are relatively wide.

In the contracted state (bottom), the interdigitation of the thin and thick filaments is increased according to the degree of contraction.

In the stretched state (top), the thin and thick filaments do not interact; the H and I bands are very wide. The length of the A band always remains the same and corresponds to the length of the thick filaments; the lengths of the H and I bands change

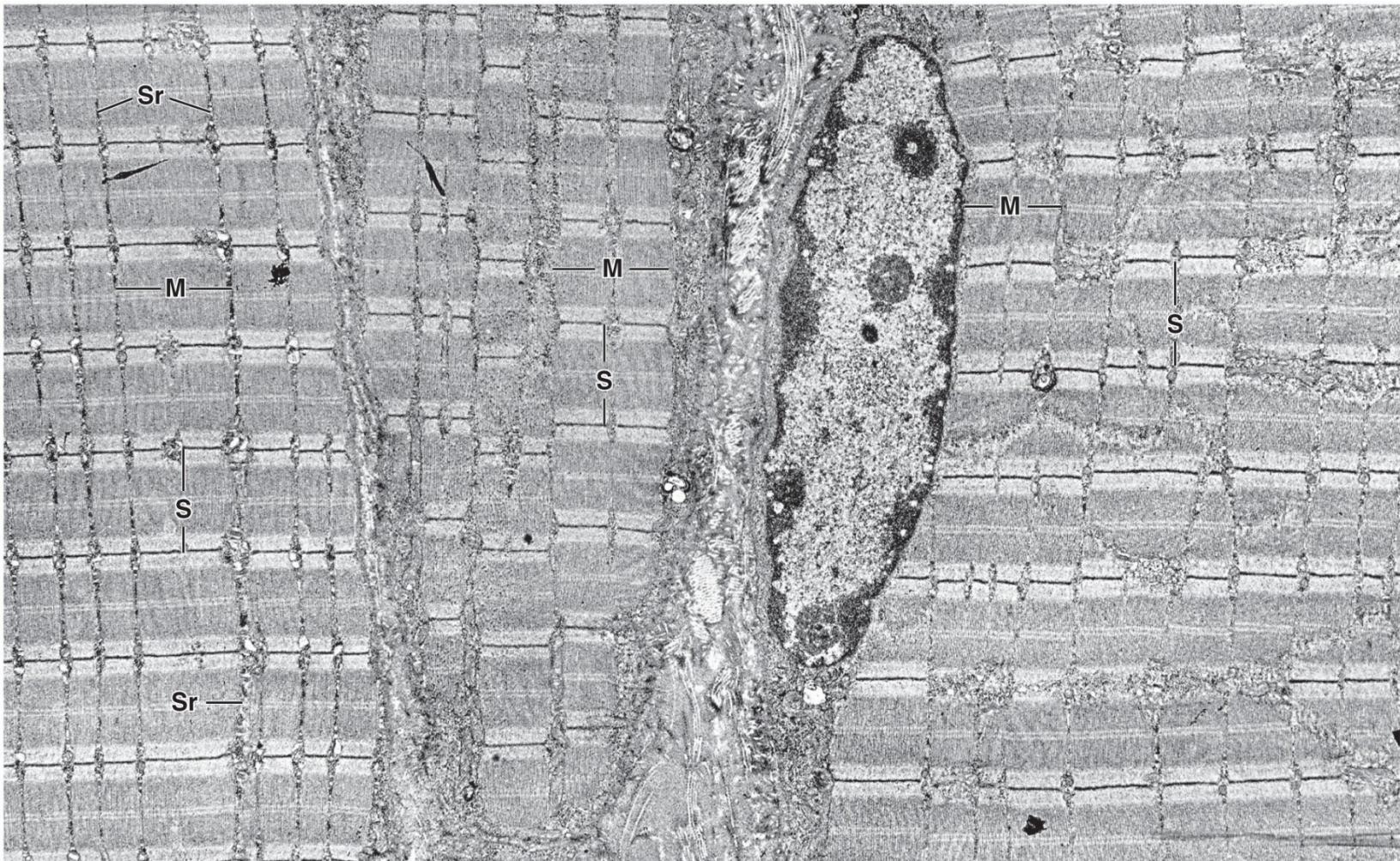
Structure of a myofibril: A series of sarcomeres.



The myosin-containing thick filaments are restricted to the central portion of the sarcomere (i.e., the A band).

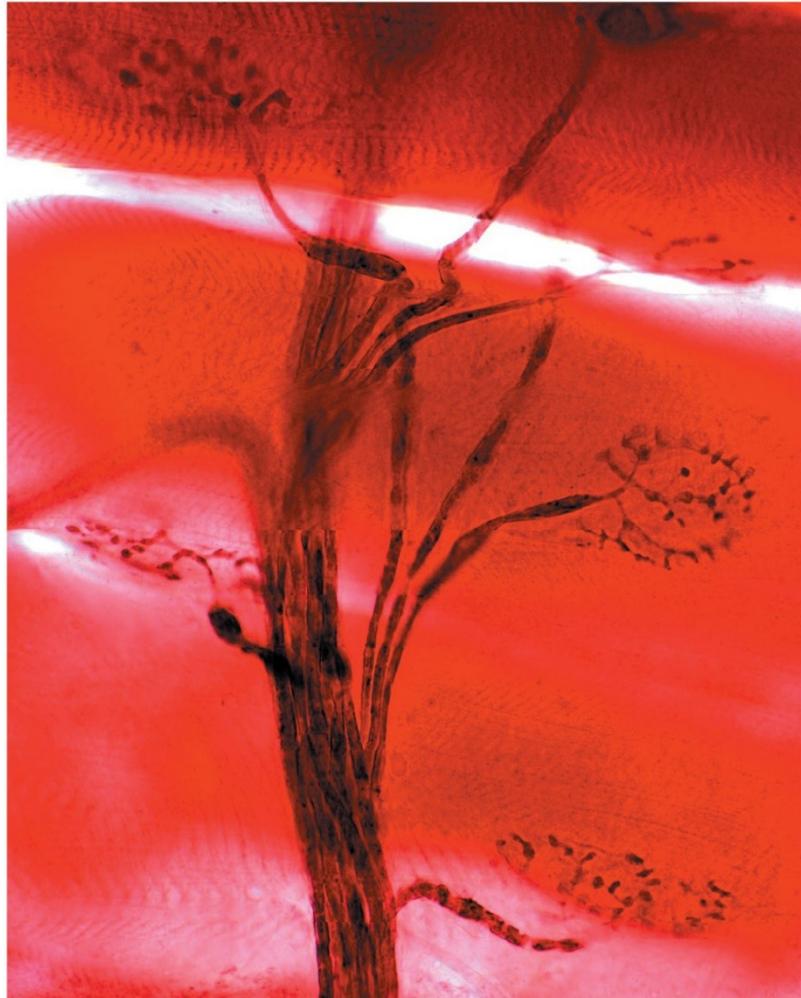
Actin-containing thin filaments attach to the Z line and extend into the A band to the edge of the H band.

When a muscle contracts, each sarcomere shortens, but the myofilaments remain the same length.

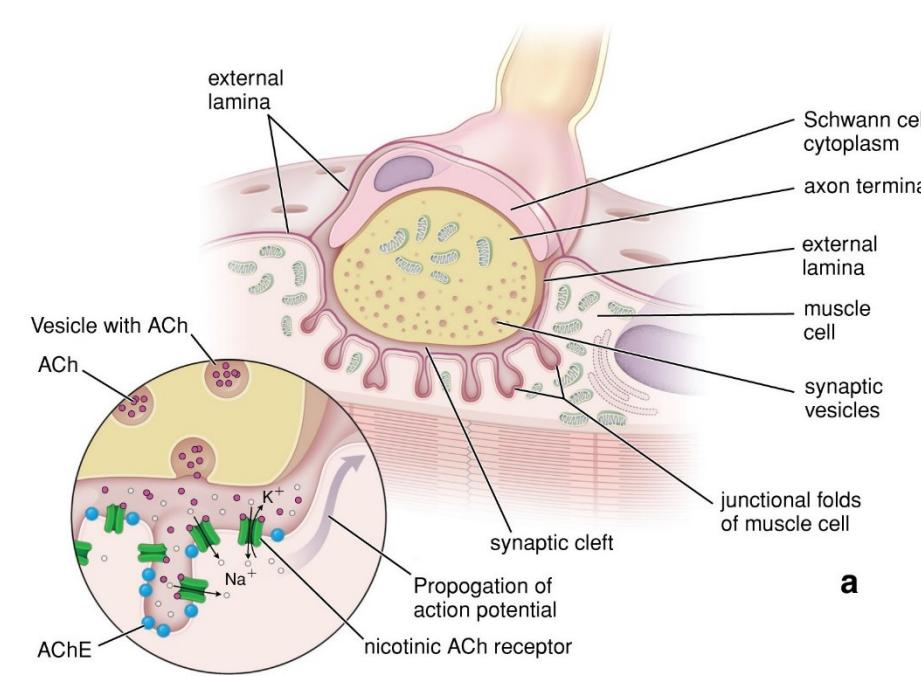


Two fibers—one in the middle and another on the left—exhibit regular profiles of myofibrils separated by a thin layer of surrounding sarcoplasm (Sr). Each repeating part of the myofibril between adjacent Z lines is a sarcomere (S). The cross-banded pattern visible on this micrograph reflects the arrangement, in register, of the individual myofibrils (M); a similar pattern found in the myofibril reflects the arrangement of myofilaments.

The neuromuscular junction is the contact made by the terminal branches of the axon with the muscle fiber

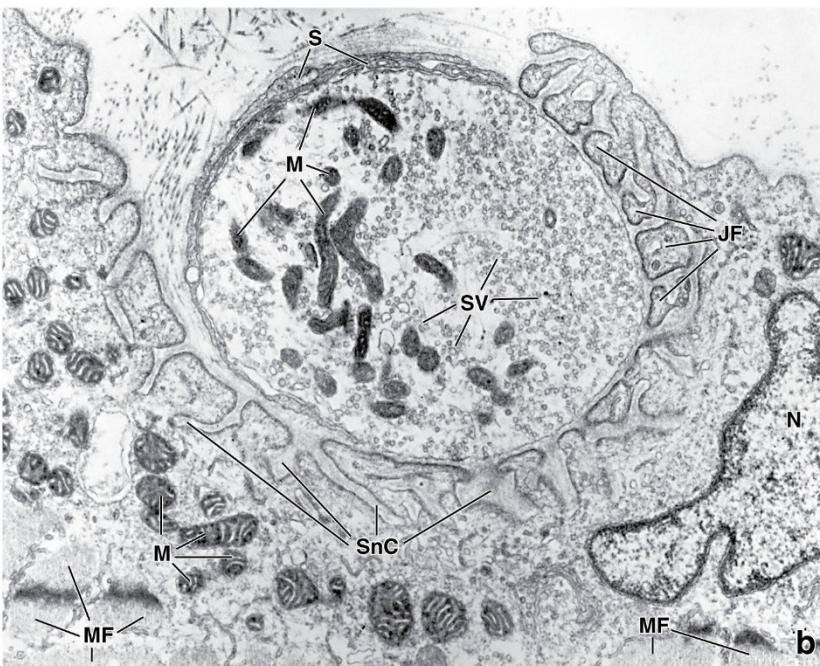


A motor nerve and its final branches that lead to the neuromuscular junctions (motor end plates). The skeletal muscle fibers are oriented horizontally in the field and are crossed perpendicularly by the motor nerve fibers. Note that these fibers distally lose their myelin sheath and divide extensively into small swellings, forming a cluster of neuromuscular junctions.

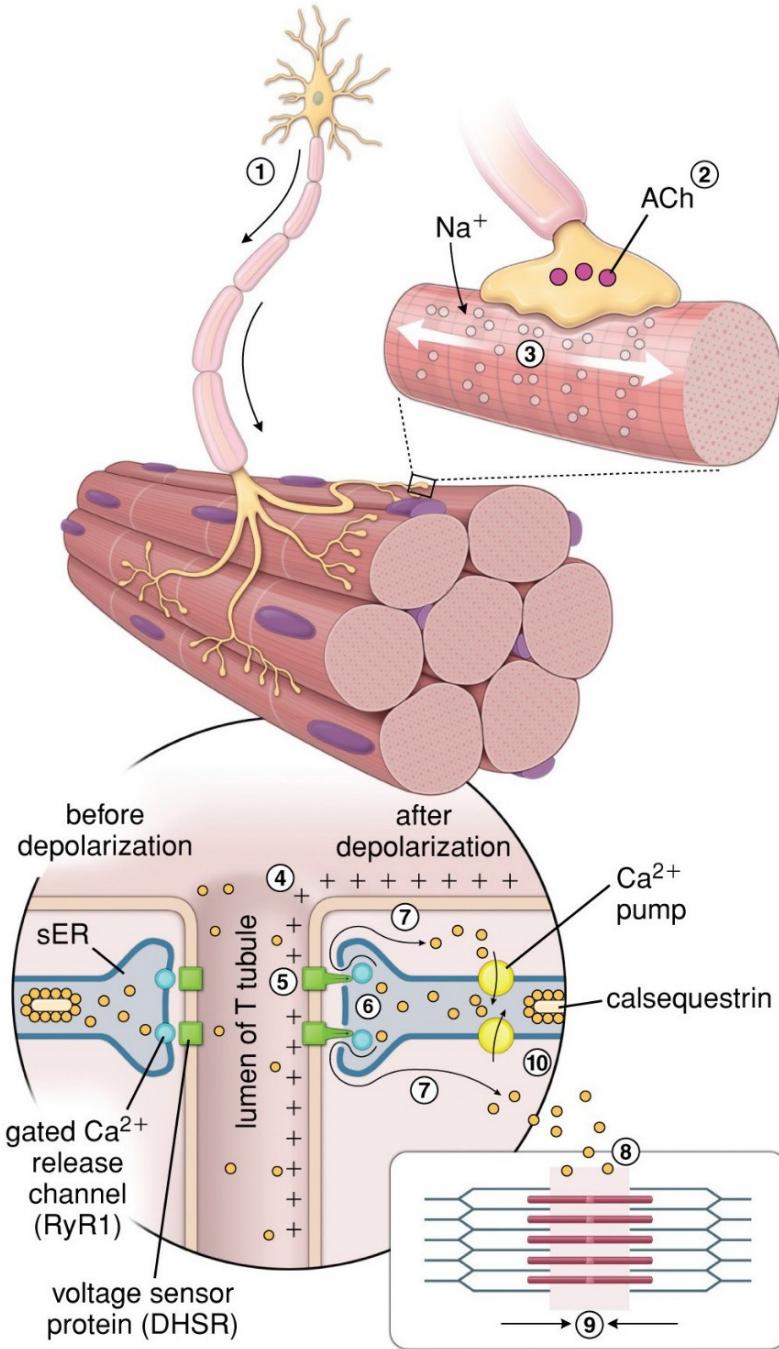


Release of acetylcholine into the synaptic cleft initiates depolarization of the plasma membrane, which leads to muscle cell contraction.

If the nerve supply to a muscle is disrupted, the muscle cell undergoes regressive changes known as tissue atrophy



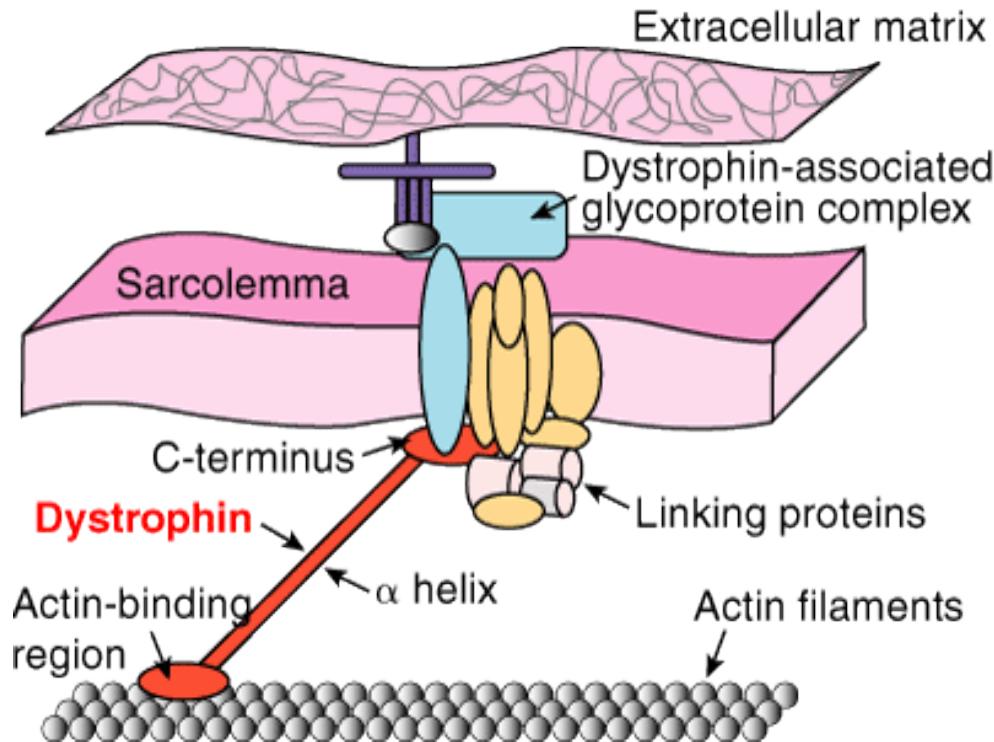
MEDICAL APPLICATION Myasthenia gravis is an autoimmune disorder that involves circulating antibodies against proteins of acetylcholine receptors. The disease follows a progressive course. The extraocular muscles of the eyes are commonly the first affected.



The events leading to contraction of skeletal muscle

1. Nerve impulse.
2. release of acetylcholine into the synaptic cleft, ACh-gated Na channels cause local depolarization of sarcolemma.
3. Voltage-gated Na channels open
4. General depolarization spreads of the muscle cell
5. Voltage sensors in the plasma membrane of T tubules change their conformation.
6. At the muscle cell triads, sarcoplasmic reticulum gated Ca release activated
7. Ca is rapidly released
8. Ca binds troponin complex.
9. Acto-myosin cross-bridge cycle is initiated.
- 10.Ca is returned to the terminal cisternae of the sarcoplasmic reticulum.

Duchenne muscular dystrophy

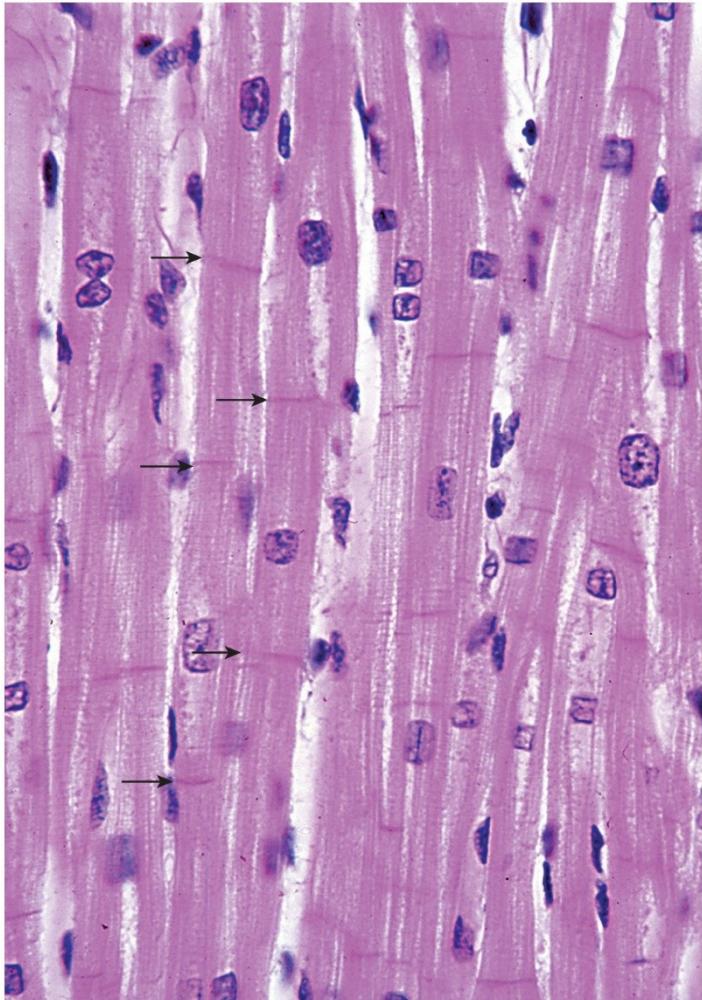


MEDICAL APPLICATION

Dystrophin is a large actin-binding protein located just inside the sarcolemma of skeletal muscle fibers which is involved in the functional organization of myofibrils.

Research on Duchenne muscular dystrophy revealed that mutations of the dystrophin gene can lead to defective linkages between the cytoskeleton and the extracellular matrix (ECM). Muscle contractions can disrupt these weak linkages, causing the atrophy of muscle fibers typical of this disease.

Cardiac muscle has the same types and arrangement of contractile filaments as skeletal muscle



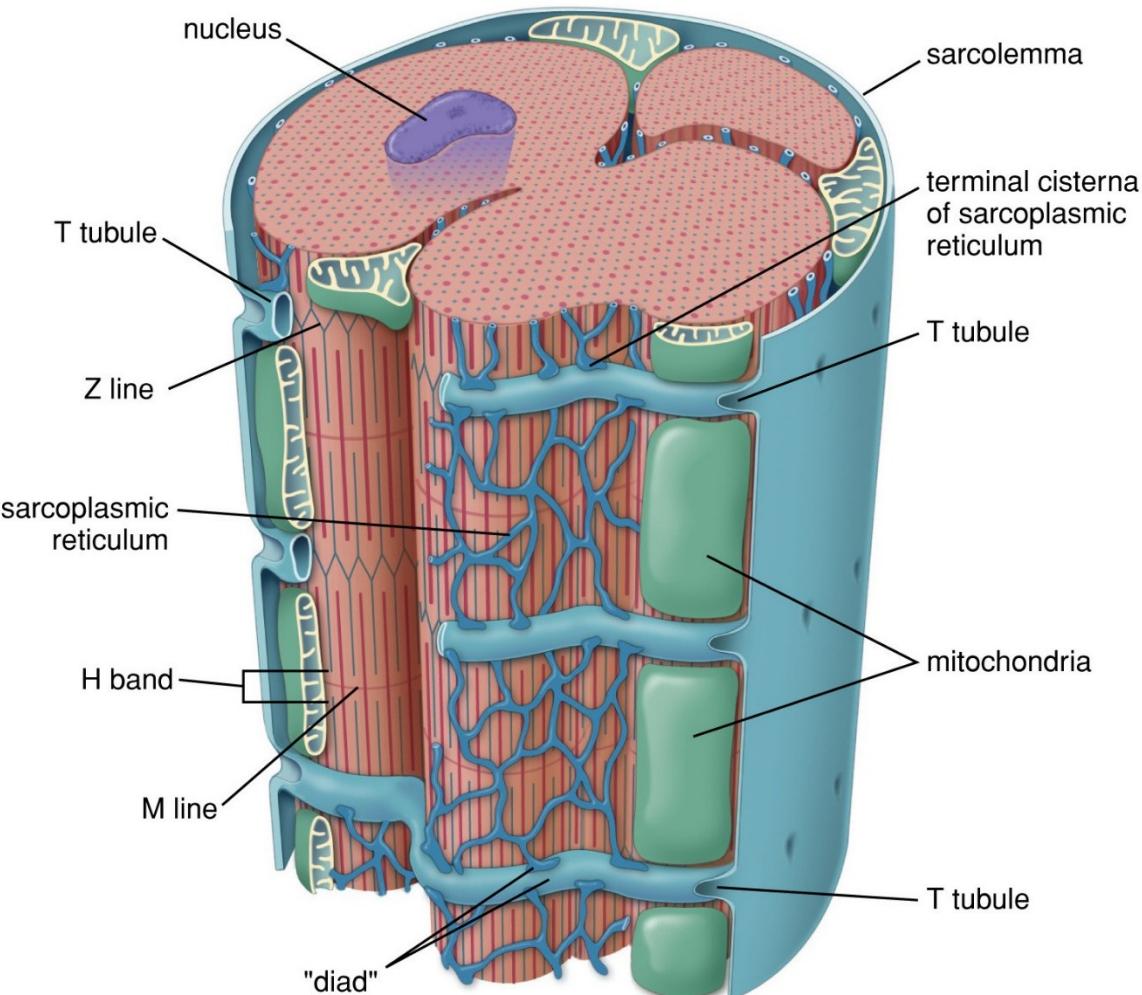
Unlike skeletal and visceral striated muscle fibers that represent multinucleated single cells, cardiac muscle fibers consist of numerous cylindrical cells arranged end to end.

In addition, cardiac muscle fibers exhibit densely staining cross-bands, called **intercalated discs**.

Gap junctions (communicating junctions) constitute the major structural element of the lateral component of the intercalated disc. Gap junctions provide ionic continuity between cells, permitting cardiac muscle fibers to behave as a syncytium while retaining cellular integrity and individuality

The central location of the nucleus in cardiac muscle cells is one feature that helps distinguish them from multinucleated skeletal muscle fibers.

Organization of cardiac muscle fiber



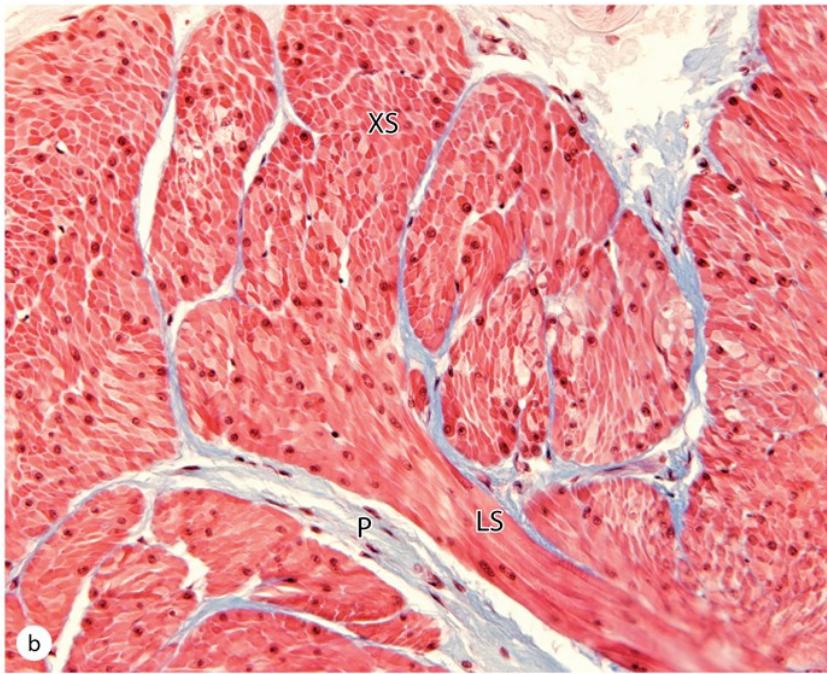
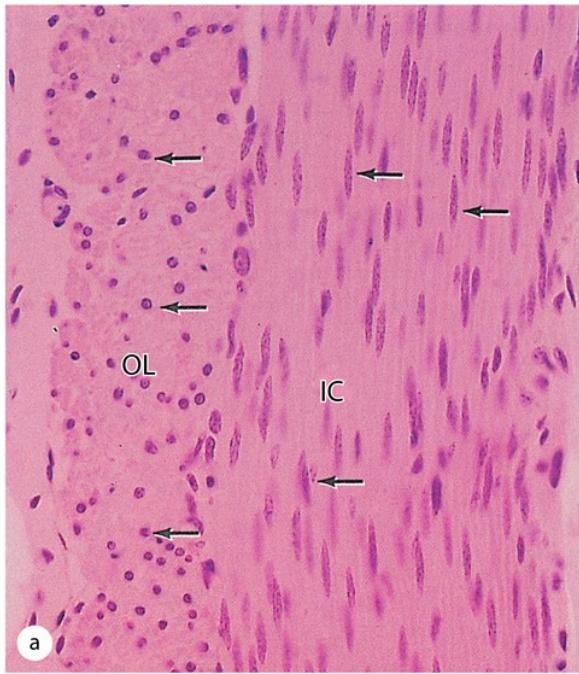
The T tubules of cardiac muscle are much larger than the T tubules of skeletal muscle. They also differ in that they are located at the level of the Z line.

MEDICAL APPLICATION

Ischemia: tissue damage due to lack of oxygen when coronary arteries are occluded by heart disease.

Adult mammalian cardiac muscle has little potential to regenerate after injury. However, certain fish and amphibians, as well as newborn mice, do form new muscle when the heart is partially removed, despite the lack of satellite cells. Research on the possibility of mammalian heart muscle regeneration builds on work with the animal models, focusing primarily on the potential of mesenchymal stem cells to form new, site-specific muscle.

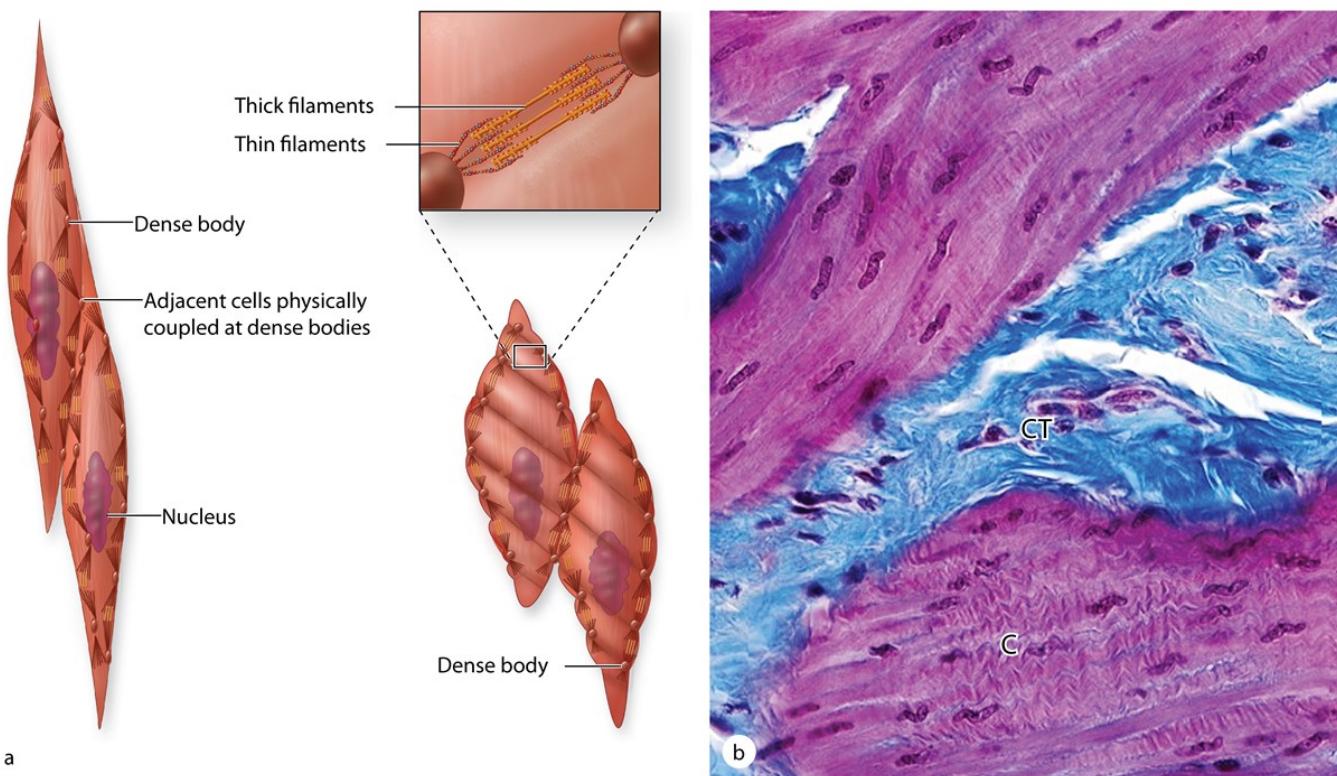
Cells of smooth muscle are long, tapering structures with elongated nuclei centrally located at the cell's widest part.



(a) wall of the small intestine cells of the inner circular (**IC**) layer are cut lengthwise and cells of the outer longitudinal layer (**L**) are cut transversely.

(b) Section of smooth muscle in bladder shows fibers in cross section (**XS**) and longitudinal section (**LS**) with the same fascicle.

Filaments of smooth muscle are arranged differently and appear less organized.



(a) thin filaments attach to **dense bodies** located at the cell membrane and deep in the cytoplasm. This arrangement of both the cytoskeleton and contractile apparatus allows the multicellular tissue to contract as a unit, providing better efficiency and force.

(b) Contracted (**C**) region of smooth muscle, with contraction decreasing the cell length and deforming the nuclei. The long nuclei of individual fibers assume a cork-screw shape when the fibers contract, reflecting the reduced cell length at contraction. Connective tissue (**CT**) of the perimysium outside the muscle fascicle is stained blue.

	Skeletal	Cardiac	Smooth
Structural features			
Muscle cell	Large, elongate cell, 10–100 µm in diameter, up to 100 cm in length (sartorius m.)	Short, narrow cell, 10–15 µm in diameter, 80–100 µm in length	Short, elongate, fusiform cell, 0.2–2 µm in diameter, 20–200 µm in length
Location	Muscles of skeleton visceral striated (e.g., tongue, esophagus, diaphragm)	Heart, superior and inferior vena cava, pulmonary veins	Vessels, organs, and viscera
Connective tissue components	Epimysium, perimysium, endomysium	Endomyxium (subendocardial and subepicardial connective tissue)	Endomyxium, sheaths, and bundles
Fiber	Single skeletal muscle cell	Linear branched arrangement of several cardiac muscle cells	Single smooth muscle cell
Striation	Present	Present	None
Nucleus	Many peripheral	Single central, surrounded by juxtanuclear region	Single central
T tubules	Present at A-I junction (triad: with two terminal cisternae), two T tubules/sarcomere	Present at Z lines (diad: with small terminal cisternae), one T tubule/sarcomere	None, well-developed sER, many invaginations and vesicles similar to caveolae
Cell-to-cell junctions	None	Intercalated discs containing 1. Fasciae adherentes 2. Macula adherens (desmosome) 3. Gap junctions	Gap junctions (nexus)
Special features	Well-developed sER and T tubules	Intercalated discs	Dense bodies, caveolae, and cytoplasmic vesicles
Functions			
Type of innervation	Voluntary	Involuntary	Involuntary
Efferent innervation	Somatic	Autonomic	Autonomic
Type of contraction	"All or none" (type I and type II fibers)	"All or none" rhythmic (pacemakers, conductive system of the heart)	Slow, partial, rhythmic, spontaneous contractions (pacemakers of stomach)
Regulation of contraction	By binding of Ca ²⁺ to TnC, causes tropomyosin movement and exposes myosin-binding sites on actin filaments	By binding of Ca ²⁺ to TnC, causes tropomyosin movement and exposes myosin-binding sites on actin filaments	By phosphorylation of myosin light chain by myosin light chain kinase in the presence of Ca ²⁺ -calmodulin complex
Growth and regeneration			
Mitosis	None	None (in normal condition)	Present
Response to demand	Hypertrophy	Hypertrophy	Hypertrophy and hyperplasia
Regeneration	Limited (satellite cells and myogenic cells from bone marrow)	None (in normal condition)	Present