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Факултет медицинских наука
Интегрисане академске студије медицине
Катедра за Хистологију и ембриологију

Muscle and nerve tissue

Week 5

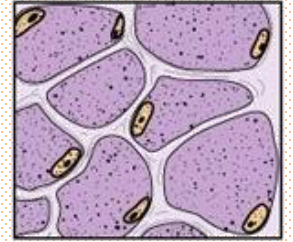
MUSCLE TISSUE

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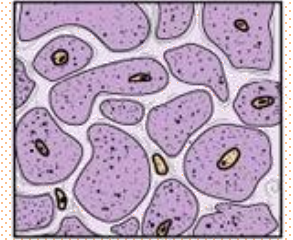
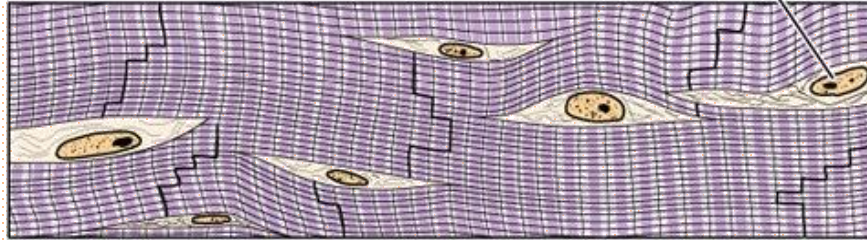
- Muscle tissue is made up of cells that can lengthen and shorten (contract) to a significant extent.
- By changing the length, the muscle cells allow the body to move and change the shape and size of the internal organs.
- Muscle cells are called **myocytes**, their cytoplasm is called **sarcoplasm**, cell membrane - **sarcolemma**, and endoplasmic reticulum - **sarcoplasmic reticulum**.

Muscle tissue types

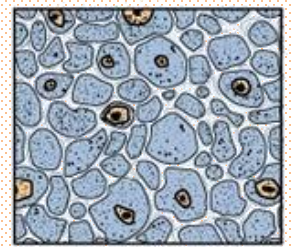
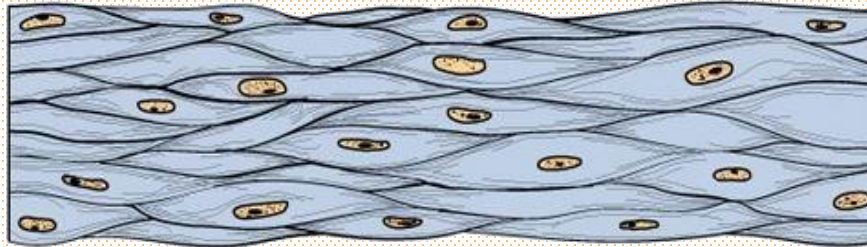
- Skeletal

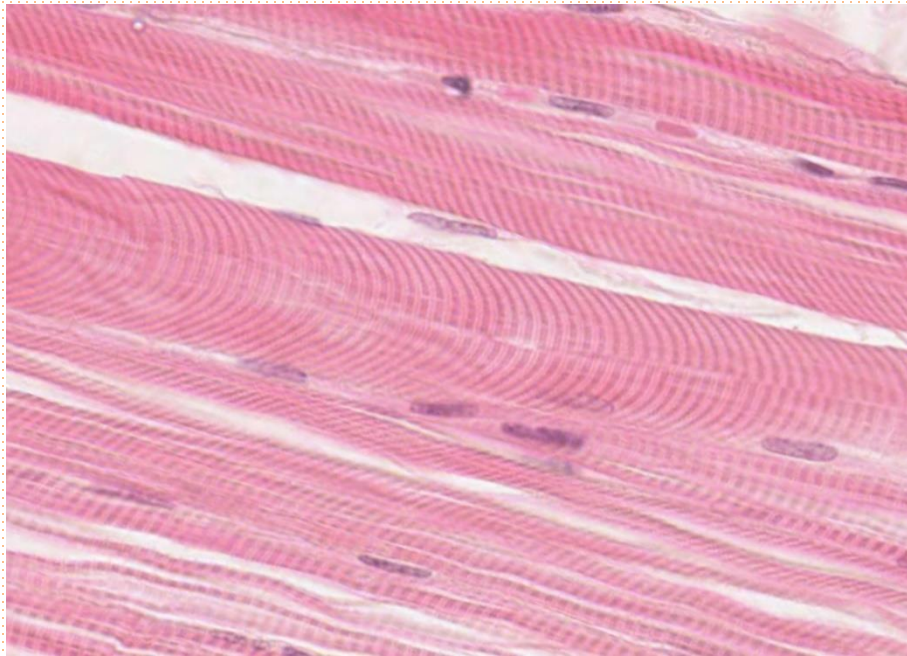


- Cardiac



- Smooth

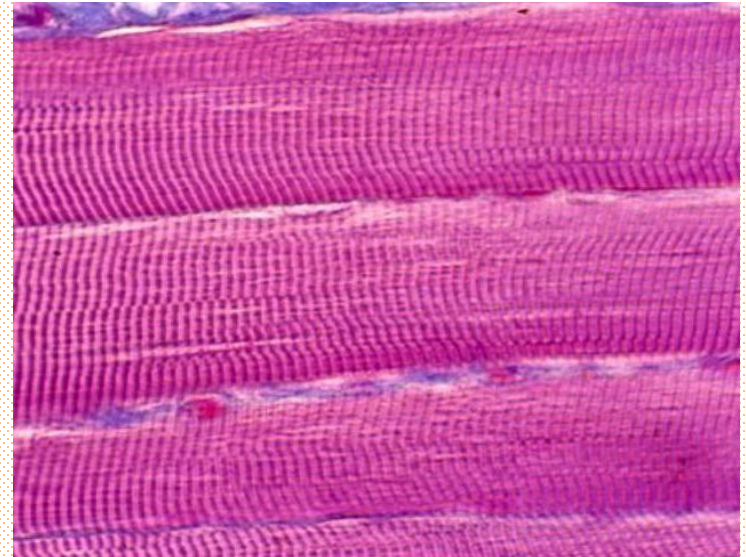
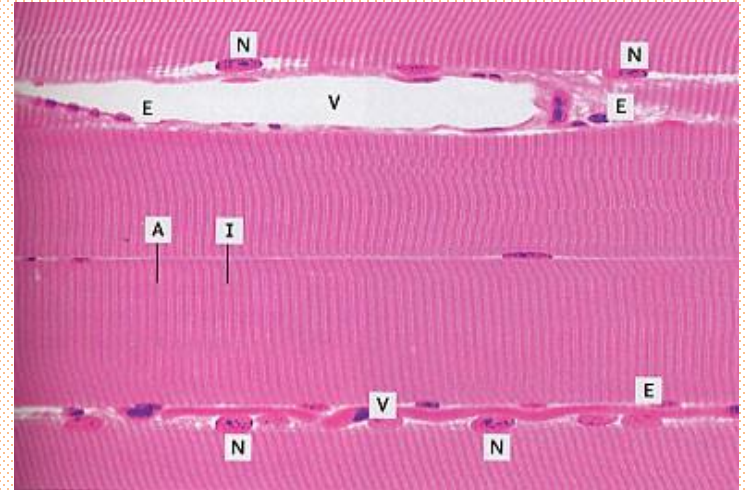




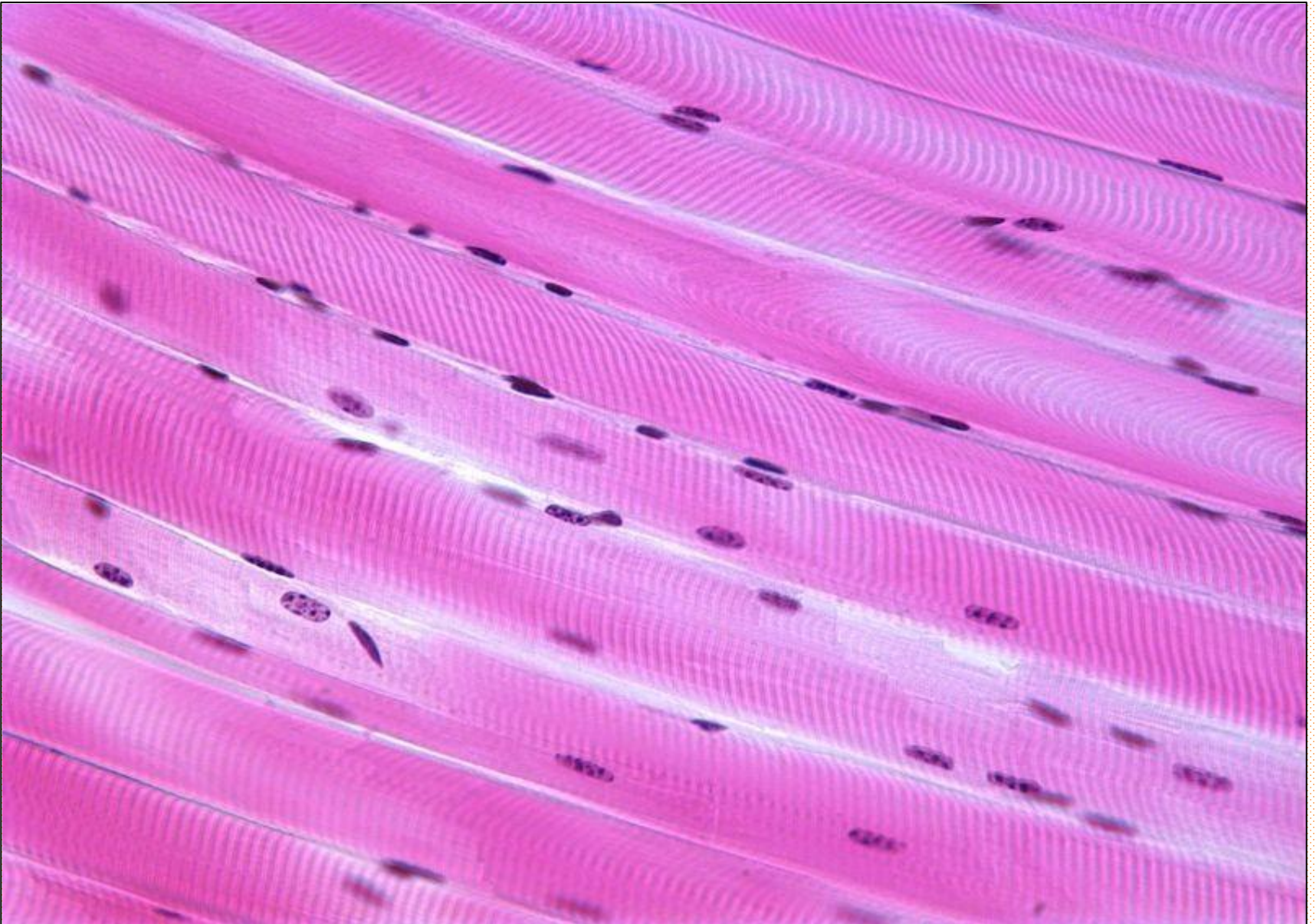
**Skeletal (striated)
muscle tissue**

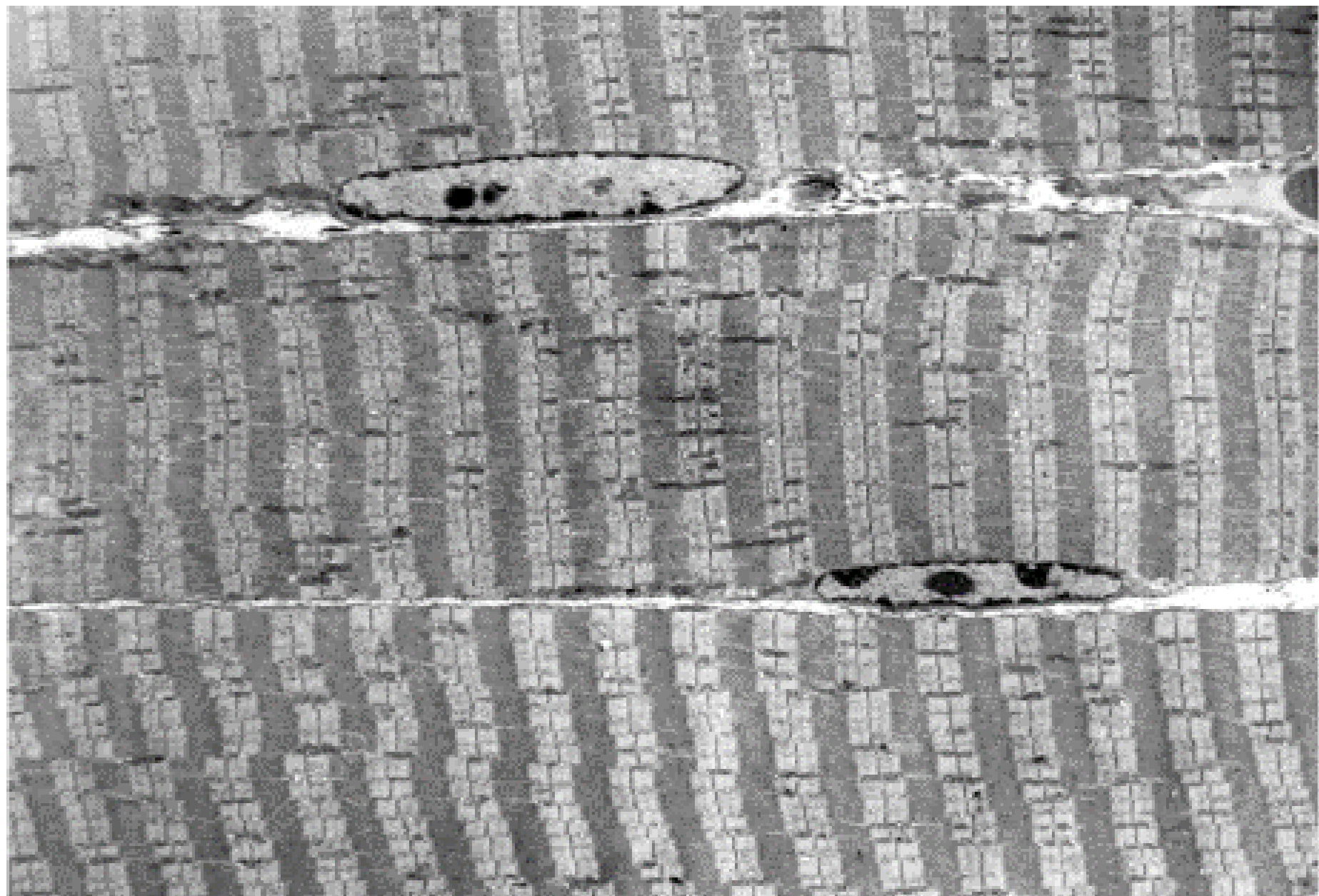
Skeletal muscle tissue

- Skeletal myocytes are **relatively thin and very long cells** that are often called muscle fibers because of their cylindrical shape.
- Each cell contains a large number (sometimes over 100) of elongated nuclei, located directly under the sarcolemma.
- A small population of reserve progenitor cells called muscle **satellite cells** remains adjacent to most fibers of differentiated skeletal muscle

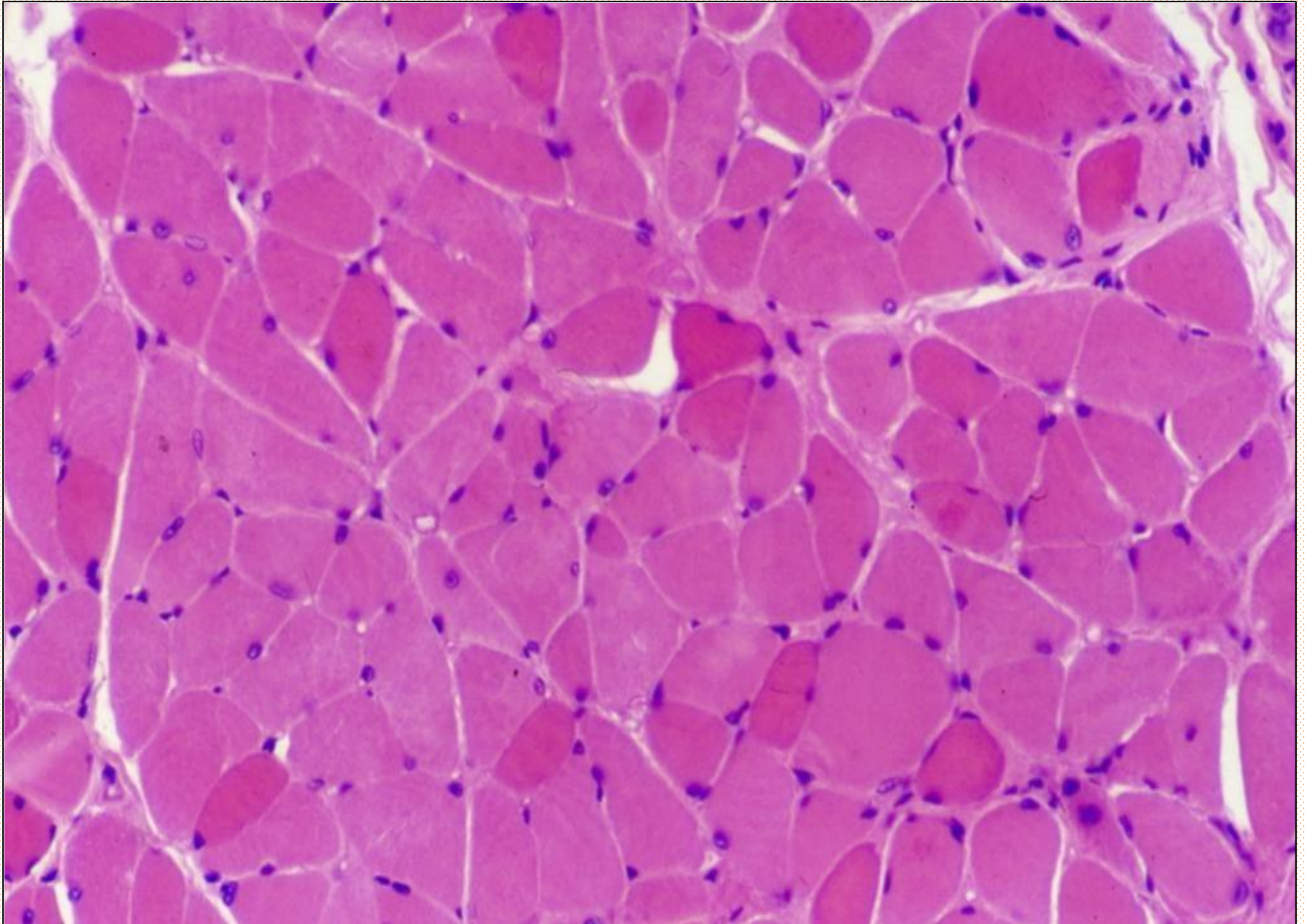


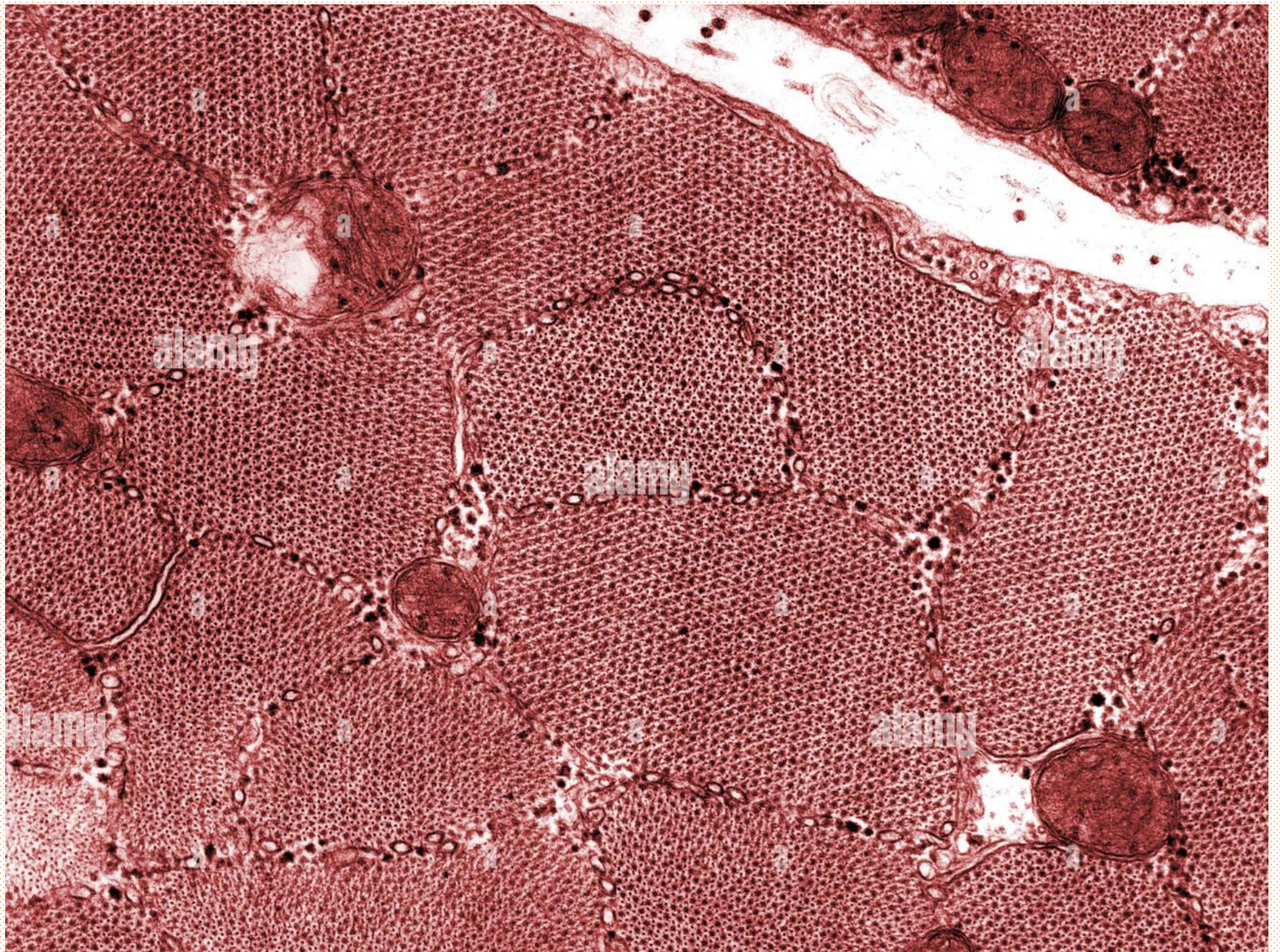
Skeletal muscle tissue



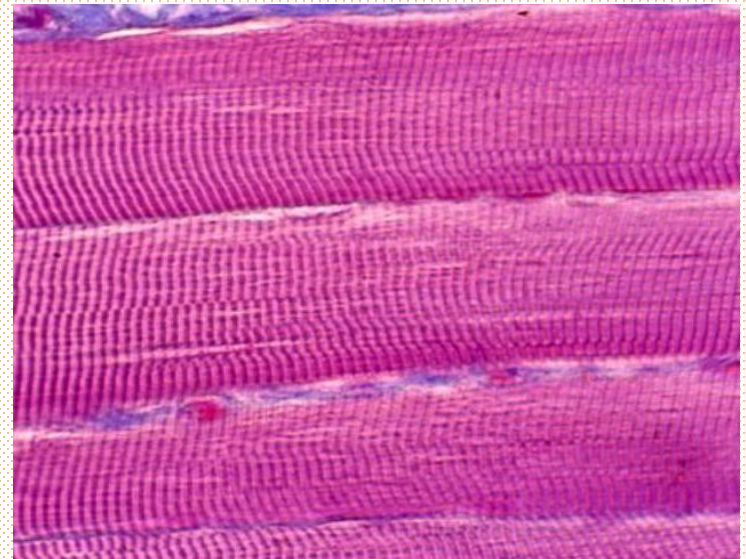
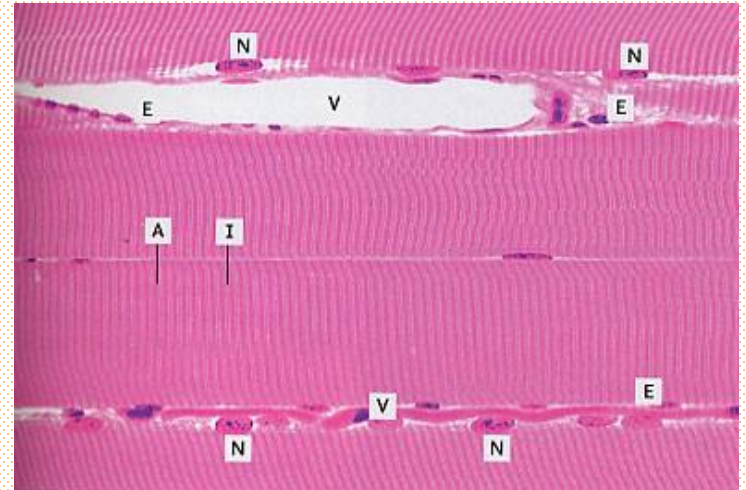


Skeletal muscle tissue - cross



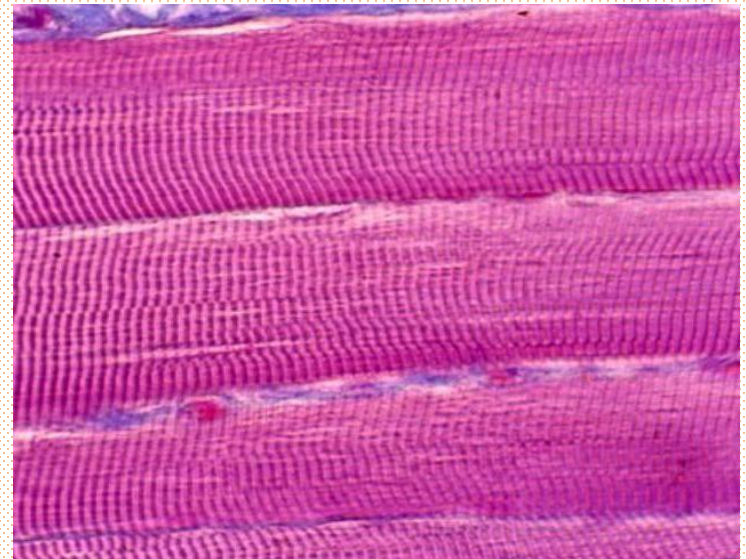
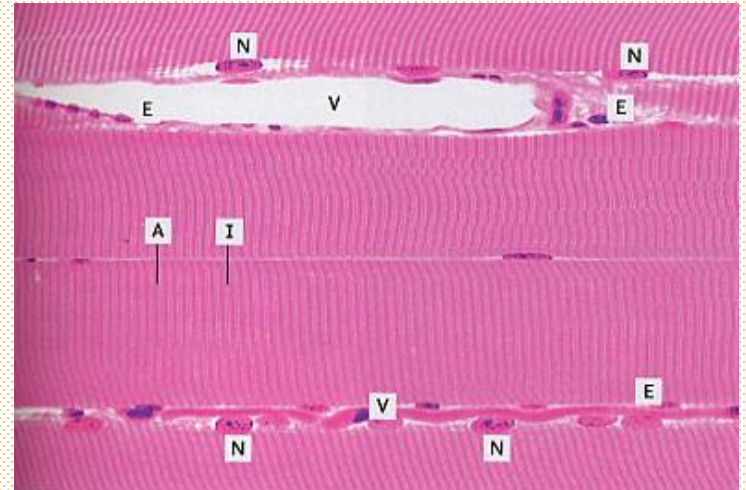


- In the sarcoplasm of the skeletal muscle cell, there are cell organelles, but the largest part of the muscle cell is occupied by protein complexes of a mesh form called **myofibrils**.
- Myofibrils are made of myofilaments.
- **Thin (actin)** and **thick (myosin)** filaments.



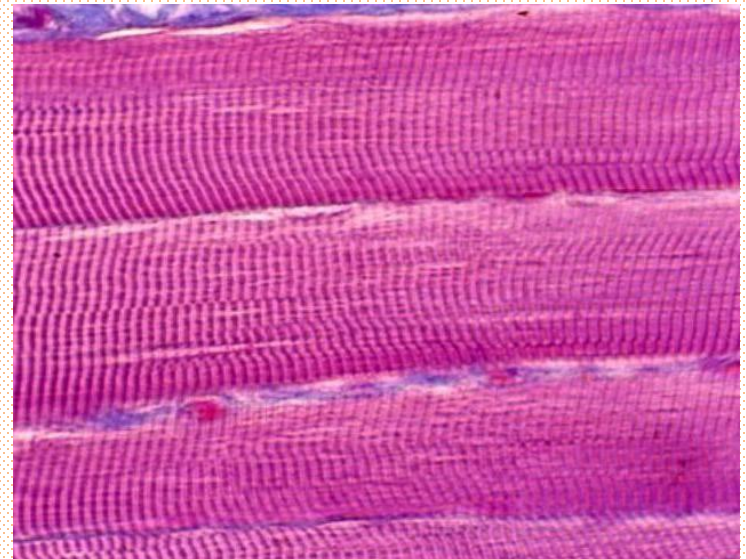
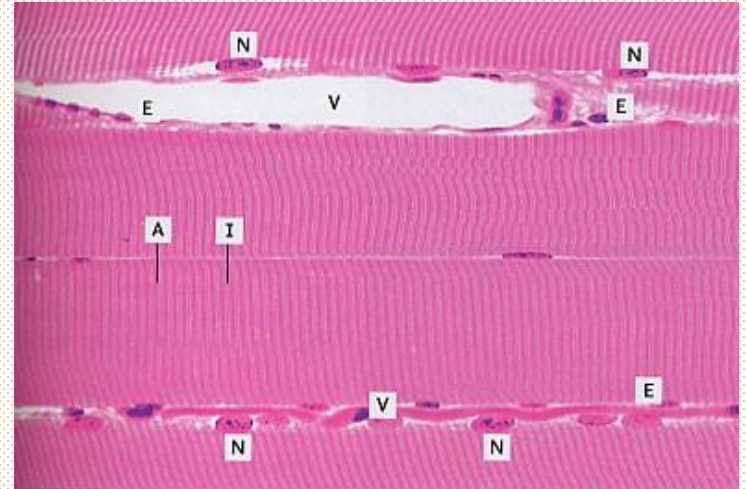
Skeletal muscle tissue

- Myofilaments are commonly called **contractile filaments** because they allow the muscle cell to contract.
- However, during the contraction process they **do not change their length** (they do not contract) **but slide** over each other.

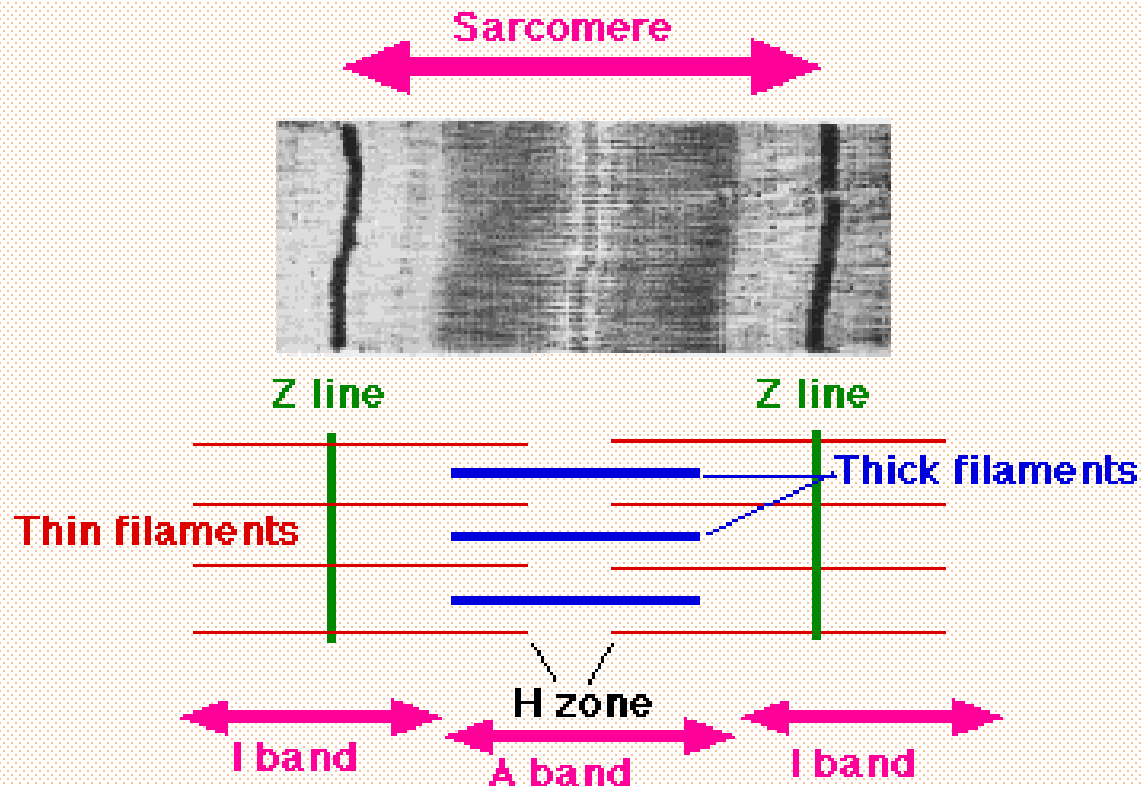


Skeletal muscle tissue

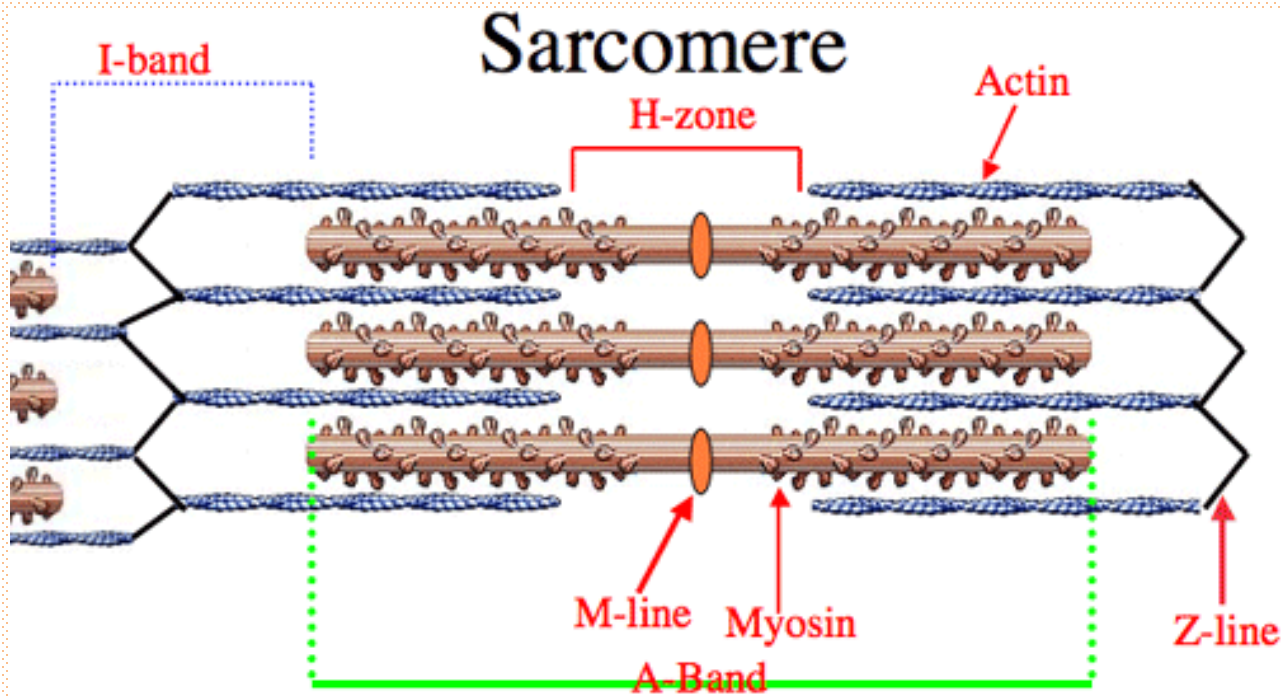
- Thin and thick filaments are regularly distributed in space.
- Therefore, at higher magnifications of the light microscope, **a cross-striation** of the skeletal musculature is observed.



- The part of the muscle cell that contains only thin filaments transmits light better and is registered as a bright, **isotropic or I-band on the microscope**.
- The part of the cell containing the thick filaments transmits less light and is darker in color, which is referred to as dark, **anisotropic, or A-band**.

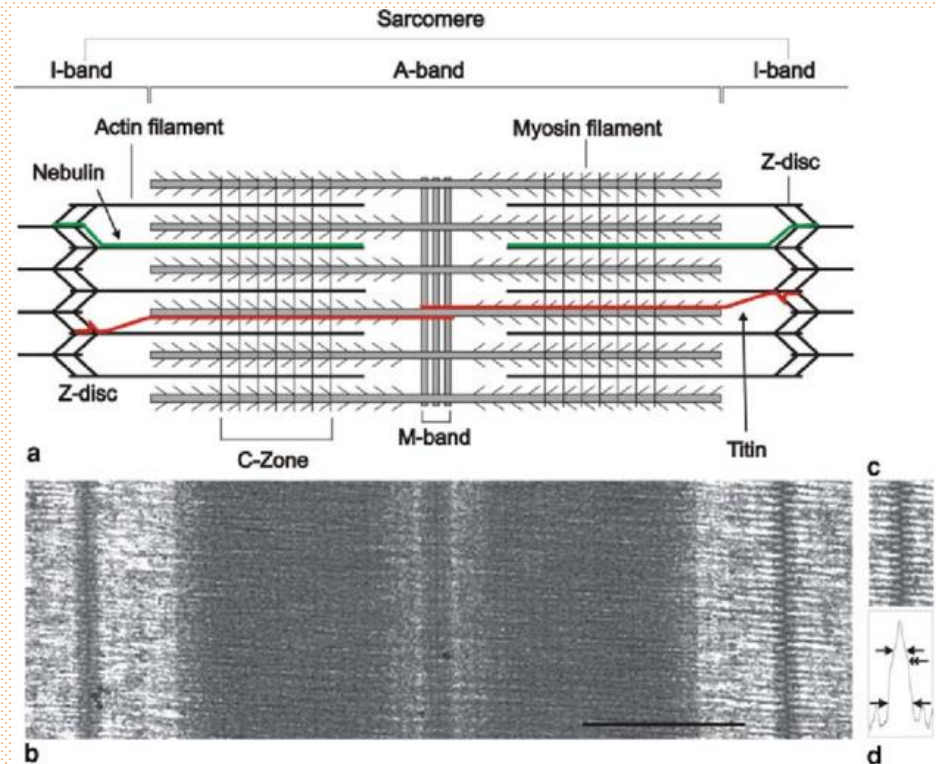


- Light and dark stripes alternate at regular intervals.
- A **thin dark Z-line** extends through the middle of the light I-stripe.
- At the level of the Z-line, the proteins to which the thin filaments are attached are concentrated.
- The segment located between the two Z-lines is called a **sarcomere**.
- The sarcomere is the basic contractile unit of skeletal muscle.



Sarcomere

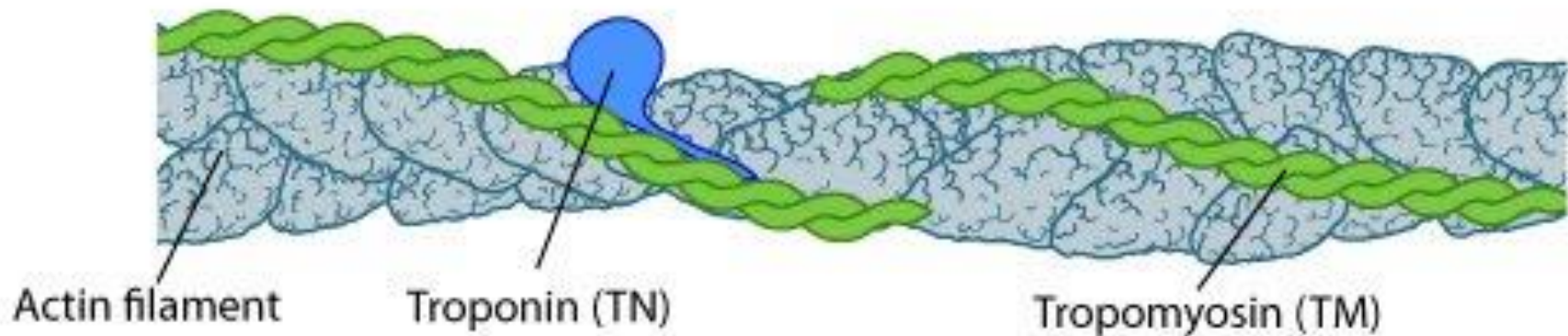
- The central part of the A-band is slightly lighter since it contains only thick filaments and that part of the dark stripe is called the **H-zone**.
- In the middle of the H-zone is a dark one **M-line**.
- The rest, the peripheral part of the dark A-band is much darker ("thickest") because thin (joined on the Z-line) and thick filaments (joined on the M-line) overlap in that part.

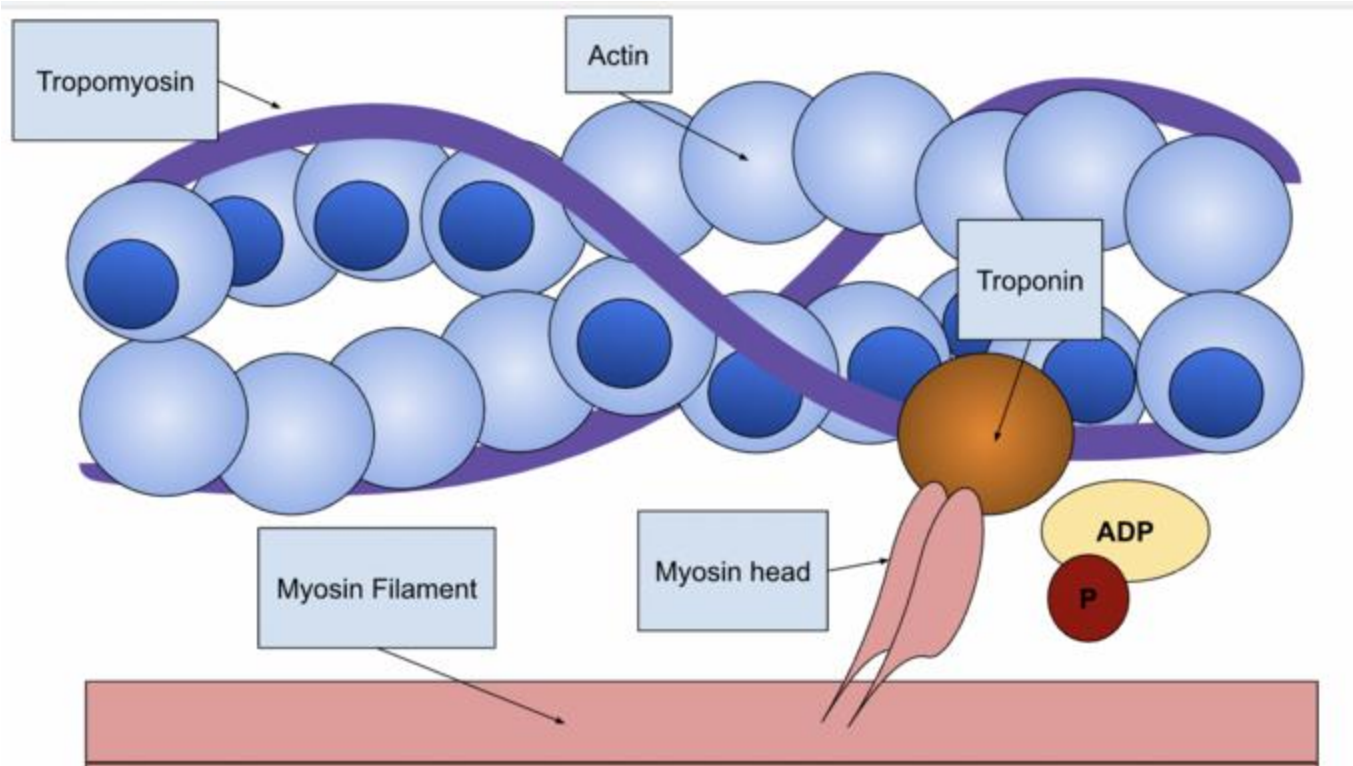


Thin filaments

- Thin filaments are mostly made of actin protein, which is why they are also called **actin filaments**.
- In addition to actin, their composition includes two other proteins: **troponin** and **tropomyosin**.
- **Actin is a globular protein** monomer prone to polymerization.
- Actin filaments consist of two spirally twisted chains of F-actin.
- Each of the two chains of **F-actin** consists of polymerized globular monomers of **G-actin**.
 - Each monomer of G-actin contains an active site for binding the heads of myosin filaments during muscle contraction.

- **Troponin** is a protein complex made up of three globular subunits marked with the letters **T, C and I**.
- Troponin, a complex of three subunits: **TnT**, which attaches to tropomyosin; **TnC**, which binds Ca^{2+} ; and **TnI**, which regulates the actin-myosin interaction

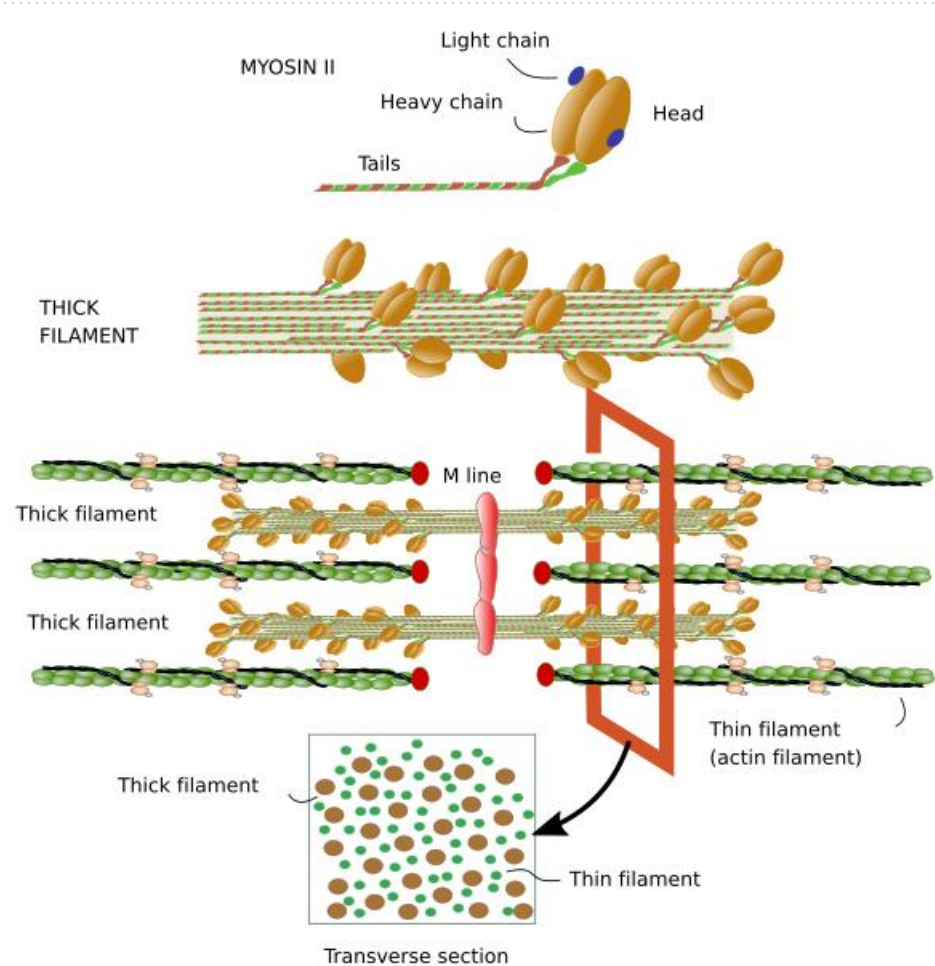




- **Tropomyosin** is a long and thin protein molecule composed of two polypeptide chains, spirally twisted around each other.
- When the muscle is relaxed, tropomyosin covers the active sites on G-actin, which prevents the binding of myosin heads. During contraction, it is pulled into the groove between two actin chains, releasing the active sites.

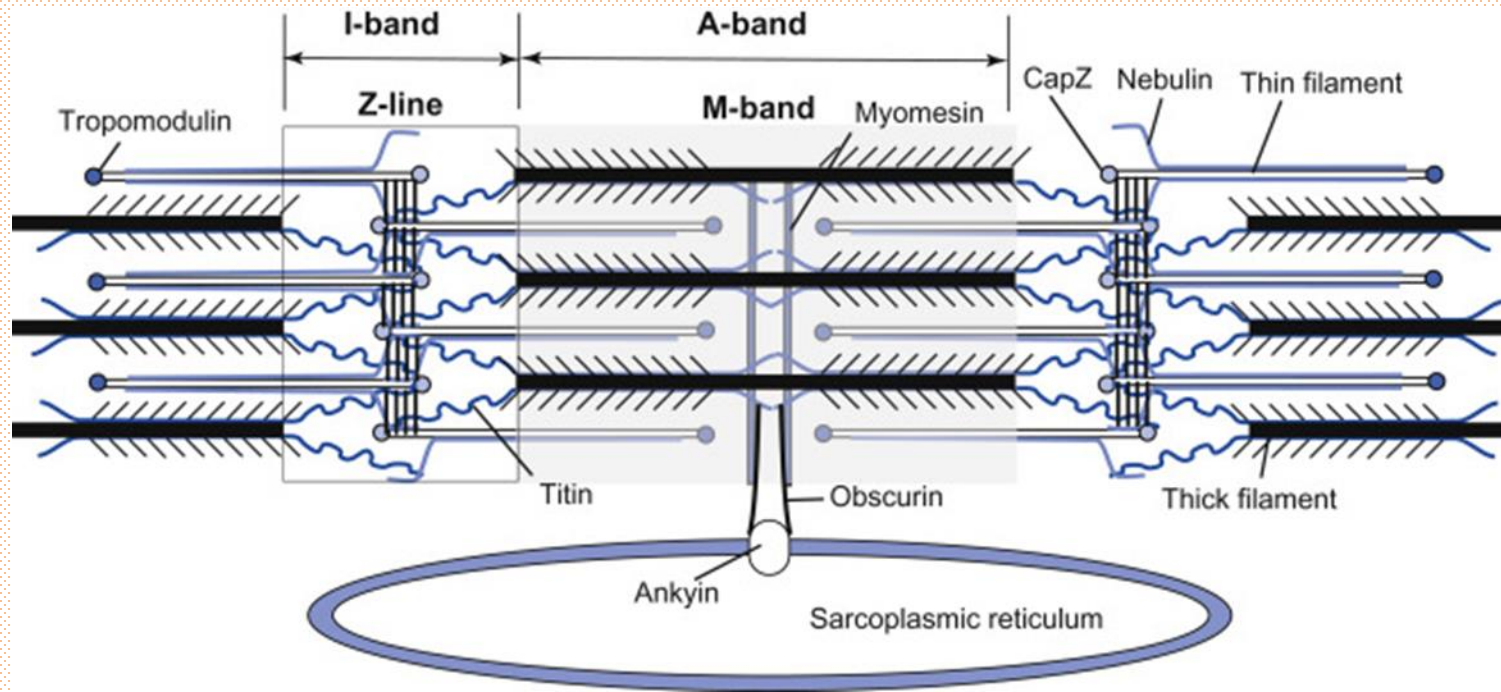
Thick filaments

- Thick filaments are made of **myosin** molecules, which is why they are also called myosin filaments.
- One myosin filament contains 200-350 myosin molecules that look like a golf club.
- The largest part of the myosin molecule consists of a rod-shaped tail to which the ball-shaped head is hinged.
- Myosin heads have a helical arrangement so that one turn of the helix forms six heads.
- **Each myosin filament is surrounded by six actin filaments.**



Additional proteins

- **Desmin** – intermediate filament that connects adjacent myofibrils at the level of the Z or M line thus insuring the vertical alignment of myofibrils resulting in transverse striations.
- Actin filaments are anchored perpendicularly on the Z disc by the actin-binding protein **α -actinin**.
- **Titin**, the largest protein in the body, with scaffolding and elastic properties, which supports the thick myofilaments and connects them to the Z disc.
- **Nebulin**, binds each thin myofilament laterally, helps anchor them to α -actinin

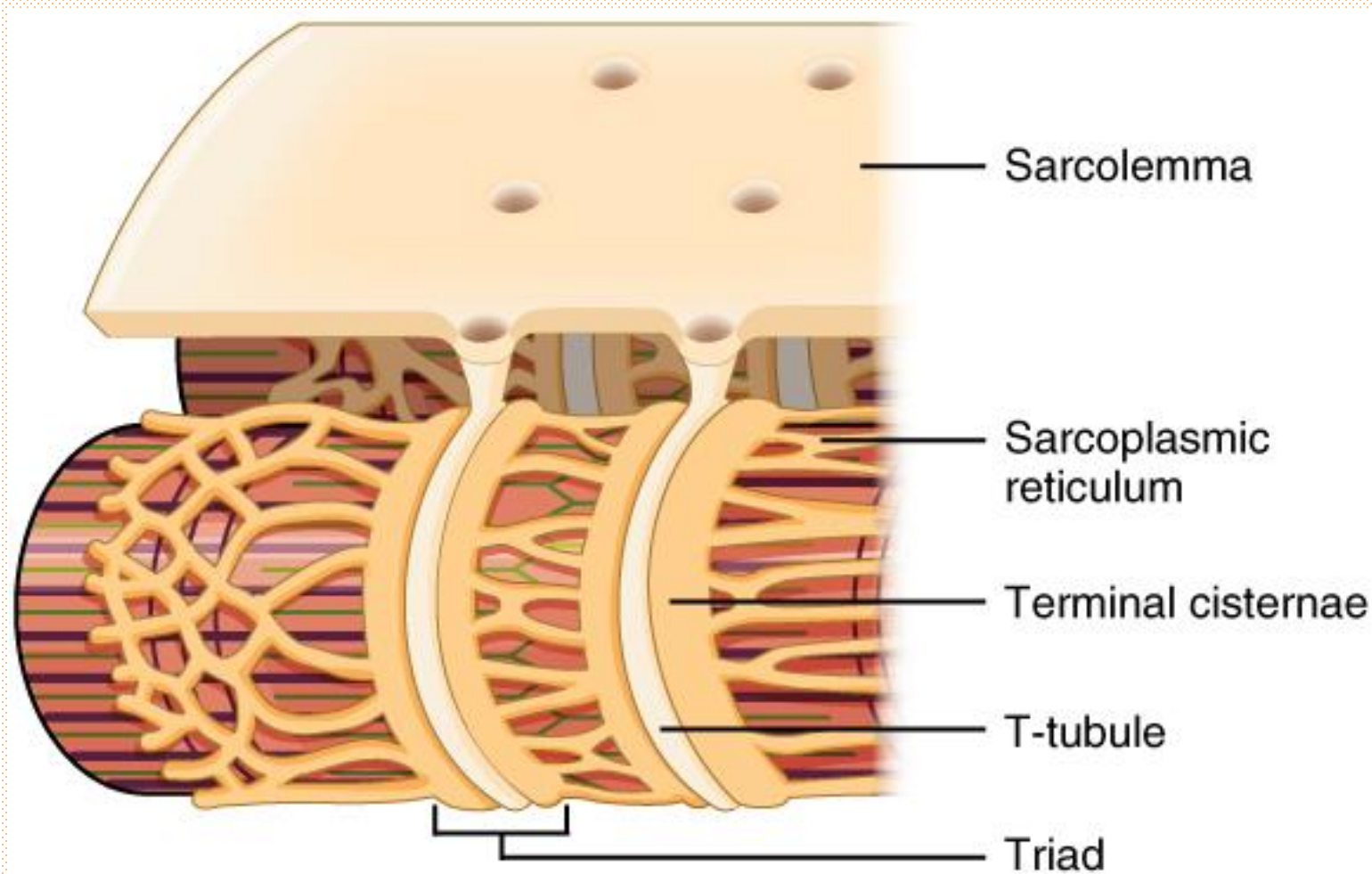


Myocyte structure

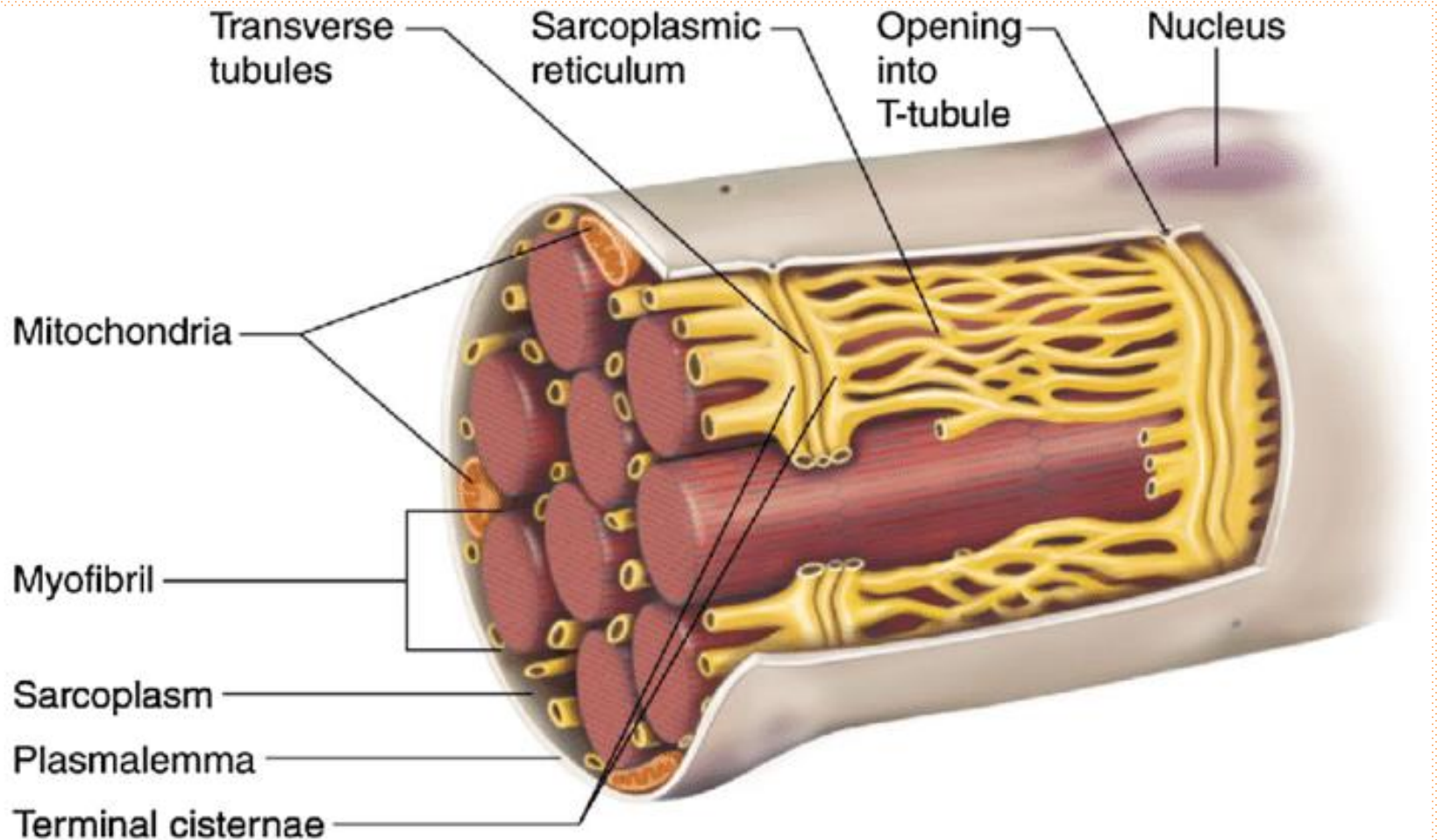
- In the sarcoplasm, **mitochondria** (source of energy for muscle contractions) and **sarcoplasmic reticulum** (depot of calcium ions) stand out.
- The sarcoplasmic reticulum consists of a branched network of tubes that widen at the border between the dark and light stripes and build ring-shaped channels around the myofibrils called end or **terminal cisternae**.
- Between the two terminal cisterns are inserted the necks of the sarcolemma called transverse or **T-tubules**.

This complex of a T-tubule with two terminal cisternae is called
a triad

- Via the transverse tubules, the stimulus (wave of depolarization) spreads from the surface to the interior of the muscle cell.

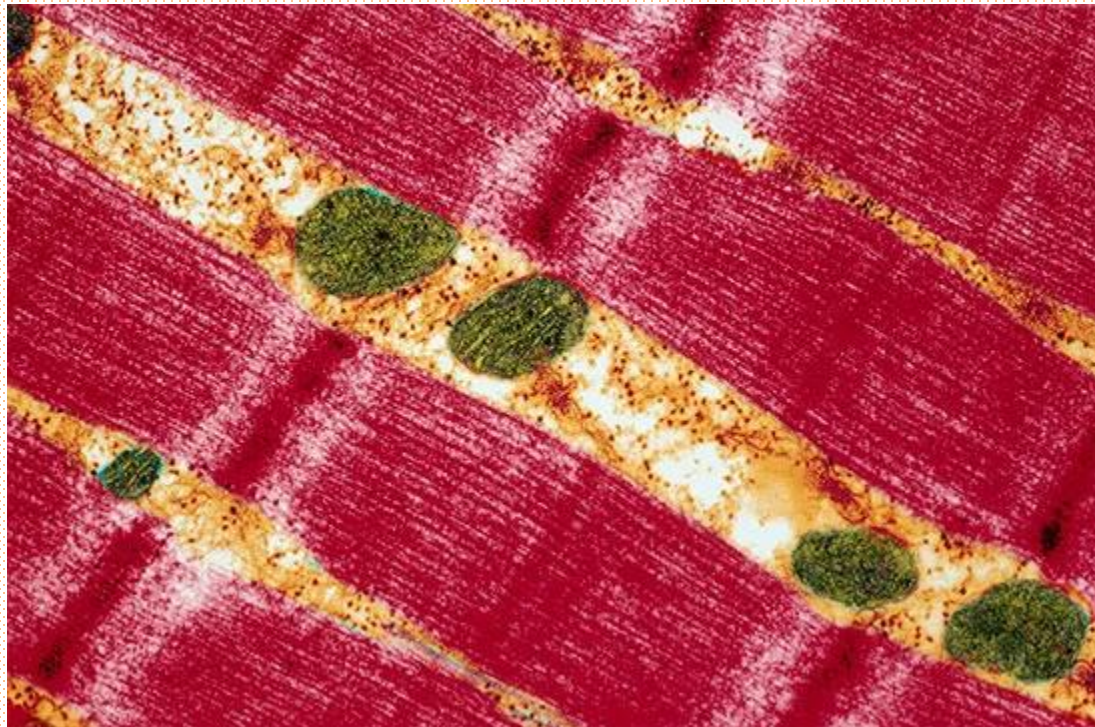


Sarcoplasmic reticulum



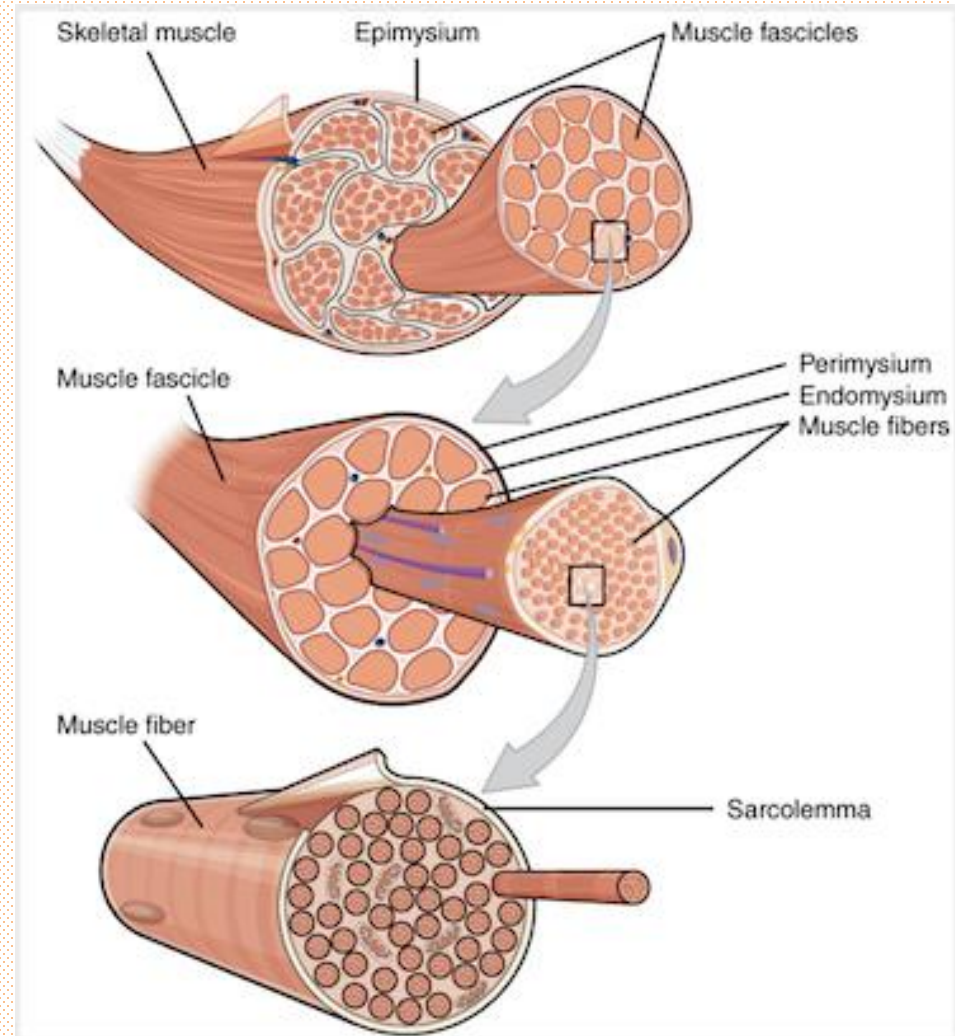
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- Mitochondria are responsible for regulating the metabolic status of skeletal muscle. These organelles exhibit remarkable plasticity by adapting their volume, structure, and function in response to chronic exercise.
- Located between myofibrils



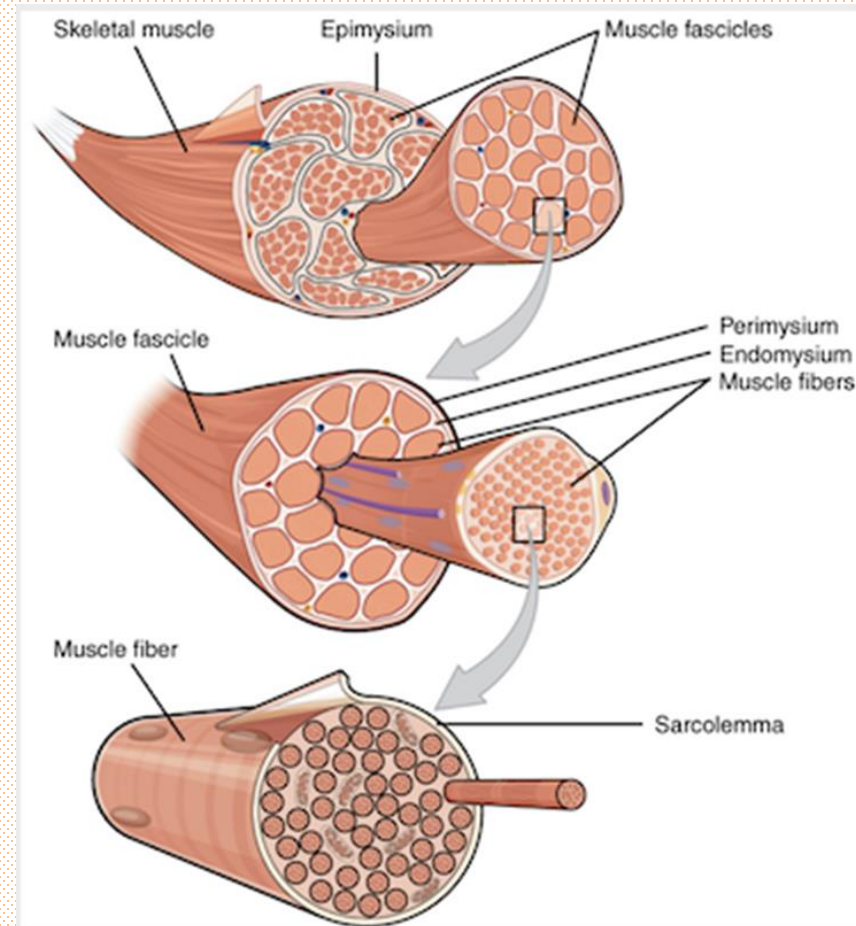
Muscle

- Myocytes join together to form **muscle bundles**, and a larger number of bundles build a **muscle**.
- Each muscle cell, bundle or muscle is surrounded by a layer of loose connective tissue.
- **Epimysium**, an external sheath of dense irregular connective tissue, surrounds the entire muscle. Septa of this tissue extend inward, carrying the larger nerves, blood vessels, and lymphatics of the muscle.



➤ **Perimysium** is a thin connective tissue layer that immediately surrounds each bundle of muscle fibers termed a fascicle. Each fascicle of muscle fibers makes up a functional unit in which the fibers work together. Nerves, blood vessels, and lymphatics penetrate the perimysium to supply each fascicle.

➤ Within fascicles a very thin, delicate **layer of reticular fibers and scattered fibroblasts, the endomysium**, surrounds the external lamina of individual muscle fibers



Skeletal Muscle Fiber Types

On the basis of their maximal rate of contraction (fast or slow fibers)
and major pathway for ATP synthesis

Type I (SLOW)

- slow, prolonged contractions
- high myoglobin level
- numerous mitochondria
- aerobic metabolism
- it's hard to get tired
- better blood circulation

example:

- back muscles

Type II (FAST)

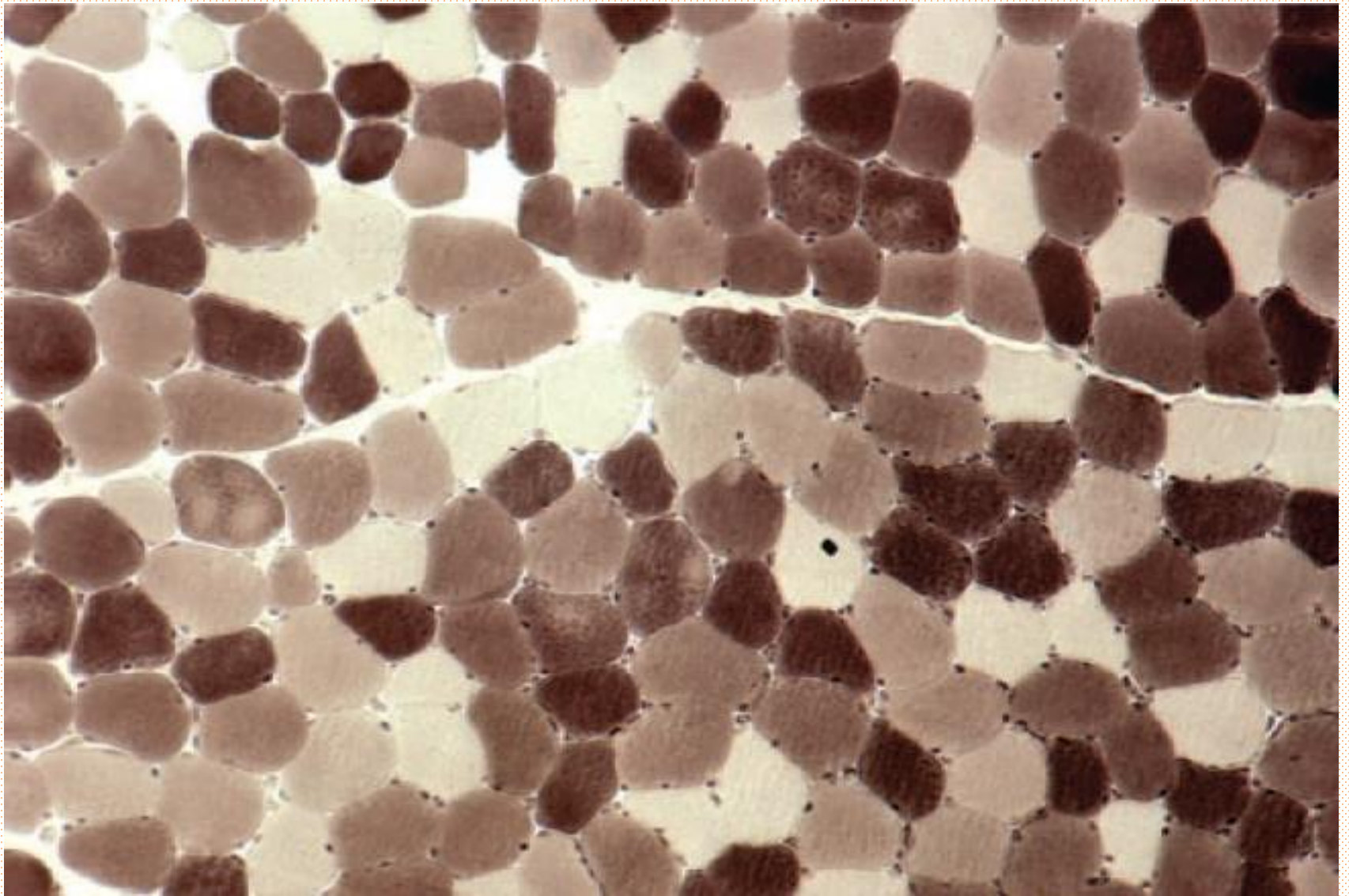
- fast, short-lived contractions
- low myoglobin
- fewer mitochondria
- anaerobic metabolism
- he gets tired easily

example:

- facial muscles

- pectoral muscles ("white meat")

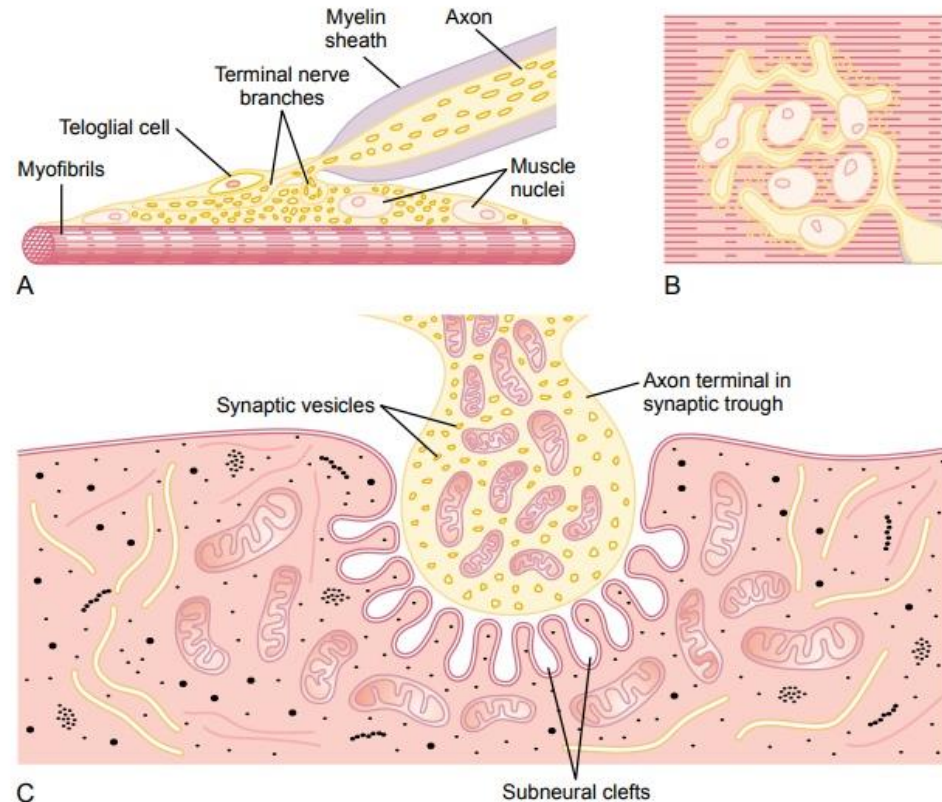
Type III (INTERMEDIATE)

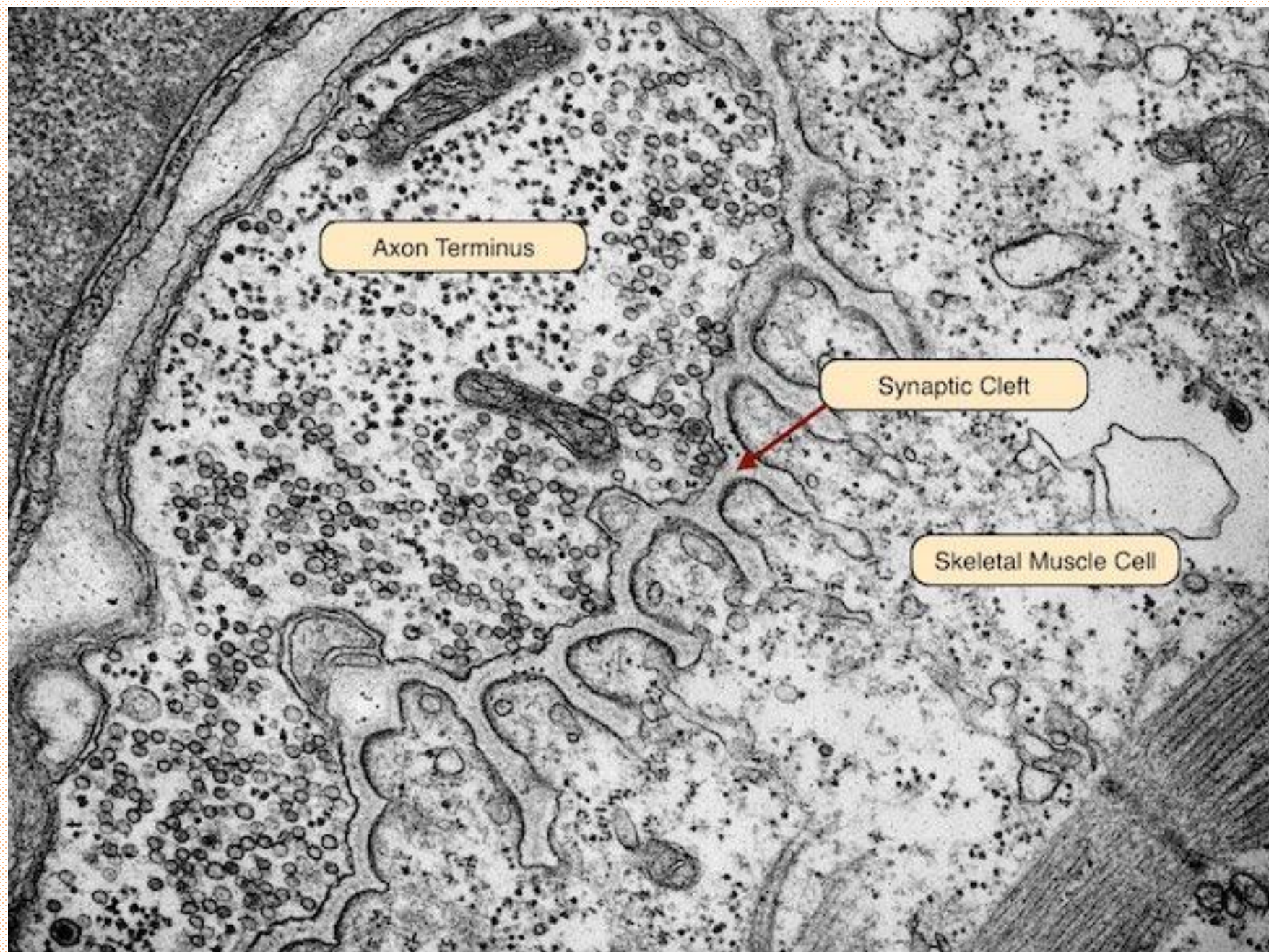


Innervation

- Skeletal muscle is innervated by **motor and sensory** nerve fibers.
- Motor innervation of the skeletal muscle is carried out through neurons whose bodies are located in the spinal cord.
- In the perimysium, the nerve fibers of motoneurons branch into a large number of branches, each of which ends on a muscle cell in a neuromuscular synapse - which is called a **motor end plate**.
- One motor neuron and all the muscle cells innervated by it together form a **motor unit**.

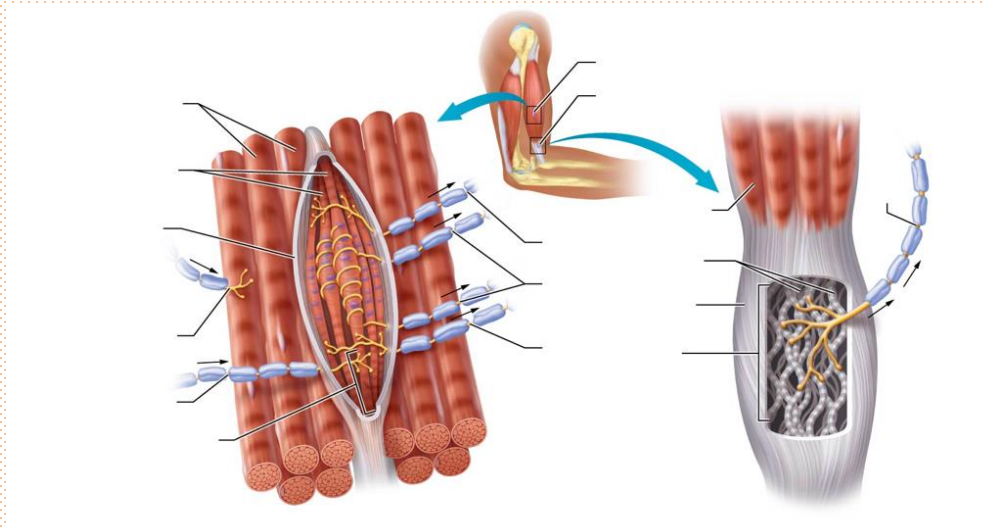
- Synaptic vesicles contain the neurotransmitter **acetylcholine**. Between the axon and the muscle is the synaptic cleft. Adjacent to the synaptic cleft, the sarcolemma is thrown into numerous deep junctional folds.
- Larger muscles with coarser movements have motor axons that typically branch profusely and innervate 100 or more muscle fibers.





Sensory innervation with muscle spindles and Golgi tendon organs

- Among the muscle fascicles are stretch detectors known as **muscle spindles**, approximately 2-mm long and 0.1-mm wide encapsulated by modified perimysium, with concentric layers of flattened cells, containing interstitial fluid and a few thin muscle fibers filled with nuclei and called **intrafusal fibers**
- **Golgi tendon organs**, much smaller encapsulated structures that detect changes in tension within tendons produced by muscle contraction and act to inhibit motor nerve activity if tension becomes excessive.

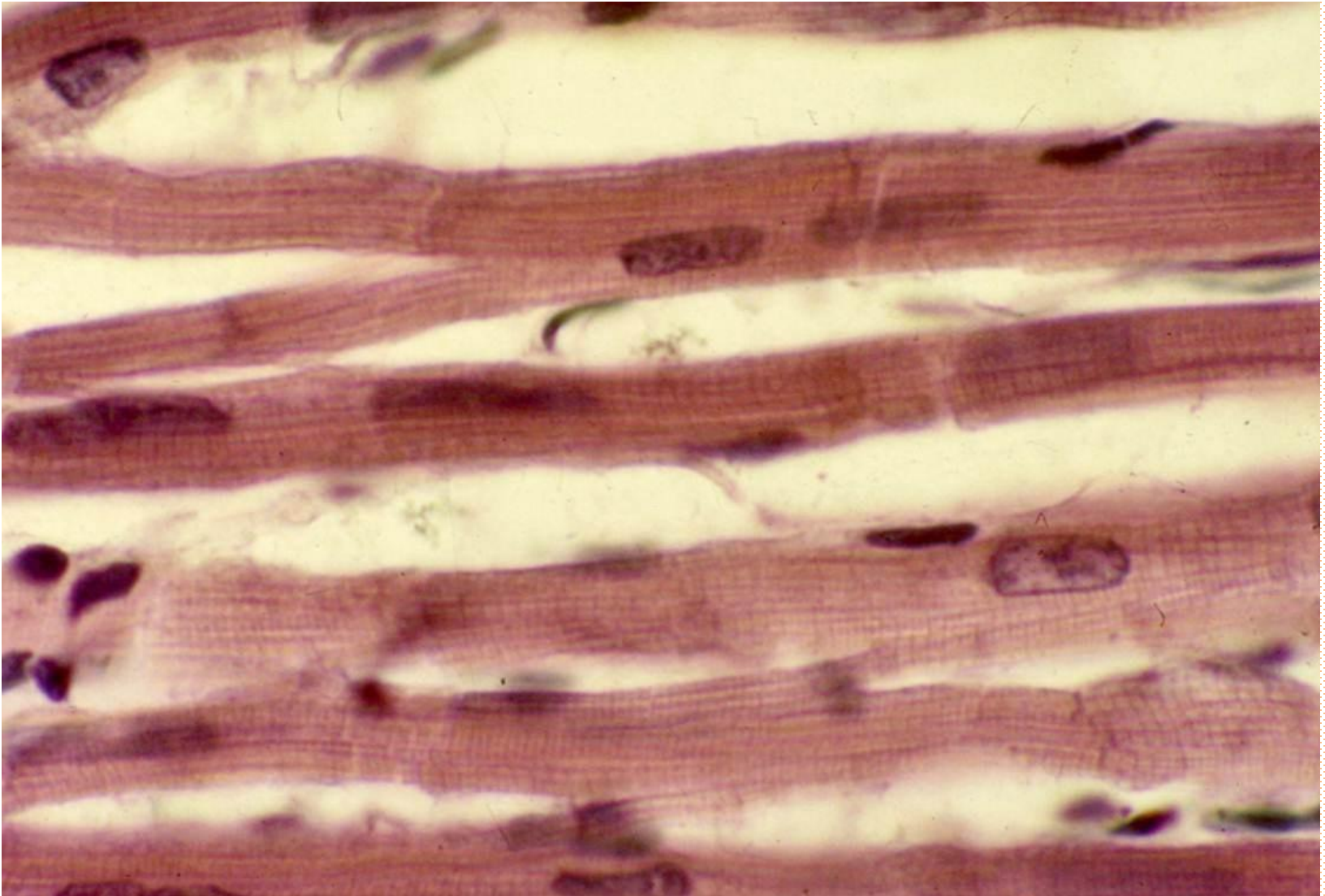


Cardiac muscle tissue

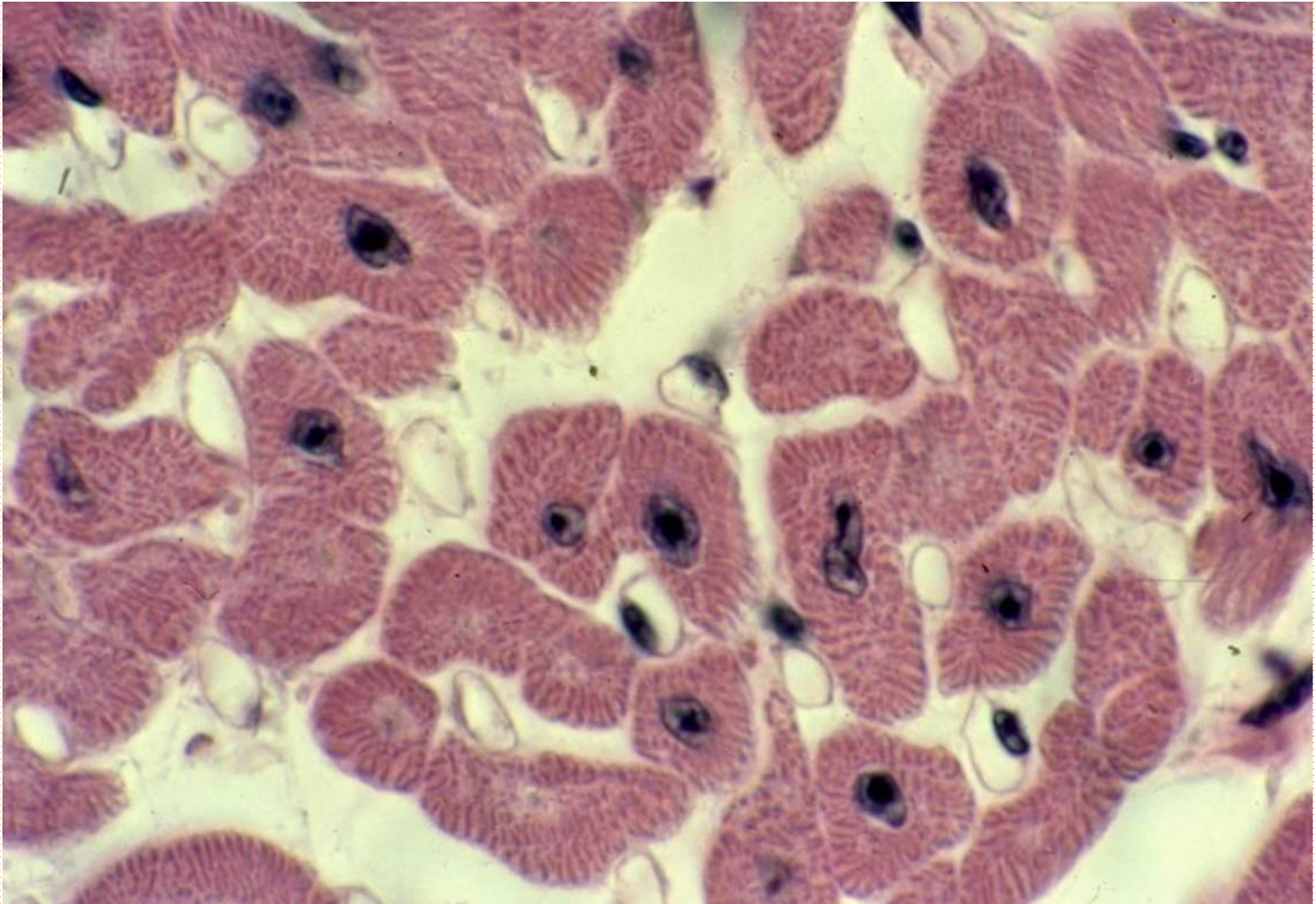
Cardiac muscle

- Heart muscle tissue is located in the **myocardium**.
- It is made up of cardiac muscle cells - **cardiomyocyte** (15-30 μm in diameter and 85-120 μm long)
- Cardiomyocytes are shorter and thinner cells than skeletal myocytes.
- In the sarcoplasm, they contain myofibrils, the specific arrangement of which causes cross striations (it can be seen on the longitudinal section of the cell, less pronounced than in skeletal myocytes).
- They contain **one or two centrally placed nuclei**
- Cardiomyocytes are connected in a complex three-dimensional network by **intercalated discs**.

Cardiac muscle

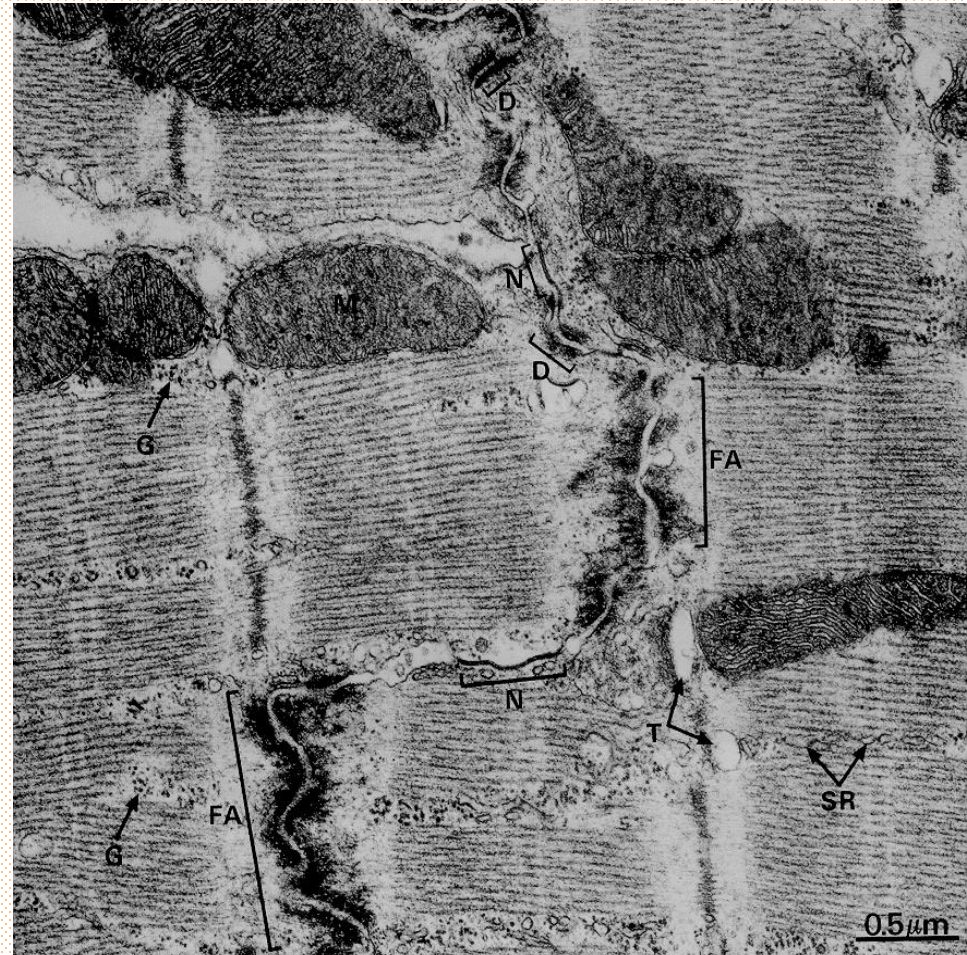


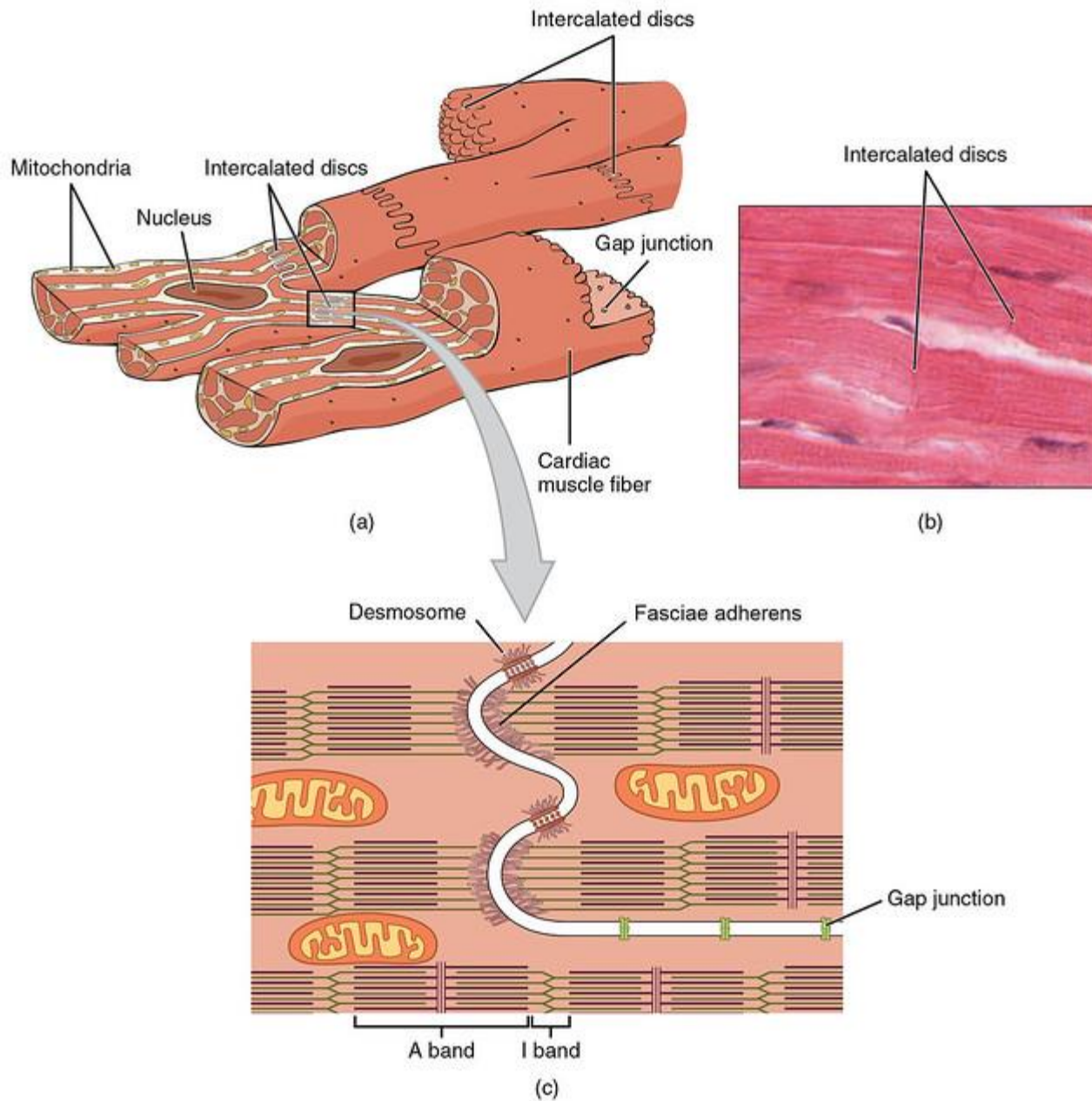
Cardiac muscle - cross



Intercalated discs

- Intercalated disc is a specific joint found only in cardiomyocytes.
- It consists of **adherent fascia**, **desmosomes** and **gap junctions**.
- Desmosomes and adherent fascia provide a mechanical connection between adjacent cells.
- The nexus is a communication junction that electrochemically "couples" neighboring cells and enables synchronized contractions of the heart muscle.





Cytology

- The most abundant organelle are mitochondria (source of energy for muscle contractions); they occupy 40% of the cardiac muscle cells.
- The sarcoplasmic reticulum serves as a calcium depot.
- Sarcoplasmic reticulum is a mesh structure with extensions in contact with plasmalemma openings (T tubules) that form **dyads**.
- Other cell organelles are less pronounced and located mostly near the nucleus.



Cardiomyocyte types

- Most cardiac muscle cells have an exclusively contractile role - **contractile cardiomyocytes**.
- In addition to them, there are also endocrine and **conducting cardiomyocytes**.
- **Endocrine cardiomyocytes** contain granules in which the hormone atrial natriuretic peptide (ANP) is deposited.
- This hormone promotes the elimination of sodium and water in the kidneys and thus lowers blood pressure.

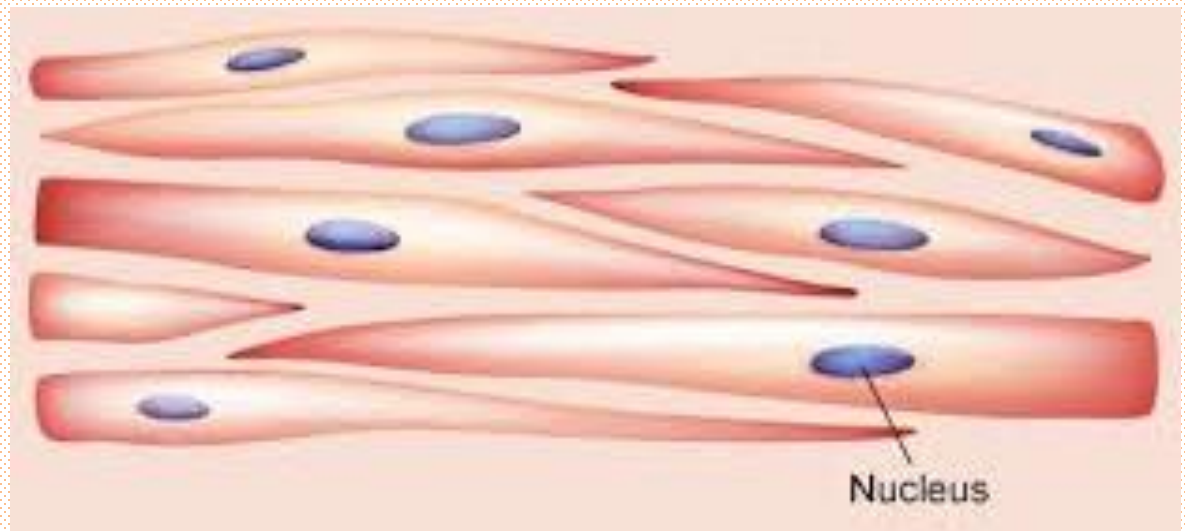
Smooth muscle tissue

Smooth muscle tissue

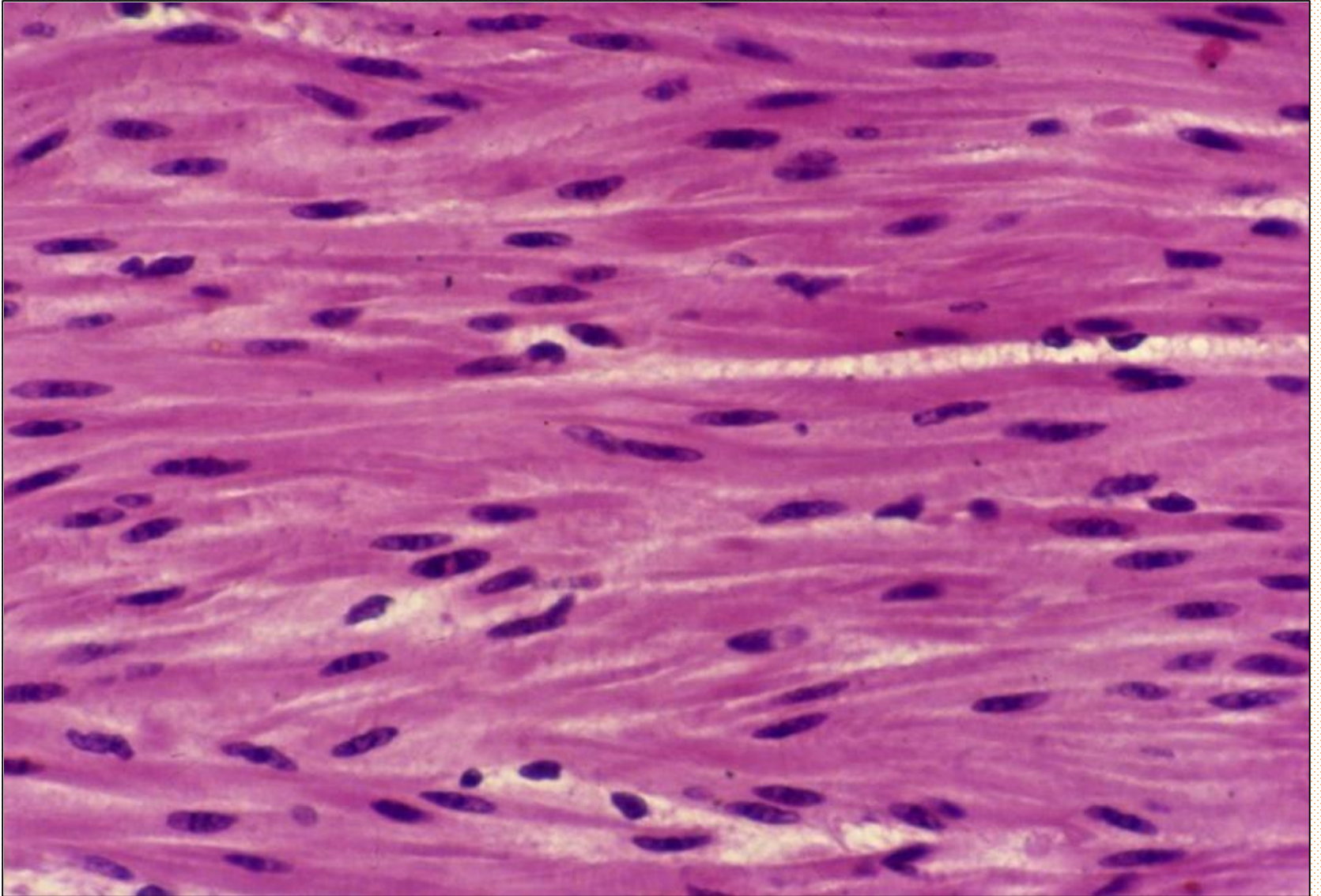
- Smooth muscle tissue participates in the structure of internal organs.
- It is present in the walls of the digestive, respiratory and urogenital tracts, blood vessels, excretory ducts, the sheaths of certain organs, etc.
- It contracts without the influence of the will, whereby the contractions are of lower intensity, but can last much longer compared to skeletal muscles.
- Unlike skeletal and cardiac myocytes, smooth myocytes have the ability to partially contract.

Smooth muscle cells

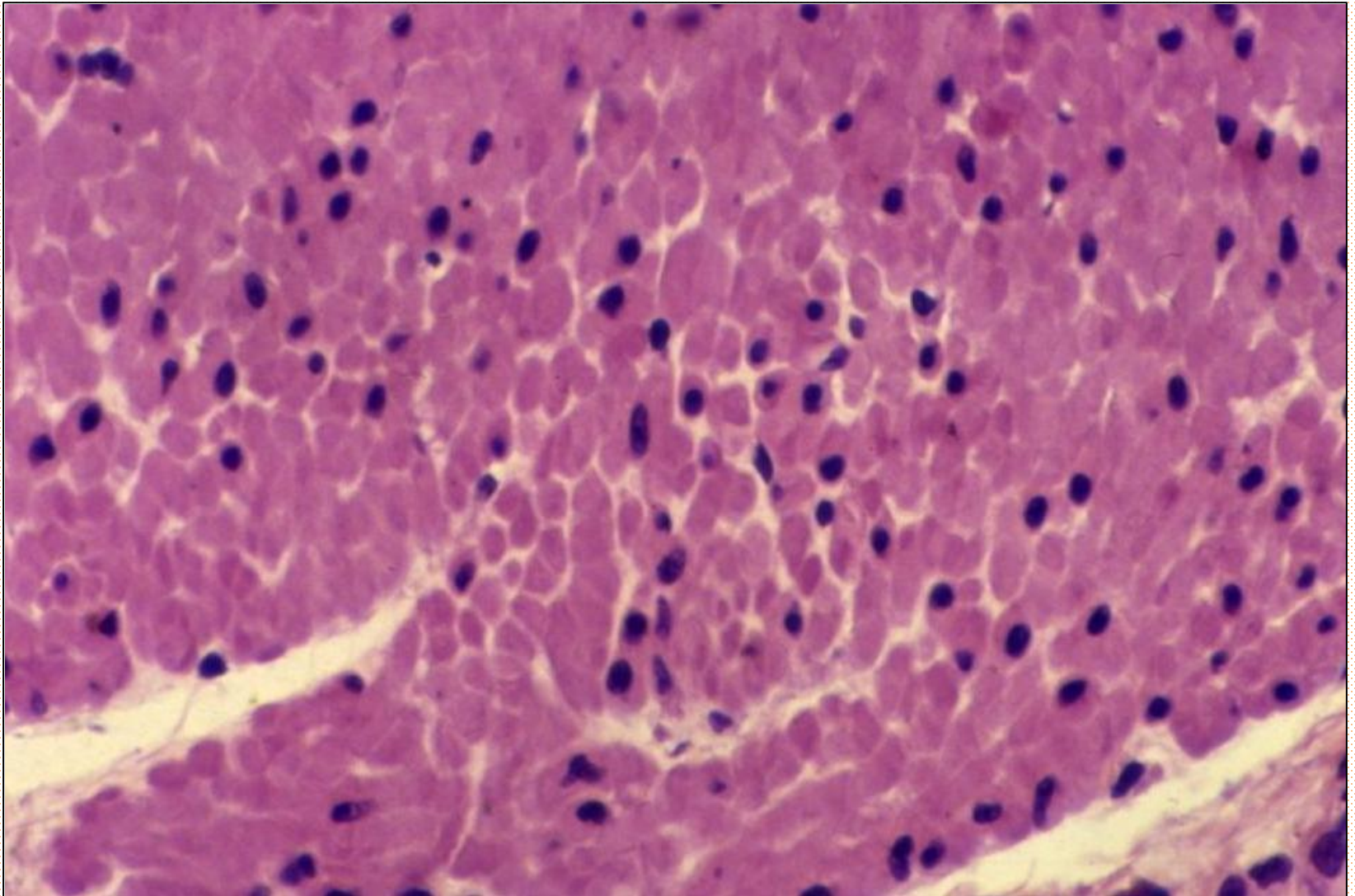
- Smooth muscle cells are spindle-shaped, connected to each other by nexuses, and surrounded by sparse endomysium.
- Within the bundle, smooth myocytes are arranged so that the wider part of one cell abuts the narrower parts of neighboring cells.
- Each cell contains one centrally placed nucleus.
- In a relaxed myocyte, the nucleus is ellipsoidal or spindle-shaped, and in a contracted smooth myocyte, the nucleus has the appearance of a corkscrew.



Smooth muscle tissue

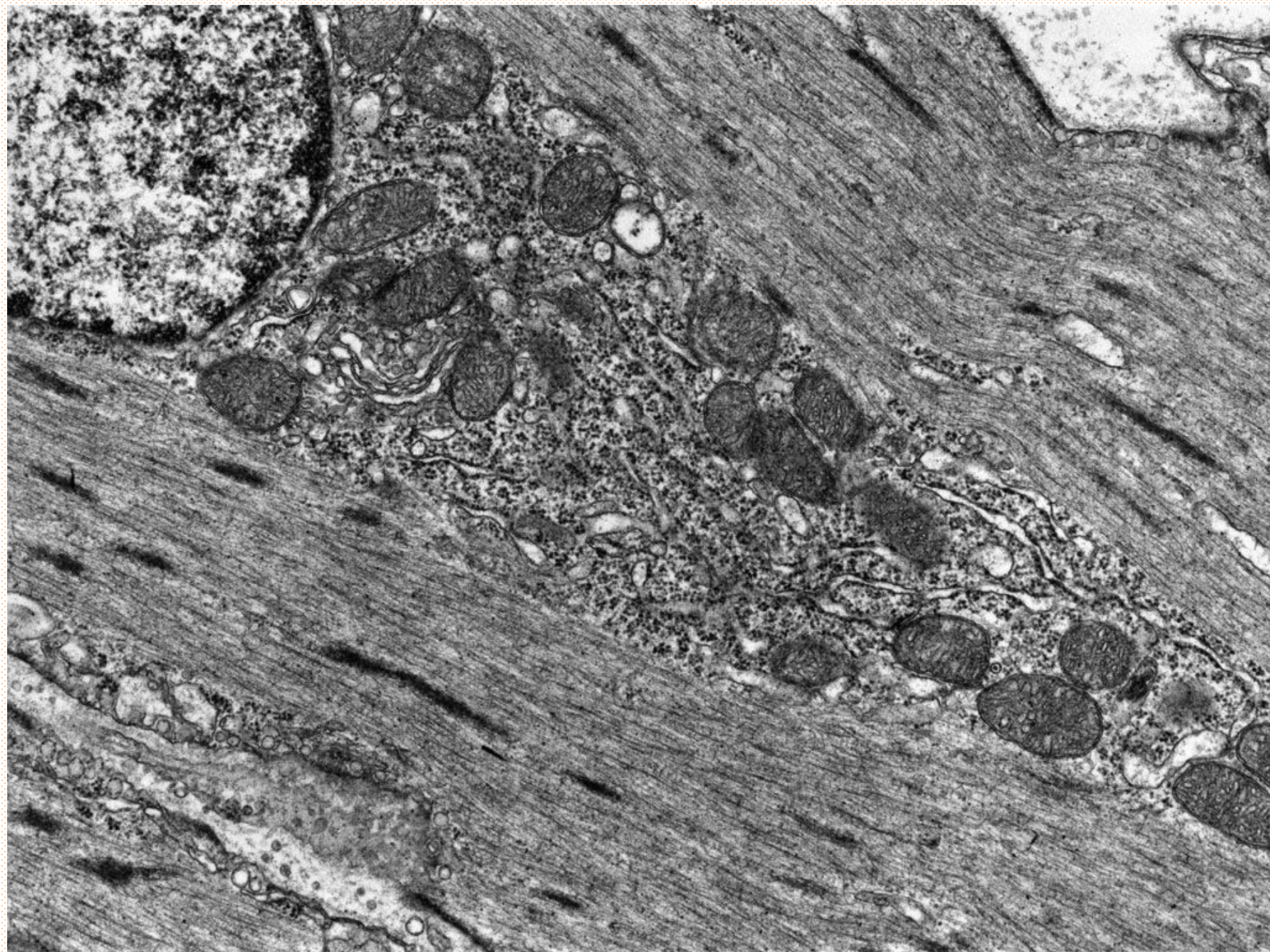


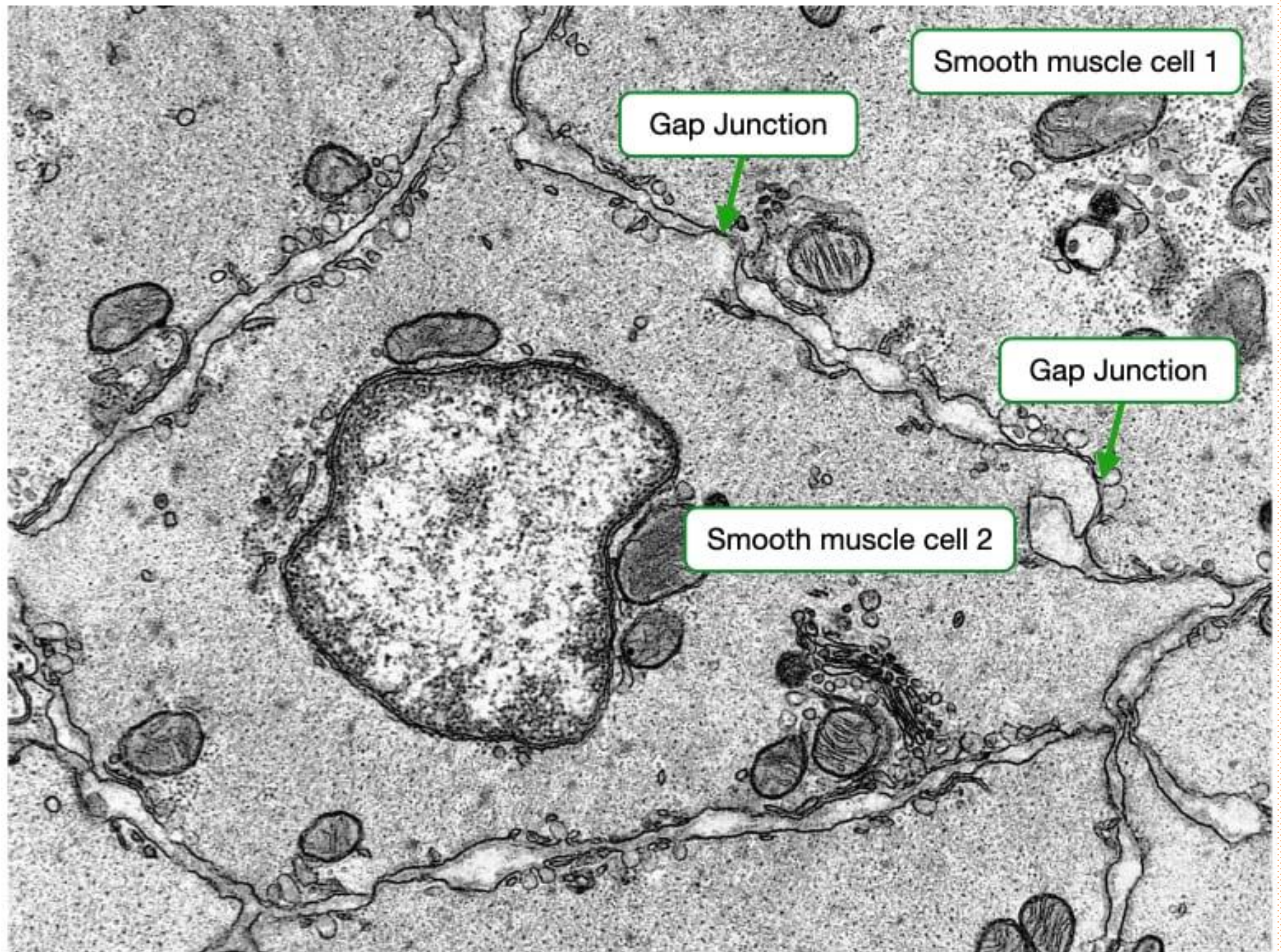
Smooth muscle tissue - cross



Smooth muscle cells

- Concentrated near the nucleus are mitochondria, polyribosomes, RER, and vesicles of a Golgi apparatus.
- Actin and myosin filaments are irregularly distributed (there is no cross striation as in skeletal and cardiac muscle)
- Each myosin filament is surrounded by 12 actin filaments.
- Actin and intermediate filaments are attached to dense bodies.
- There are no T tubules, the plasmalemma has shallow openings - caveolae.
- Cells are connected to each other by gap junction.
- In addition to actin and myosin, smooth muscle cells also have desmin and vimentin intermediate filaments in the cytoplasm.

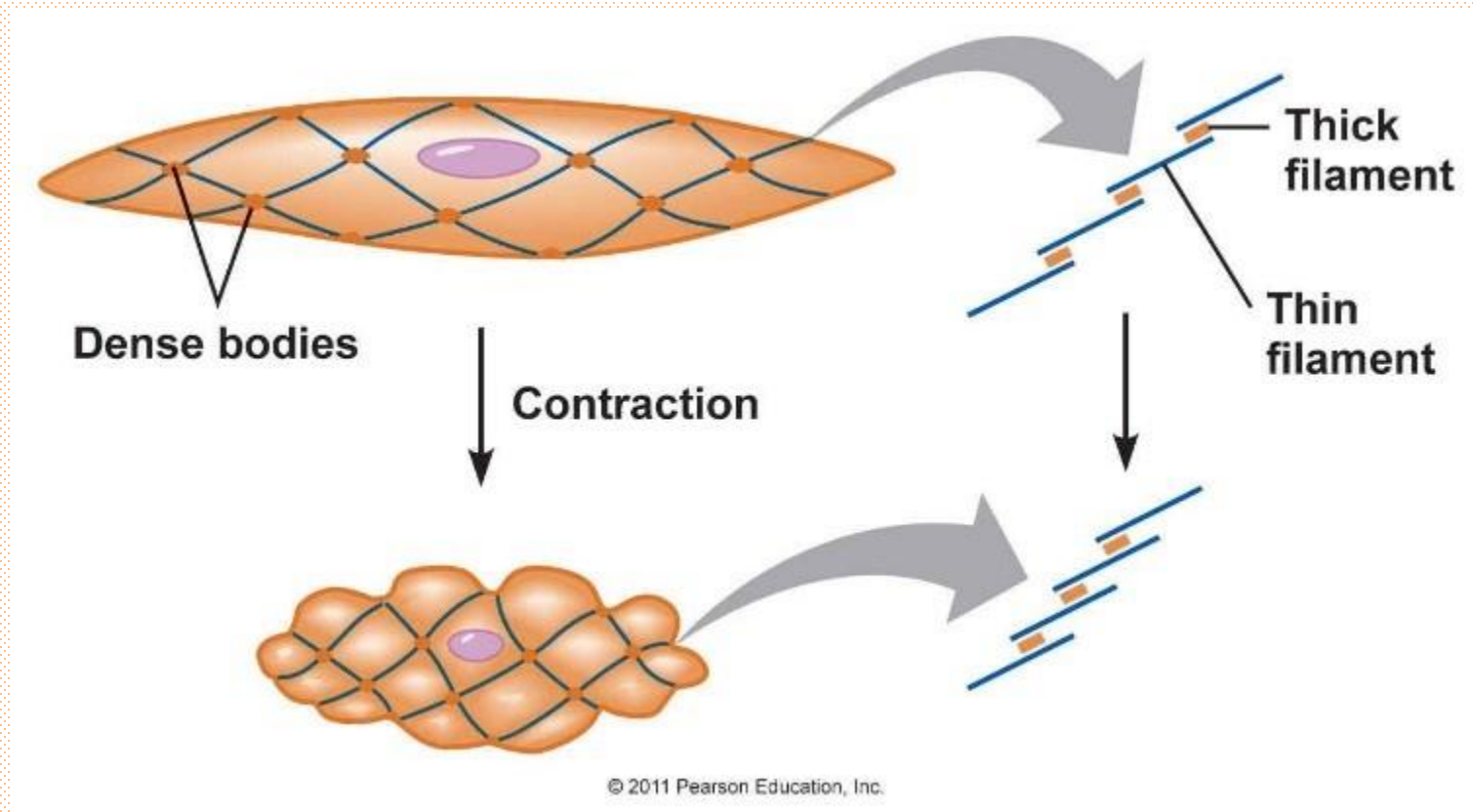




Filaments

- Thin filaments in a smooth myocyte are made of **actin and tropomyosin**, and thick filaments of **myosin** molecules.
- The **absence of troponin** in thin filaments reflects the contraction mechanism, which is different in smooth myocytes compared to skeletal and cardiac myocytes.
- Contraction is initiated by Ca^{++} ions that reach the cytosol from the extracellular environment, endocytosis vesicles and to a lesser extent from the sarcoplasmic reticulum.
- Calcium binds to the protein **calmodulin**.
- The Ca^{2+} -calmodulin complex leads to the phosphorylation of myosin heads and their attachment to actin filaments, which is the initial stage in the contraction of a smooth muscle cell.

Actin myofilaments insert into anchoring cytoplasmic and plasmalemma associated **dense bodies** which **contain α -actinin and are functionally similar to the Z discs**



Innervation

- Smooth muscles are innervated by fibers of the **autonomic nervous system**.
- Innervation is scarce, and the **stimulus is transmitted from one cell to another via the nexus**.
- On their way through the endomysium, nerve fibers form numerous extensions filled with neurotransmitters.
- The extensions are usually distant from the muscle cells so that the released transmitters diffuse in all directions and at the same time attract more myocytes.
- Such neuromuscular synapses are called "transient synapses" or "**distance synapses**".

Non-muscle cells with marked contraction ability

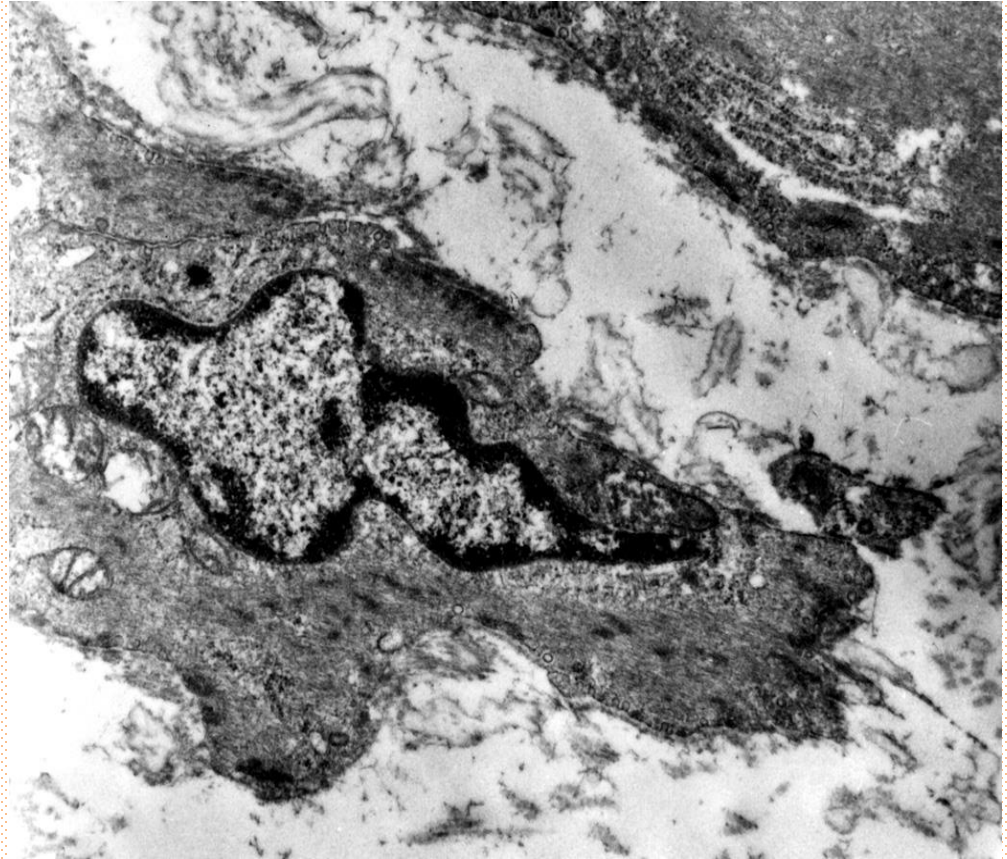
- Myoepithelial cells
 - Myofibroblasts
 - Pericytes

Myoepithelial cells

- Contractile cells of ectodermal origin.
- They are located around the secretory parts of the salivary, lacrimal, sweat and mammary glands.
- They contain a heterochromatic nucleus, bright cytoplasm with moderately developed organelles and a well-defined cytoskeleton.
- In some characteristics, they are similar to epithelial, in others, smooth muscle cells.
- As epithelial cells: keratin filaments; adherent junctions (desmosomes).
- Like smooth muscle cells: actin, myosin, desmin and dense bodies in the cytoplasm.
- Contraction takes place under the influence of the ANS, in the acini of the breast and under the influence of oxytocin.

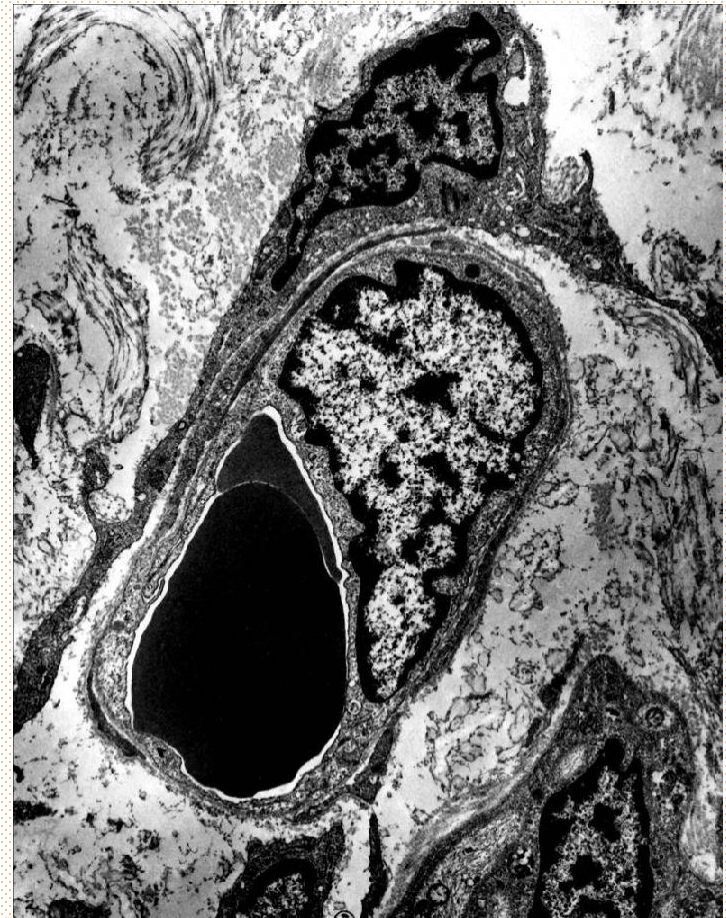
Myofibroblasts

- Synthetically active like fibroblasts, they have contractile properties like smooth muscle cells.
- They differ from fibroblasts by the presence of actin, desmin and dense bodies.
- Under certain conditions, fibroblasts can differentiate into myofibroblasts.



Pericyte

- They are located in the wall of capillaries and post-capillary venules.
- Extensions include the vascular wall.
- Connected with endothelial cells by nexus.
- They have a heterochromatic core, less developed organelles, actin, myosin and tropomyosin in the cytoplasm.
- They have the ability of phagocytosis.
- They arise from mesenchyme.
- They can differentiate into endothelial cells, smooth muscle cells, adipocytes or macrophages.



Nerve tissue

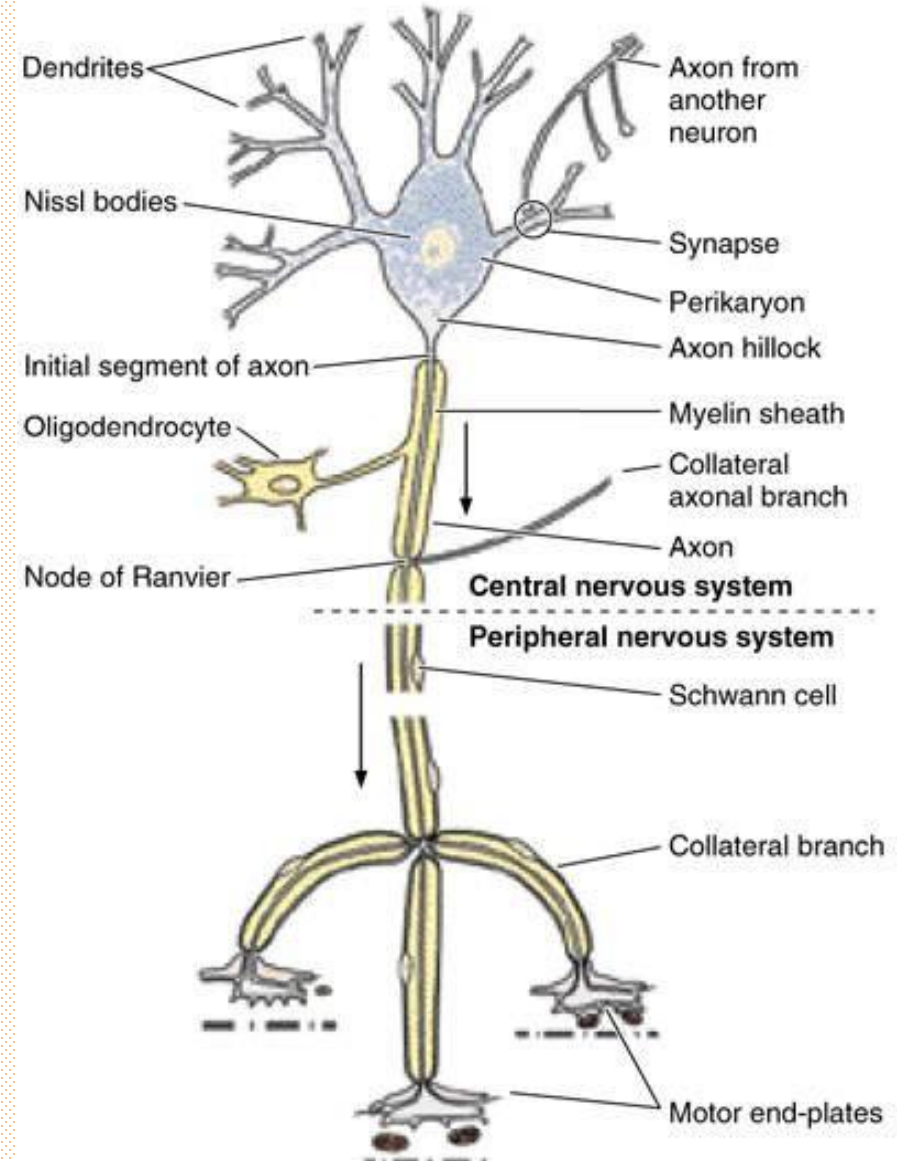
Basics

Nervous tissue is HIGHLY cellular tissue made up of two basic types of highly differentiated cells:

- ❖ **Neurons** (main cell type)
- ❖ **Glial cells** (support cells with numerous functions)

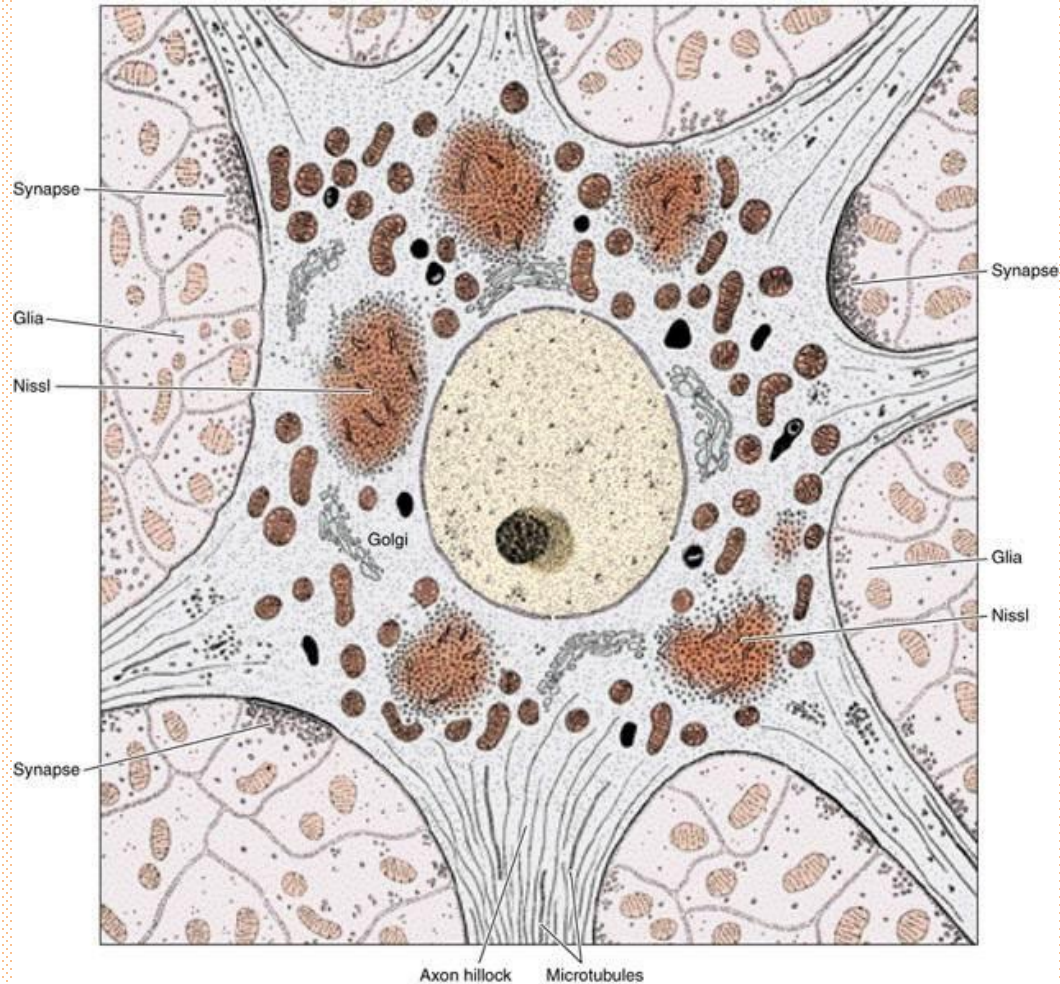
Neuron

- A neuron is **the basic functional unit** of nervous tissue.
- A neuron has a **body** (soma, perikaryon) and two types of extensions:
 - **Dendrites** (short processes)
 - **Axon** (single long process)

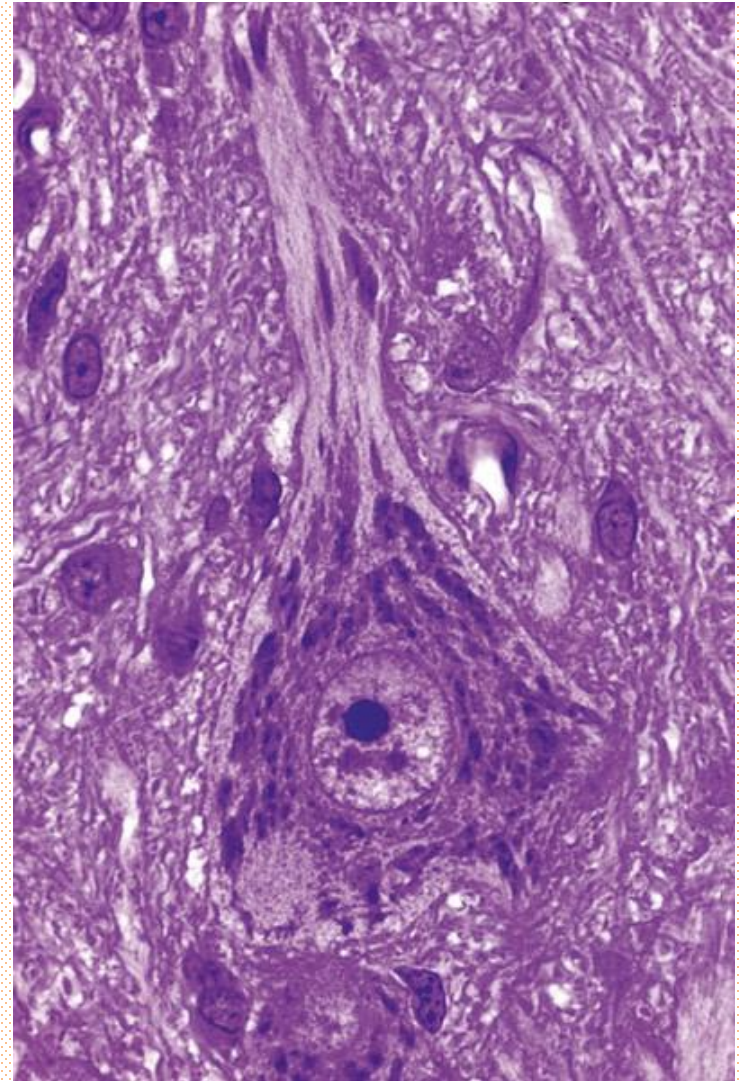


Soma (perikaryon)

- **Cell body** contains the nucleus and surrounding cytoplasm, exclusive of the cell processes.
- Acts as a trophic center, producing most cytoplasm for the processes.



- The nucleus, organelles and inclusions are located in the body of the neuron.
- Neurons contain a large, **euchromatic nucleus** with a prominent nucleolus.
- In the cytoplasm, there are clusters of **rER cisterns and free ribosomes** - **Nissl's substance**.
- Nissl's substance is present in all parts of the perikaryon except in the area of hillock (the beginning of the axon).



Soma (perikaryon)

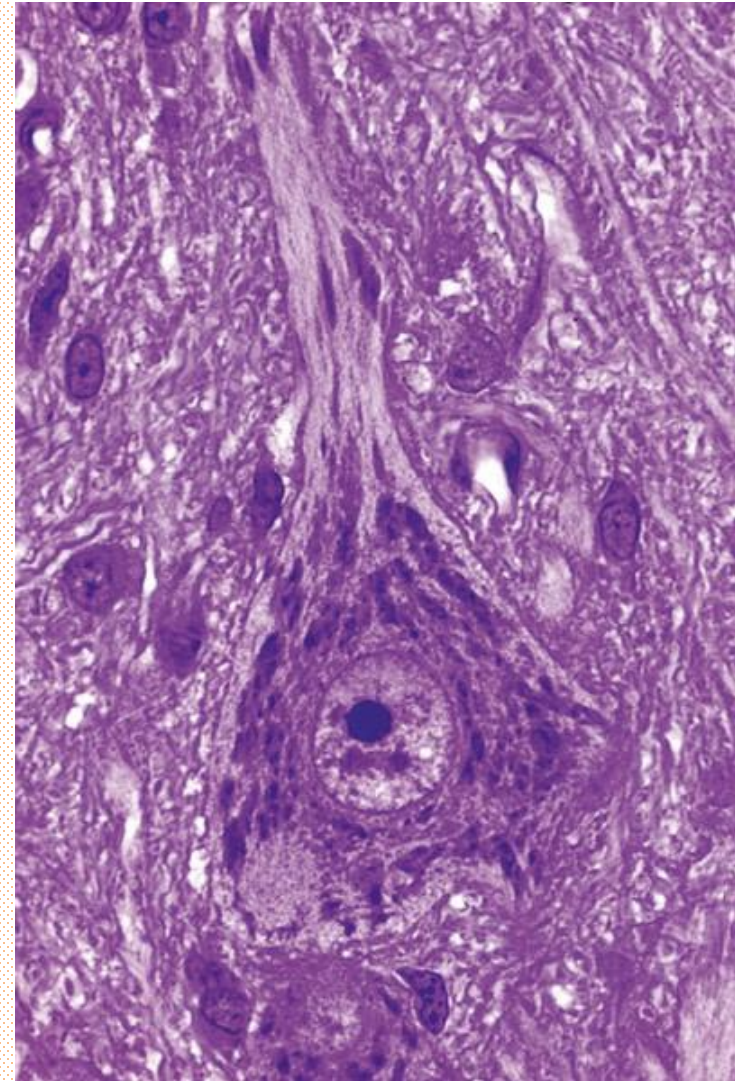
The perikaryon also contains:

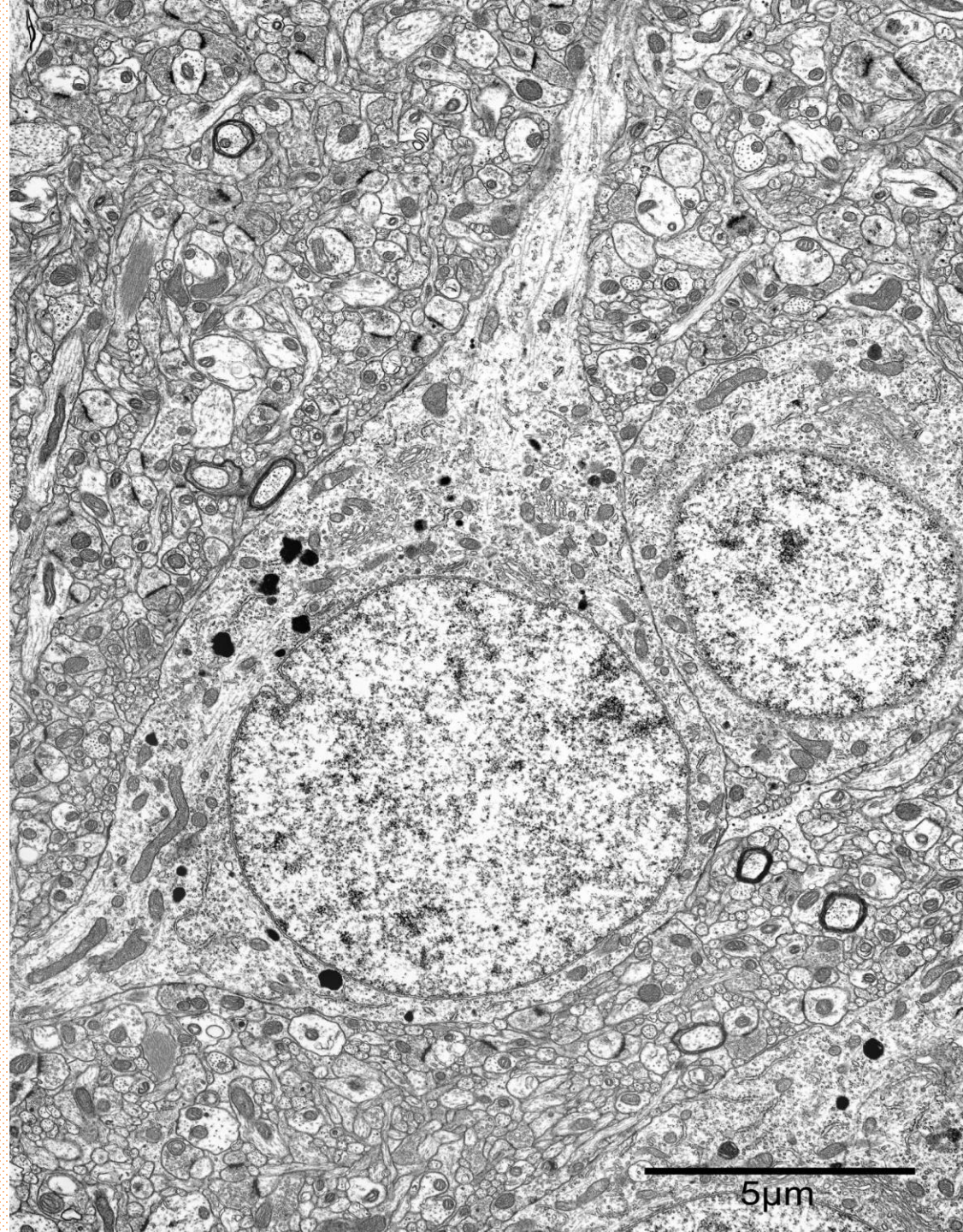
- well developed Golgi apparatus
- numerous mitochondria
- lysosomes
- pigments lipofuscin

and

Elements of the cytoskeleton

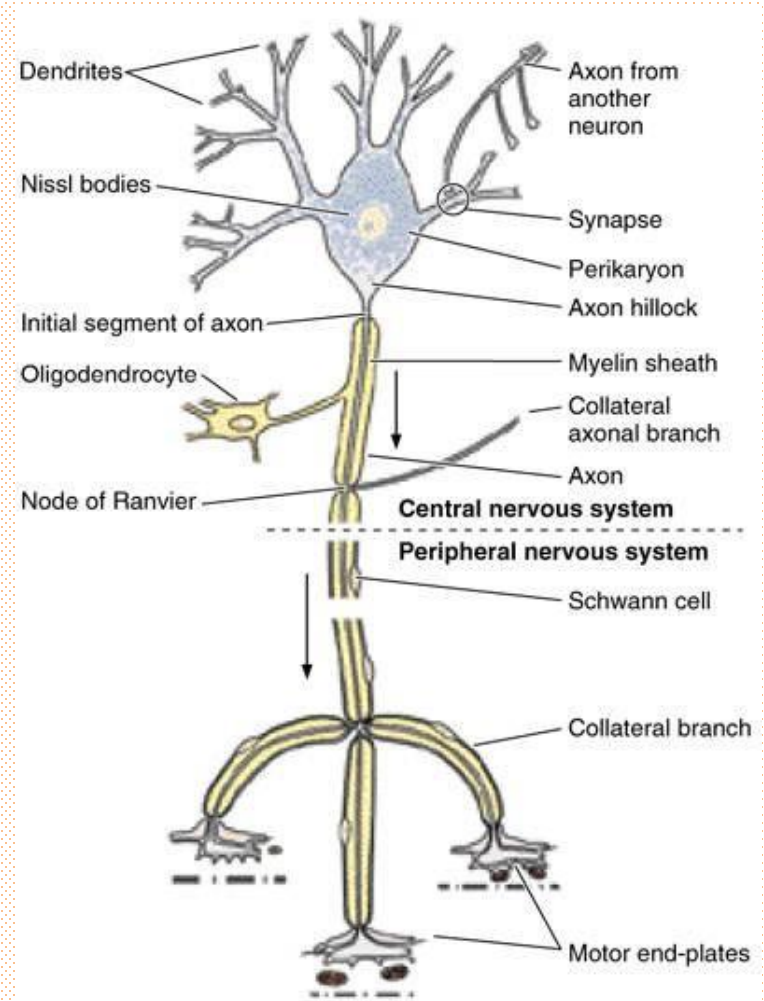
- Microfilaments
- Neurofilaments
- Microtubules





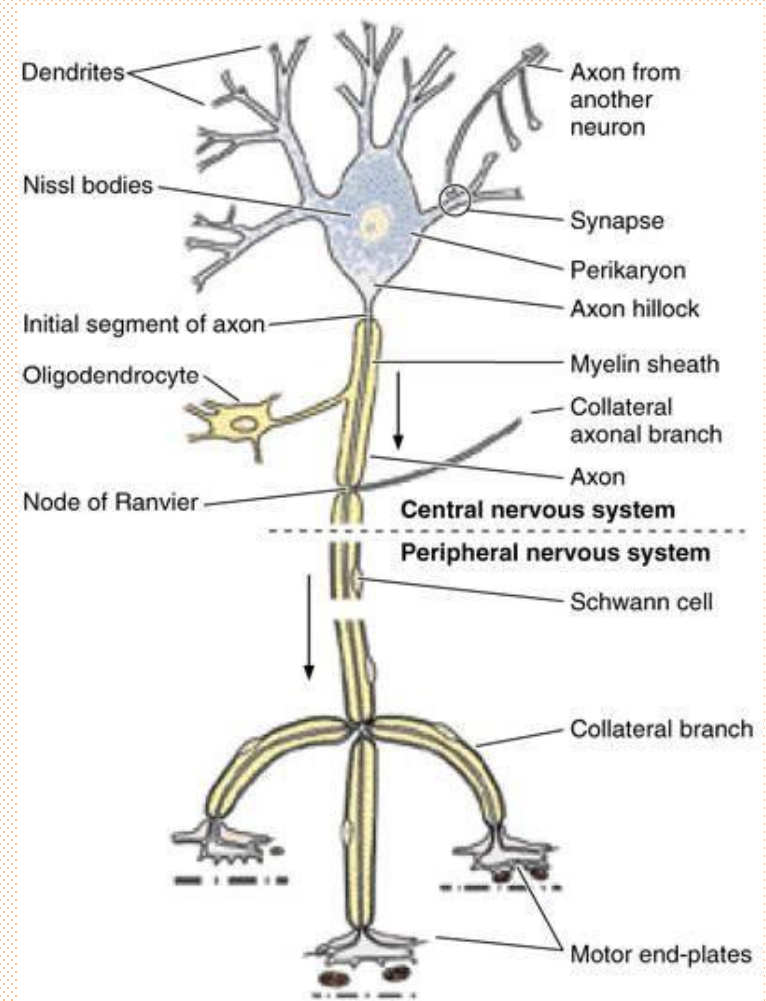
Dendrites

- Dendrites are short, unmyelinated extensions that branch near the perikaryon.
- The neuron receives stimuli via dendrites.
- The number of dendrites and their degree of branching are determined by the type of neuron.
- Dendrites are widest at their base on the perikaryon, and gradually narrow with each branching.
- They are sprinkled with dendritic spines.



Axon

- The **axon** is the longest extension of the neuron (up to 1m in length).
- The beginning of the axon is called **axon hillock** (it does not contain Nissl's substance or the Golgi apparatus).
- It has a uniform thickness along its entire length.
- The cytoplasm of the axon is called **axoplasm**, and the plasmalemma is called **axolemma**.
- Mitochondria, microtubules, microfilaments and rare sER tubules are found in the axoplasm.



Bidirectional transport of molecules large and small occurs within axons.

- **Anterograde transport** moves organelles and macromolecules synthesized in the cell body along axonal microtubules via **kinesin** to the synaptic terminals.
- **Retrograde transport** in the opposite direction along microtubules via **dynein** carries certain other macromolecules, such as material taken up by endocytosis (including viruses and toxins), from the periphery to the cell body.

Structural classes of neurons

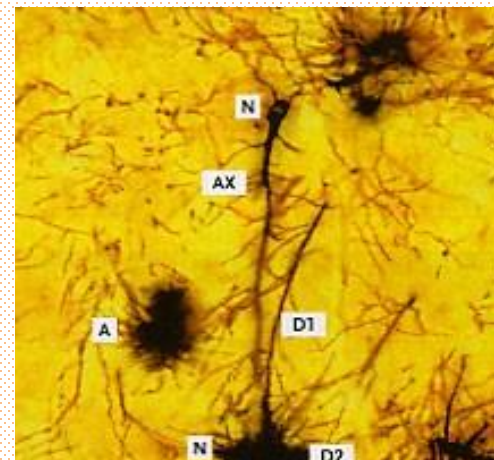
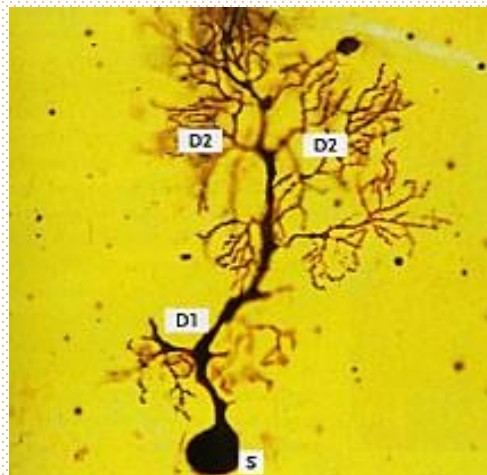
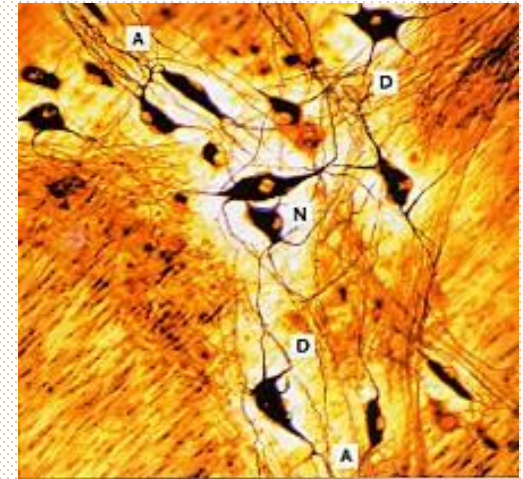
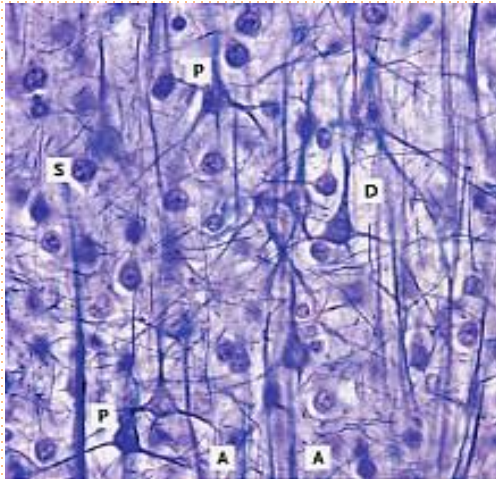
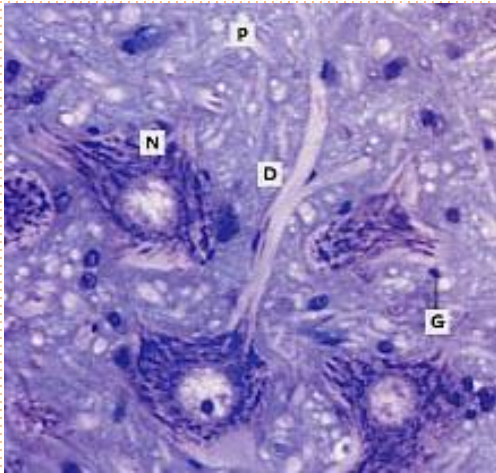
Neurons can be classified in different ways:

- according to the shape of the perikaryon
 - according to function
- according to the length of the axon or
- according to the number of processes

According to the **shape of the perikaryon**, neurons are divided into

- spherical
 - oval
- pyramidal
 - stellate
 - fusiform
 - granular
- basket-shaped
- pear-shaped etc.

According to the shape of the perikaryon



According to function

According to function, neurons are divided into:

➤ sensory (afferent)

- They detect different stimuli and transmit the stimulus to the centers in the CNS.

➤ motor (efferent)

- They transmit information from the CNS to effector (muscle, glandular) cells.

➤ Interneurons

- They connect sensory and motor neurons in a unique network.

Percentage-wise, the largest part of nerve cells belongs to interneurons.

According to the length of the axon

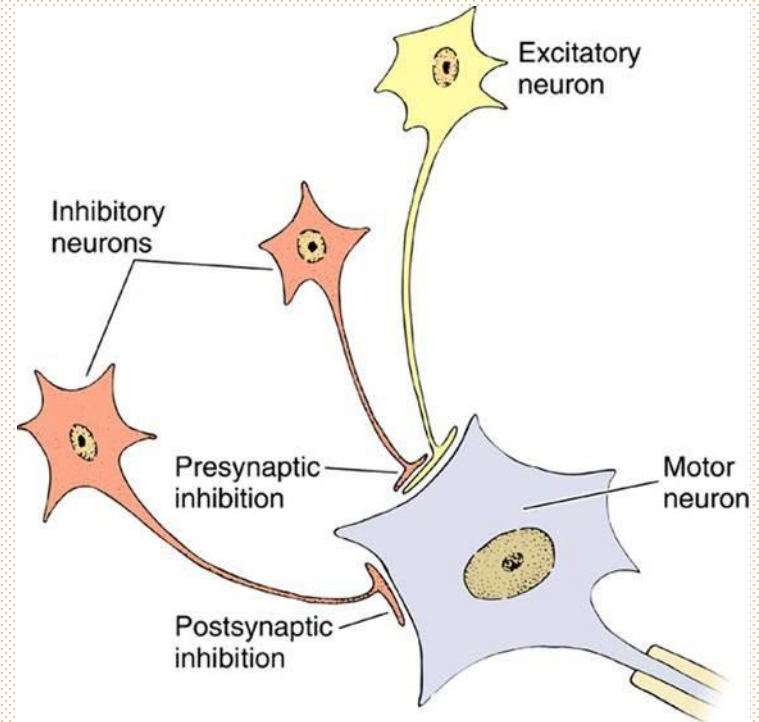
According to the length of the axon, neurons are divided into:

➤ Golgi type I

- (Main neurons, long axon) They enter the composition of tracts in the brain or spinal cord or enter the composition of spinal and cerebral nerves.

➤ Golgi type II

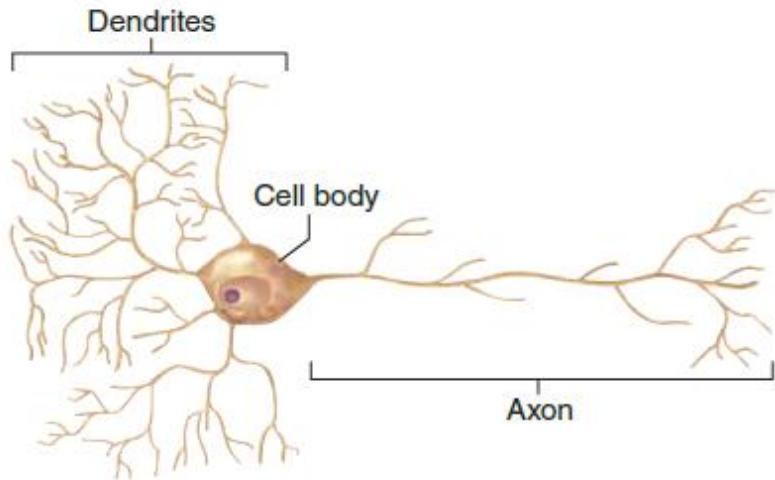
- (Interneurons, short axon) They have a small body and a short axon which ends not far from the perikaryon.



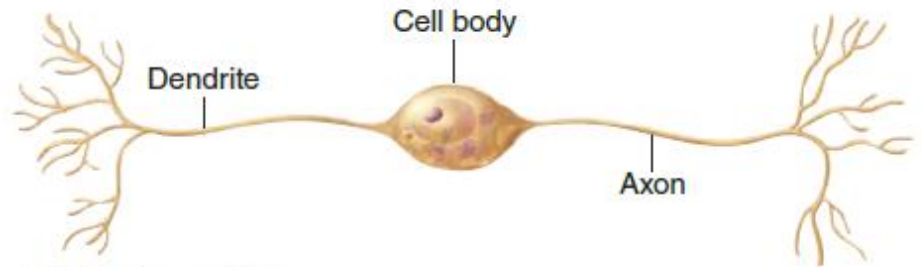
According to the number of processes

- **Multipolar neurons**, each with one axon and two or more dendrites, are the most common.
- **Bipolar neurons**, with one dendrite and one axon, comprise the sensory neurons of the retina, the olfactory epithelium, and the inner ear.
- **Unipolar or pseudounipolar neurons**, each have a single process that bifurcates close to the perikaryon, with the longer branch extending to a peripheral ending and the other toward the CNS.
- **Anaxonic neurons**, with many dendrites but no true axon, do not produce action potentials, but regulate electrical changes of adjacent CNS neurons

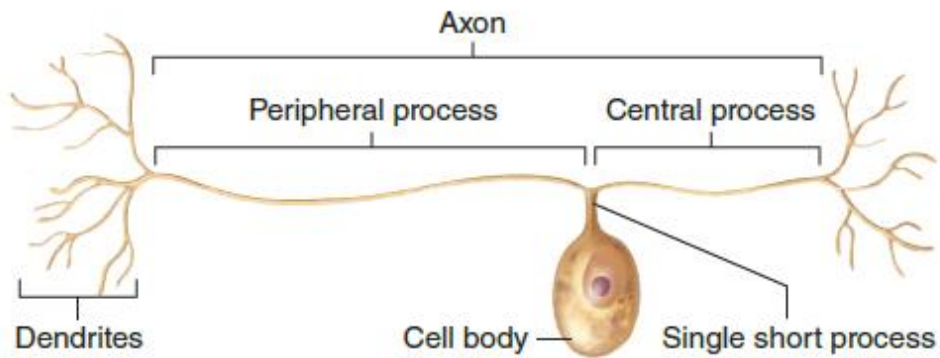
According to the number of processes



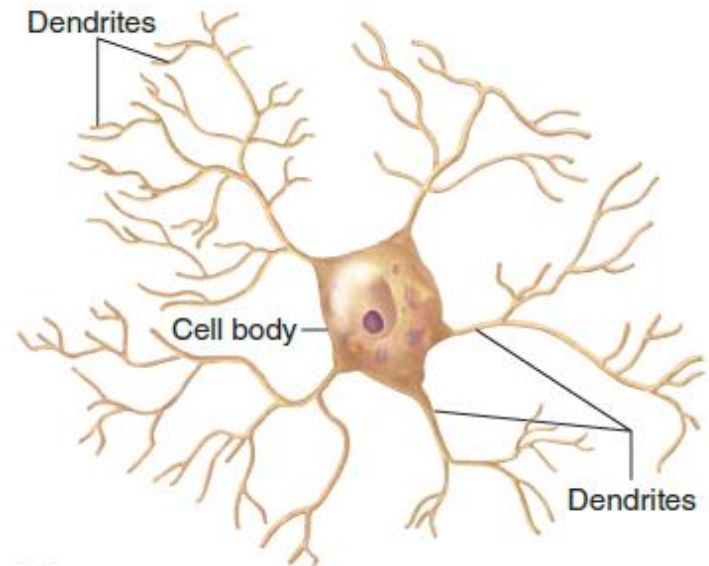
(a) Multipolar neuron



(b) Bipolar neuron



(c) Unipolar neuron



(d) Anaxonic neuron

Glial cells

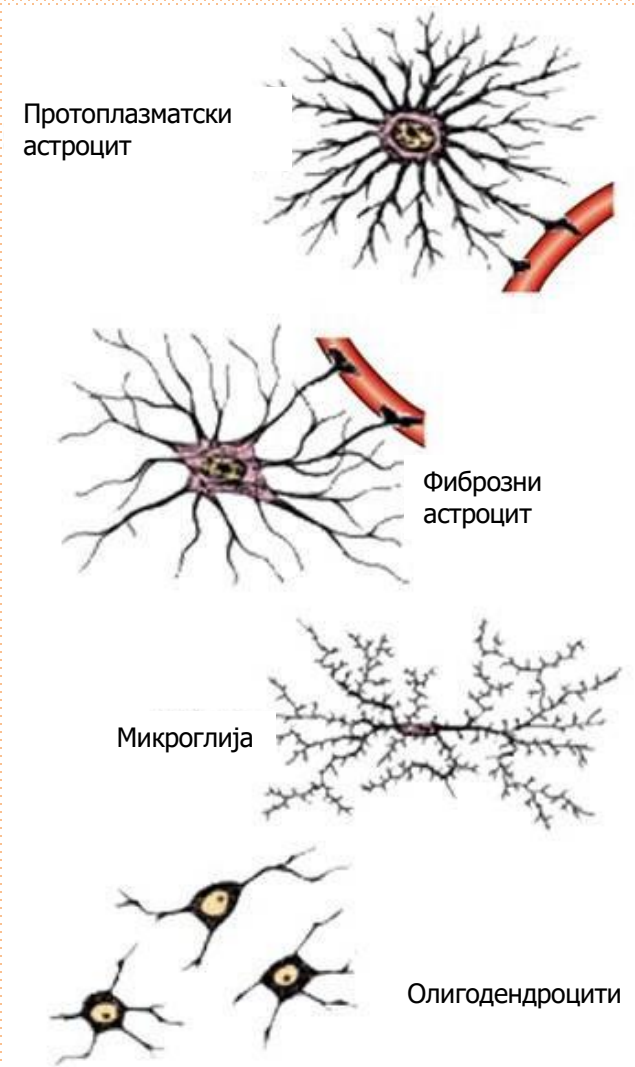
Glial cells support neuronal survival and activities, and are 10 times more abundant than neurons in the mammalian brain.

Peripheral glial cells

- Schwann cells
- satellite cells

Central glial cells

- astrocytes
 - fibrous (white matter)
 - protoplasmic (gray matter)
- oligodendocytes
- ependymocytes
- microglia



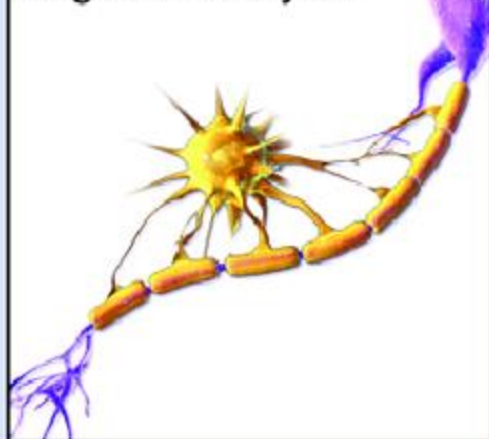
Types of Neuroglia

Central Nervous System

Ependymal cells



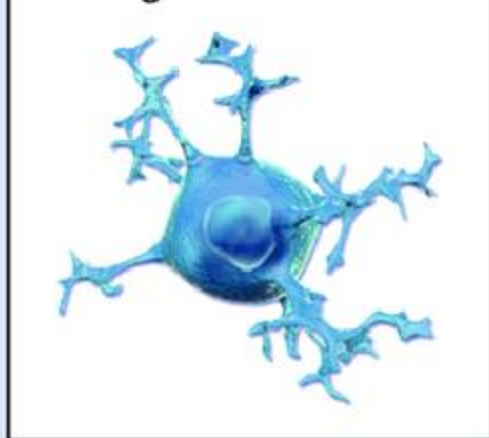
Oligodendrocytes



Astrocytes

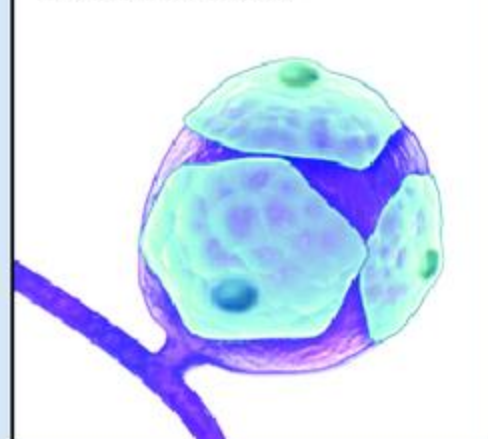


Microglia

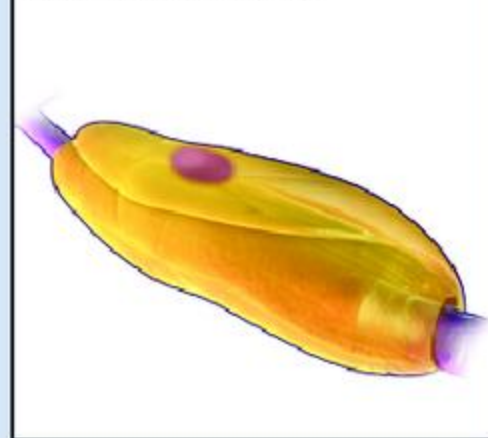


Peripheral Nervous System

Satellite cells



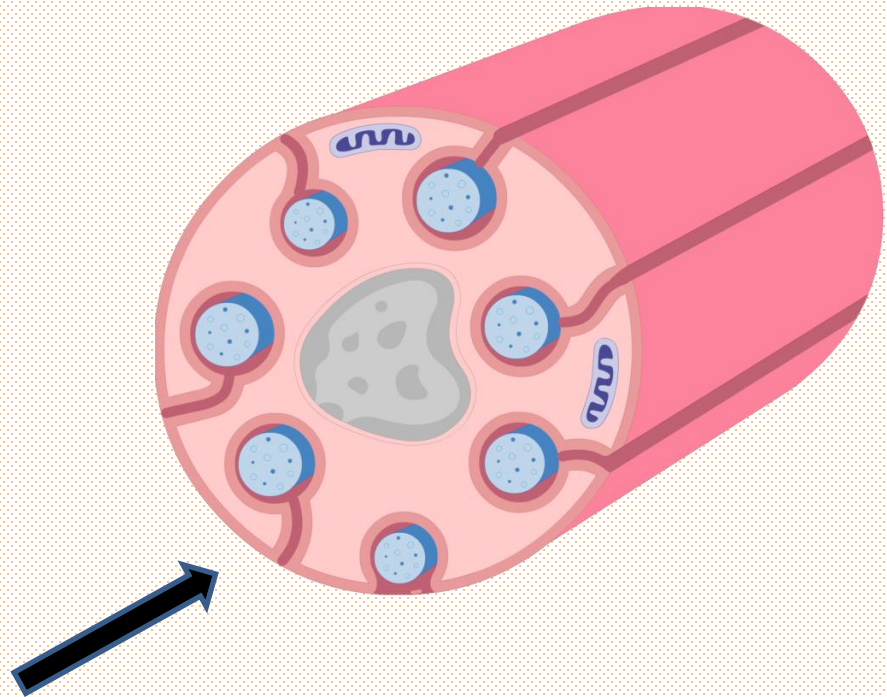
Schwann cells



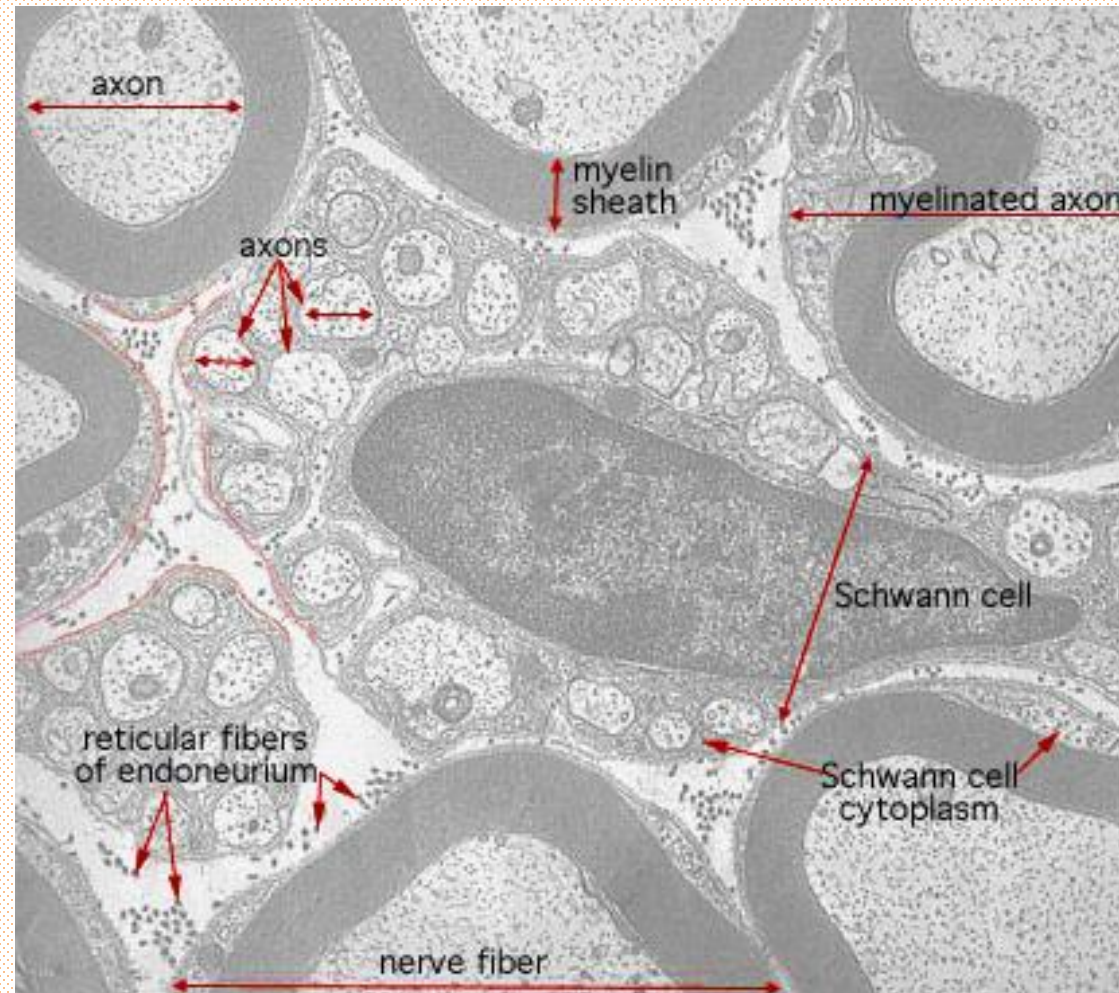
Schwann cells

- Trophic interactions with axons and most importantly forming their **myelin sheathes** that electrically insulates the axon and facilitates rapid transmission of nerve impulses.
- Axon can be **unmyelinated and myelinated**

Several unmyelinated axons are enveloped by one Schwann cell

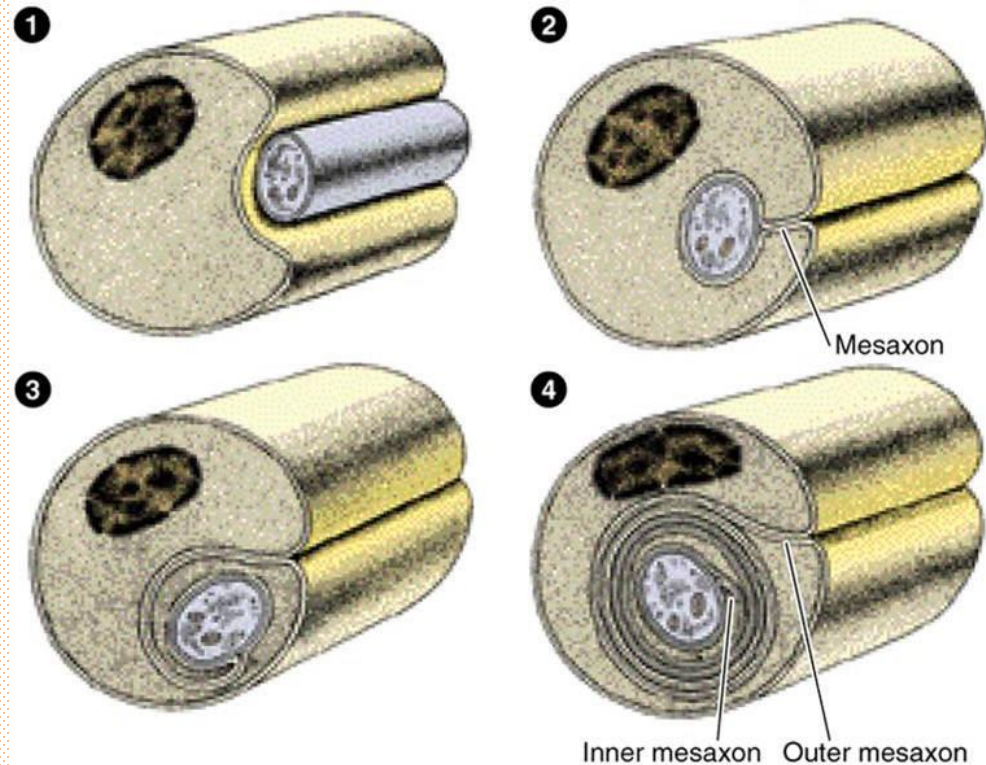


- They are then placed in tubular recesses (grooves) of which there can be up to 20 in one Schwann cell
- One or more axons can be found in each groove, and sometimes an entire axon bundle.

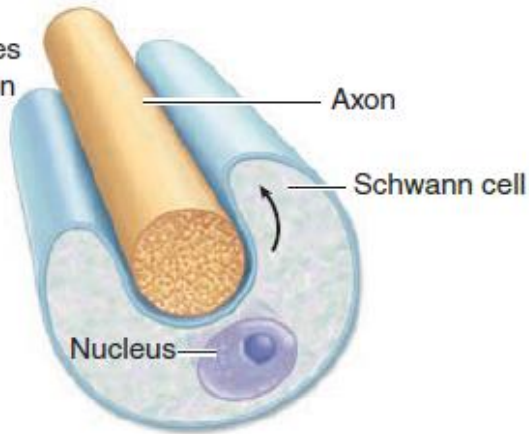


Myelinated axons PNS

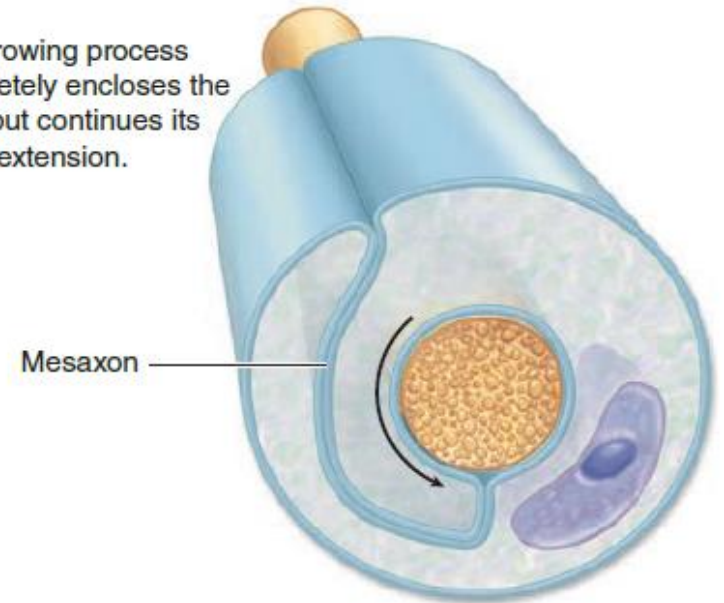
- Multiple layers of Schwann cell membrane unite as a thick myelin sheath composed mainly of lipid bilayers and membrane proteins.
- Plasma membrane of each covering Schwann cell fuses with itself at an area termed the [mesaxon](#).



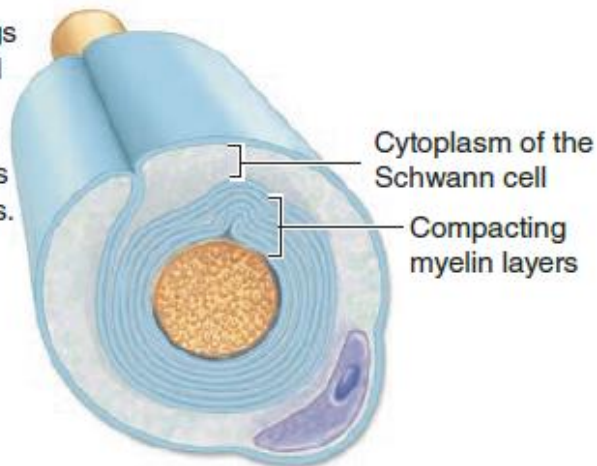
- ① Schwann cell becomes aligned along the axon and extends a wide cytoplasmic process to encircle it.



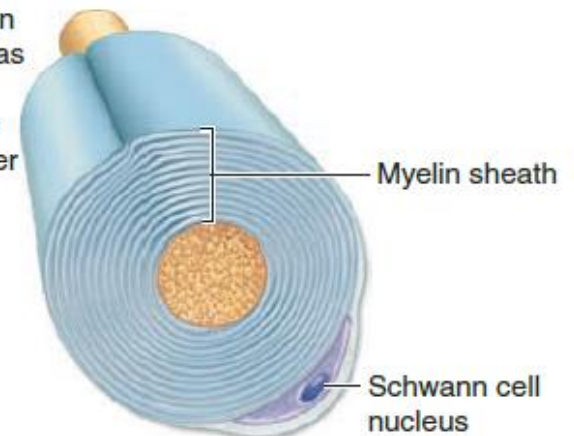
- ② The growing process completely encloses the axon but continues its spiral extension.



- ③ The spiral wrappings become compacted layers of cell membrane (myelin) as cytoplasm leaves the growing process.



- ④ The mature Schwann cell myelin sheath has up to 100 lamellae, with most cytoplasm in the outermost layer with the cell body.

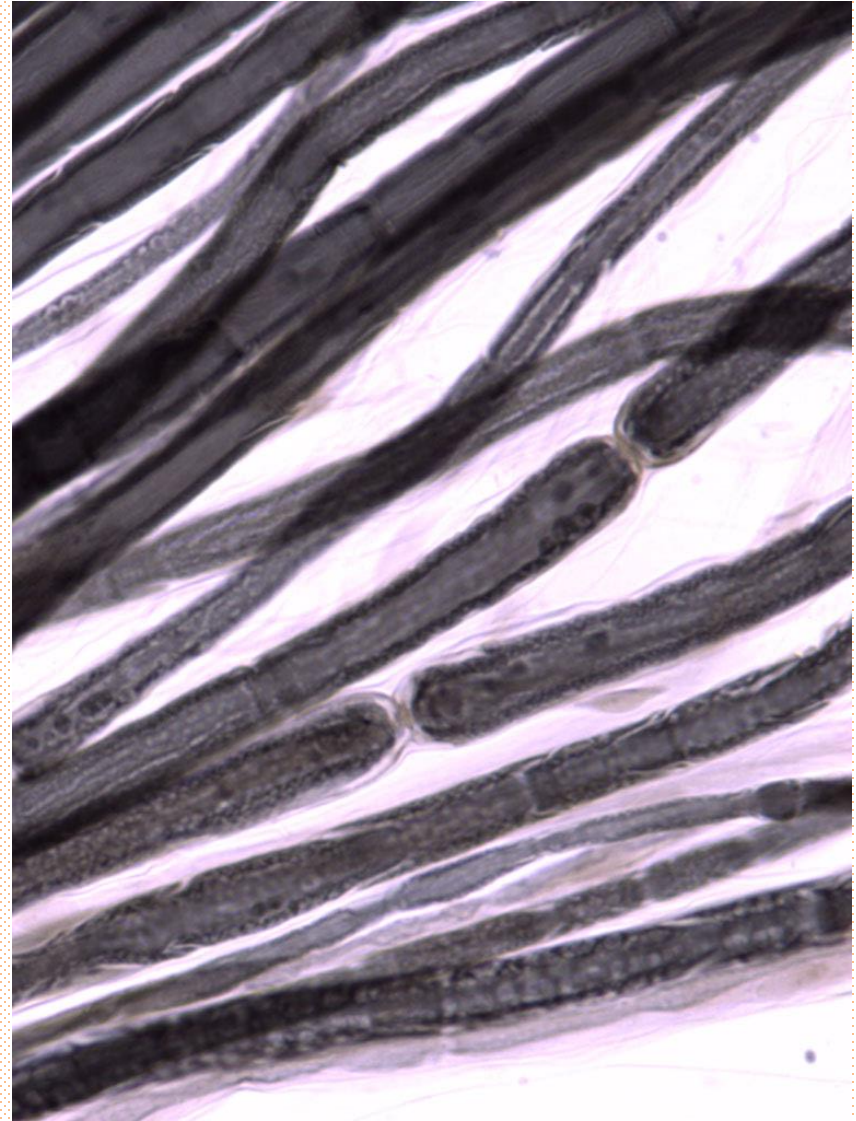


- Myelination covers the entire axon except for its initial segment and terminal branches that form synapses.
- The myelin sheath is interrupted at the points where two adjacent Schwann cells meet - **nodes of Ranvier**.
- The segment of myelin between two nodes of Ranvier is called an **internodal segment** (corresponds to one Schwann cell).



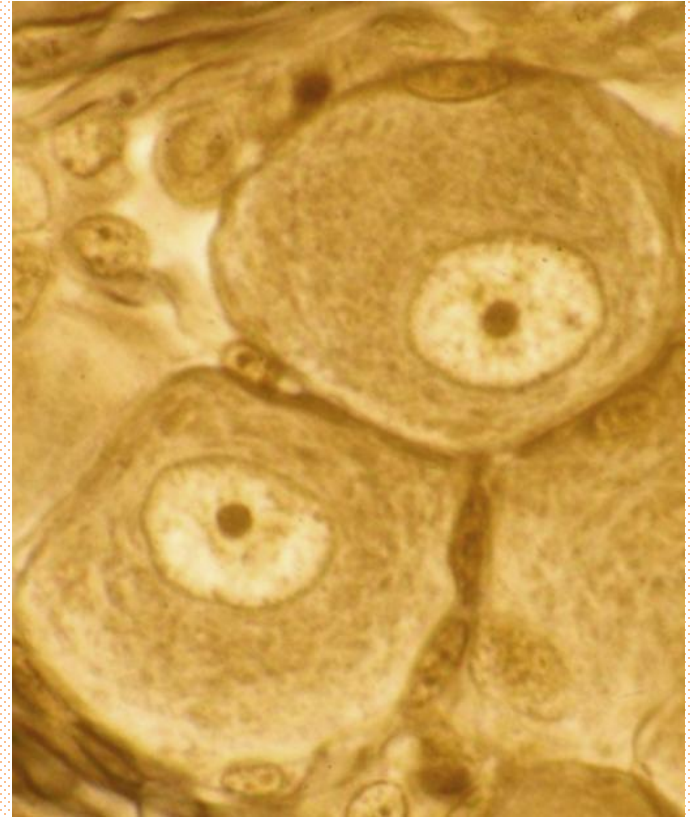


- There are voltage-dependent Na^+ channels in the nodes, so depolarization occurs only in those places.
- This is why the action potential "jumps" from node to node - saltatory conduction and faster conduction of impulses up to 50 times compared to a non-myelinated axon.



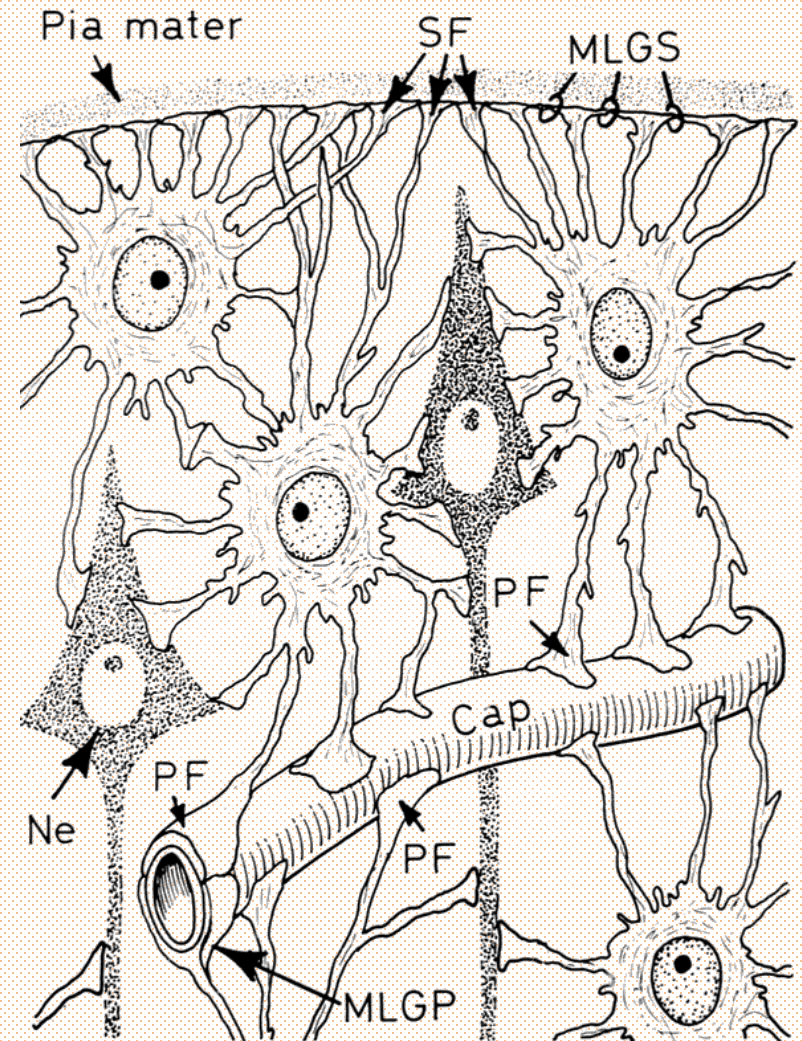
Satelite cells

- Satellite cells form a thin glial layer around each large neuronal cell body in the ganglia of the PNS..
- They are flattened in shape, with poorly developed organelles.
- They are separated from the surrounding tissue basal lamina.

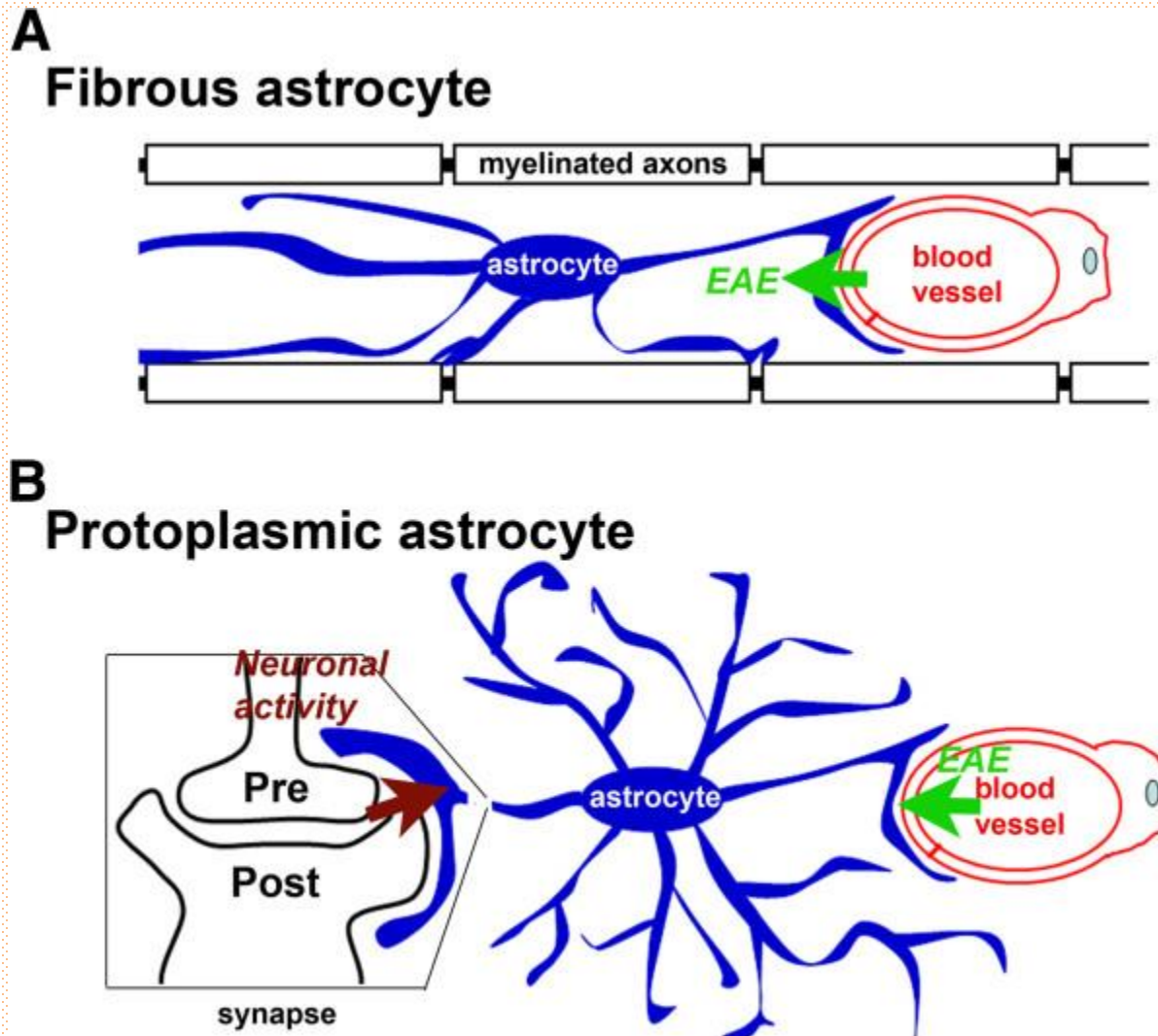


Astrocytes

- **Astrocytes** (Gr. astro-, star + kytos) have a large number of long radiating, branching processes
- Extending fibrous processes with expanded **perivascular feet** that cover capillary endothelial cells and modulate blood flow and help move nutrients, wastes, and other metabolites between neurons and capillaries
- Forming a barrier layer of expanded protoplasmic processes, called the **glial limiting membrane**, which lines the meninges at the external CNS surface



- **Fibrous astrocytes**, with long delicate processes, are abundant in white matter;
- **Protoplasmic astrocytes**, those with many shorter processes and predominate in the gray matter.



Oligodendrocyte

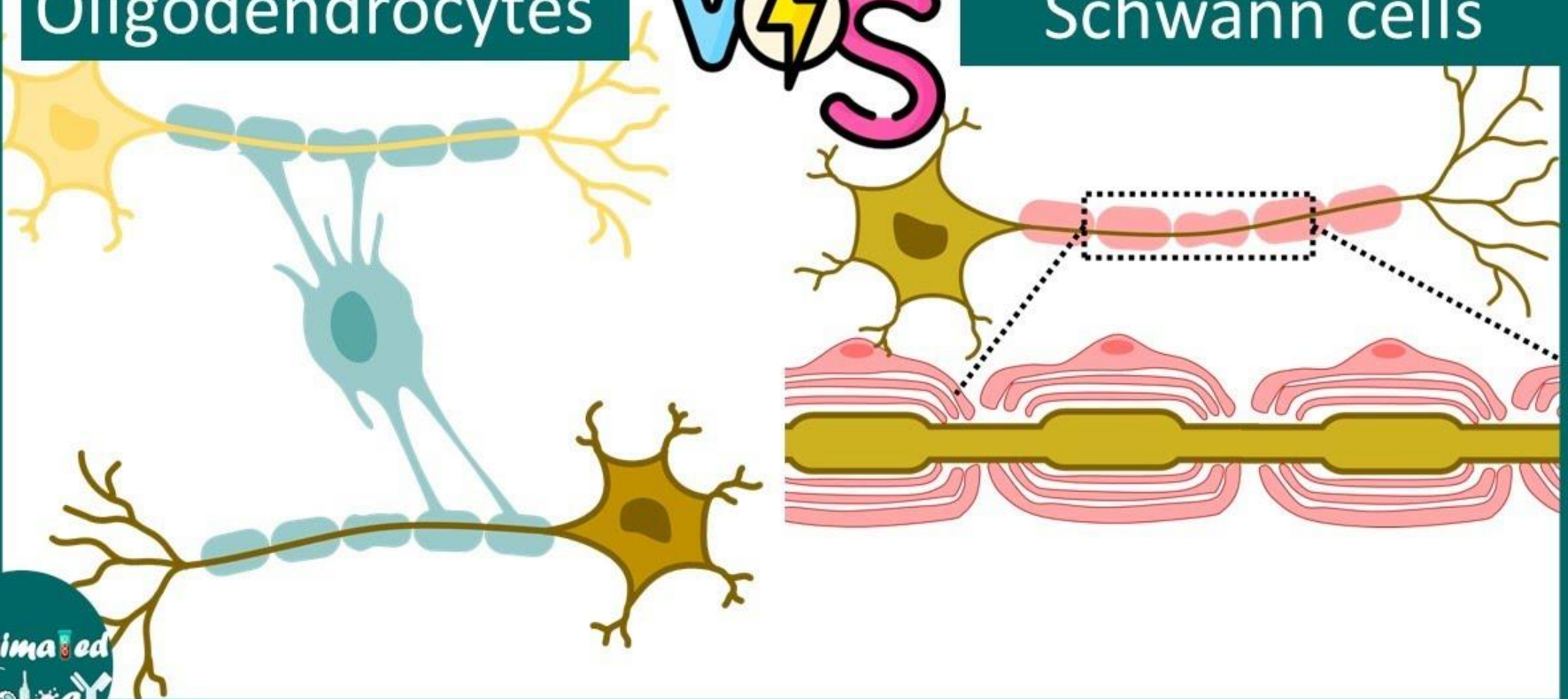
- **Oligodendrocytes** extend many processes, that wraps repeatedly around a portion of a nearby CNS axon
- Provide support and insulation to axons within the central nervous system (CNS)
- Smaller than astrocytes
- Form multiple compacted layers of cell membrane termed **myelin**.
- Single oligodendrocyte can extend its processes to cover around 50 axons.



Oligodendrocytes

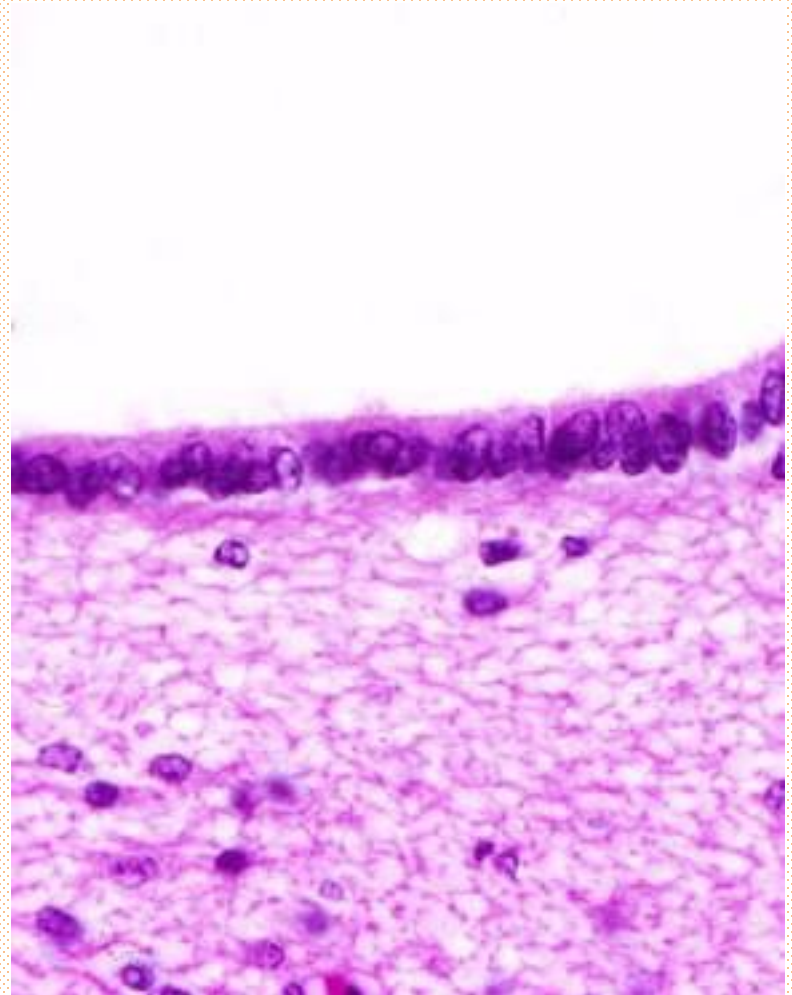


Schwann cells



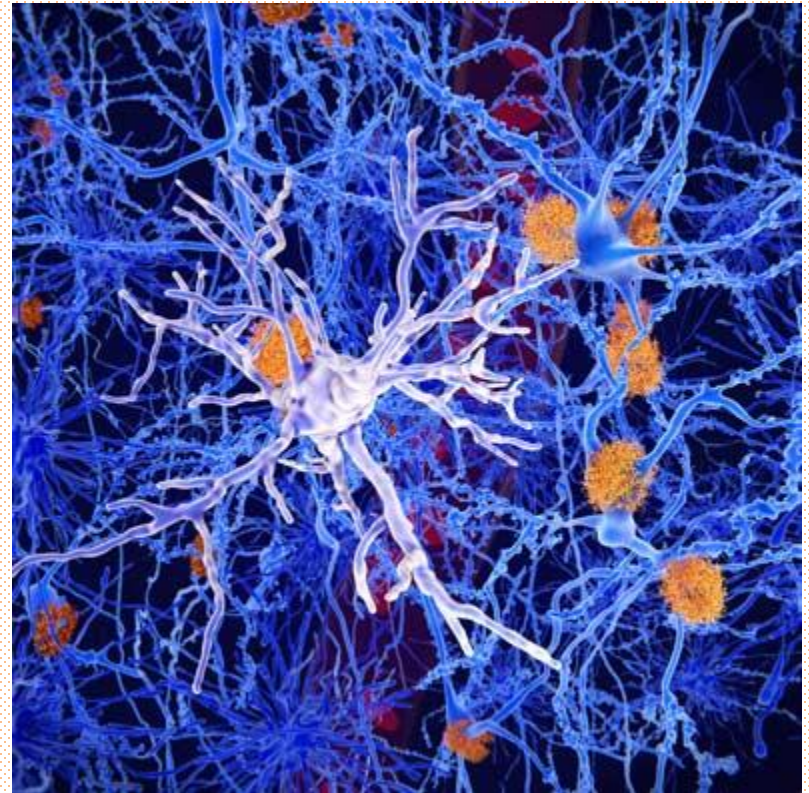
Ependymal cells

- Ependymal cells line the ventricles and canals of the brain and the central canal of the spinal cord.
- Arranged in one layer, they are cuboid or cylindrical .
- They resemble epithelium, but do not have a basal lamina.
- On the apical surface they have microvilli, on the lateral sections they have nexuses and desmosomes.
- Modified ependymal cells of the choroid plexus possess occlusive junctions and produce cerebrospinal fluid.



Microglia

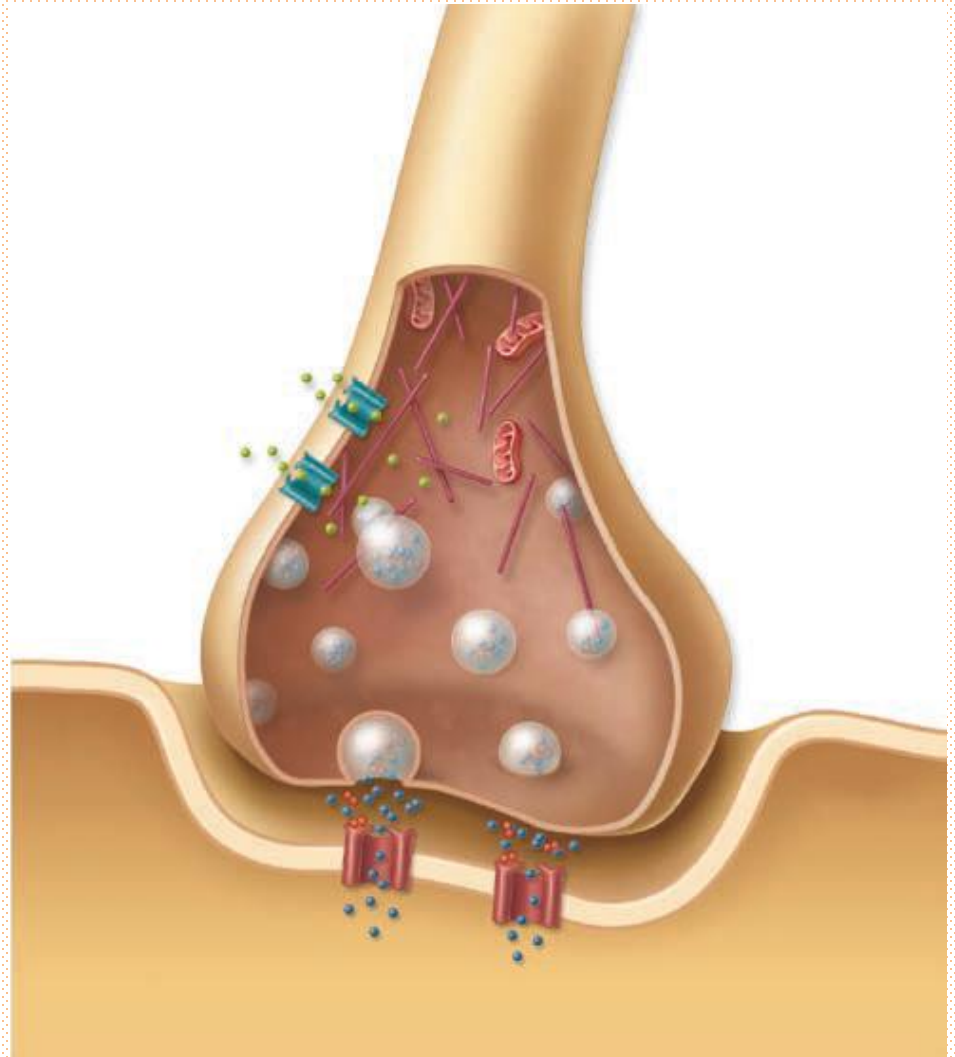
- Microglia are small cells with actively mobile processes evenly distributed throughout gray and white matter.
- As the **resident macrophage** cells, they act as the first and main form of active immune defense in the central nervous system
- Have scant cytoplasm and a large number of extensions.



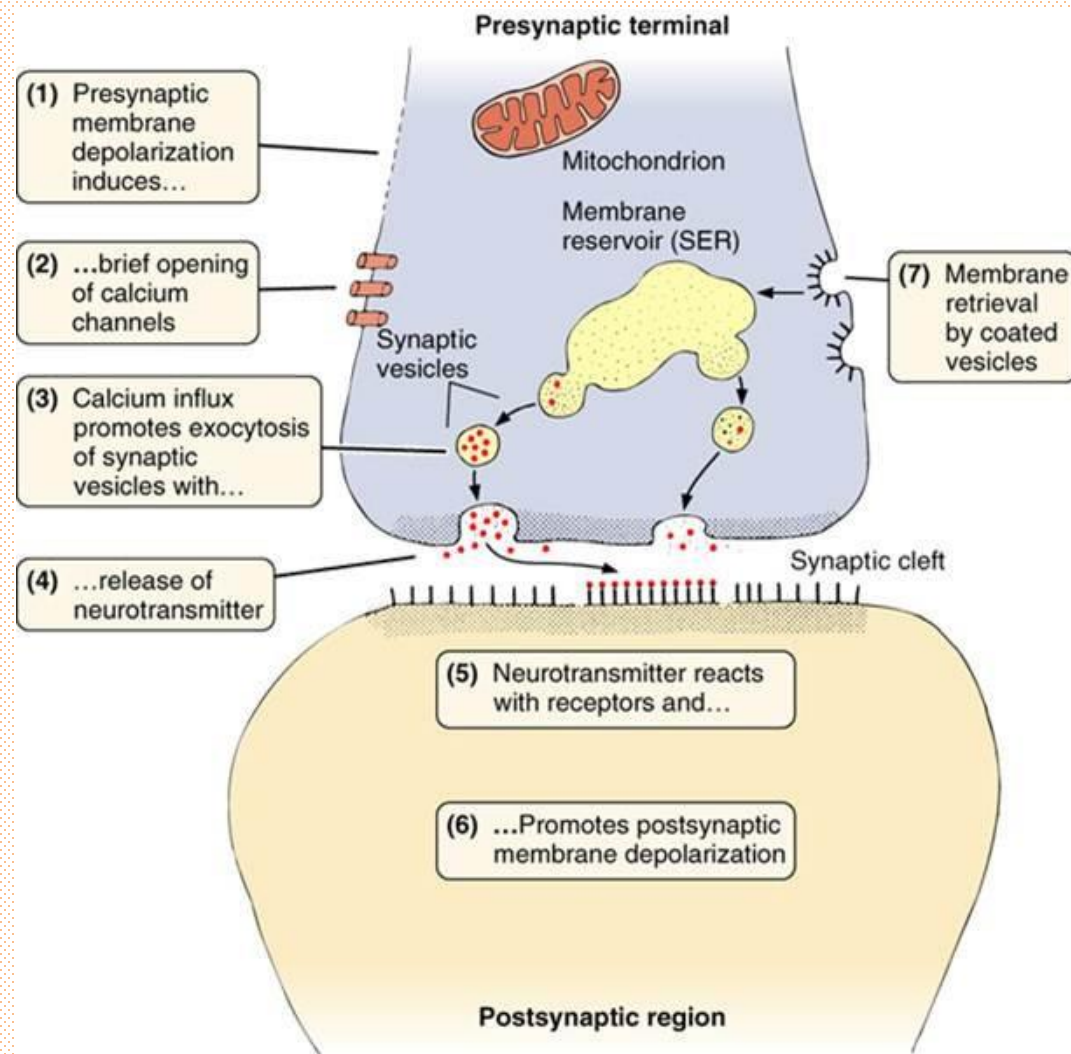
Synapse

- **Synapses** are specialized intercellular junctions through which nerve impulses are transmitted from one cell to another.
- The cell that transmits the information (presynaptic cell) is always a neuron.
- The cell that receives the signal (postsynaptic cell) can be a **neuron, gland or muscle cell**.
- Depending on the mechanism of signal transmission, synapses are divided into **electrical and chemical**.
- **Electrical synapses** are present in invertebrates, while in mammals they are found only in some parts of the brain stem, in the cerebral cortex and in the retina.
- This type of synapse does not require the presence of neurotransmitters.

- Chemical synapses, communication between cells is achieved by **chemical mediators** - **neurotransmitters**.
- Through chemical synapses, neurons establish functional connections with other neurons (interneuronal synapses), glandular cells (neuroglandular synapses) or with myocytes (neuromuscular synapses).

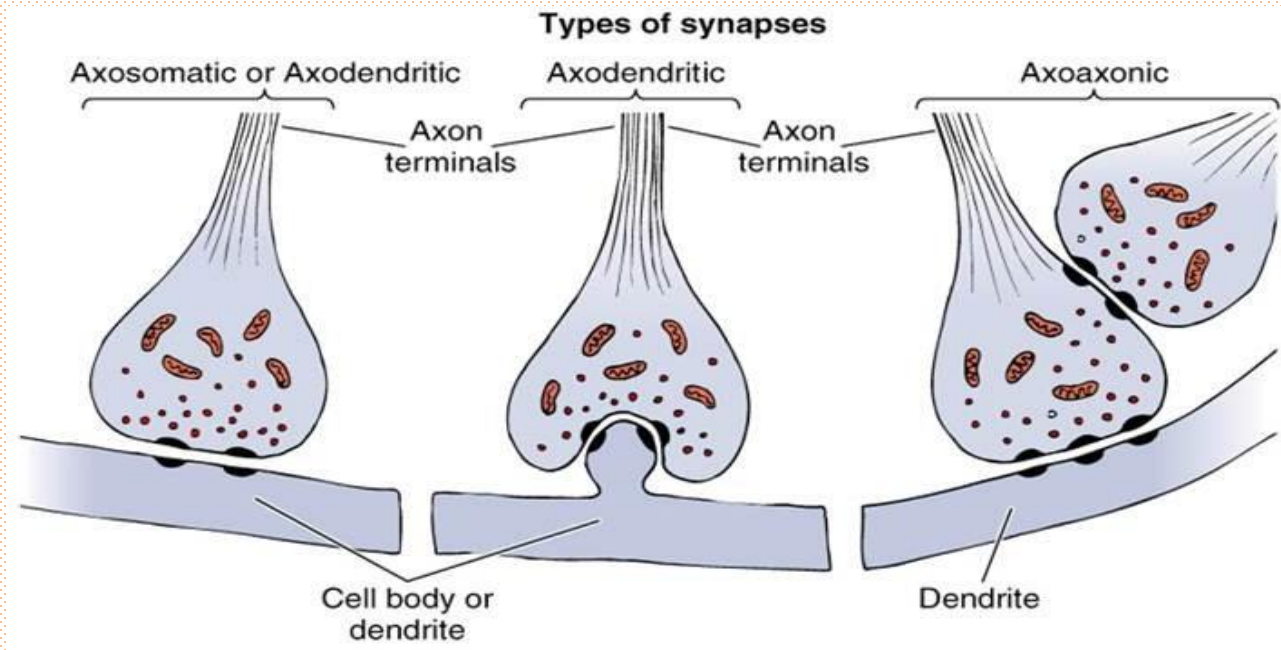


- **Presynaptic axon terminal**
(terminal bouton) contains mitochondria and numerous synaptic vesicles from which neurotransmitter is released by exocytosis.
- **Postsynaptic cell membrane**
contains receptors for the neurotransmitter, and ion channels or other mechanisms to initiate a new impulse.
- A 20- to 30-nm-wide intercellular space called the **synaptic cleft** separates these presynaptic and postsynaptic membranes



Neurotransmitters

- The chemical transmitter common at neuromuscular junctions is **acetylcholine**.
- Certain amino acids (often modified), such as glutamate and γ -aminobutyrate (**GABA**)
- Monoamines, such as serotonin (5-hydroxytryptamine or 5-HT) and **catecholamines**, such as dopamine, all of which are synthesized from amino acids
- Small polypeptides, such as endorphins and substance P



Synapse (TEM)

