Lecture 17

BT 636
Tissue Engineering and Regenerative Medicine
(3-0-0-6)

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Tissue

- The body contains at least 200-220 distinct cell types. These cells contain essentially the same internal structures, yet they vary enormously in shape and function.

- The different types of cells are not randomly distributed throughout the body; rather, they occur in organized layers, a level of organization referred to as tissue.

- The term tissue is used to describe a group of cells found together in the body and serves a common function. The cells within a tissue share a common embryonic origin. Microscopic observation reveals that the cells in a tissue share morphological features and are arranged in an orderly pattern that achieves the tissue's functions.

- From the evolutionary perspective, tissues appear in more complex organisms. For example, multicellular protists, ancient eukaryotes, do not have cells organized into tissues.

- Having tissue-level organization increases the efficiency of the body, as different shapes and internal structures are better suited to carry out different functions.

- Having different tissues for different functions allows for a greater speed of activity and greater effectiveness in performing the various activities.

Different types of tissues present in a human body

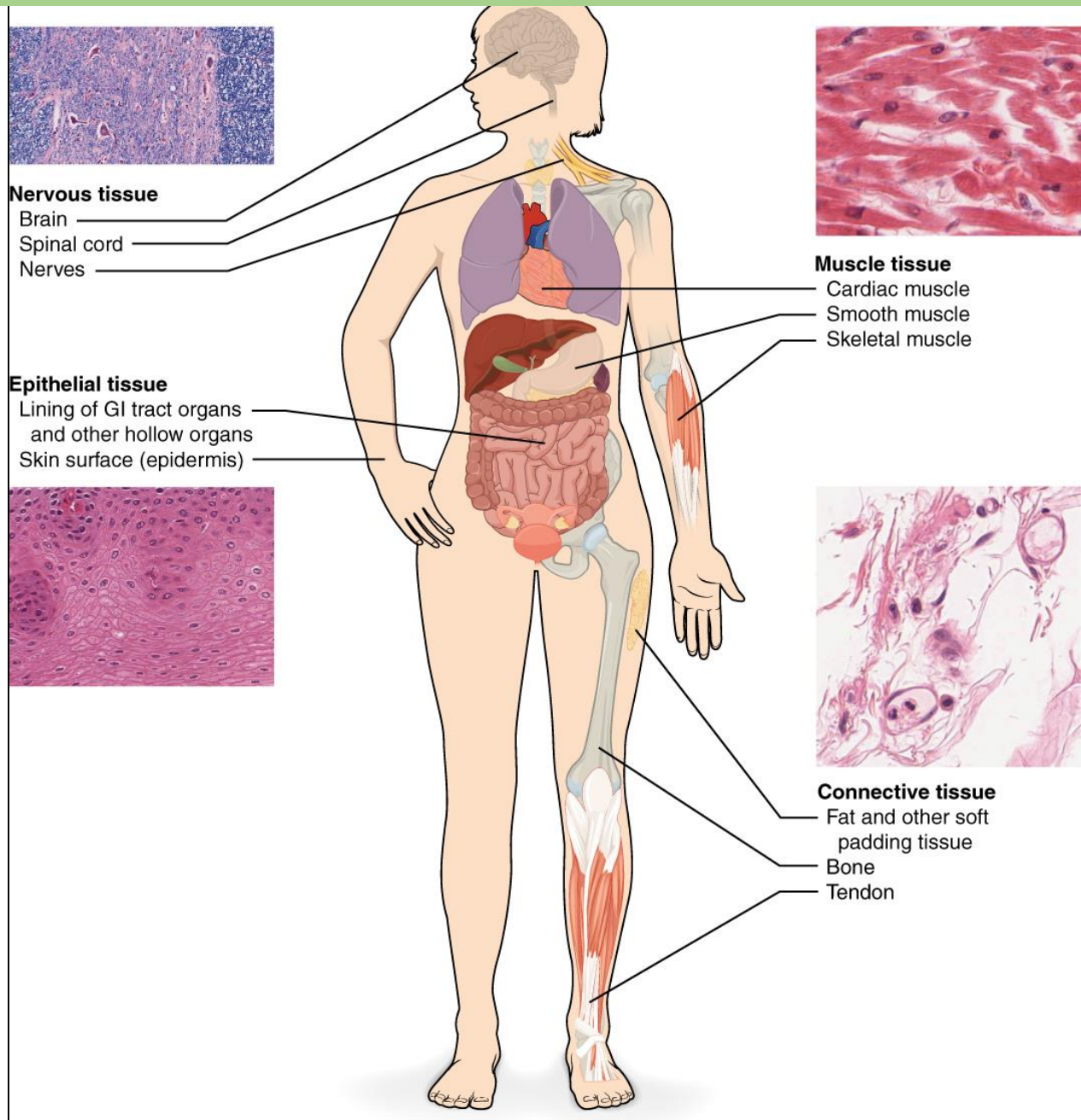
Human body tissue consists of groups of cells with a similar structure working together for a specific function. There are four main types of tissues in a body.

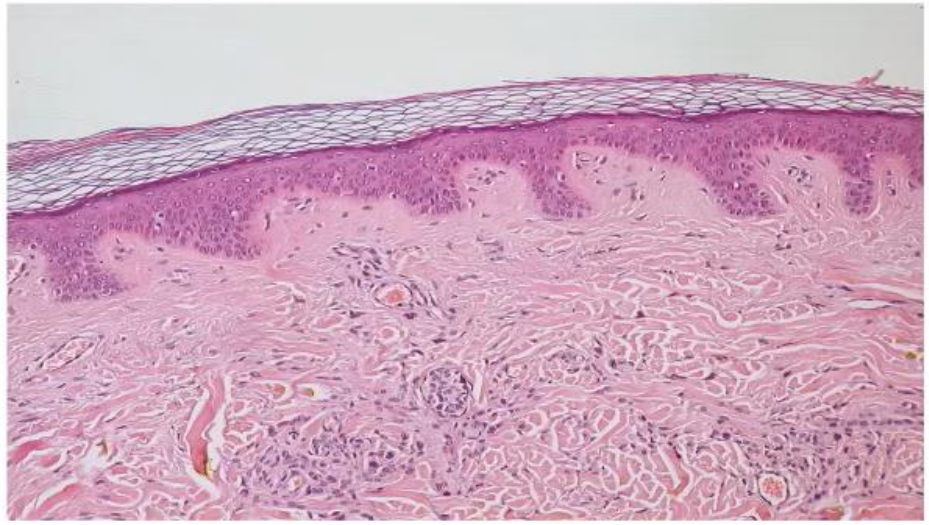
Epithelial tissue (epithelium)
- is made of layers (sheets) of cells that cover the surfaces of the body that come into contact with the exterior world, lines internal cavities and passageways, and form glands.

Connective tissue
- binds the cells and organs of the body together and performs many functions, especially in the protection, support, and integration of the body.

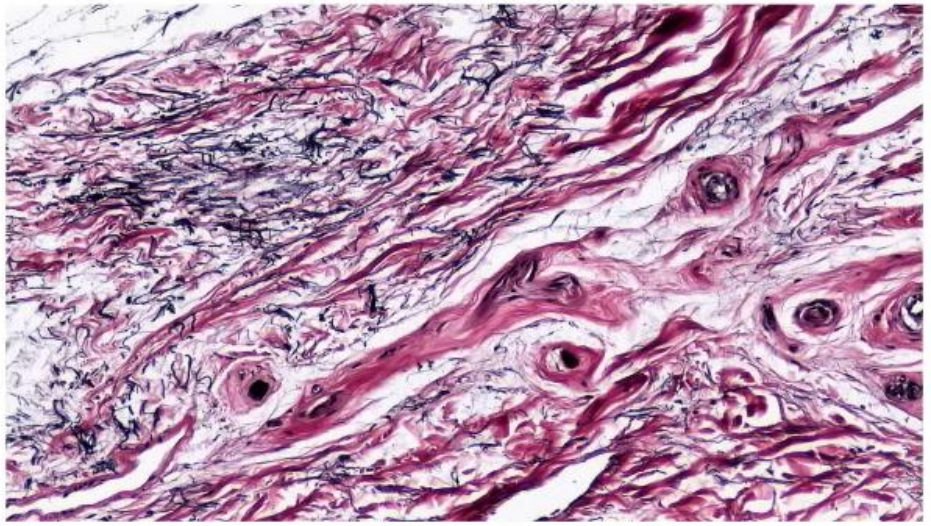
Muscle tissue
- is excitable, responds to stimulation and contracts to provide movement.
- occurs as three major types: skeletal (voluntary) muscles, smooth muscles, and the cardiac muscle in the heart.

Nervous tissue
- is also excitable, allows the body to receive signals and transmit information as electric impulses from one region of the body to another.



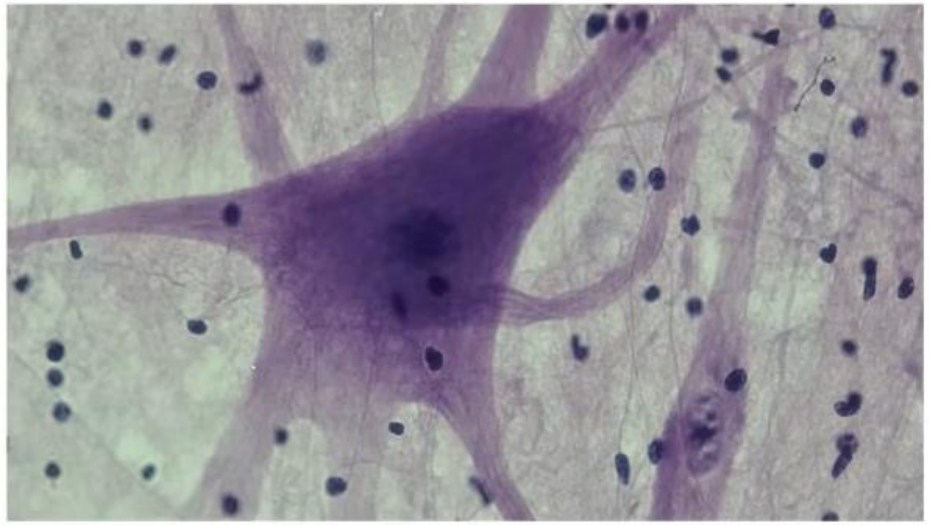


EPITHELIAL TISSUE

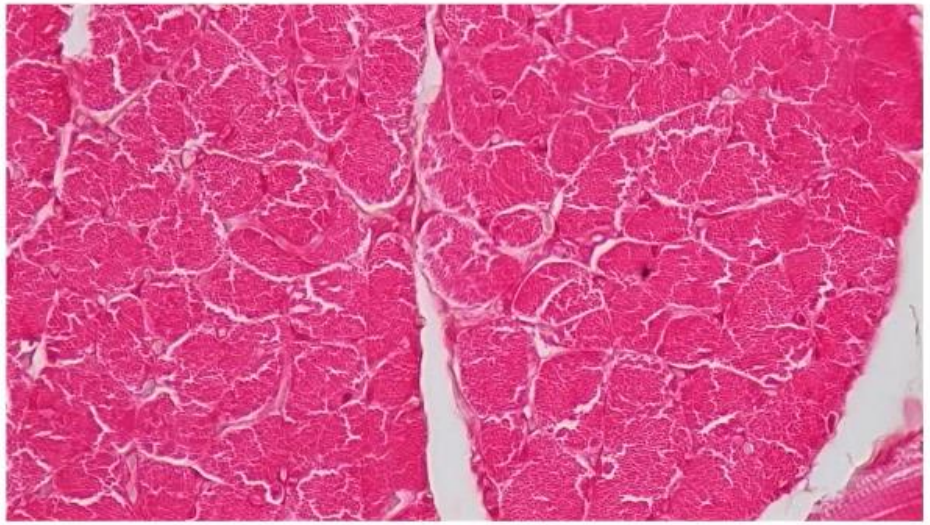


CONNECTIVE TISSUE

NERVOUS TISSUE



MUSCLE TISSUE



Tissue

- Although there are many types of cells in the human body, they are organized into four major categories of tissues: **epithelial, connective, muscle, and nervous**.

- Each of these categories is characterized by specific functions that contribute to the overall health and maintenance of the body.
- A disruption of the structure is a sign of injury or disease. Such changes can be detected through histology, the microscopic study of tissue appearance, organization, and function.

- **Epithelial tissue**, also referred to as epithelium, refers to the sheets of cells that cover exterior surfaces of the body, lines internal cavities and passageways, and forms certain glands.
- **Connective tissue**, as its name implies, binds the cells and organs of the body together and functions in the protection, support, and integration of all parts of the body.
- **Muscle tissue** is excitable, responding to stimulation and contracting to provide movement, and occurs as three major types: skeletal (voluntary) muscle, smooth muscle, and cardiac muscle in the heart.
- **Nervous tissue** is also excitable, allowing the propagation of electrochemical signals in the form of nerve impulses that communicate between different regions of the body.

- The next level of organization is the **organ**, where several types of tissues come together to form a working unit. Just as knowing the structure and function of cells helps you in your study of tissues, knowledge of tissues will help you understand how organs function.

Muscle Tissue

- Muscle tissue comprises all the muscles in the body, and the specialized nature of the tissue is what allows muscles to contract.
- Responds to stimulation from the nervous system causing them to shorten.
- Produce voluntary and involuntary movement.

- Muscle tissue is classified into three types according to structure and function:
  - Skeletal muscle
  - Cardiac muscle
  - Smooth muscle

- **Skeletal muscle** anchors tendons to bones and allows the body to move.
- **Cardiac muscle** is found in the heart and contracts to pump blood.
- **Smooth muscle** is found in the intestines, where it helps move food through the digestive tract, and it is also found in other organs like blood vessels, the uterus, and the bladder.

- Skeletal and cardiac muscles are striated; this means that they contain sarcomeres (a unit of muscle tissue) that are arranged in a uniform pattern. Smooth muscle does not have sarcomeres.

- Duchenne muscular dystrophy is an example of a muscle tissue disorder. It is an inherited disorder that causes muscles to atrophy over time. The muscles shorten as they atrophy, which can cause scoliosis and immobile joints. Individuals with the disorder are usually male because the gene responsible for it is found on the X chromosome (of which males have only one).

Muscle Tissue

Muscle Tissue

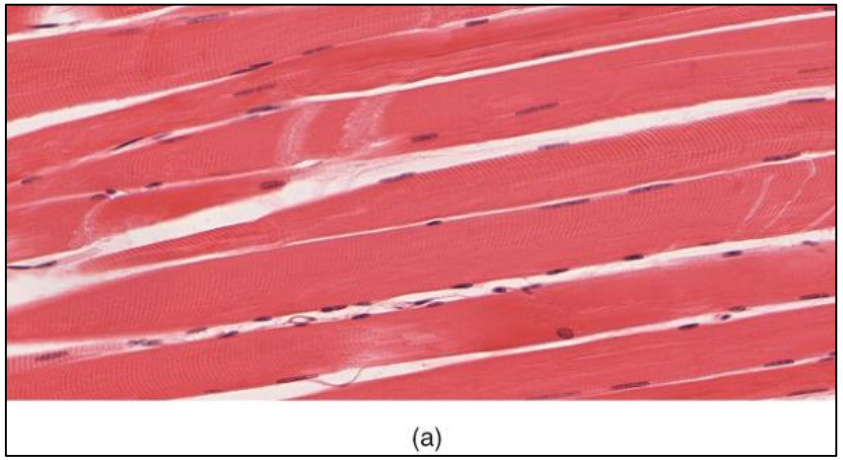
- Muscle tissue is characterized by properties that allow movement.
- Muscle cells are excitable; they respond to a stimulus.
- They are contractile, meaning they can shorten and generate a pulling force.
- When attached between two movable objects, in other words, bones, contractions of the muscles cause the bones to move.
- Some muscle movement is voluntary, which means it is under conscious control.
- For example, a person decides to open a book and read a chapter on anatomy.
- Other movements are involuntary, meaning they are not under conscious control, such as the contraction of your pupil in bright light.

Muscle Tissue

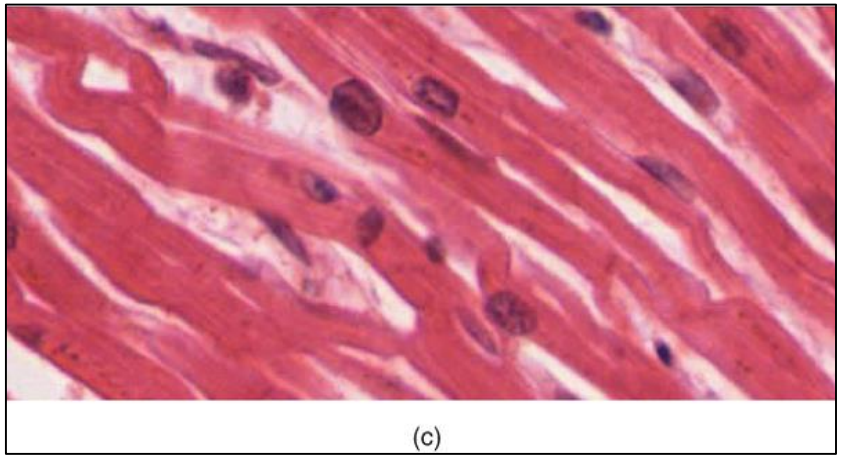
Tissue	Histology	Function	Location
Skeletal	Long cylindrical fiber; striated; many peripherally-located nuclei	Voluntary movement; thermogenesis; organ protection	Attached to bones; found around entrance points to the body (e.g., mouth, anus)
Cardiac	Short, branched fibers; striated; single central nucleus	Contracts to pump blood	Heart walls
Smooth	Short, spindle-shaped fibers; no evident striation; single nucleus	Involuntary movement; moves material through the digestive tract and ducts; regulates blood flow in arteries	Walls of major organs and passageways

Table: Comparison of structure and properties of muscle tissue types

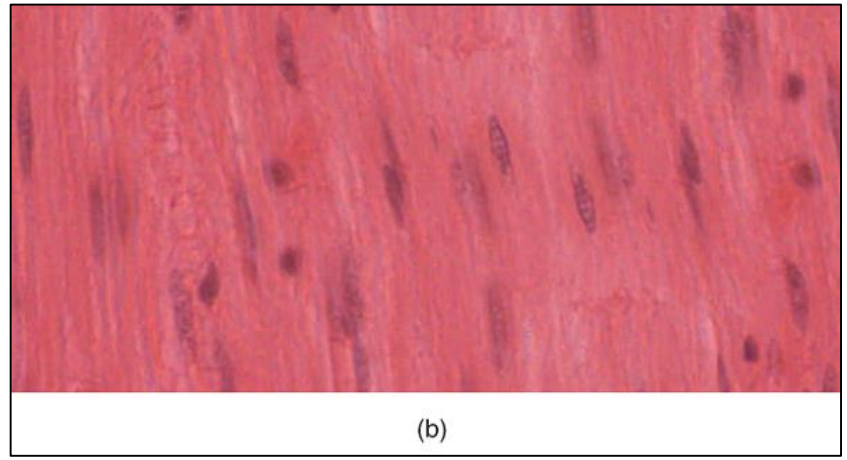
Muscle Tissue



Skeletal muscle
Skeletal muscle cells have prominent striation and nuclei on their periphery

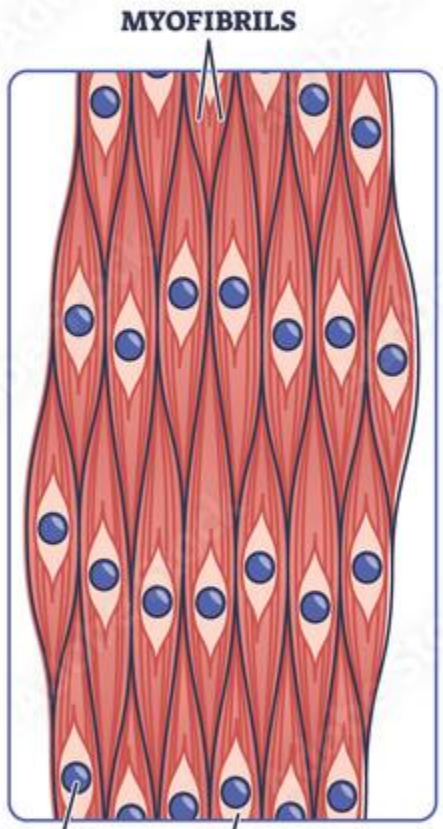


Cardiac muscle
Cardiac muscle cells appear striated and have a single nucleus

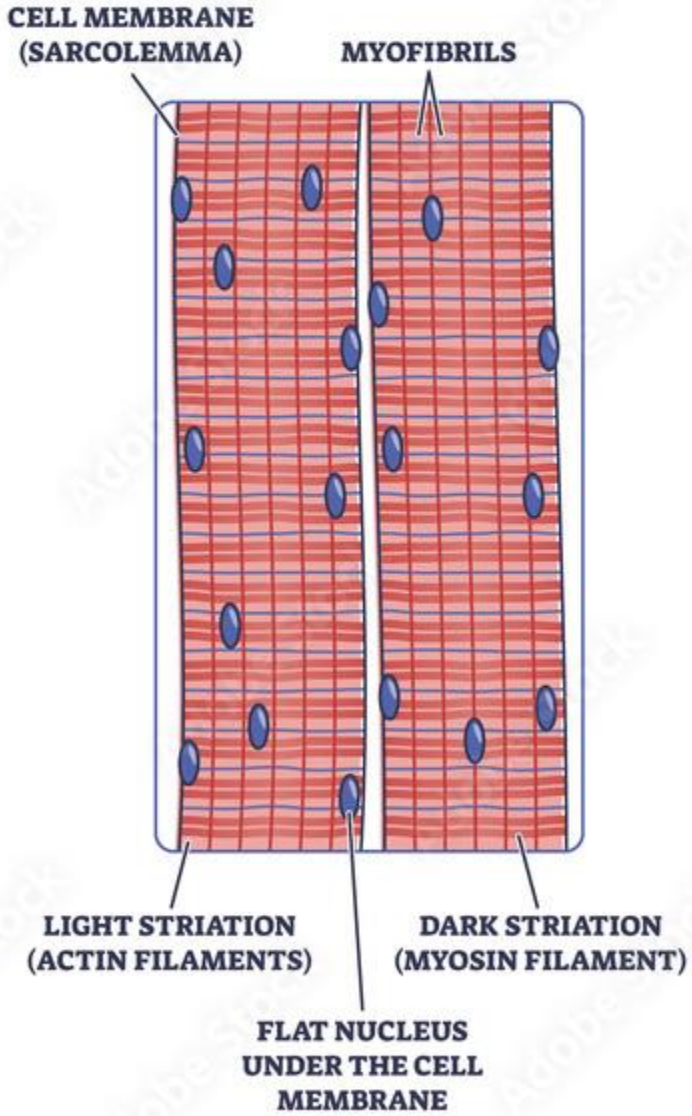


Smooth muscle
Smooth muscle cells have a single nucleus and no visible striations

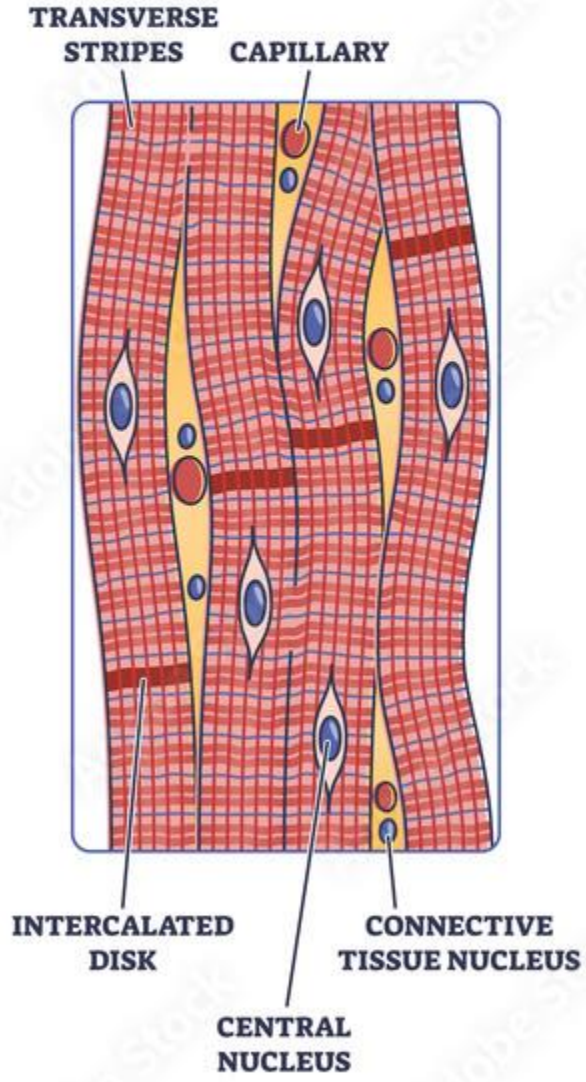
SMOOTH MUSCLE TISSUE



STRIATED (SKELETAL) MUSCLE TISSUE



CARDIAC MUSCLE TISSUE



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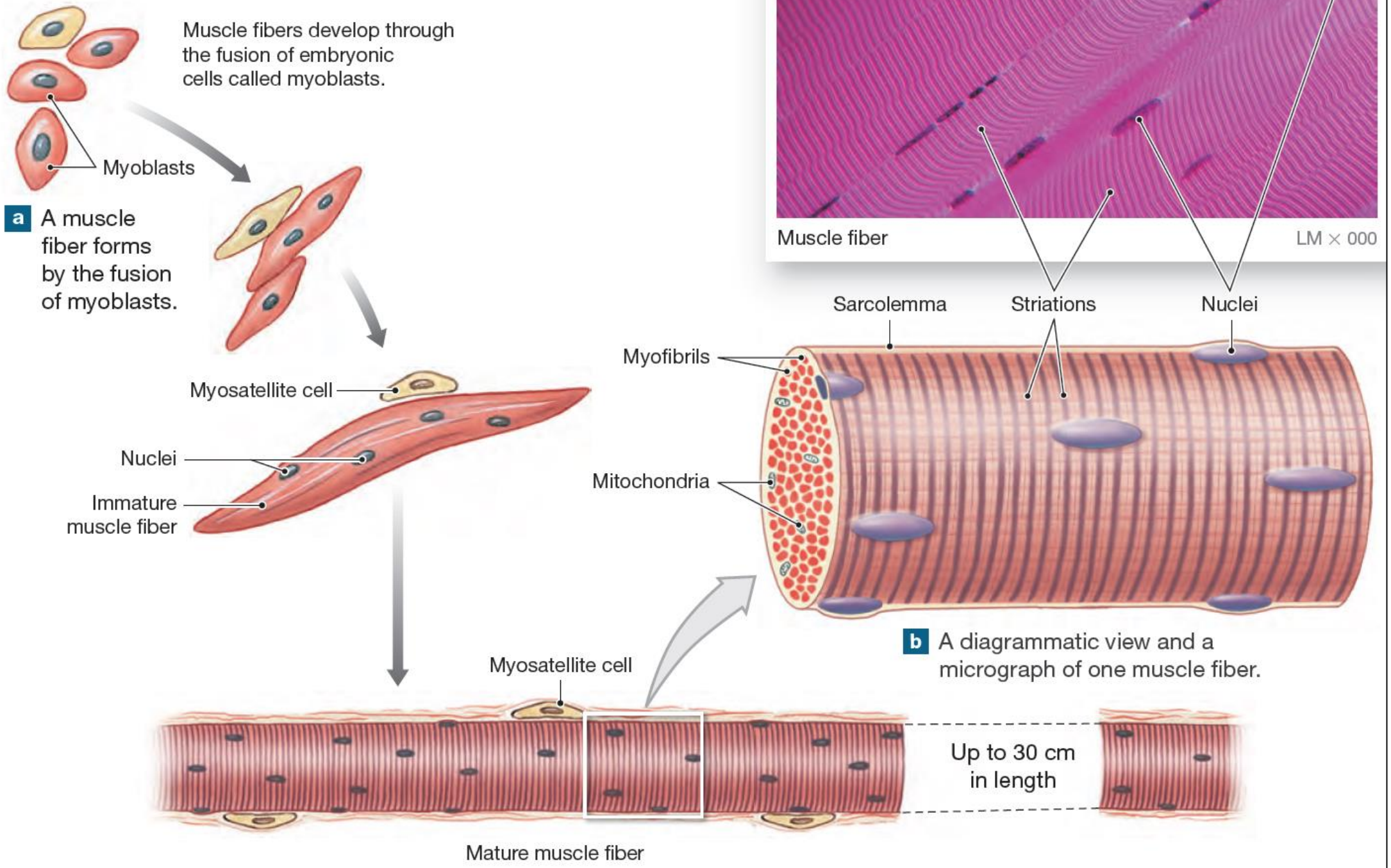
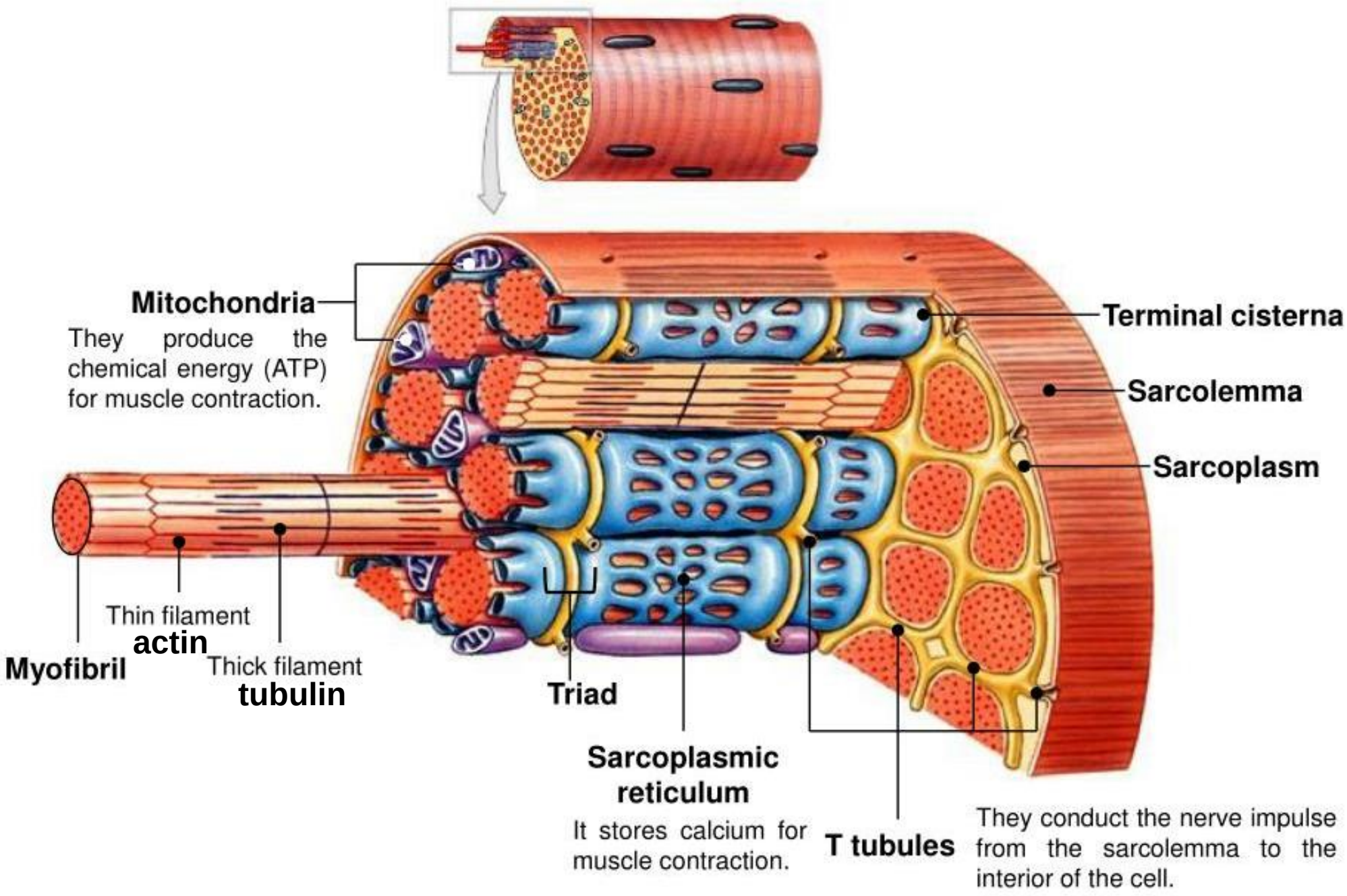
Skeletal Muscle

- Skeletal muscle is attached to bones, and its contraction makes possible locomotion, facial expressions, posture, and other voluntary movements of the body.
- Forty percent of your body mass is made up of skeletal muscle.
- Skeletal muscles generate heat as a byproduct of their contraction and thus participate in thermal homeostasis.
- Shivering is an involuntary contraction of skeletal muscles in response to perceived lower-than-normal body temperature.

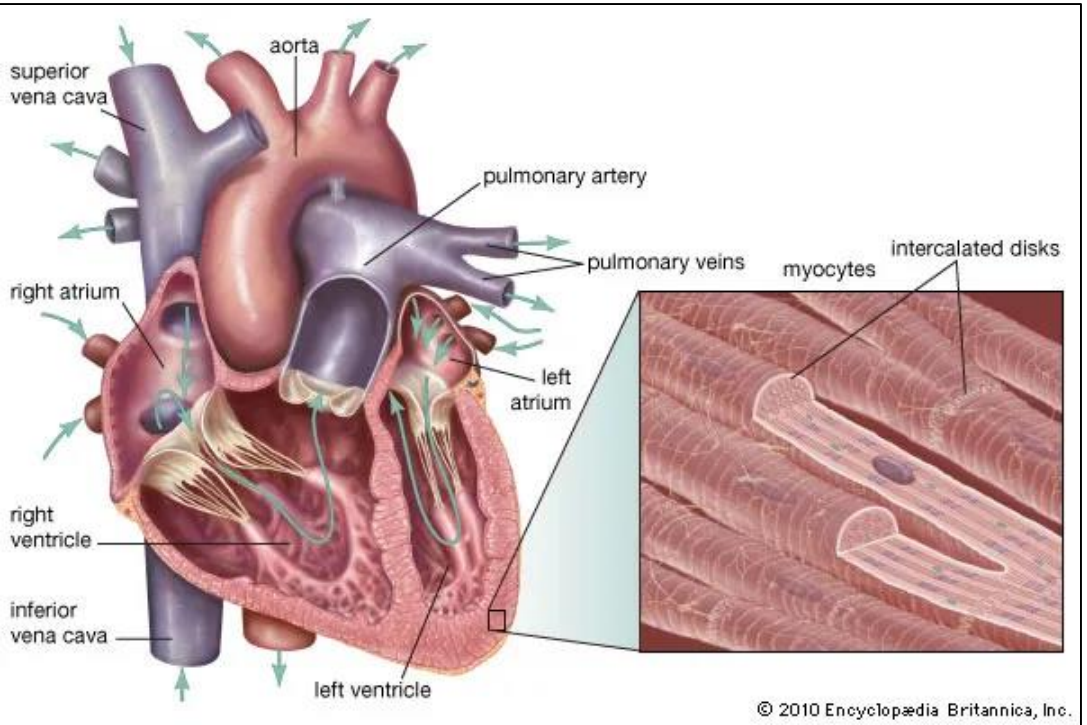
- The muscle cells, muscle fibers or myocytes, and their numbers remain relatively constant throughout life. Skeletal muscle tissue is arranged in bundles surrounded by connective tissue.
- Under the light microscope, muscle cells appear striated with many nuclei squeezed along the membranes.
- The striation is due to the regular alternation of the contractile proteins actin and myosin, along with the structural proteins that couple the contractile proteins to connective tissues.
- The cells are multinucleated as a result of the fusion of the many myoblasts that fuse to form each long muscle fiber.

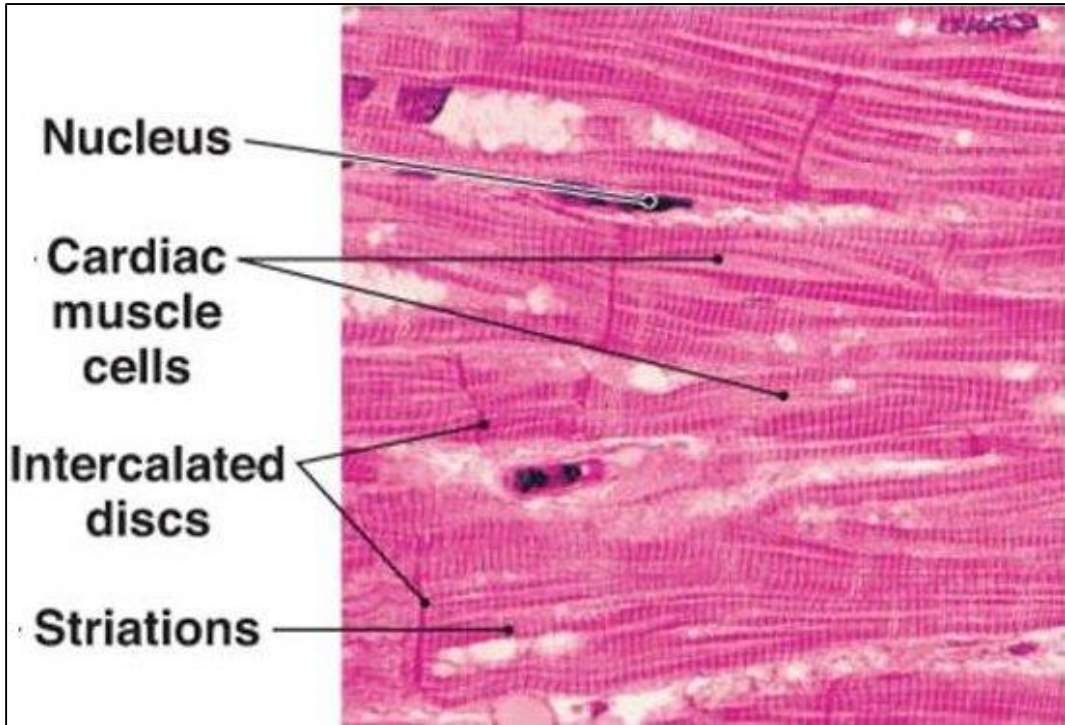

Muscle fibers develop through the fusion of embryonic cells called myoblasts.
Myoblasts
a A muscle fiber forms by the fusion of myoblasts.
Myosatellite cell
Nuclei
Immature muscle fiber
Muscle fiber
LM × 000
Sarcolemma
Striations
Nuclei
Myofibrils
Mitochondria
b A diagrammatic view and a micrograph of one muscle fiber.
Myosatellite cell
Up to 30 cm in length
Mature muscle fiber


Mitochondria
They produce the chemical energy (ATP) for muscle contraction.
Terminal cisterna
Sarcolemma
Sarcoplasm
Myofibril
Thin filament
actin
Thick filament
tubulin
Triad
Sarcoplasmic reticulum
It stores calcium for muscle contraction.
T tubules
They conduct the nerve impulse from the sarcolemma to the interior of the cell.

Cardiac Muscle

- Cardiac muscle forms the contractile walls of the heart. The cells of cardiac muscle, known as **cardiomyocytes**, also appear striated under the microscope. Unlike skeletal muscle fibers, cardiomyocytes are single cells typically with a single centrally located nucleus.
- A principal characteristic of cardiomyocytes is that they contract on their own intrinsic rhythms without any external stimulation.
- Cardiomyocyte attach to one another with specialized cell junctions called **intercalated discs**.
- Attached cells form long, branching cardiac muscle fibers that are, essentially, a mechanical and electrochemical syncytium allowing the cells to synchronize their actions.
- The cardiac muscle pumps blood through the body and is under involuntary control.

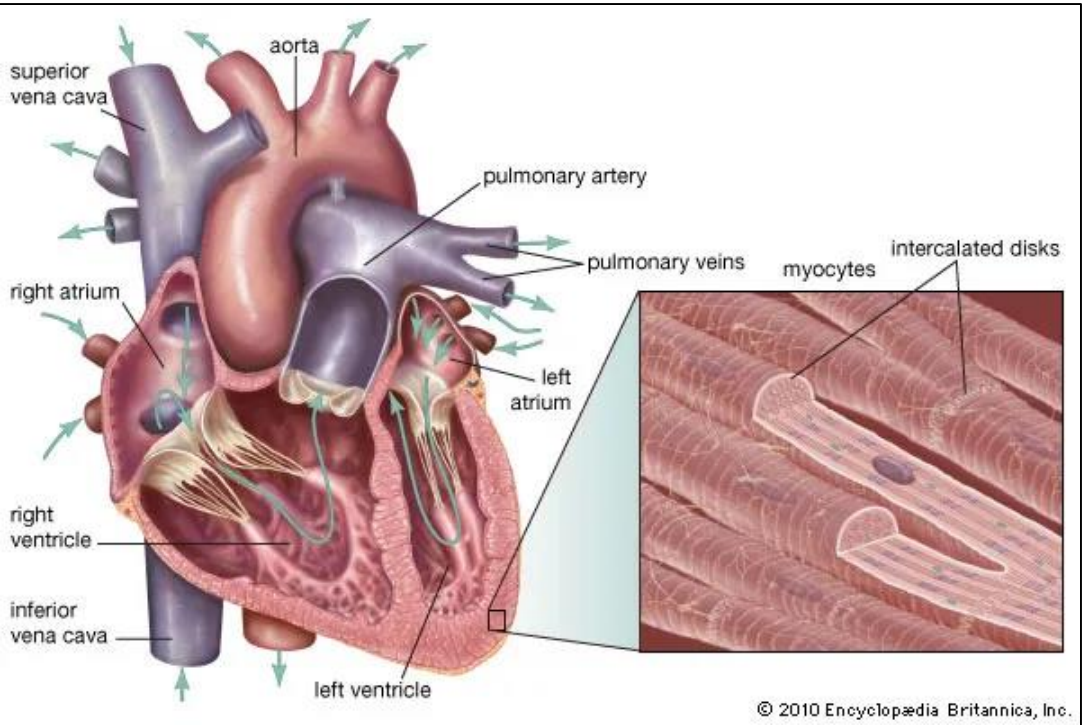


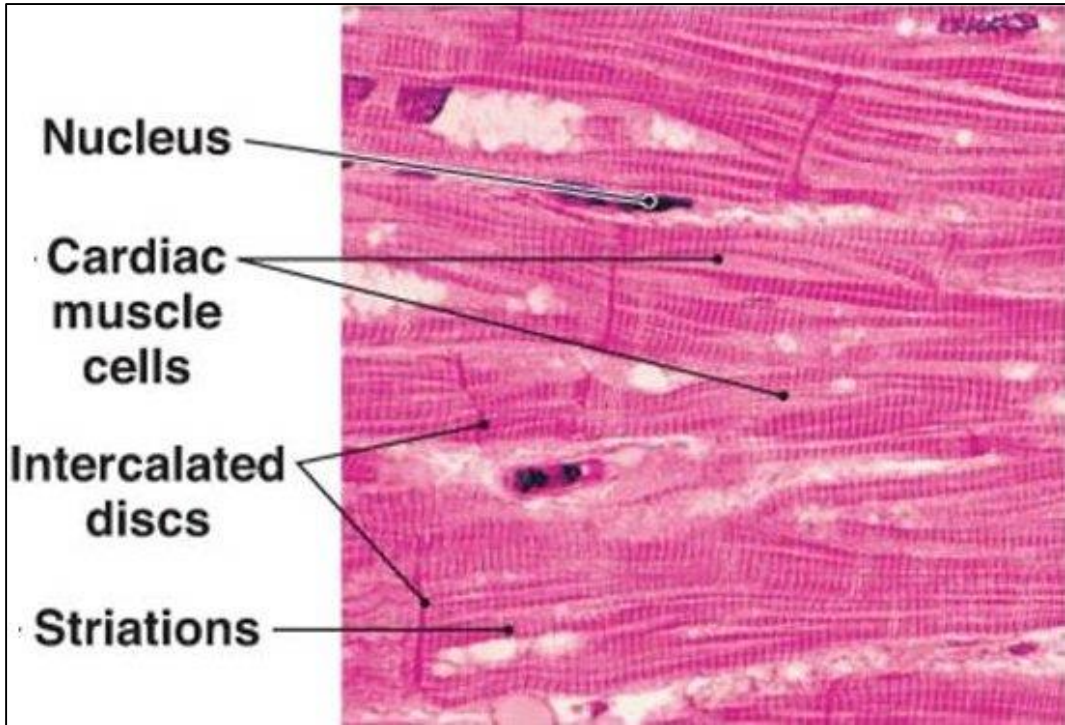


Cardiac Muscle

- **Intercalated discs**, which form porous junctions, bring the membranes of adjacent cardiomyocytes very close together. These pores (gap junctions) permit ions, such as sodium, potassium, and calcium, to easily diffuse from cell to cell, establishing a cell-cell communication. This joining is called electric coupling, and it allows the quick transmission of action potentials and the coordinated contraction of the entire heart.

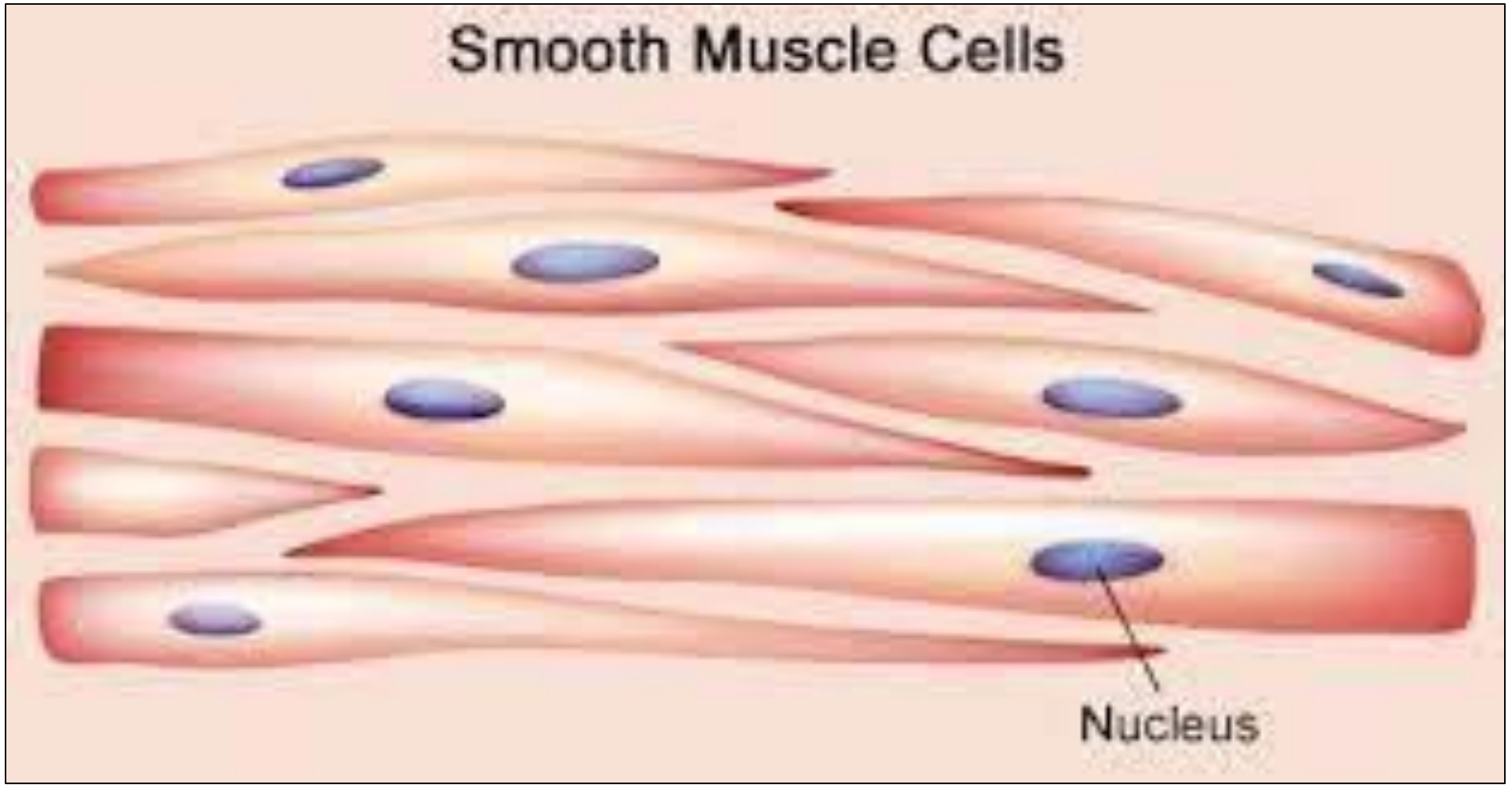
- Intercalated discs also function as mechanical anchor points that enable the transmission of contractile force from one cardiomyocyte to another (by desmosomes and adherens junctions). This allows for the heart to work as a single coordinated unit.

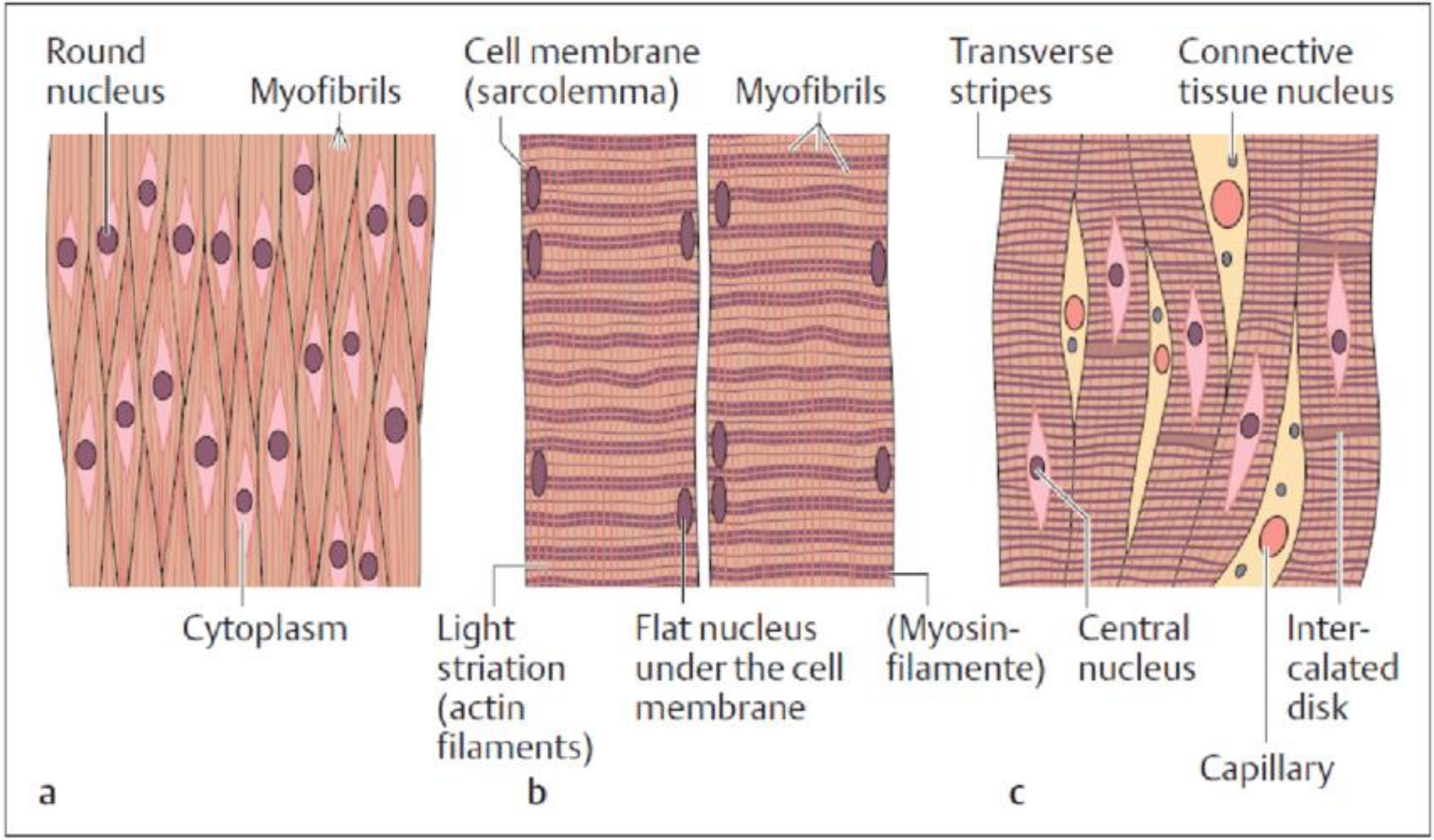




Smooth Muscle

- Smooth muscle tissue contraction is responsible for involuntary movements in the internal organs. It forms the contractile component of the digestive, urinary, and reproductive systems as well as the airways and arteries. Each cell is spindle shaped with a single nucleus and no visible striations.




Round nucleus
Myofibrils
Cytoplasm
a
Cell membrane (sarcolemma)
Myofibrils
Light striation (actin filaments)
Flat nucleus under the cell membrane
(Myosin-filamente)
b
Transverse stripes
Connective tissue nucleus
Central nucleus
Inter-calated disk
Capillary
c

Nervous Tissue

Nervous Tissue

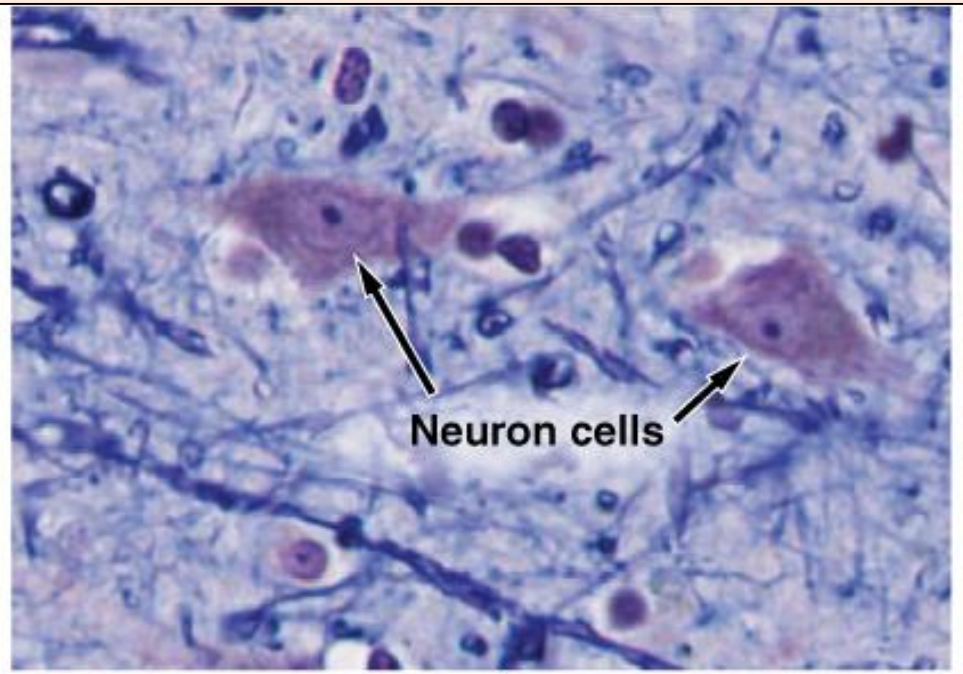
- Nervous tissue is characterized as being excitable and capable of sending and receiving electrochemical signals that provide the body with information.

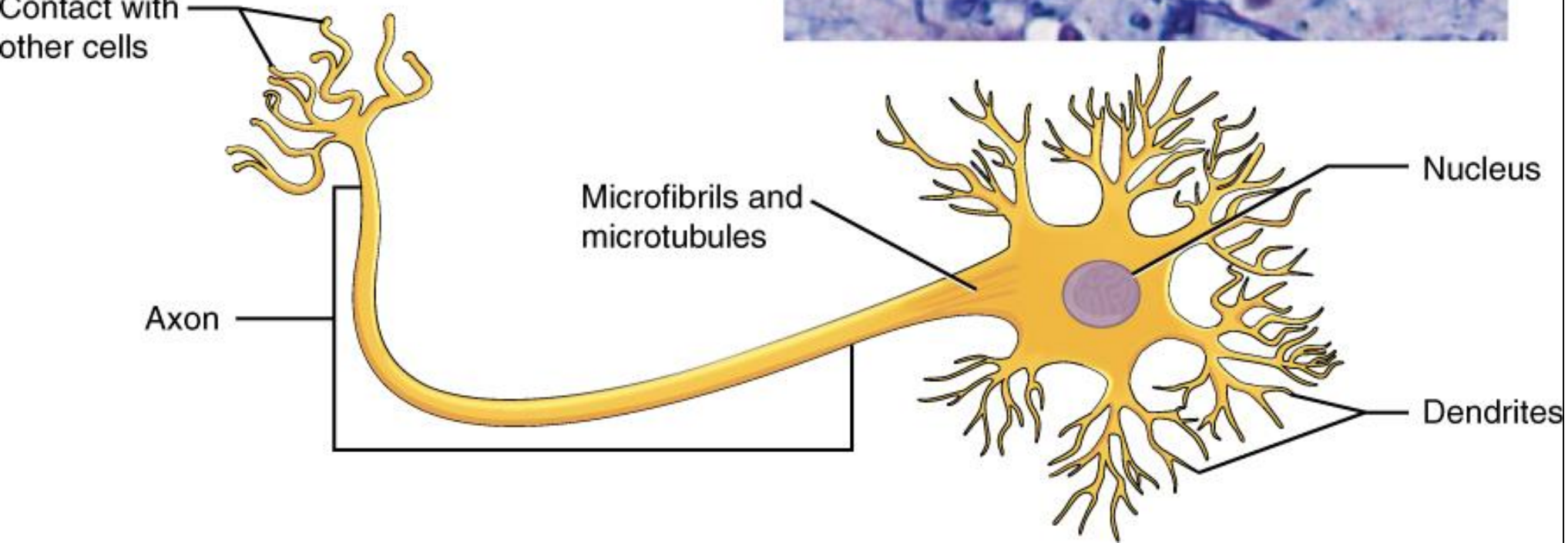
- Two main classes of cells make up nervous tissue:
  - **the neuron**
  - **neuroglia**

- **Neurons propagate information via electrochemical impulses, called action potentials, which are biochemically linked to the release of chemical signals.**
- Non-neuronal Neuroglia cells play an essential role in supporting neurons and modulating their information propagation. Neuroglia cells in the central nervous system (brain and spinal cord) and the peripheral nervous system that do not produce electrical impulses. The neuroglia make up more than one half the volume of neural tissue in the human body. They maintain homeostasis, form myelin in the peripheral nervous system, and provide support and protection for neurons. In the central nervous system, glial cells include oligodendrocytes, astrocytes, ependymal cells and microglia, and in the peripheral nervous system they include Schwann cells and satellite cells.

- Neurons display distinctive morphology, well suited to their role as conducting cells, with three main parts. The cell body includes most of the cytoplasm, the organelles, and the nucleus. Dendrites branch off the cell body and appear as thin extensions. A long “tail,” the axon, extends from the neuron body and can be wrapped in an insulating layer known as myelin, which is formed by accessory cells. The synapse is the gap between nerve cells, or between a nerve cell and its target, for example, a muscle or a gland, across which the impulse is transmitted by chemical compounds known as neurotransmitters.

Nervous Tissue - The Neuron





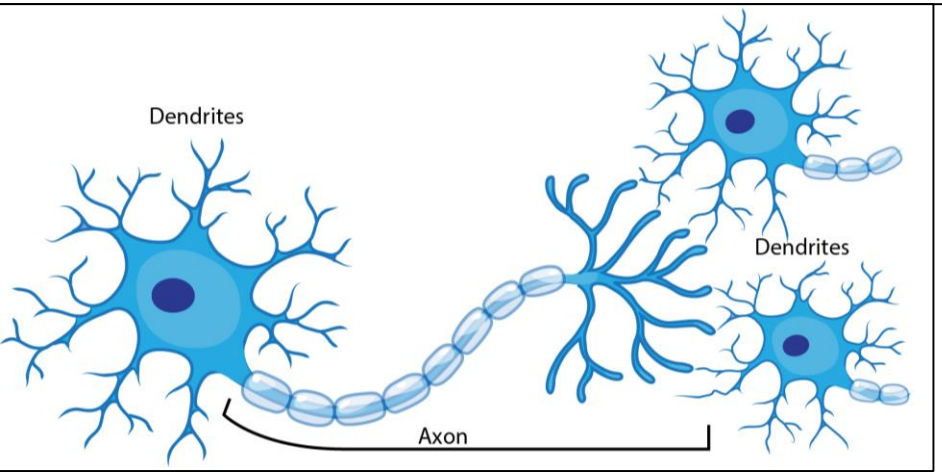
The Neuron.

The cell body of a neuron, also called the soma, contains the nucleus and mitochondria.

The dendrites transfer the nerve impulse to the soma.

The axon carries the action potential away to another excitable cell.

Nervous Tissue - The Neuron



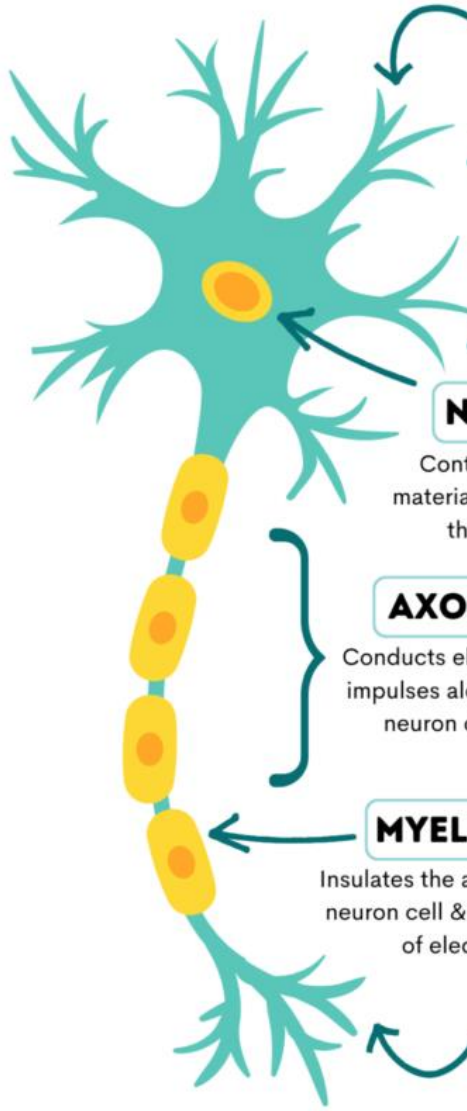
The Neuron.

The cell body (soma) of a neuron, also called the soma, contains the nucleus and mitochondria.

The dendrites transfer the nerve impulse to the soma.

The axon carries the action potential away to another excitable cell.

PARTS OF A NEURON



DENDRITES

Receive signals from other neuron cells.

CELL BODY

Contains the cell nucleus.

NUCLEUS

Contains the genetic material (chromosomes) of the neuron cell.

AXON

Conducts electrical impulses along the neuron cell.

MYELIN SHEATH

Insulates the axon to help protect the neuron cell & speed up transmission of electrical impulses.

AXON TERMINAL

Transmits electrical & chemical signals to other neuron cells & effector cells.

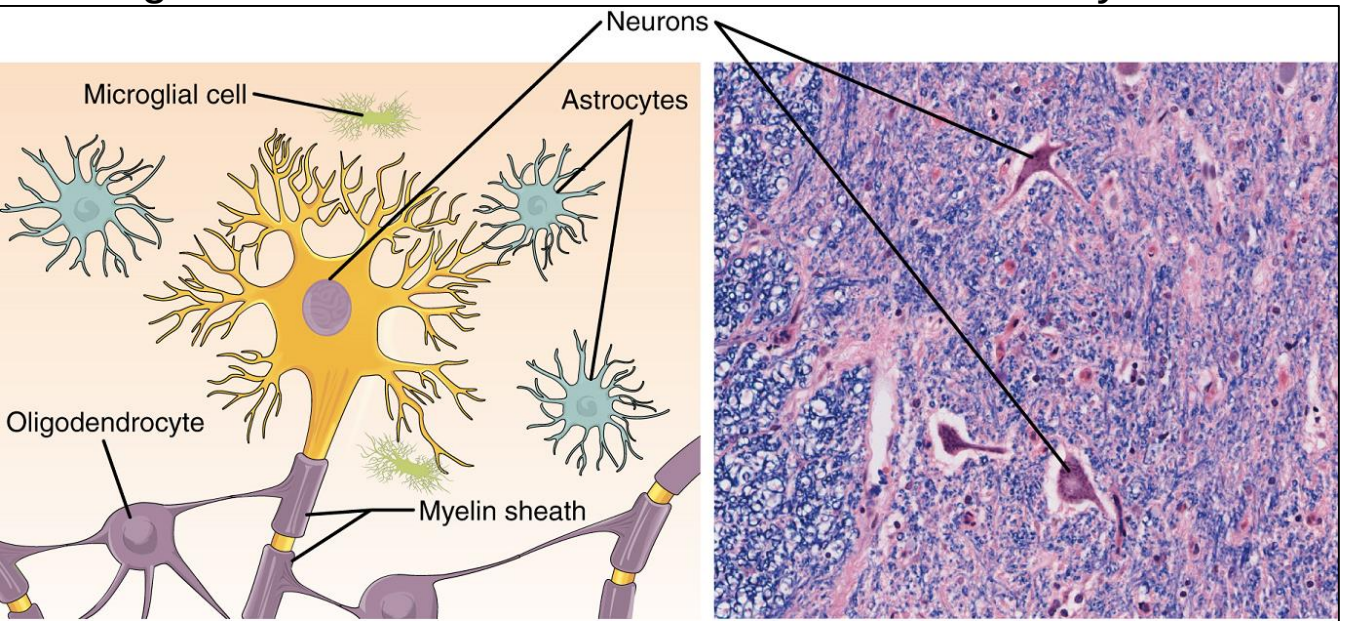
Nervous Tissue - Neuroglia or Glial cells

The **second class of neural cells** comprises the **neuroglia or glial cells**, which have been characterized as having a simple support, protect, and provide a framework for neurons.

They have four main functions:

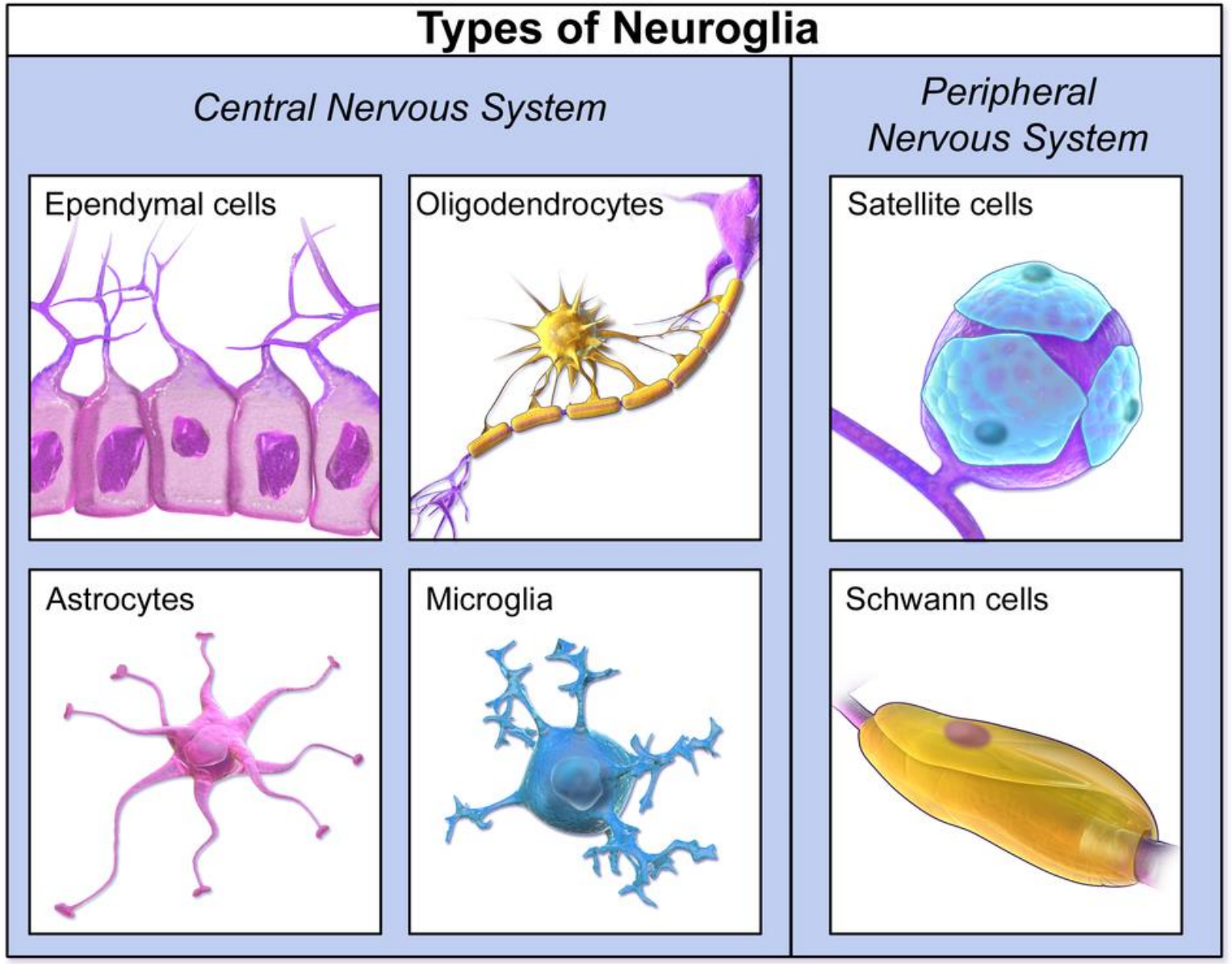
- ❑ to surround neurons and hold them in place
- ❑ to supply nutrients and oxygen to neurons and regulate the extracellular fluid of the brain, especially surrounding neurons and their synapses.
- ❑ to insulate one neuron from another
- ❑ to destroy pathogens and remove dead neurons.
- ❑ They also play a role in neurotransmission and synaptic connections, and in physiological processes such as breathing.

The word “glia” comes from the Greek word for glue. Recent research is shedding light on the more complex role of neuroglia in the function of the brain and nervous system.



Nervous Tissue.
Nervous tissue is made up of neurons and neuroglia. The cells of nervous tissue are specialized to transmit and receive impulses.

Nervous Tissue - Neuroglia or Glial cells



Nervous Tissue - Neuroglia or Glial cells

- **Cells in Central Nervous System:**
- **Ependymal cells, also named ependymocytes,** line the spinal cord and the ventricular system of the brain. These cells are involved in the creation and secretion of cerebrospinal fluid (CSF) and beat their cilia to help circulate the CSF and make up the blood-CSF barrier. They are also thought to act as neural stem cells.
- **Astrocytes** perform many functions, including biochemical control of endothelial cells that form the blood–brain barrier, provision of nutrients to the nervous tissue, maintenance of extracellular ion balance, regulation of cerebral blood flow, and a role in the repair and scarring process of the brain and spinal cord following infection and traumatic injuries.
- **Oligodendrocytes** are cells that coat axons in the Central Nervous System (CNS) with their cell membrane, forming a specialized membrane differentiation called myelin, producing the myelin sheath. The myelin sheath provides insulation to the axon that allows electrical signals to propagate more efficiently.
- **Microglia** are specialized macrophages capable of phagocytosis that protect neurons of the central nervous system.

- **Cells in Peripheral Nervous System:**
- **Satellite glial cells** are small cells that surround neurons in sensory, sympathetic, and parasympathetic ganglia. These cells help regulate the external chemical environment. Like astrocytes, they are interconnected by gap junctions and respond to ATP by elevating the intracellular concentration of calcium ions. They are highly sensitive to injury and inflammation and appear to contribute to pathological states, such as chronic pain.
- **Schwann cells** have similar function to oligodendrocytes, Schwann cells provide myelination to axons in the peripheral nervous system (PNS). They also have phagocytotic activity and clear cellular debris that allows for regrowth of PNS neurons.

Nervous Tissue

The presence of the nervous tissue throughout the body and its organization allows it to receive, integrate, and provide information to the entire body. This ensures that appropriate responses can occur among all body systems within an intact organism, both under normal conditions as well as during times of stress.

Connective Tissue

General Structure of Connective Tissue

- As may be obvious from its name, one of the major functions of connective tissue is to connect tissues and organs. Unlike epithelial tissue, which is composed of cells closely packed with little or no extracellular space in between, connective tissue cells are dispersed in a matrix. The matrix usually includes a large amount of extracellular material produced by the connective tissue cells that are embedded within it. The matrix plays a major role in the functioning of this tissue. The major component of the matrix is a ground substance often crisscrossed by protein fibers. This ground substance is usually a fluid, but it can also be mineralized and solid, as in bones. Connective tissues come in a vast variety of forms, yet they typically have in common three characteristic components: cells, large amounts of amorphous ground substance, and protein fibers. The amount and structure of each component correlate with the function of the tissue, from the rigid ground substance in bones supporting the body to the inclusion of specialized cells; for example, a phagocytic cell that engulfs pathogens and also rids tissue of cellular debris.

Functions of Connective Tissues

- Connective tissues perform many functions in the body, but most importantly, they support and connect other tissues; from the connective tissue sheath that surrounds muscle cells to the tendons that attach muscles to bones and to the skeleton that supports the positions of the body. Protection is another major function of connective tissue, in the form of fibrous capsules and bones that protect delicate organs and, of course, the skeletal system. Specialized cells in connective tissue defend the body from microorganisms that enter the body. Transport of fluid, nutrients, waste, and chemical messengers is ensured by specialized fluid connective tissues, such as blood and lymph. Adipose cells store surplus energy in the form of fat and contribute to the thermal insulation of the body.

Classification of Connective Tissue

- The three broad categories of connective tissue are classified according to the characteristics of their ground substance and the types of fibers found within the matrix. Connective tissue proper includes loose connective tissue and dense connective tissue. Both tissues have a variety of cell types and protein fibers suspended in a viscous ground substance. Dense connective tissue is reinforced by bundles of fibers that provide tensile strength, elasticity, and protection. In loose connective tissue, the fibers are loosely organized, leaving large spaces in between. Supportive connective tissue—bone and cartilage—provide structure and strength to the body and protect soft tissues. A few distinct cell types and densely packed fibers in a matrix characterize these tissues. In bone, the matrix is rigid and described as calcified because of the deposited calcium salts. In fluid connective tissue—lymph and blood—various specialized cells circulate in a watery fluid containing salts, nutrients, and dissolved proteins.

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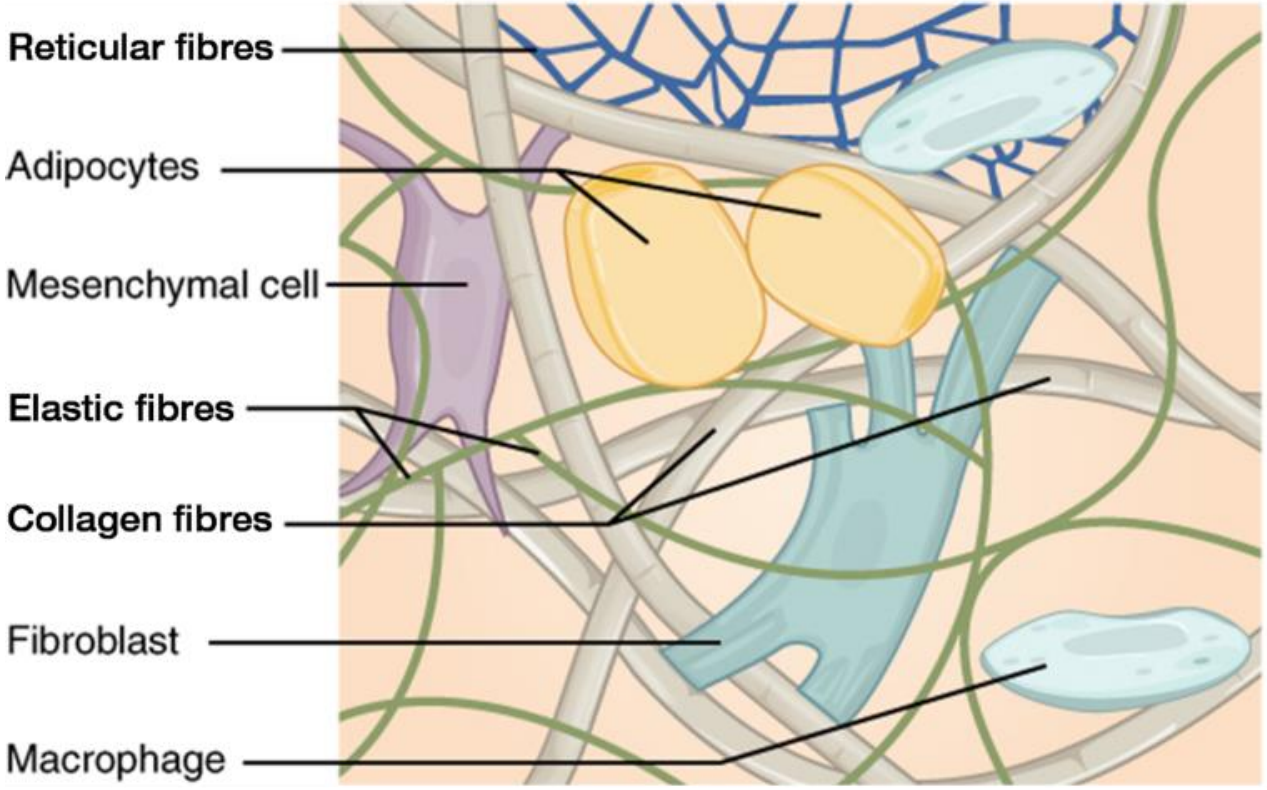
Classification of Connective Tissue

Connective tissue proper	Supportive connective tissue	Fluid connective tissue
Loose connective tissue	Cartilage	
Areolar	Hyaline	Blood
Adipose	Fibrocartilage	
Reticular	Elastic	
Dense connective tissue	Bones	
Regular	Compact bone	Lymph
Irregular	Cancellous bone	

Connective tissue examples

Connective Tissue Proper

- Fibroblasts are present in all connective tissue proper. Fibroblasts are the most abundant cells in connective tissue proper. Fibrocytes, adipocytes, and mesenchymal cells are fixed cells, which means they remain within the connective tissue. Other cells move in and out of the connective tissue in response to chemical signals. Macrophages, mast cells, lymphocytes, plasma cells, and phagocytic cells are found in connective tissue proper but are actually part of the immune system protecting the body.



Connective Tissue Proper.
Fibroblasts produce this fibrous tissue.
Connective tissue proper includes the fixed cells fibrocytes, adipocytes, and mesenchymal cells.

Connective Tissue Proper

- Adipocytes are cells that store lipids as droplets that fill most of the cytoplasm. The mesenchymal cell is a multipotent adult stem cell. These cells can differentiate into any type of connective tissue cells needed for the repair and healing of damaged tissue. The macrophage is a large type of blood cell, which enters the connective tissue matrix from the blood vessels. The macrophage cells are an essential component of the immune system, which is the body's defense against potential pathogens and degraded host cells. The mast cell found in connective tissue proper, when irritated or damaged, releases histamine, which causes vasodilation and increased blood flow at a site of injury or infection, along with itching, swelling, and redness you recognize as an allergic response.

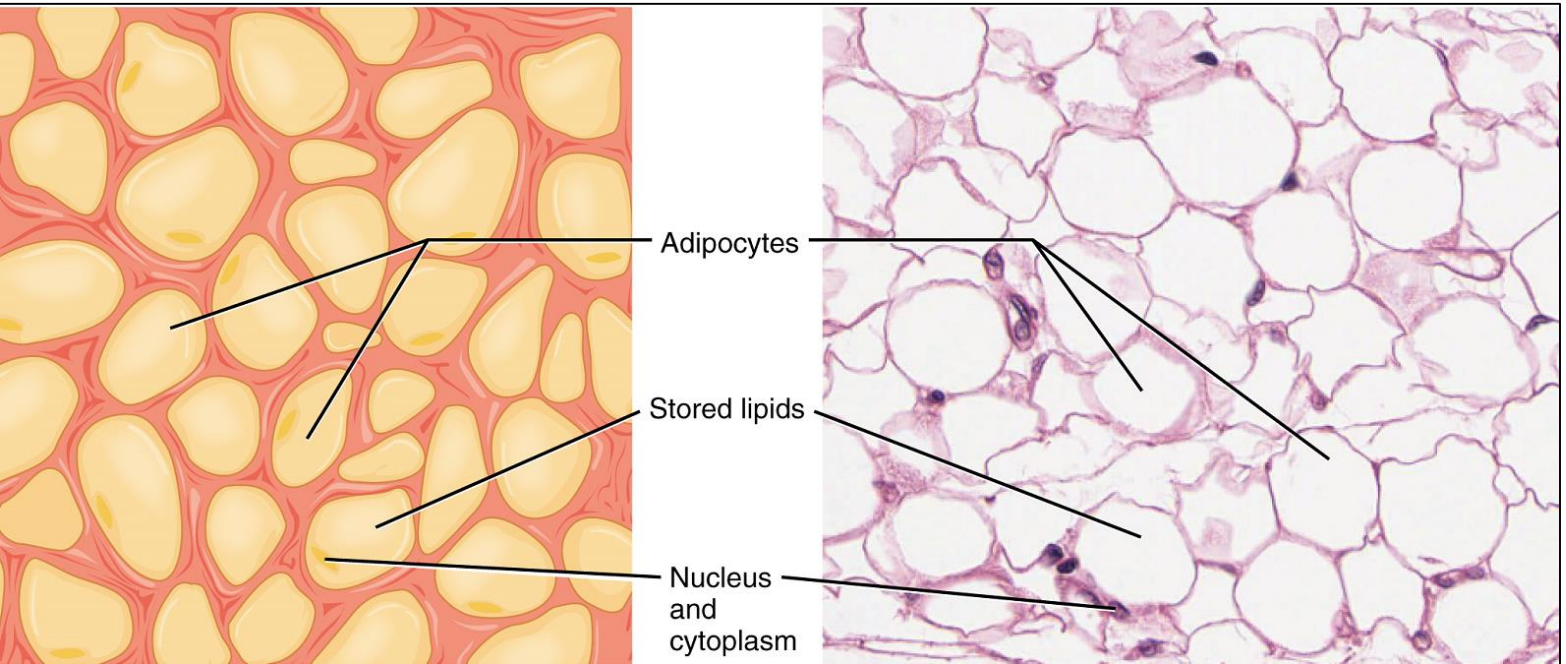
- Three main types of fibers are secreted by fibroblasts: collagen fibers, elastic fibers, and reticular fibers. Collagen fibers, while flexible, have great tensile strength, resist stretching, and give ligaments and tendons their characteristic resilience and strength. These fibers hold connective tissues together, even during the movement of the body. Elastic fibers after being stretched or compressed will return to its original shape. Elastic fibers are prominent in elastic tissues found in skin and the elastic ligaments of the vertebral column. Reticular fibers are narrow and are arrayed in a branching network. They are found throughout the body but are most abundant in the reticular tissue of soft organs, such as liver and spleen, where they anchor and provide structural support to the parenchyma (the functional cells, blood vessels, and nerves of the organ). All of these fiber types are embedded in ground substance, a clear, viscous, colorless matrix made of polysaccharides and proteins, forming the extracellular matrix.

Loose Connective Tissue

- Loose connective tissue is found between many organs where it acts both to absorb shock and bind tissues together. It allows water, salts, and various nutrients to diffuse through adjacent or embedded cells and tissues.

- Areolar tissue shows little specialization. It contains all the cell types and fibers previously described and is distributed in a random, web-like fashion. It fills the spaces between muscle fibers, surrounds blood and lymph vessels, and supports organs in the abdominal cavity. Areolar tissue underlies most epithelia and represents the connective tissue component of epithelial membranes, which are described further in a later section.

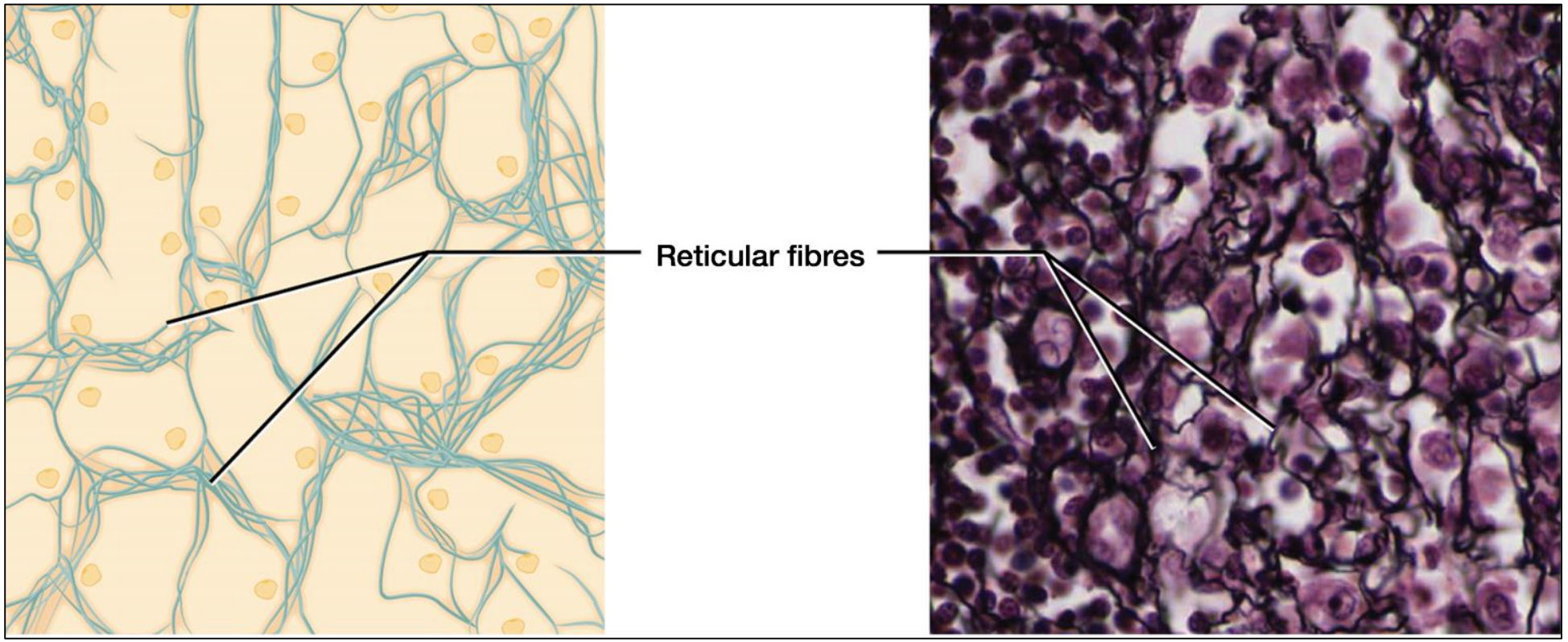
- Adipose tissue consists mostly of fat storage cells, with little extracellular matrix. A large number of capillaries allow rapid storage and mobilization of lipid molecules. Fat contributes mostly to lipid storage and can serve as insulation from cold temperatures and mechanical injuries.



Adipose Tissue.
This is a loose connective tissue that consists of fat cells with the little extracellular matrix. It stores fat for energy and provides insulation.

Loose Connective Tissue

- Reticular tissue is a mesh-like, supportive framework for soft organs such as lymphatic tissue, the spleen, and the liver. Reticular cells produce the reticular fibers that form the network to which other cells attach. It derives its name from the Latin reticulus, which means “little net.”



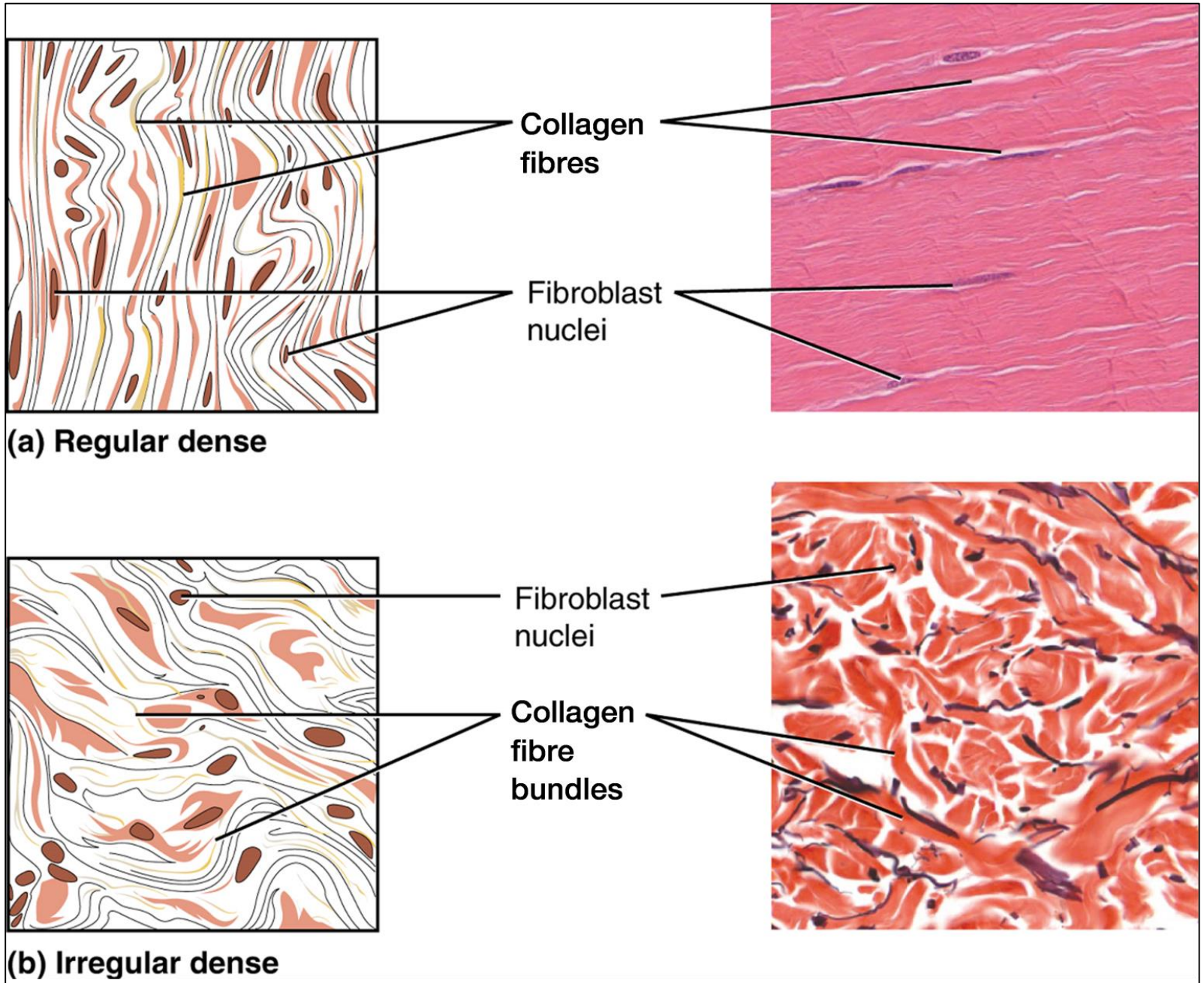
Reticular Tissue.
This is a loose connective tissue made up of a network of reticular fibers that provides a supportive framework for soft organs.

Dense Connective Tissue

- Dense connective tissue (also called fibrous connective tissue) contains more collagen fibers than loose connective tissue. As a consequence, it displays greater resistance to stretching. There are two major categories of dense connective tissue: regular and irregular. Dense regular connective tissue fibers are parallel to each other, enhancing tensile strength and resistance to stretching in the direction of the fiber orientations. Ligaments and tendons are made of dense regular connective tissue, but in ligaments, not all fibers are parallel. Dense regular elastic connective tissue contains elastin fibers in addition to collagen fibers, which allows the ligament to return to its original length after stretching. The ligaments in the vocal folds and between the vertebrae in the vertebral column are elastic.

- In dense irregular connective tissue, the direction of fibers is random. This arrangement gives the tissue greater strength in all directions and less strength in one particular direction. In some tissues, fibers crisscross and form a mesh. In other tissues, stretching in several directions is achieved by alternating layers where fibers run in the same orientation in each layer, and it is the layers themselves that are stacked at an angle. The dermis of the skin is an example of dense irregular connective tissue rich in collagen fibers. Dense irregular elastic connective tissue gives arterial walls the strength and the ability to regain their original shape after stretching

Dense Connective Tissue



Dense Connective Tissue.

(a) Dense regular connective tissue consists of collagenous fibers packed into parallel bundles.

(b) Dense irregular connective tissue consists of collagenous fibers interwoven into a mesh-like network.

Supportive Connective Tissues

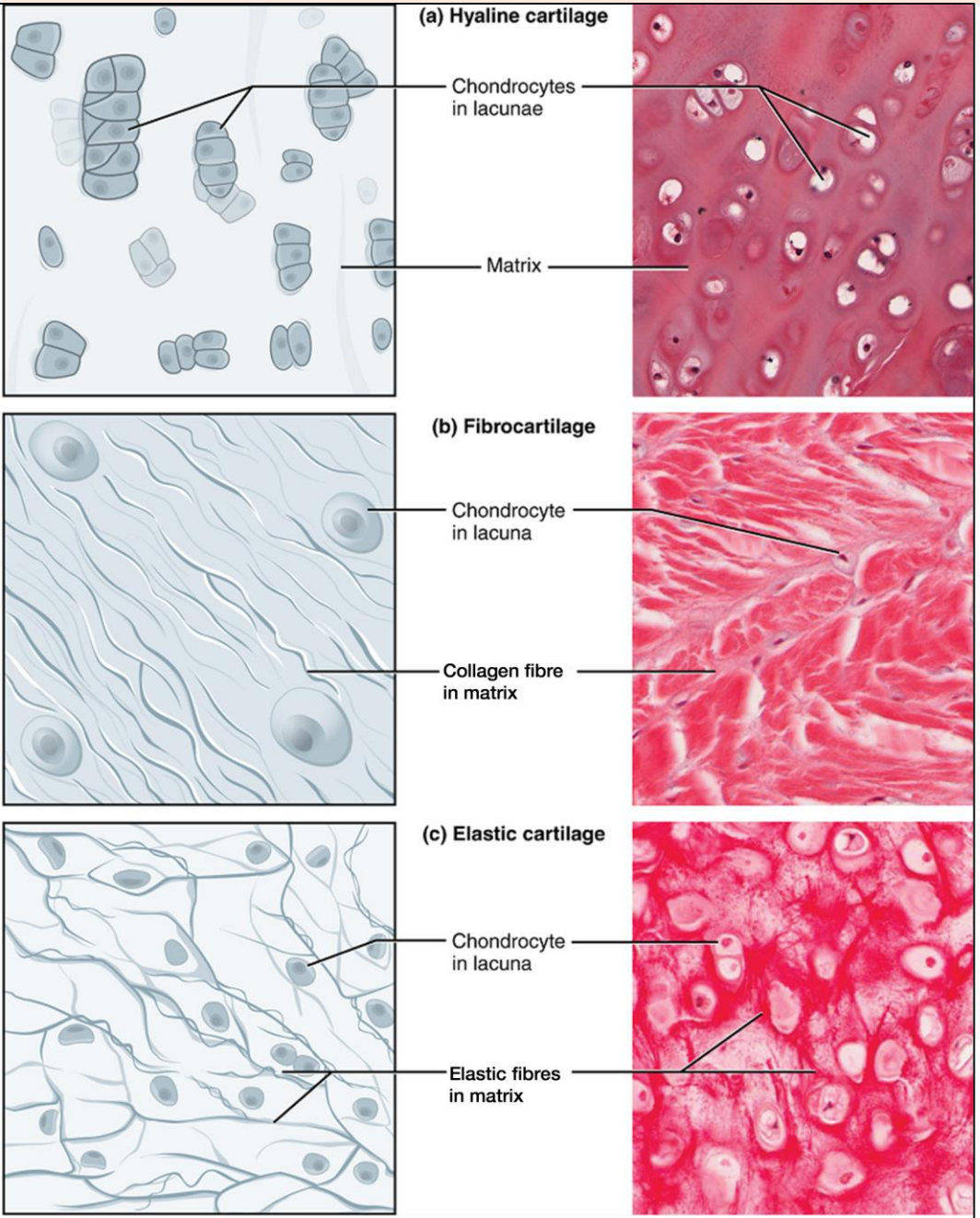
Two major forms of supportive connective tissue, cartilage and bone, allow the body to maintain its posture and protect internal organs.

Supportive Connective Tissue - Cartilage

- The distinctive appearance of cartilage is due to polysaccharides, which bind with ground substance proteins to form the extracellular matrix. Embedded within the cartilage matrix are chondrocytes, or cartilage cells, and the space they occupy are called lacunae (singular = lacuna). A layer of dense irregular connective tissue, the perichondrium, encapsulates the cartilage. Cartilaginous tissue is avascular, thus all nutrients need to diffuse through the matrix to reach the chondrocytes. This is a factor contributing to the very slow healing of cartilaginous tissues.

- The three main types of cartilage tissue are hyaline cartilage, fibrocartilage, and elastic cartilage. Hyaline cartilage, the most common type of cartilage in the body, contains short and dispersed collagen fibers in the matrix. Both strong and flexible, the hyaline cartilage is found in the rib cage and nose and covers bones where they meet to form moveable joints. It makes up a template of the embryonic skeleton before bone formation. A plate of hyaline cartilage at the ends of bone allows continued growth until adulthood. Fibrocartilage is tough because it has thick bundles of collagen fibers dispersed through its matrix. The knee and jaw joints and the intervertebral discs are examples of fibrocartilage. Elastic cartilage contains elastic fibers as well as collagen. This tissue gives rigid support as well as elasticity. Tug gently at your ear lobes, and notice that the lobes return to their initial shape. The external ear contains elastic cartilage.

Supportive Connective Tissue - Cartilage



Types of Cartilage.

Cartilage is a connective tissue consisting of collagenous fibers embedded in a firm matrix of chondroitin sulfates.

(a) Hyaline cartilage provides support with some flexibility. The example is from dog tissue.

(b) Fibrocartilage provides some compressibility and can absorb pressure.

(c) Elastic cartilage provides firm but elastic support.

Supportive Connective Tissue - Bone

- Bone is the hardest connective tissue. It provides protection to internal organs and supports the body. Bone's rigid extracellular matrix contains mostly collagen fibers embedded in a mineralized ground substance containing hydroxyapatite, a form of calcium phosphate. Both components of the matrix, organic and inorganic, contribute to the unusual properties of bone. Without collagen, bones would be brittle and shatter easily. Without mineral crystals, bones would flex and provide little support. Osteocytes, bone cells similar to chondrocytes, are located within lacunae. The histology of transverse tissue from long bone shows a typical arrangement of osteocytes in concentric circles around a central canal. Bone is a highly vascularized tissue. Unlike cartilage, bone tissue can recover from injuries in a relatively short time.

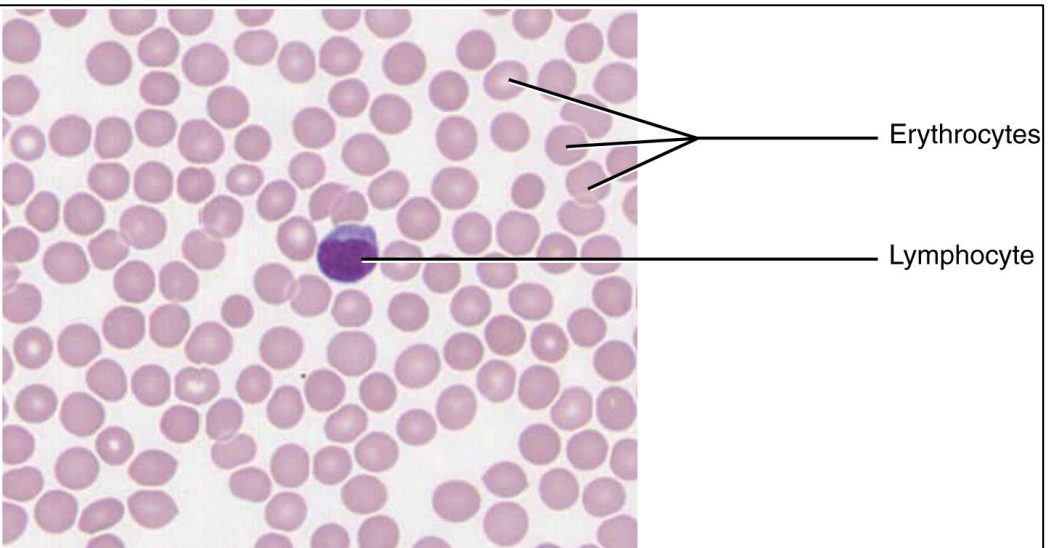
- Cancellous bone ("trabecular bone" or "spongy bone") looks like a sponge under the microscope and contains empty spaces between trabeculae, or arches of bone proper. It is lighter than compact bone and found in the interior of some bones and at the end of long bones. Compact bone is solid and has greater structural strength.

Fluid Connective Tissue

- Blood and lymph are fluid connective tissues. Cells circulate in a liquid extracellular matrix. The formed elements circulating in the blood are all derived from hematopoietic stem cells located in bone marrow (Figure 9). Erythrocytes, red blood cells, transport oxygen and some carbon dioxide. Leukocytes, white blood cells, are responsible for defending against potentially harmful microorganisms or molecules. Platelets are cell fragments involved in blood clotting.

- Some white blood cells have the ability to cross the endothelial layer that lines blood vessels and enter adjacent tissues. Nutrients, salts, and wastes are dissolved in the liquid matrix and transported through the body.

- Lymph contains a liquid matrix and white blood cells. Lymphatic capillaries are extremely permeable, allowing larger molecules and excess fluid from interstitial spaces to enter the lymphatic vessels. Lymph drains into blood vessels, delivering molecules to the blood that could not otherwise directly enter the bloodstream. In this way, specialized lymphatic capillaries transport absorbed fats away from the intestine and deliver these molecules to the blood.



Blood: A Fluid Connective Tissue.
Blood is a fluid connective tissue containing erythrocytes and various types of leukocytes that circulate in a liquid extracellular matrix.
In this figure, a photo of a microscopy slide shows the peripheric smear of the blood with labels for erythrocytes and a lymphocyte.

Thank you for your attention