Histology

Second year

by

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جامعة الكرخ

Histology

Histology: is the study of the body organ structure by using the microscope.

The human body is composed of four principal or primary types of tissues:

First: Epithelial tissues
Second: Connective tissues
Third: Muscular tissue
Fourth: Nervous tissue

First: Epithelial tissues

Classification of the epithelial tissue:

Epithelial tissue is classified according to their structure and function into:

1- Covering and lining epithelium	2- Glandular epithelium

Classification of covering and lining epithelium

The covering and lining epithelium is classified according to the number of cell layers into:

A- Simple epithelium.

B- Pseudostratified columnar epithelium.

C- Stratified epithelium.

The classification of simple epithelium

The simple epithelium can be classified according to the cell shape into:

1- Simple squamous epithelium.
2-Simple cuboidal epithelium.
3- Simple columnar epithelium.

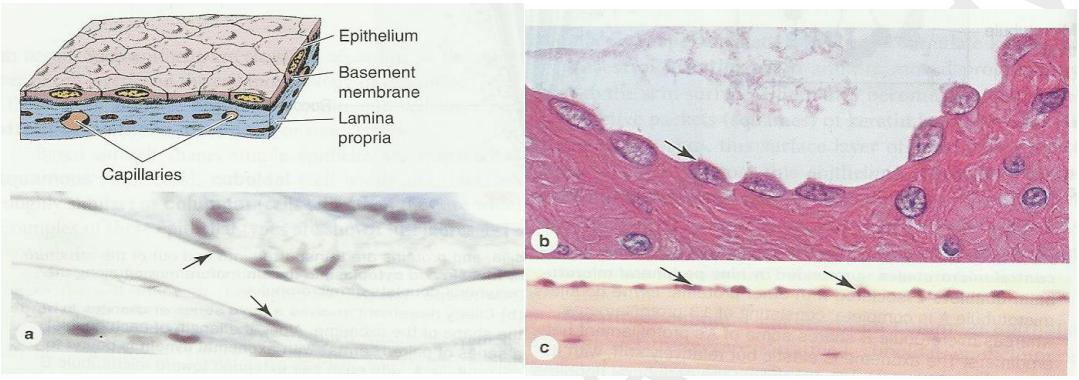
1- The characteristic of simple squamous epithelium

1- Is a single layer of packed, similar and adhesive cells, which rest on the basement membrane.

2- Scale like flattened cells with centrally located nuclei.

3- Found in [mesothelium (covering tissue), endothelium (lining tissue) and Bowman's capsule in the kidney (lining tissue)].

4- The main function involved diffusion and lubrication.



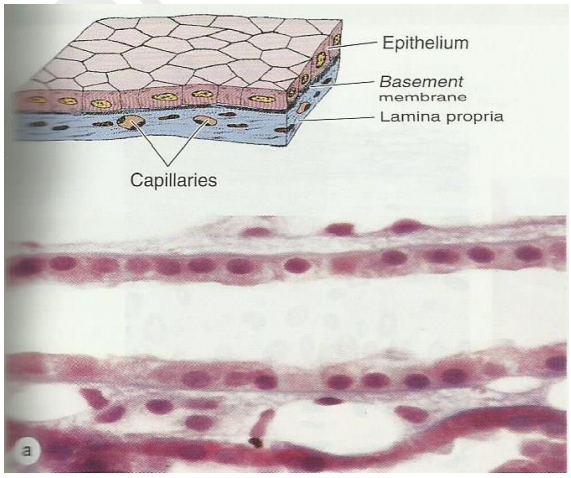
2- The characteristic of simple cuboidal epithelium

1- Is a single layer of packed, similar adhesive cells, which rest on the basement membrane.

2- Square like cells with spherical and centrally located nuclei.

3- Is found in the kidney tubules.

4- The main function involved absorption, secretion and protection.



3- <u>The characteristic of simple columnar epithelium</u>

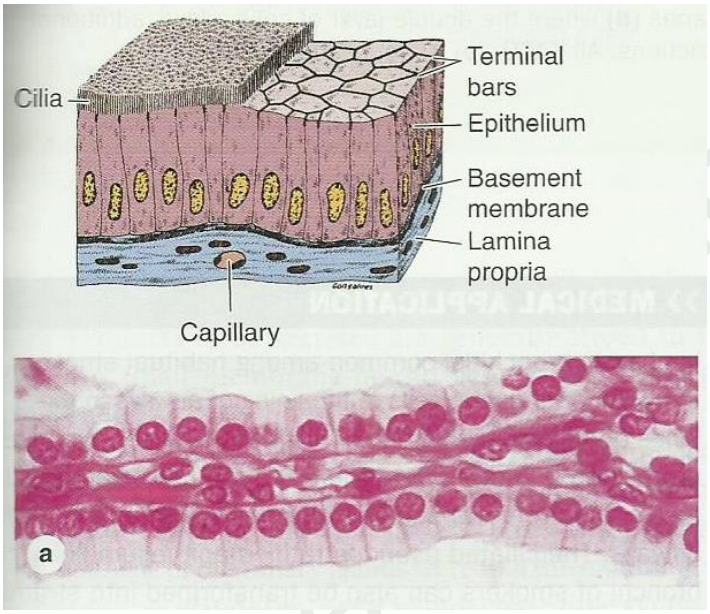
1- Is a single layer of packed, similar and adhesive cells, which rest on the basement membrane.

2- Tall cells with elongated and basely located nuclei.

3- Is found in the intestine and stomach.

4- The main function involved absorption, secretion and protection.

5- The apical cell surface bear cilia or microvilli or ….etc.



4- <u>The characteristic of pseudostratified columnar epithelium</u>

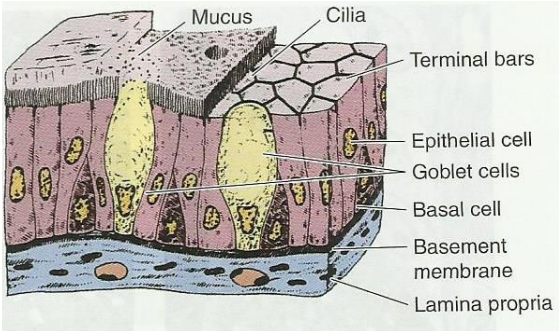
1- Is a single layer of packed and adhesive cells, which rest on the basement membrane.

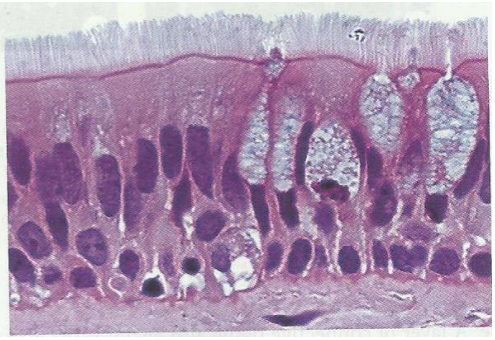
2- Contains different cells (basal, fusiform and columnar cells) with nuclei that found at varying levels.

3- Is found in trachea.

4- The main function involved absorption, secretion and transportation.

5- The apical cell surface bear cilia or sterocilia or ……etc..





Classification of stratified epithelium

The stratified epithelium can be classified according to the shape of the superficial cell layer into:

1- Stratified squamous epithelium:

a- Non-keratinized stratified squamous epithelium.
b- Keratinized stratified squamous epithelium.

2- Stratified cuboidal epithelium.

3- Stratified columnar epithelium.

4- Transitional epithelium (urothelium)

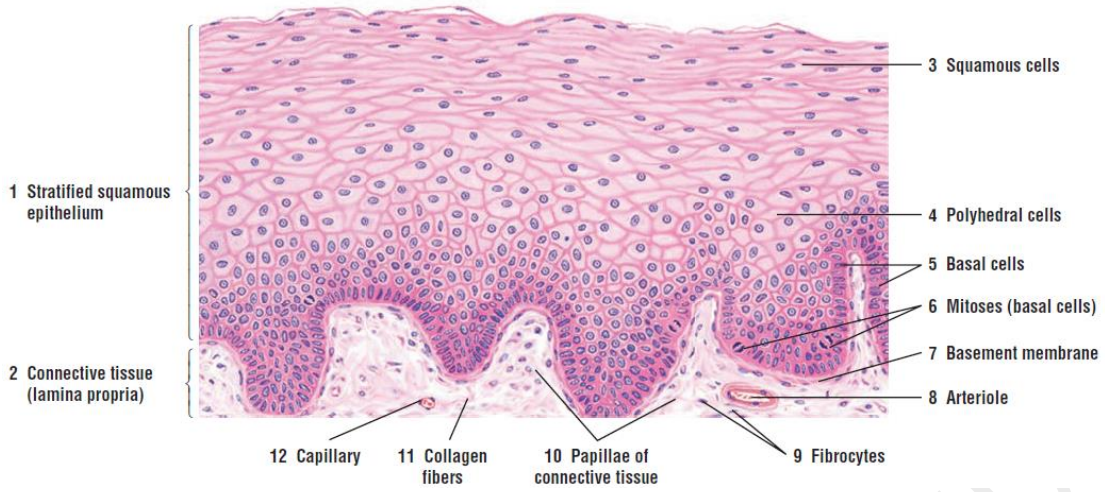
1- The characteristic of stratified squamous epithelium

1- Made up of multiple cell layers and only the basal layer rest on the basement membrane.

2- The superficial cell layer lives in non-keratinized stratified squamous epithelium and non-living in keratinized stratified squamous epithelium.

3- Is found in esophagus, mouth and pharynx (non-keratinized stratified squamous epithelium) while the keratinized stratified squamous epithelium is found in the skin.

4- The main function is a protection.



Non-Keratinized

Keratinized

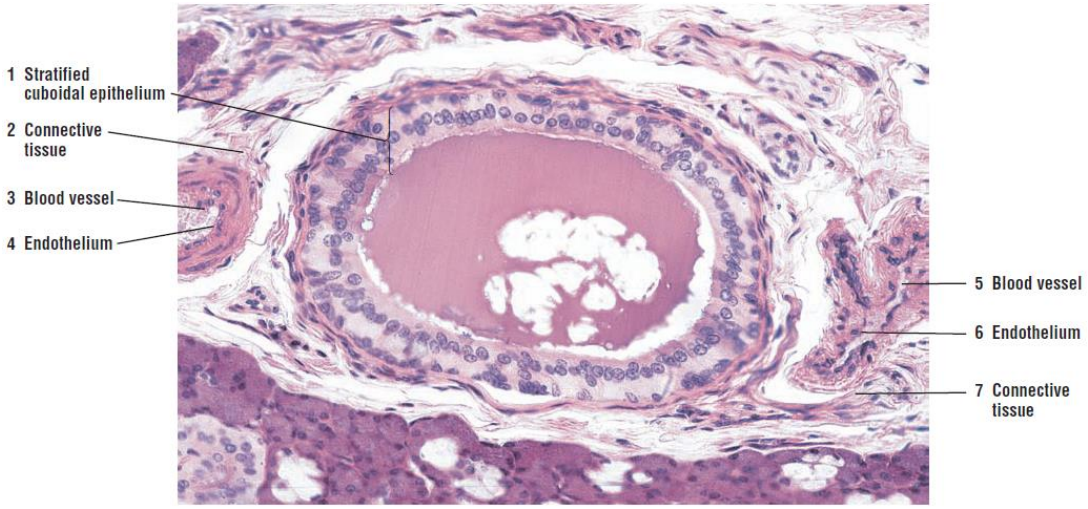
2- The characteristic of stratified cuboidal epithelium

1- Made up of multiple cell layers and only the basal layer rest on the basement membrane.

2- The superficial cell layer had cubical shape.

3- Is found in the duct of sweat glands.

4- The main function involved absorption and secretion.



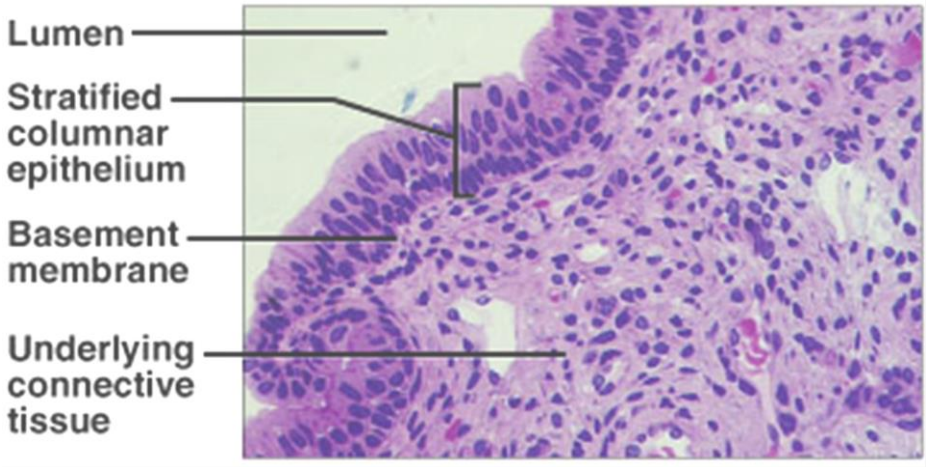
3- The characteristic of stratified columnar epithelium

1- Made up of multiple cell layers and only the basal layer rest on the basement membrane.

2- The superficial cell layer had long shaped.

3- This tissue is rare, it is found in the small areas in the human body such as salivary glands.

4- The main function involved protection and secretion.



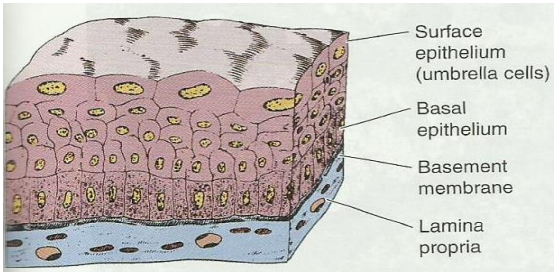
4- The characteristic of transitional epithelium

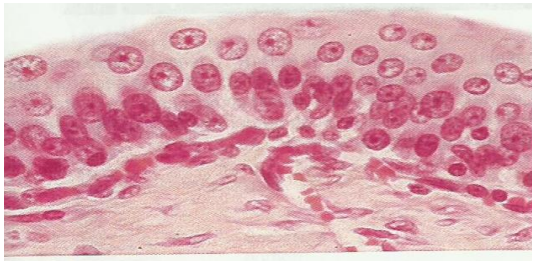
1- Made up of multiple cell layers and only the basal layer rest on the basement membrane.

2- The superficial cell layer changes its shape in response to its function from dome like shaped to flattened shaped.

3- Is found in the urinary bladder and urethra.

4- The main function involved filtration, reabsorption, excretion and protection.





Basement membrane

1- Is a thin, non-cellular region that separates the epithelium from the underlying connective tissues.

2- Is consist of:

a- Basal lamina (lamina densa and lamina lucida).

b- Reticular lamina.

3- It is also found in the other tissue.

The characteristic of epithelial tissue

1- Single layer of packed and adhesive cells, which rest on the basement membrane (simple epithelium).

2- Multiple cell layers and only the basal layer rest on the basement membrane (stratified epithelium).

3- The tissue is a vascular.

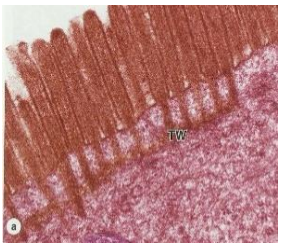
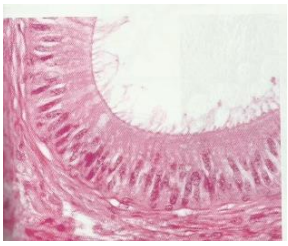
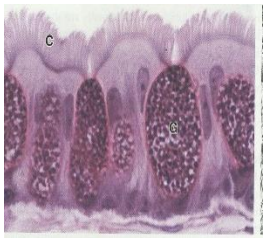
4- Epithelial cells are renewed continuously by mitotic activity. It can repair and replacement of damaged cells.

5- The epithelial cells show polarity.

6- Epithelial cells in different organs show special cell membrane modifications on their surface, and these modifications include:

A- On the apical surface:

1- Microvilli 2- Stereocilia 3- Cilia 4- Flagella

B- on the lateral surface

1- Desmosomes

2- Gap junction

7- Tissues have several functions such as: protection, secretion, filtration, reabsorption, excretion, absorption, transportation, diffusion and lubrication.

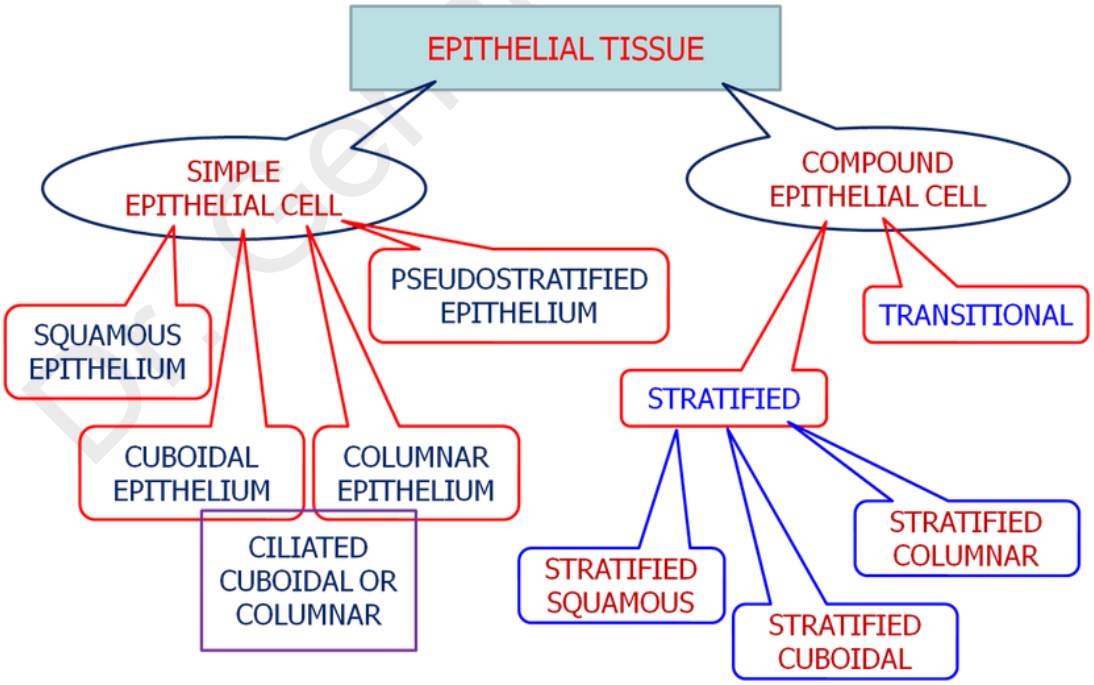


Diagram shows the classification of the epithelial tissue according to the shape and number of layers

2- The glandular epithelium

The glandular epithelium defined as epithelial cells specialized to secret and stored special molecules as secretary granules.

Classification of the glandular epithelium

The glandular epithelium can be classified according to:

A- The presence or absence of ducts which is divided into:

1- Endocrine glands: they do not have ducts for their secretory products and had rich blood capillaries. This type of gland is found as individual cells, tissue or organs. For example, Thyroid glands.

2- Exocrine glands: secrete their product into ducts. For example, variety of glands.

3- Mixed glands: a gland having both exocrine and endocrine portions. For example, pancreas.

B- Number of cells (structure) can be divided into:

1- Unicellular glands: consist of single cells. For example, goblet cells that secrete mucus. This type of gland found in the trachea and intestine.

2- Multicellular glands: consist of secretory portion and duct portion.

C- Structure of their duct portion. It can be divided into:

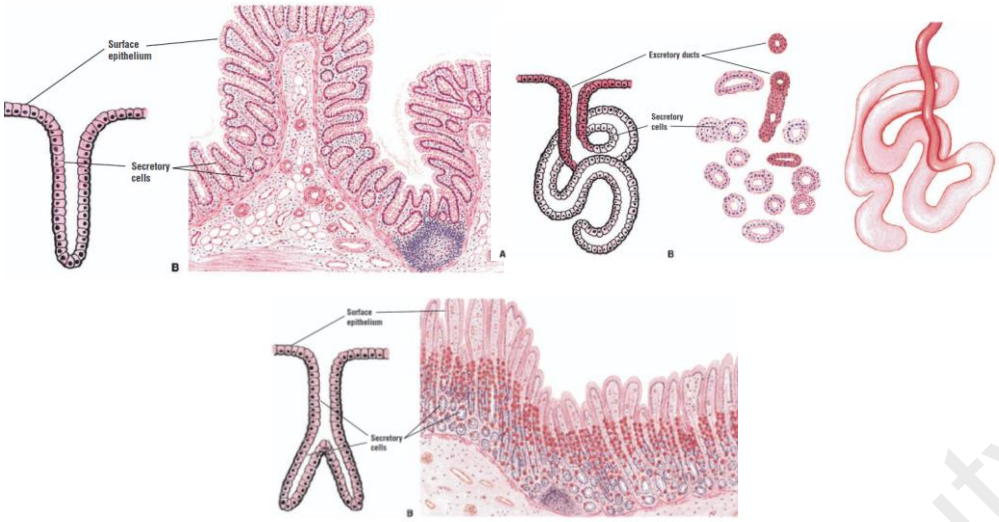
1- Simple multicellular exocrine glands: consist of unbranched duct and different shape of secretory portion such as:

a- Tubular gland: it can be either:

1- Straight tubular, for example: intestinal gland.

2- Coiled tubular, for example: sweat gland.

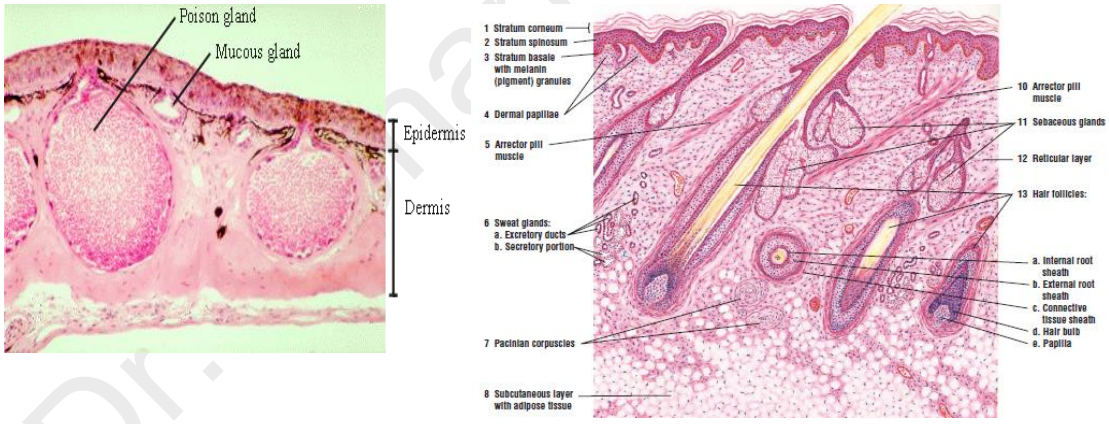
3- Branched tubular, for example: gastric gland.



b- Acinus: it can be either:

1- Unbranched acinus, for example: mucous gland in frog skin.

2- Branched acinus, for example: sebaceous gland in the skin.

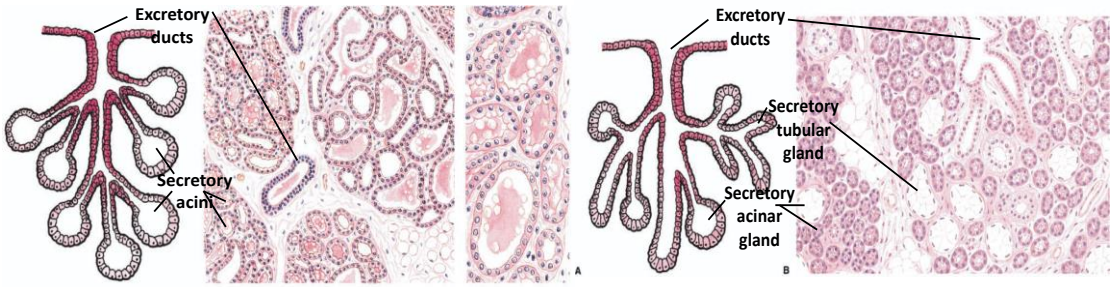


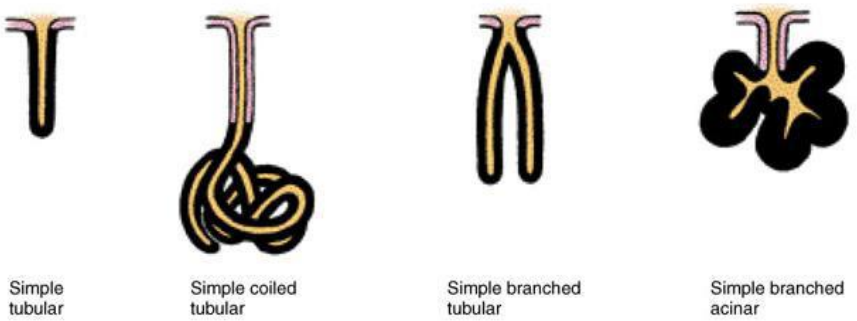
2- Compound multicellular exocrine glands: this type can be divided into:

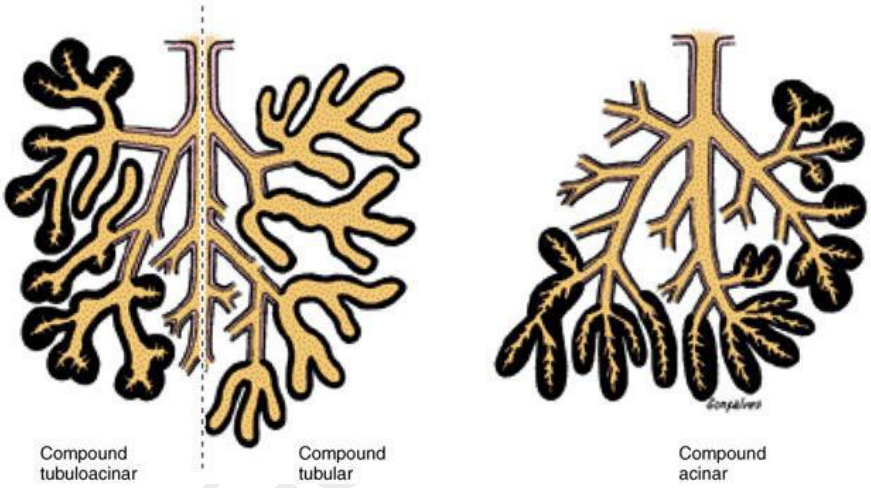
a- Compound tubular gland, for example: kidney and Brunner's glands.

b- Compound acinar gland, for example: mammary gland and pancreas.

c- Tubuloacinar gland, for example: salivary gland.





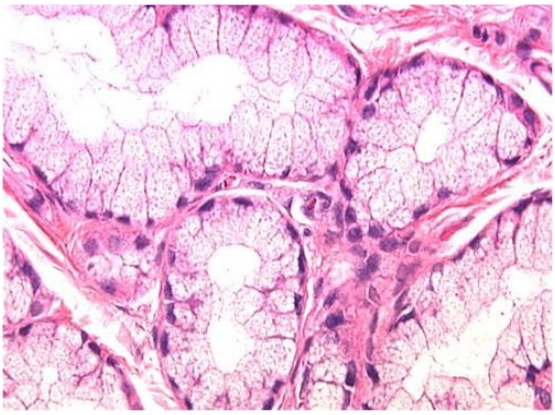


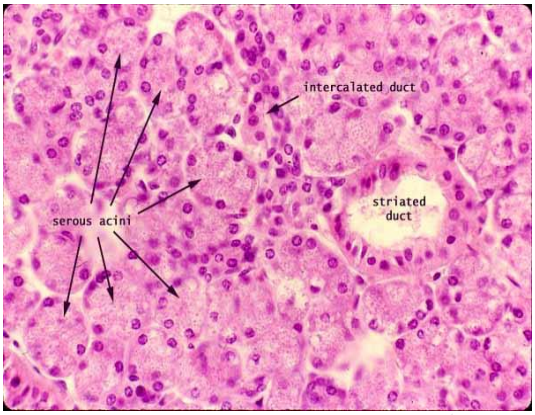
D- The secretory products of their cells. It can be divided into:

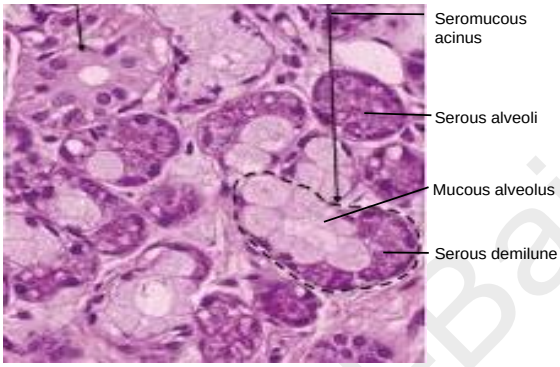
1- Mucous glands: Glands that contain cells that produce a viscous secretion that lubricates or protects the inner lining of the organs (e.g., esophageal gland).

2- Serous glands: Glands with cells that produce watery secretions often rich in enzymes (e.g., parotid gland).

3- Mixed glands: Certain glands in the body contain a mixture of both mucous and serous secretory cells (e.g., sub maxillary gland).





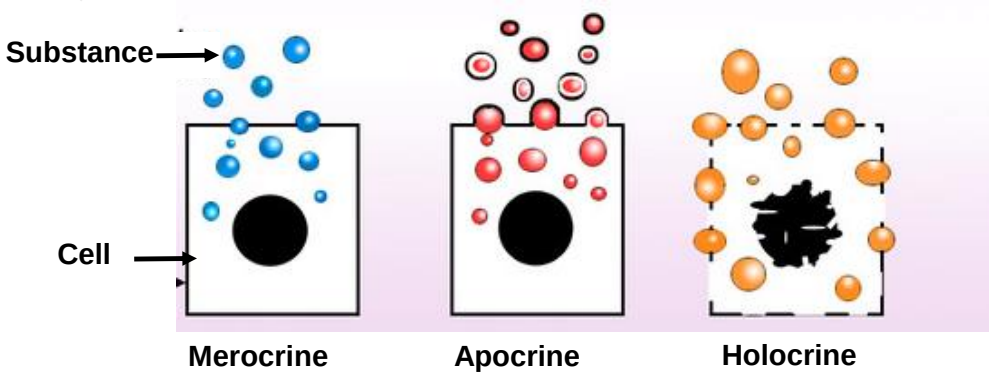


E- The method by which their secretory product is discharged. It can be divided into:

1- Mero glands: release their products by exocytosis without any loss of cellular components, for example: pancreas.

2- Apocrine glands: discharge parts as a secretory product, for example: mammary gland.

3- Holocrine glands: the cells themselves become the secretary products, for example: sebaceous gland.



Connective Tissues

General characteristics of connective tissues

1- Many functions are attributed to connective tissues such as: connect, hold, support and protect other tissues.

2- They are formed of cells, fibers and matrix (intercellular substance).

- ❖ The cells are separated from one another, and have different types and functions.
- ❖ The fibers are collagens, elastic and reticular. These fibers are products of cells and not cells.
- ❖ The matrix is either watery or soft (loose connective tissue), rubbery and firm (cartilage), hard and calcified (bone) or even liquid (blood).

3- The connective tissue may be vascular (loose Conn.T.), highly vascular (bone), or avascular (cartilage).

4- According to the types of cells and physical property of matrix, connective tissues can be classified into:

A- Connective tissue proper, B- Cartilage and C- bone. Blood is also considered as a special type of connective tissue containing cells and fluid matrix but not fibers.

Connective tissue proper

Connective tissue proper forms of many types of cell, fibers, and jellylike ground matrix. It acts as a kind of packing material between other tissues and organs.

A- Cells of connective tissues proper

The cell of connective tissue is assigned to two categories, fixed cells and free cells.

a- The fixed cells

1- They are a relatively stable population of long lived cells.

2- They include, fibroblast, fixed macrophages, adipose cells, mesenchymal cells, pericytes, endothelial cells and reticular cells.

b- The free cells

1- They are a changing population of motile cells that enter the Connective tissue from the blood and wander through its ground substance.

2- Most of these are short lived.

3- They include free macrophage, plasma cells, mast cells, pigment cells and leukocytes.

Cell types of the connective tissues

Fibroblasts

1- Is an elongated cell with cytoplasmic projections, an ovoid nucleus with sparse chromatin, and one or two nucleoli.

2- Produce fibers and ground substances that form the matrix of the tissue.

3- They found in the periodontal ligament.

4- The fibrocyte is a more mature, smaller spindle-shaped cell without cytoplasmic projections; the nucleus is similar but smaller than that in the fibroblast.

Adipocytes (Fat cells)

1- These cells exhibit a narrow rim of cytoplasm and a flattened, eccentric nuclei.

2- Store fat (lipid) and provide protective packing material in and around numerous organs.

3- It can be found isolated or in groups.

4- There are two types of adipose cells:

a- White adipose cell. b- Brown adipose cell.

5- In histologic sections, the large fat globules of adipose cells have been dissolved by different chemicals, leaving a large empty space.

Macrophages

1- Most numerous in loose connective tissue.

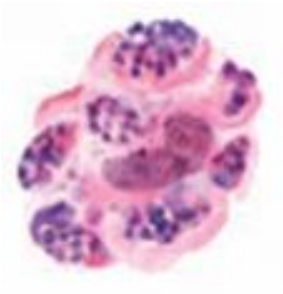
2- Have irregular surface with an eccentrically located, oval or kidney shaped nucleus.

3- Ingest bacteria, dead cells, cell debris, and foreign matter.

4- Are antigen-presenting cells to lymphocytes for immunologic response.

5- Derived from circulating blood monocytes.

6- Called Kupffer cells in liver, osteoclasts in bone, and microglia in central nervous system.



Lymphocytes

1- Most numerous in loose connective tissue of respiratory and gastrointestinal tracts.

2- The large lymphocyte and small lymphocyte are spherical cells that differ primarily in the greater amount of cytoplasm that is present in the large lymphocyte.

3- The dense staining nuclei of all lymphocytes have condensed chromatin but no nucleoli.

4- Produce antibodies and kill virus-infected cells.

Small lymphocyte

Large lymphocyte

Plasma Cells

1- Characterized by chromatin distributed in a radial pattern (clock face).

2- The large, ovoid cells with spherical eccentrically nuclei location.

3- Derived from lymphocytes exposed to antigens.

4- Produce antibodies to destroy specific antigens.

5- Plasma cells are only seen in the walls of the intestines and in inflamed tissue.

Mast Cells

1- Closely associated with blood vessel.

2- Found in skin, respiratory, and digestive system C.T.

3- Are oval or irregularly shaped cells with centrally located nuclei.

4- The cytoplasm is filled with regular basophilic secretory granules.

5- Synthesize and release histamine when exposed to allergens, causing allergic reactions.

6- Release heparin that acts locally as an anti-coagulant.

Neutrophils

1- A type of granulo-leukocytes that have ability to stain by neutral dyes.

2- The cytoplasm contains granules stain pink or purple-blue.

3- The nucleus consists of two to five lobes joined together by hairlike filaments.

4- Active phagocytes; engulf and destroy bacteria.

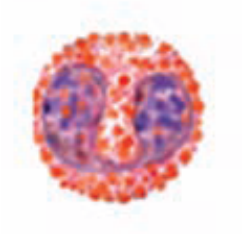
Eosinophils

1- Increase after parasitic infestation.

2- Polymorphonuclear leukocyte characterized by many large cytoplasmic granules that are uniform in size and orange when treated with eosin stain.

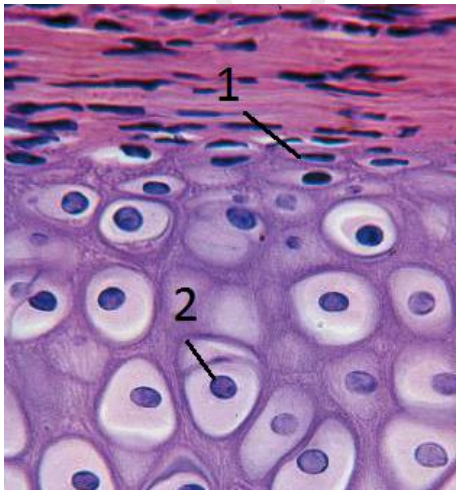
3- The nuclei are usually larger than those of neutrophils and have two lobes.

4- Phagocytize antigen–antibody complexes during allergic reactions.



Chondroblast and chondrocytes

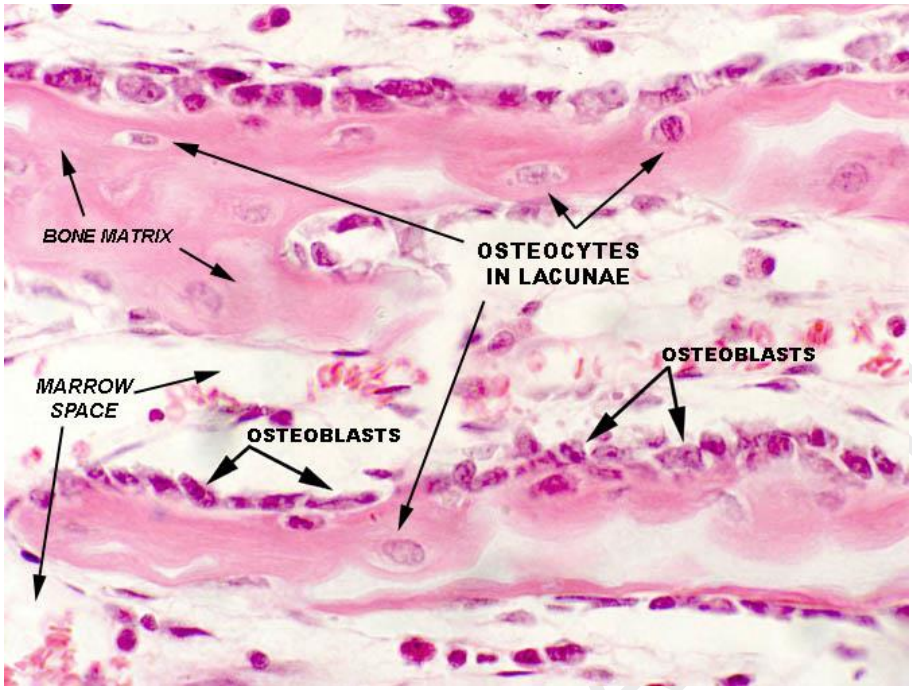
These are a matrix secreting cell of cartilage.



1- Chondroblast
2- Chondrocytes

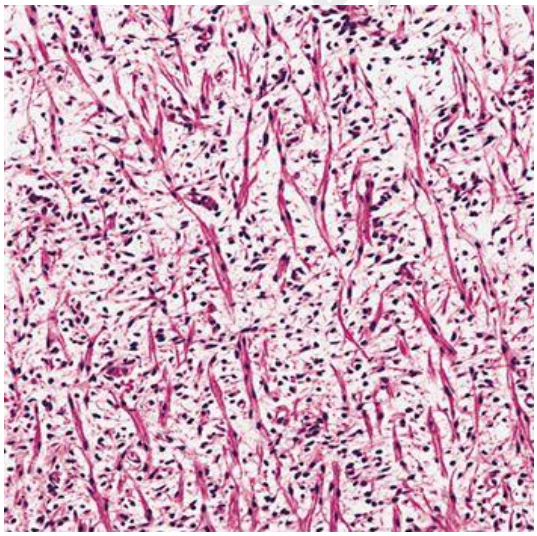
Osteoblasts and osteocytes

These are a matrix secreting cell of bone.



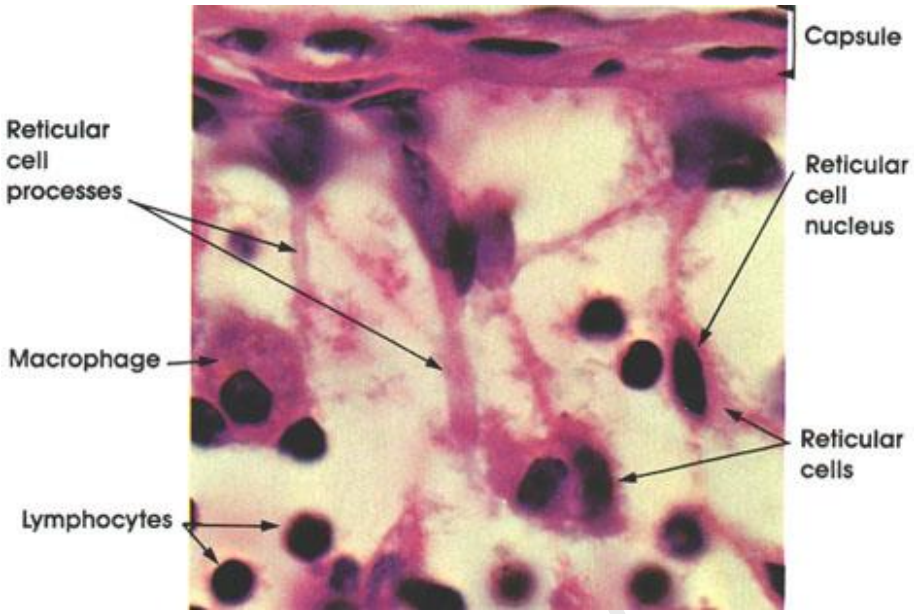
Undifferentiated mesenchyme cells

These are cells that retain the multiple potentials of embryonic mesenchyme cells.



Reticular cells

These are specialized fibroblasts, they are dispersed along the framework of the reticular fibers and ground substance with their cytoplasmic processes. (lymph node)



Melanocytes (pigment cells)

Is melanin-producing cells located in the bottom layer (the stratum basal) of the skin's epidermis.

B- Fibers of connective tissue proper (extracellular fibers)

There are three types of fibers: 1- White (collagen) fiber. 2- Yellow (elastic) fiber. 3- Reticular fibers. Each type of fiber is formed by proteins made of long peptide chains.

Types	Characters	Component	Location
White (collagen) fibers	They are seen as wavy bundles of various thickness.	Alpha polypeptide chain	Tendon, ligament, skin, cornea, cartilage, bone, blood vessel, gut, and intervertebral disc.
Yellow (elastic) fiber.	These are usually single thin and branched. They can be stretched.	Elastic micro fibril and elastin	Elastic ligaments, some cartilage (elastic cartilage) and large arteries (elastic arteries).
Reticular fibers	They are arranged in a mesh-like pattern form a delicate supporting network around cells.	Type III collagen	Liver, bone marrow, lymphatic organs.

C- Ground matrix of connective tissue proper

1- The ground substance is found between the different types of cells and fibers.

2- It allows the diffusion of tissue fluid, nutrients and waste products, between blood and lymphatic capillaries and the cells.

3- The ground substance is formed of acid mucopolysaccharide.

4- Fibroblasts are responsible for the formation of this matrix.

Classification of connective tissues

A- Embryonic connective tissues.

1- Mesenchymal connective tissues.

2- Mucous connective tissues.

B- Connective tissue proper.

According to the density of ground substance and to the main cells and fibers found, connective tissue proper is classified into:

1- Loose connective tissue.

a- Areolar connective tissue.

b- Reticular connective tissues.

c- Adipose connective tissues.

2- Dense connective tissue.

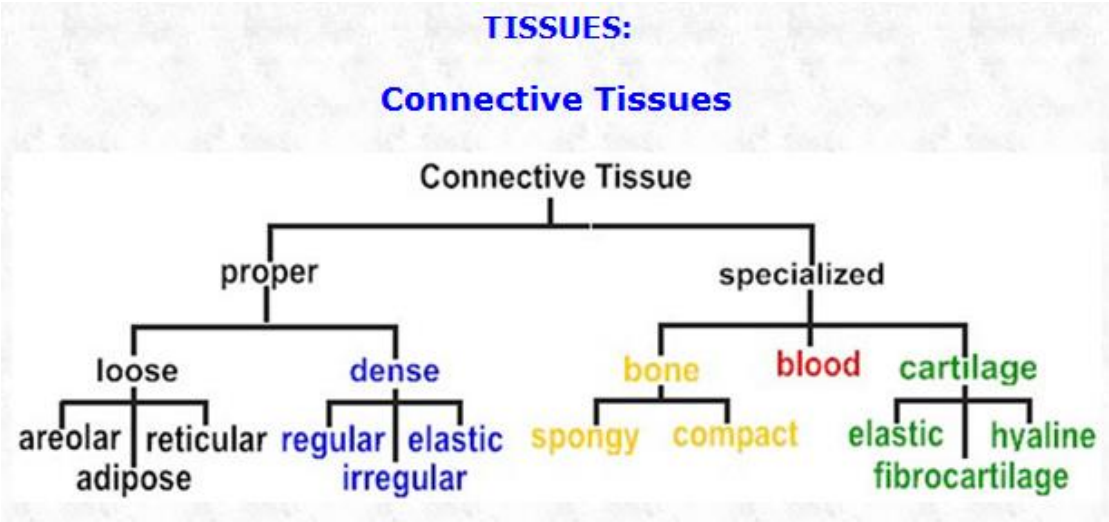
a- Dense irregular connective tissues.

b- Dense regular connective tissues.

1- Collagenous. 2- Elastic.

C- Specialized connective tissues.

1- Cartilage. 2- Bone. 3- Blood. 4- Hemopoietic.



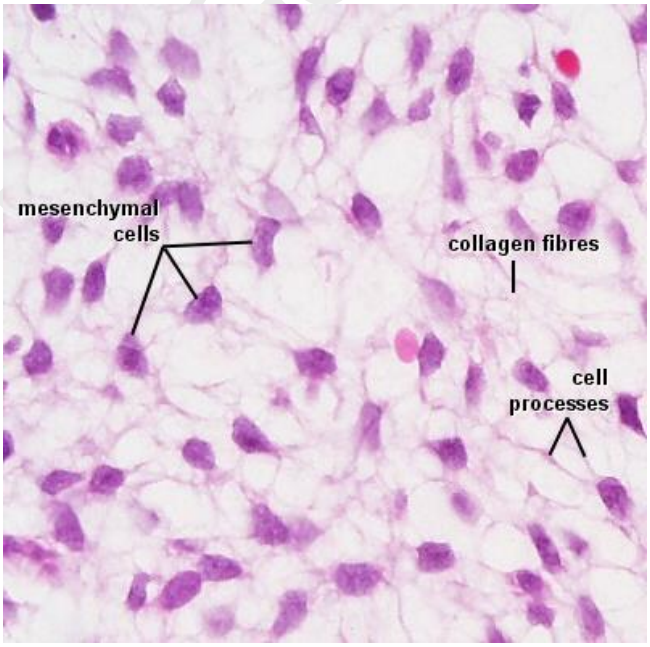
A- Embryonic connective tissues.

1. Mesenchymal connective tissues

1- It is present only in the embryo.

2- It consists of undifferentiated mesenchymal cells in a gel-like, amorphous ground substance containing scattered reticular fibers.

3- It has an oval nucleus showing a fine chromatin network and prominent nucleoli.

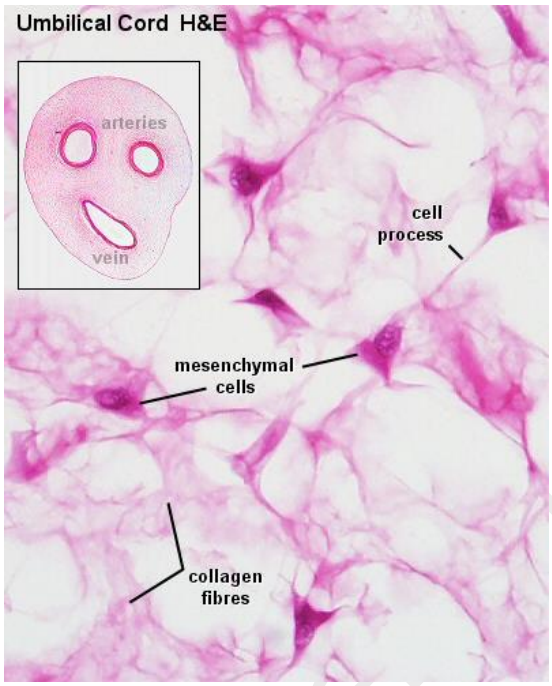


2. Mucous connective tissues

1- It is a loose, amorphous connective tissues showing a jelly-like matrix.

2- It is formed of stellate fibroblasts, abundant ground substance and fine collagenous fibers.

3- It is found only in the umbilical cord.



Loose connective tissues (areolar)

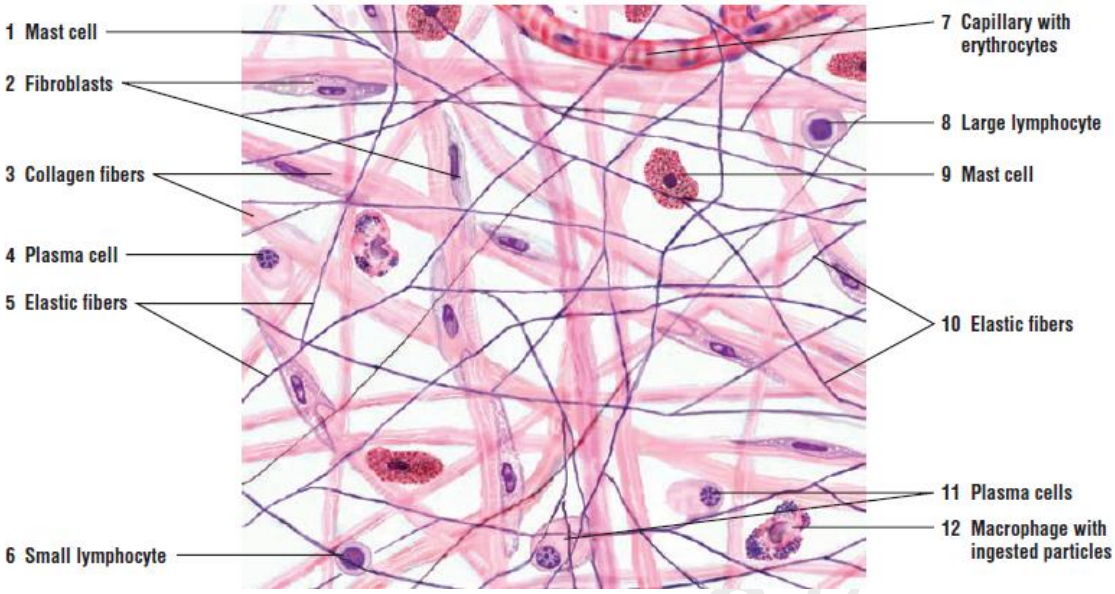
1- It is the packing and anchoring material and the embedding medium of many structures, including nerves and blood as well as lymphatic vessels.

2- It binds other tissues, organ components, and organs together.

3- It consists of a mesh-work of collagen, elastic, and reticular fibers.

4- Fibroblast, plasma cells, adipocytes, mast cells and macrophages are embedded within the areolar connective tissue.

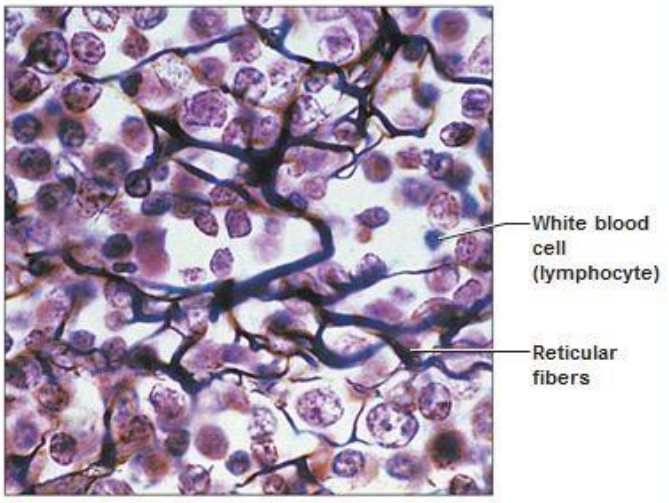
5- It is found in the papillary layer of the dermis and in the hypodermis.



Reticular connective tissues

1- It is a primitive type of connective tissue that is characterized by the presence of a network of reticular fibers associated with primitive reticular cells (mesenchymal like cells).

2- It is form the framework of solid organs e.g., lymphoid organs, bone marrow and liver.

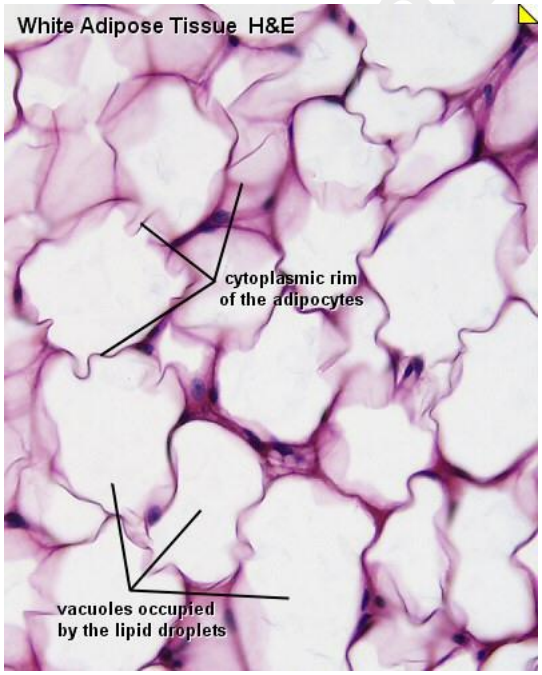


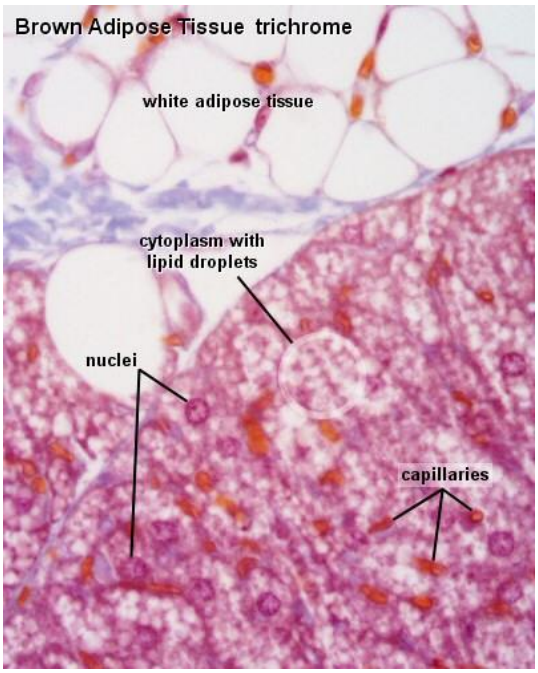
Adipose connective tissues

1- According to the vascularity and the function, there are two types of adipose connective, white and brown.

2- White adipose connective tissue A- represents the primary site of fat metabolism and storage in the body. B- Is composed of unilocular fat cells. C- This tissue has a rich blood supply. D- It is found in the subcutaneous layers throughout the body.

3- Brown adipose connective tissue A- plays an important role to provide heat. B- It is present in small amount in adult and in large amount in fetuses and neonates and then it is gradually replaced by white fat. C- The tissue appears reddish brown because of its abundant mitochondria and large numbers of blood capillaries. D- It is composed of multilocular fat cells.





Dense connective tissue

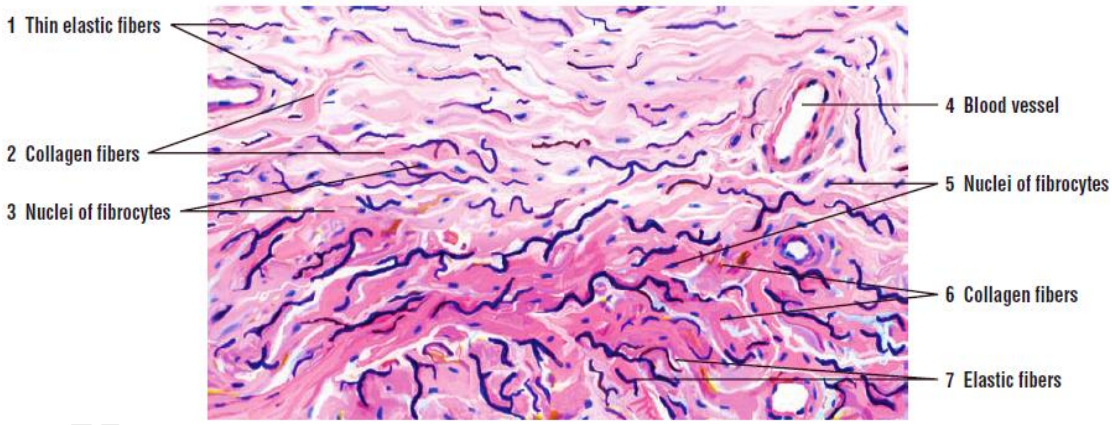
Dense connective tissue is characterized by

1- The close packing of their fibers, few cells (fibroblasts and fibrocytes) and only small amount of intercellular material.

2- There are two types of dense Connective tissue:

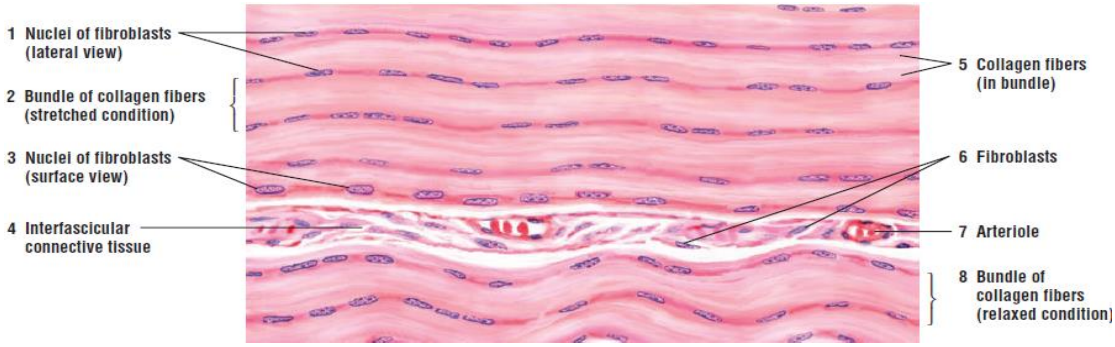
A- Dense Irregular Connective Tissue

- ❖ Consists primarily of fibroblasts, and thick and densely packed collagen fibers.
- ❖ Fewer other cell types and minimal ground substance.
- ❖ Collagen fibers exhibit random orientation and provide strong tissue support.
- ❖ Concentrated in areas where resistance to forces from different directions are needed. (e.g., dermis of skin, in capsules of different organs, and in areas that need strong support).



B- Dense Regular Connective Tissue

- Fibers densely packed with regular, parallel orientation.
- Present in tendons and ligaments that are attached to bones.
- Great resistance to forces pulling along a single axis or direction.
- Minimal ground substance; predominant cell is the fibroblast.



2- According to the type of fibers, dense regular connective tissue can be divided into: A- White collagenous connective tissue. B- Yellow elastic connective tissue.

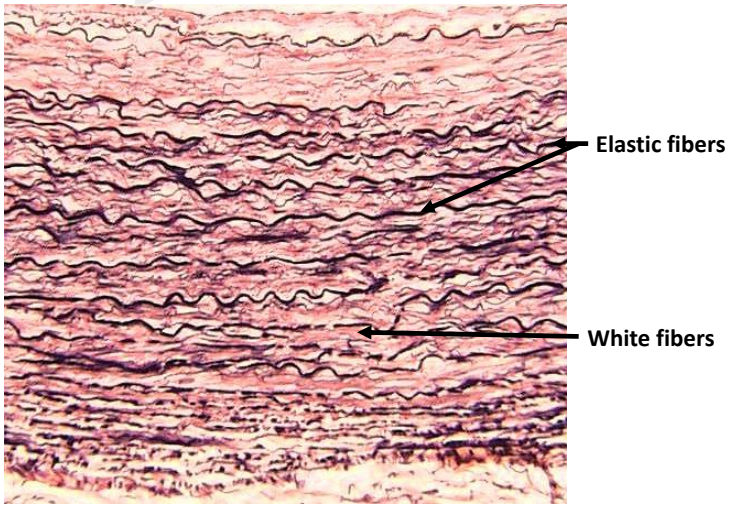
3- Both of these types can be arranged in two ways –

A: cord arrangement B: sheet arrangement.

4- In cord arrangement, bundles of collagen and matrix are distributed in regular alternate patterns.

5- In sheet arrangement, collagen bundles and the matrix are distributed in irregular patterns, sometimes it is found in the form of a network.

6- It is similar to areolar tissue but in areolar tissue, elastic fibers are completely absent.



C- Specialized connective tissue

1- Cartilages

- ❖ Cartilage is a specialized connective tissue in which intercellular substance is hardened to provide rigidity, support and attachment for the tissues.
- ❖ The cartilage is firm, flexible and strong connective tissue.
- ❖ The cartilage is formed of a- cells, b- fibers c- intercellular substance (matrix).

a- Cells

1- Chondroblasts

- They are cartilage forming cells.

2- Chondrocytes

- They are embedded in the matrix inside space called lacunae.
- They are responsible for the formation of collagen fibers and the protein of cartilage matrix.

b- Fibers

- The collagen and elastic fibers could be found in the ground substance of cartilage.

c- Ground substance (matrix)

- The intercellular substance produce by cartilage cells (chondroblasts and chondrocytes).

Types of cartilage

According to the type of fibers embedded in the matrix, cartilage is classified into:

A- Hyaline cartilage

1- The most common type of cartilage.

2- This type of cartilage is covered by a dense connective tissue called perichondrium.

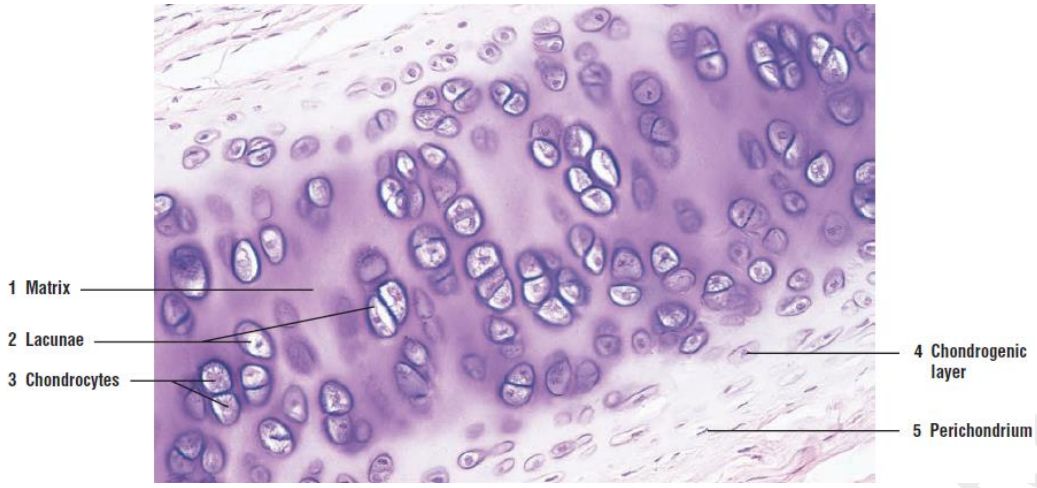
3- The chondrocytes are seen in clusters.

4- It has two layers, an outer white collagen (fibrous layer) and an inner layer of chondroblast (chondrogenic layer).

5- The matrix contains both collagen and elastic fibers.

6- Function and sites:

- Development of bones.
- Growth of bones.
- Articulation of bones.
- Maintains airways in respiratory passages.
- Is found in trachea.



B- Elastic cartilage

1- Elastic cartilage is covered by perichondrium.

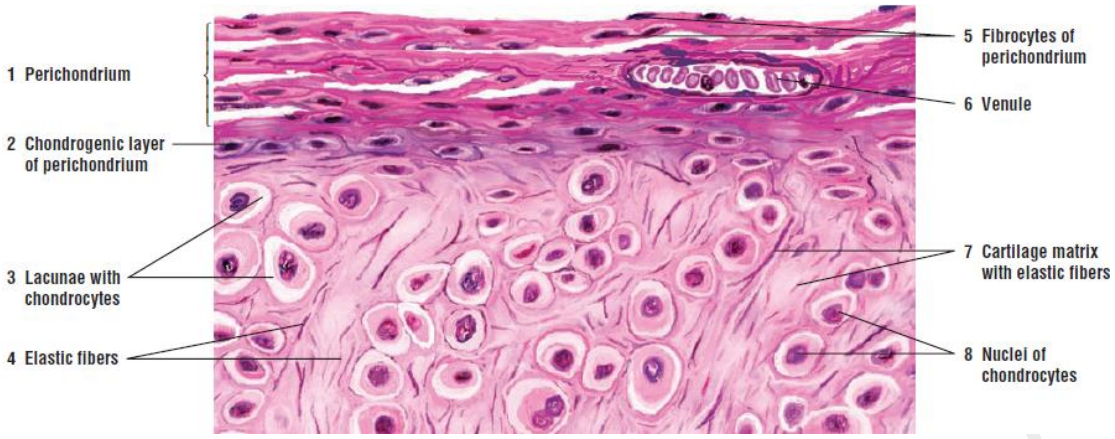
2- It has two layers, an outer white collagen fibrous vascular layer and an inner cellular layer of chondroblasts.

3- Matrix has many elastic fibers and few collagen type II fibers embedded in a small amount of intercellular matrix.

4- Chondrocytes are located inside lacunae and form cell nests.

5- Function and sites

- Provide support to surrounding structures and helps the define and maintain the shape of the area in which it is present.
- It is found in the a- external ear (pinna). b- Autitory (Eustachian tube). c- Epiglottis. d- Some cartilages of larynx (where recoil is needed).



C- White Fibro cartilage

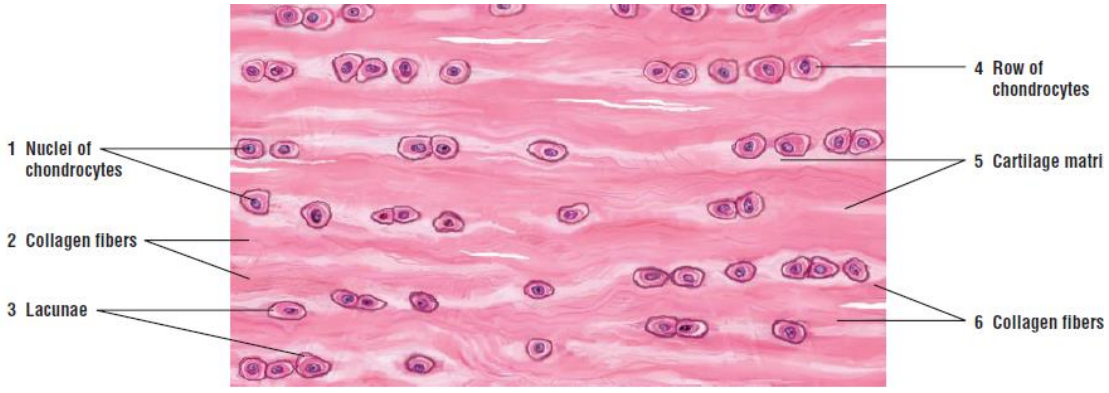
1- There is no perichondrium in collagenous fibrocartilage.

2- The intercellular matrix is full of parallel dense collagen fibers.

3- They appear in a regular bundles chondrocytes inside lacunae which are seen as rows between collagen fibers.

4- Function and sites

- ❖ It attaches bone to bone and provides restricted mobility under great mechanical stress.
- ❖ It is found in intervertebral discs and pubic symphysis.



2- Bone

- Bone is a strong, hard and rigid specialized form of connective tissue.
- It is formed of matrix (ground substance and fibers) and cells.
- In most areas bone is covered by periosteum (outer surface) and lined by endosteum (inner surface).
- There are two different types of bone structure: a- Compact bone. b- Spongy or cancellous bone.

Matrix of bone

- The matrix is consist closely packed layers or lamellae of classified collagen fibers embedded in intercellular substance rich in proteins and carbohydrate.
- Bone matrix consist of:

  a- Organic components or osteoid (35% of bone dry weight)
  It is composed of collagen fibers, protein and carbohydrates

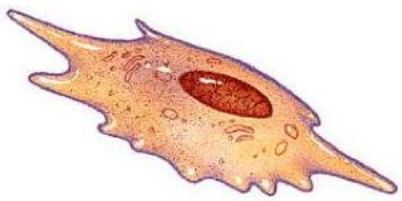
  b- Inorganic components or bone minerals (65% of bone dry weight).
  It is formed mainly of calcium phosphate, which is the cause of hardness of bone.

- Bone matrix is formed and produced by osteoblast and maintained by osteocytes.

Bone cells

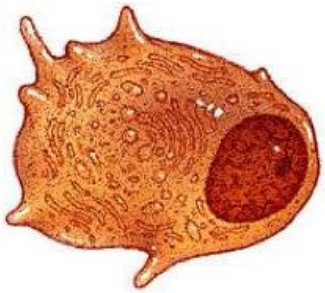
1- Osteogenic cells

- ❖ They are small oval or elongated in shape with pale cytoplasm and oval nuclei.
- ❖ Osteogenic or osteoprogenitor cells are mesenchymal stem cells found in the periosteum and endosteum.
- ❖ These cells are the only cell of the bone that can divide.
- ❖ These cells are most active during the growth of bones but are reactivated in adult life in the repair of bone fractures.
- ❖ They have a capacity for mitosis and further differentiation.



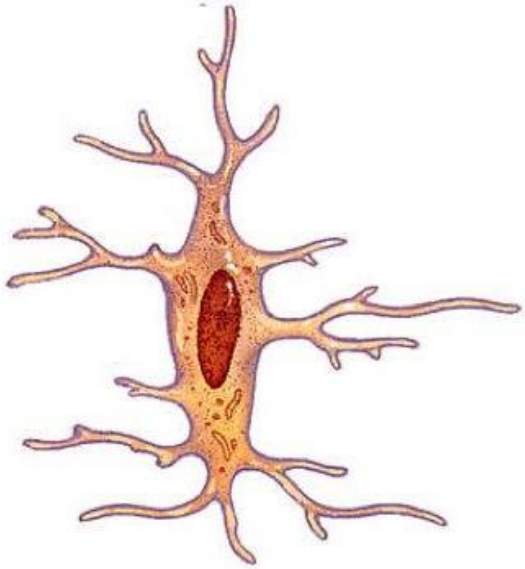
2- Osteoblasts:

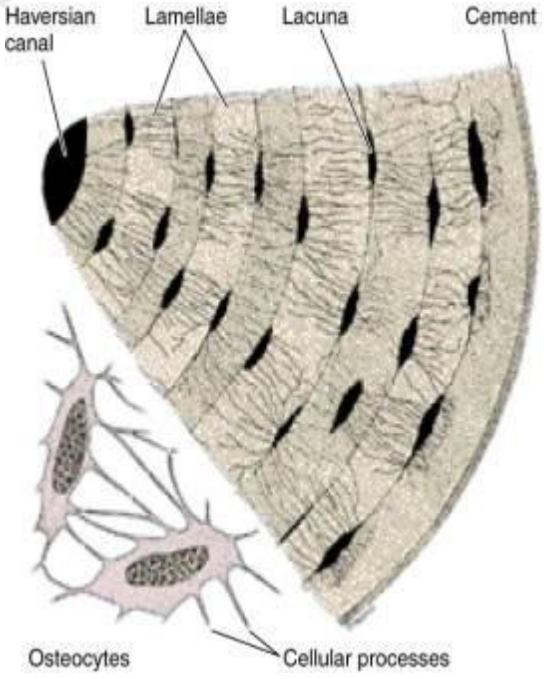
- ❖ They are large rounded branched cells, with deep basophilic cytoplasm, and eccentric nucleus.
- ❖ They are found in the periosteum and endosteum
- ❖ They are dividing cells that synthesize the organic components of bone matrix.
- ❖ They are bone forming cells, found in the growing surface of the bone.
- ❖ The osteoblasts secret alkaline phosphate which stimulates deposition of calcium salts in the matrix and around the cells and their processes.



3- Osteocytes

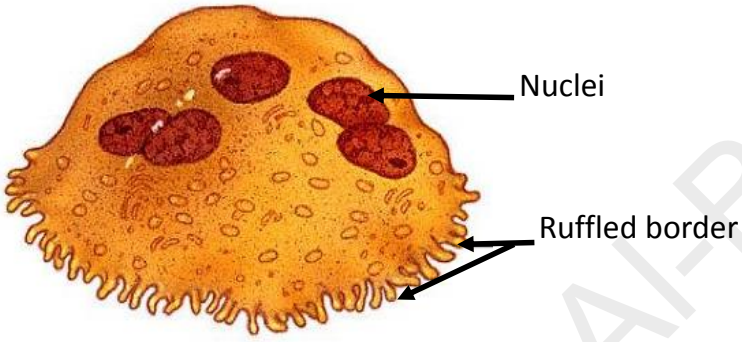
- The cells are branched, smaller than osteoblasts, and not divide.
- Osteocytes occupy small cavities called lacunae, and their processes (branches) extend into canaliculi in the hard matrix.
- When osteoblasts embedded in hard matrix (calcified matrix) they are called osteocytes.
- They are the principal cells of mature bone.
- They maintain bone matrix by sharing in the formation of the organic part of bone matrix, e.g., collagen fibers.





4- Osteoclasts

- Osteoclasts are large multinucleated cells (~ 50 nuclei), with acidophilic cytoplasm, and brush border (Ruffled border) facing the bone marrow.
- They are located in bony surfaces in shallow depression called HOWSHIP`S lacunae near bone marrow cavities.
- They are bone eating cells (Resorption).



Anatomical classification of bone

1- Long bones

- They are found in the limb**s.**
- Each has two ends or "epiphyses" and shaft or "diaphyses" and "metaphyses" in between.

2- Irregular bones

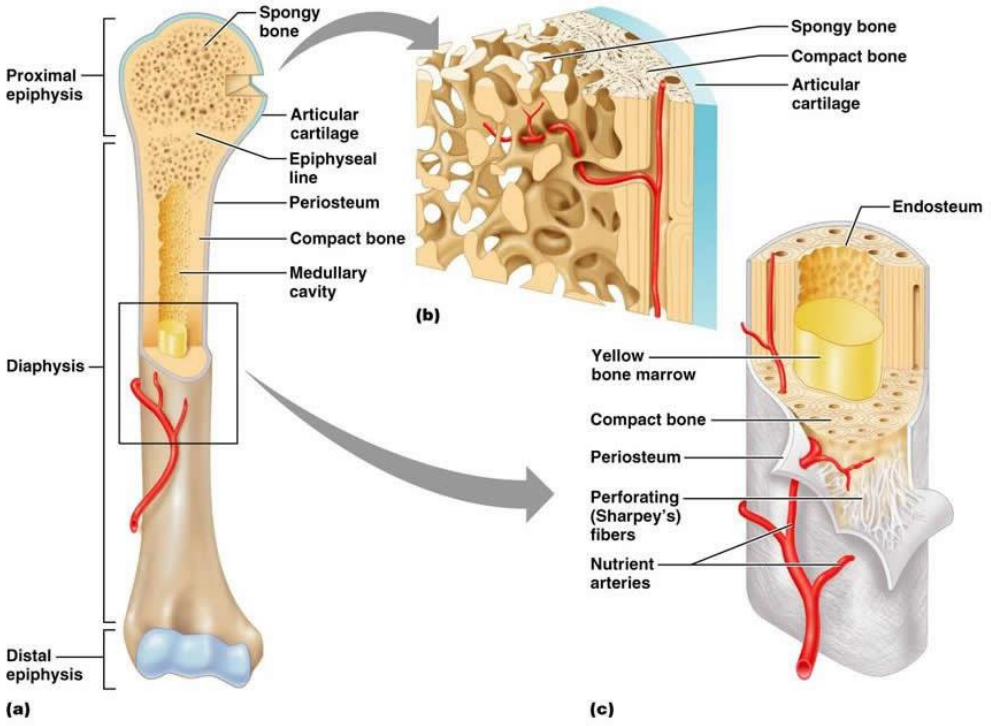
- They are found in the vertebrae.

3- Flat bones

- They are found in the skull and pelvis.

Histological classification of bone

According to the arrangement of bone lamellae, bone can be classified into **compact bone** in which lamellae are regularly arranged and **spongy bone** in which lamellae are irregularly arranged.



Compact bone

- Compact bone is a solid mass, found mainly in the shaft of long bones.
- Bone lamellae are regularly arranged.
- Periosteum covers the shaft of long bone, and formed of two layers:-
  - a- An outer fibrous layer of collagen fibers. Fibroblast, fibrocytes and blood capillaries are found in this layer.
  - b- An inner cellular layer of osteogenic cells and osteoblasts.
- Endosteum: a cellular layer lining the bone cavities, and formed of osteogenic cells and osteoblasts.

- Haversian system (osteon)

  1- Bone lamellae are arranged concentrically around the blood vessels.

  2- The bone lamellae are formed of osteocytes inside lacunae and canaliculi embedded in calcified matrix.

  3- Each Haversian system consist of 5-20 lamellae that surround the central canal in which blood vessels and nerves are running longitudinally

- Volkmann`s Canals

  They are transverse canals connecting blood vessels in the Haversian canals to each other and to those in the periosteum and in marrow cavities.

- External circumferential lamellae

  They are the bone lamellae which close to the periosteum surrounding the outer surface of the shaft of long bone.

- Internal circumferential lamellae

  They are the bone lamellae close to endosteum in the inner surface of bone toward bone marrow cavity.

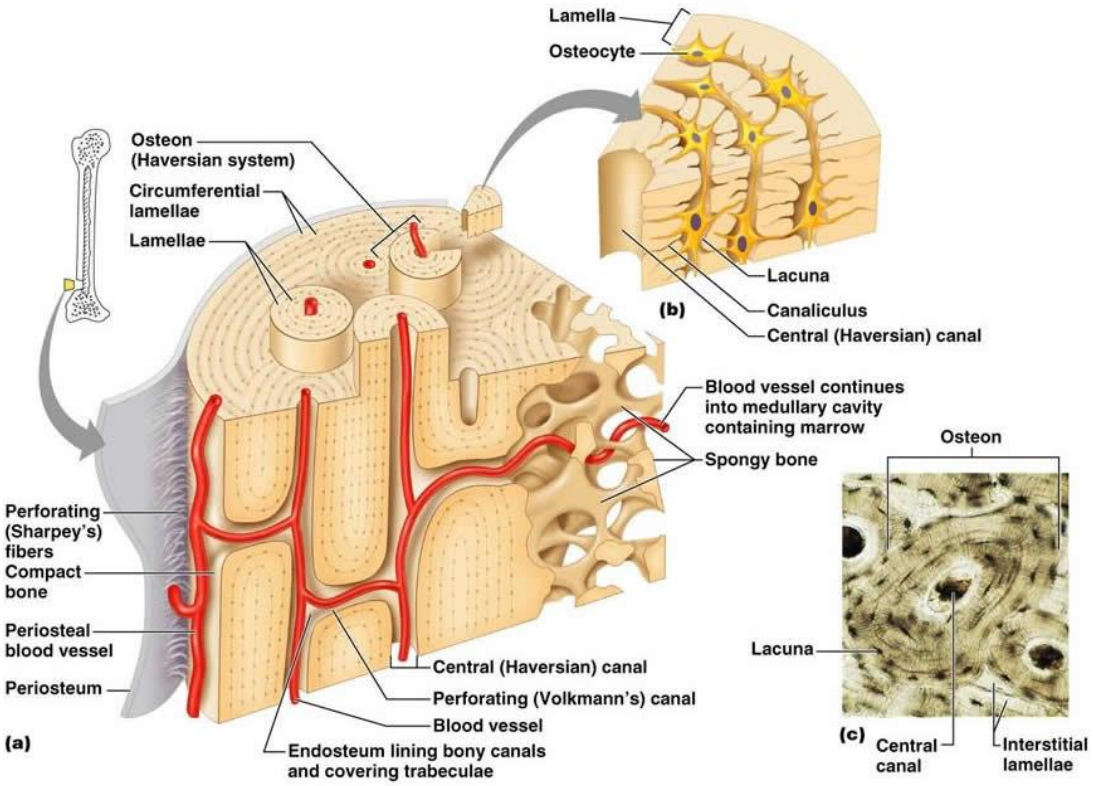
- Interstitial lamellae

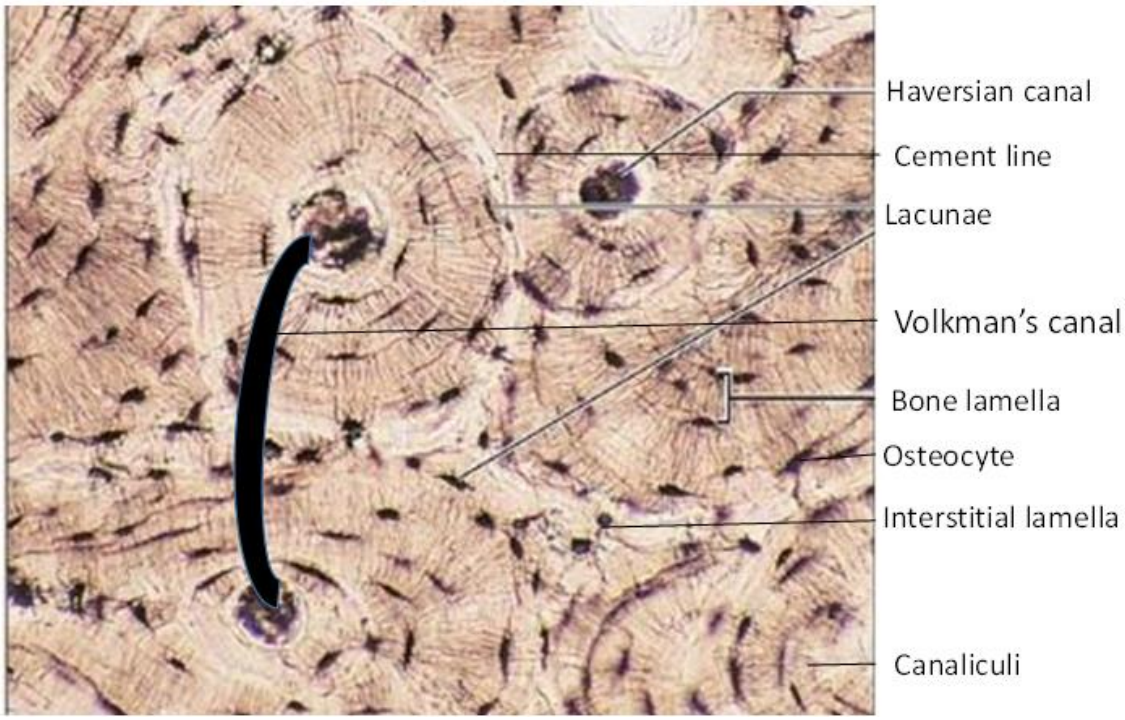
  The irregular bone lamellae in-between Haversian system.

- Sharpey’s fibers

  1- They are penetrating collagen fibers from outer layer of periosteum to Haversian systems.

  2- They are found at the sites of attachment of tendons and ligaments.

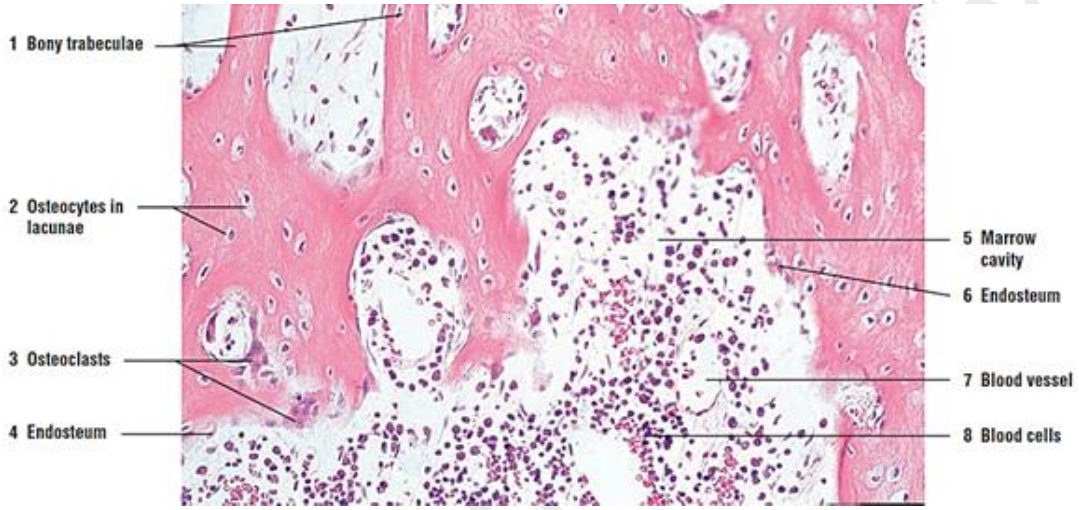




T.S. Compact bone

Spongy or cancellous bone

- There are no Haversian systems.
- It is made up of branching trabeculae, each of which is composed of irregularly arranged lamellae.
- It is found at the ends of long bones and in the center of flat and irregular bones.



Blood

Is considered as a special type of connective tissue because it develop from embryonic mesenchymal cells.

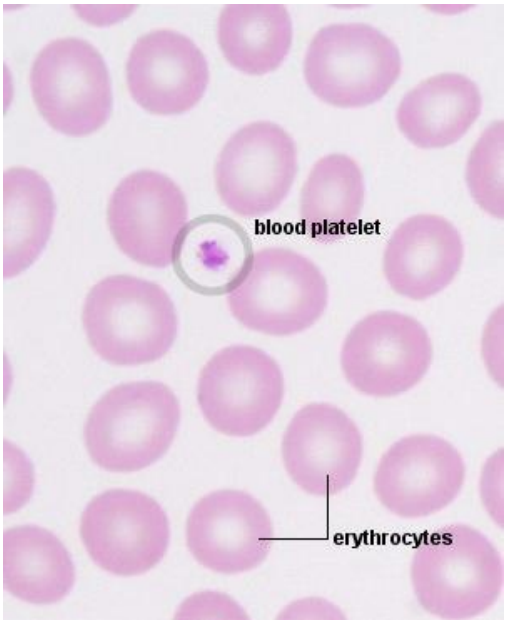
Major components and functions of blood

- The blood is composed of blood elements or cells suspended in a fluid matrix called plasma. The volume of blood in healthy adult human is about 5 liters.
- The cellular element composed of 1- Erythrocytes (red blood corpuscles). 2- Leucocytes (white blood cells). 3- Platelets or thrombocytes.

- Plasma is a viscous, translucent, and yellowish fluid composed of: 1- Water (90%). 2- Proteins (7%). 3- Organic salts (1%). 4- Organic compound (2%) such as amino acids, lipids, and vitamins.
- The ratio of erythrocytes to the total blood volume is about 43% and known as hematocrit.
- Blood functions involved:
  1- Transport of oxygen, carbon dioxide and hormones.
  2- Maintenance of acid-base balance.
  3- Removal of waste products of cell metabolism.
  4- Temperature control of the body.
  5- Defense against infection.

Erythrocytes or red blood corpuscles (RBCs)

- In the normal male the average number of (RBC) is about 5-6 million/cubic millimeter, in the female it is about 4.5-5 million/cubic millimeter.
- The life span of RBCs is 4 months.
- Mature RBCs are flexible and oval biconcave disks.
- They lack a cell nucleus and most organelles, in order to accommodate maximum space for hemoglobin.
- Erythrocytes function involved:
  1- Transport oxygen from the lungs to the tissues.
  2- Transport carbon dioxide from the tissue to the lung.



Leukocytes or white blood cell (WBC)

- Leukocytes are colorless because they do not have hemoglobin, however, each cell has a nucleus.
- In the blood stream leukocytes are spherical in shape and capable of amoeboid movement.
- According to the type of cytoplasmic granules and the shape of nuclei leukocytes are classified into:

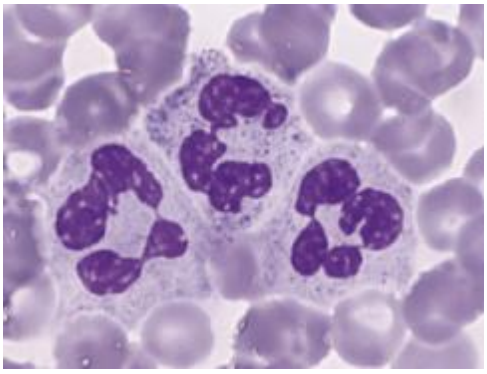
A- Granular leukocytes

They contain specific granules and lobulated nuclei. This type of leukocytes involved:

1- Neutrophils

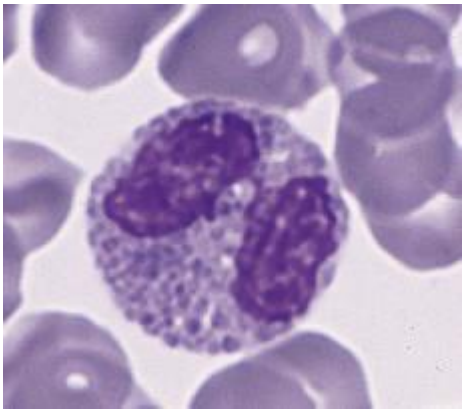
- Compose 60 to 70% of the blood leukocytes.
- Nuclei have 3-5 lobes, which are connected together by thin strands of chromatin.
- Barr body is a drumstick chromosome or condensed chromatin visible in Neutrophils contain all the organelles that make up a typical cell.

- The neutrophil cytoplasm contains fine violet or pink granules that are difficult to see with a light microscope. As a result, the cytoplasm appears clear or neutral.
- First line of cellular defense against microorganisms, especially bacteria. Phagocytose small particles and microorganisms.



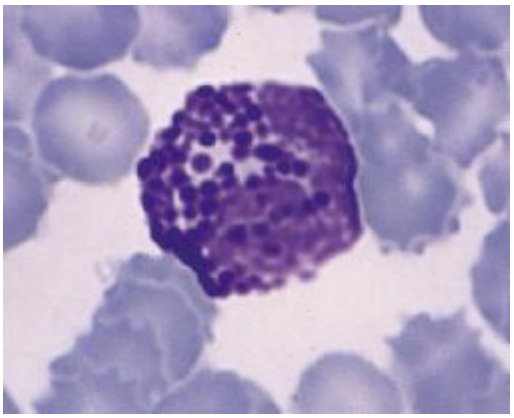
2- Eosinophils

- Compose 2 to 4% of the blood leukocytes.
- Eosinophils are identified in a blood smear by their cytoplasm, which is filled with distinct, large, eosinophilic (bright pink) granules.
- The nucleus in eosinophils typically is bi-lobed, but a small third lobe may be present.
- The cytoplasm granules are stained red or pink with eosin or other similar dyes.
- Recognize and phagocytose antigen-antibody complexes and particles that are associated with these complexes that are formed during an immune response.



3- Basophils

- The basophils constitute less than 1% of the blood leukocytes and are therefore the most difficult to find and identify in a blood smear.
- The nucleus is irregular which hidden by the large cytoplasmic granules.
- The granules in basophils are not as numerous as in eosinophils; however, they are more variable in size, less densely packed, and stain dark blue or brown.
- These cell carry histamine, heparin, and various mediators of inflammation and other protein chemicals.
- It is appear as a site of ectoparasite infection, or allergies.

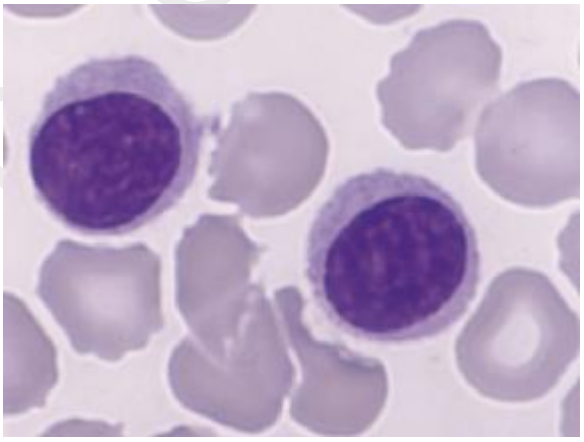


B- Non granular leukocytes

They do not have a specific granule with non-lobulated nuclei. This type can be sub divided into:

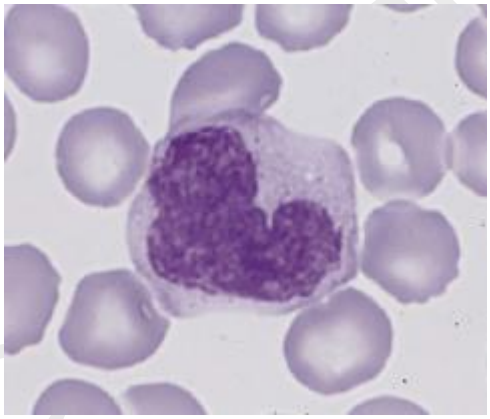
1- Lymphocytes

- Lymphocytes represent 20 to 40% of the differential white cell count.
- There are two structural types:
  - a- Small lymphocytes: ~5μm in diameter, and represent 3% of lymphocytes in peripheral blood. Most small lymphocytes in the blood stream belong to either the group of B-lymphocytes (~5%) or the group of T-lymphocytes (~90%).
  - b- Large lymphocytes: 9 to 15μm in diameter, possibly natural killer cells; possibly dividing lymphocytes
- The cell is rounded with densely stained nucleus, small amount of pale basophilic cytoplasm with free ribosomes; short microivilli (seen in EM) more numerous on B lymphocytes than T lymphocytes.
- Only blood lymphocyte capable of division outside of bone marrow.



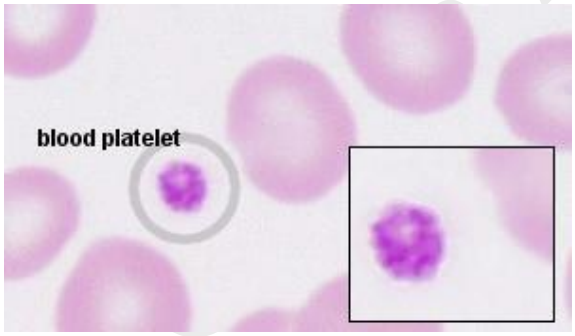
2- Monocytes

- ❖ Monocytes are large cells, 12-18 μm in diameter; represent 2 to 10 % of the differential white cell count.
- ❖ Monocytes are highly motile and phagocytic cells; i.e. they are the precursor of tissue phagocytes that migrate into tissues; engulf and destroy tissue debris & foreign material.
- ❖ Their nucleus less dense than lymphocytes; deeply indented, C-shaped or kidney shaped.
- ❖ Their cytoplasm is pale grayish blue with small pink to purple stained lysosomal granules, and contain cytoplasmic vacuoles (frosted glass).
- ❖ Monocytes contain granules (visible in the EM) which are similar to the primary granules of neutrophils, i.e. Lysosomes containing acid phosphatase, aryl granules.
- ❖ They contain also secondary granules of unknown function.



Blood platelets or thrombocytes

- ❖ Platelets or thrombocytes are small fragments of cytoplasm measuring about 2-5 µm in diameter.
- ❖ Blood platelets do not contain nucleus, they are cytoplasmic fragments of very large thrombocyte (megakaryocytes) that are found in the bone marrow.
- ❖ Their number is 150,000 - 400,000/mm3.
- ❖ They are rounded or oval, biconvex discs.
- ❖ The cytoplasm is divided into two zones: an outer hyalomere, and an inner granulomere, which contains bluish staining granules.
- ❖ The hyalomere contains cytoskeletal fibres, which include actin and myosin.
- ❖ Their cytoplasm is purple-staining, granular; organelles concentrated toward center; granules constitute about 20% volume.



Bone marrow

- ❖ Bone marrow compose 5% of the total body weight.
- ❖ It is responsible for the formation of blood cells (hemopoiesis) and store fat.
- ❖ There are two types of bone marrow based on their appearance at gross examination:

  1- Red bone marrow. 2- yellow bone marrow.

- From birth to early puberty, the majority of the bone marrow is red marrow.
- As a person grows and matures, increasing amounts of red marrow is replaced by yellow marrow.
- Bone marrow is separated into a vascular section and non-vascular sections.
- The vascular section contains blood vessels that supply the bone with nutrients and transport blood stem cells and mature blood cells away from the bone and into circulation.
- The non-vascular sections of the bone marrow are where **hematopoiesis** or blood cell formation occurs. This area contains immature blood cells, fat cells, white blood cells (macrophages and plasma cells), and thin, branching fibers of reticular connective tissue.
- While all blood cells are derived from bone marrow, some white blood cells mature in other organs such as the spleen, lymph nodes, and thymus gland.

The difference between red and yellow bone marrow

Red bone marrow	Yellow bone marrow
Present from birth to early puberty stages	Present in grow and mature stages
It has a red coloured active in the formation of blood cells	It is a yellow coloured inactive in the formation of blood cells
Contain large number of blood vessels and less amount of adipose cells	Contain less number of blood vessels and large amount of adipose cells
Can be found in flat bones such as skull	Can be found inside the hollow of long bone such as arms and legs.

Steps of the formation of erythrocytes (erythropoiesis)

Multipotential hematopoietic stem cell
Large cell, large pale nucleus, prominent nucleoli, basophilic cytoplasm

Common myeloid progenitor
More differentiated cell to form erythrocyte

Proerythroblast
Large cell, large nucleus, prominent nucleolus, basophilic cytoplasm

Basophilic erythroblast
Smaller cell, smaller nucleus, darker chromatin, basophilic cytoplasm

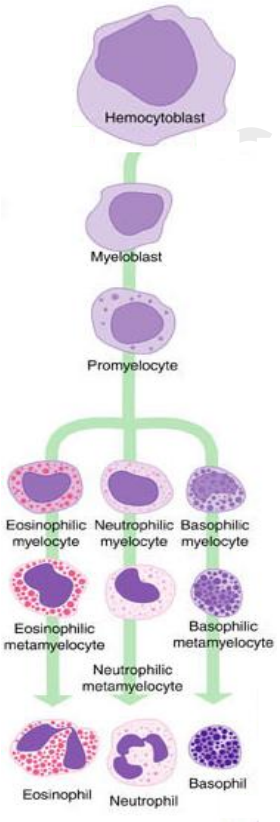
Polychromatophilic erythroblast
Smaller cell with smaller nucleus. cytoplasm contains both ribosomes (basophilic) and hemoglobin (acidophilic)

Normoblast
Small dark peripheral nucleus and acidophilic cytoplasm

Reticulocyte
No nucleus, acidophilic cytoplasm, few basophilic RER

Erythrocyte
The diameter is 7 µm, no nucleus. Acidophilic cytoplasm. Full of hemoglobin

Steps of the formation of granular leukocytes



1- **Hemocytoblast**

2- Restricted granulocyte progenitor

3- Myeloblast

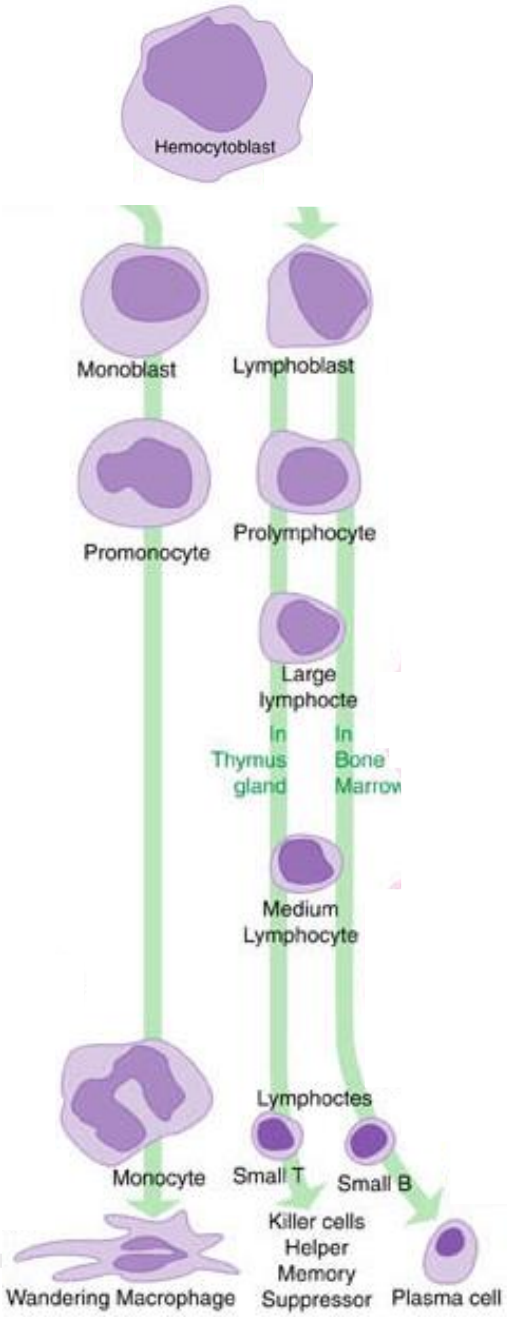
4- Promyelocyte
Big cell, pale nucleus, prominent nucleolus, pale basophilic cytoplasm, azarophilic granules, no specific granules

5- Myelocytes
Specific granules in the cytoplasm (neutral, acidophilic and basophilic)

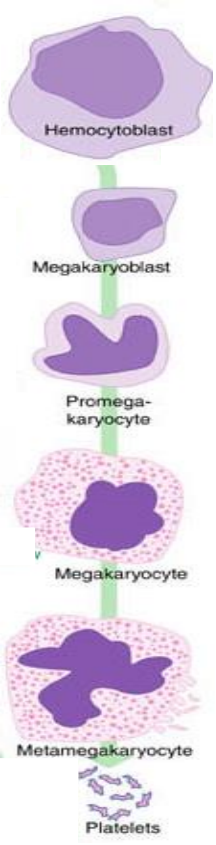
6- Metamyelocytes
(neutrophil, eosinophil, basophil) have kidney shaped nucleus

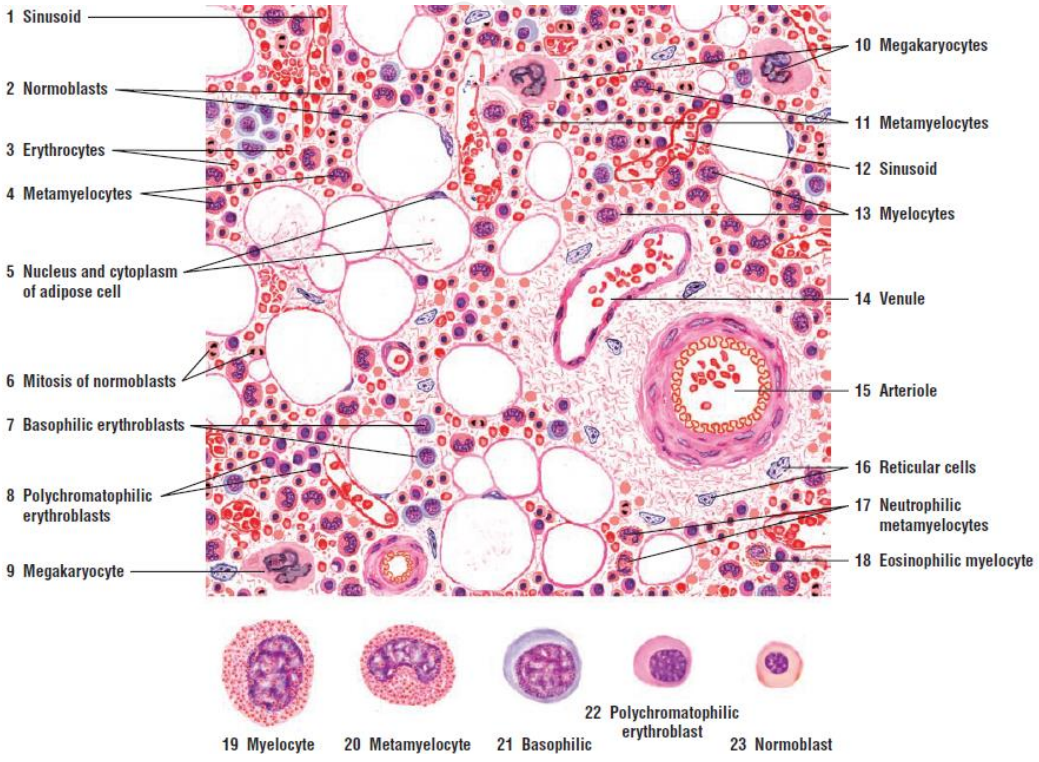
7- Mature leukocytes

Steps of the formation of nongranular leukocytes



Steps of the formation of blood platelets





Development of different blood cells in red bone marrow (decalcified).

Muscular Tissues

The characteristic of muscle tissue

1- Aggregates of specialized elongated cells arranged in parallel arrays, called fibers.

2- A muscle fiber is enclosed by a plasma membrane called the sarcolemma.

3- The cytoplasm of a muscle fiber is called a sarcoplasm.

4- Within the sarcoplasm, the T-tubules allow transport of substances throughout the muscle fiber and the sarcoplasmic reticulum stores calcium.

5- The structural and functional subunits are the myofibril which found in sarcoplasm.

6- Two types of myofilament, thin (protein actin) and thick (protein myosin), associated with muscle contraction.

7- This tissue is responsible for:

a- Movement of the body and its parts.

b- Changes the size and shape of internal organs.

8- The fibers rest on the basement membrane.

Muscle tissue classification

According to the contractile fibers, muscle tissue can be classified into:

1- Skeletal muscle fibers. 2- Smooth muscle fibers. 3- Cardiac muscle fibers.

Characteristic of skeletal muscle fibers

1- Skeletal muscle fibers are long, non-branched cylindrical and striated fibers.

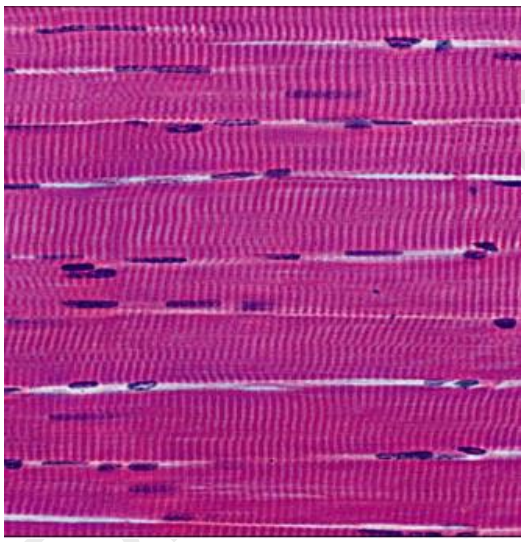
2- Multinucleated with peripheral location, immediately beneath the sarcolemma.

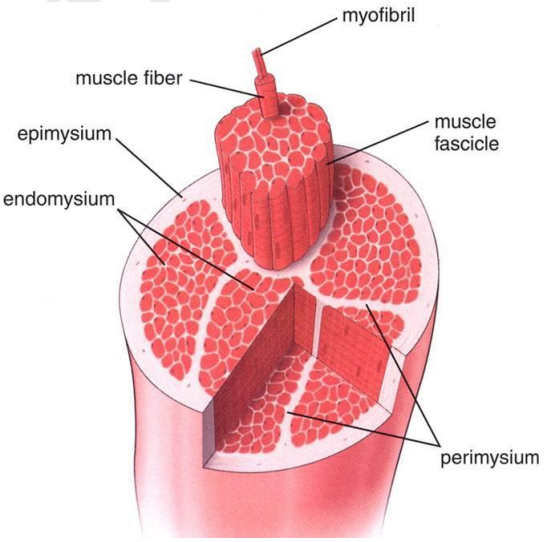
3- Found: attached to the bone and in some visceral organs.

4- It has no cell to cell junctions.

5- Voluntary contraction.

6- The fibers held together by sheaths (a- Endomysium b- Perimysium and c- Epimysium).





a- The endomysium: is a delicate layer that immediately surround the individual fibers.

b- The perimysium: is a thick layer of connective tissue, surround group of fibers that form fascicle.

c- The epimysium: is the sheath of dense connective tissue that surround a collection of fascicle.

7- There are three types of skeletal muscle fibers:

Types	Size and color	Content	Contraction	Examples
Type I (slow oxidative)	Small fibers appear red in fresh tissue	Many mitochondria, high myoglobin and cytochrome complexes.	Slow twitch fatigue resistant motor units.	Postural muscle of the neck
Type II (fast oxidative glycolytic fibers)	Medium size appear light pink in fresh tissue.	Many mitochondria, high myoglobin and large amount of glycogen.	Fast- twitch fatigue resistant motor units.	Leg muscles
Type III (fast glycolytic fibers)	Large fibers appear white in fresh tissue.	Less myoglobin, fewer mitochondria and large amounts of glycogen.	Fast- twitch fatigue prone motor units	Arm muscles

8- The special features are the presences of well-developed sER and T tubules.

9- Regeneration is limited by satellite cells and mitosis is none.

10- The cross striation are the principle histological feature of the skeletal muscle.

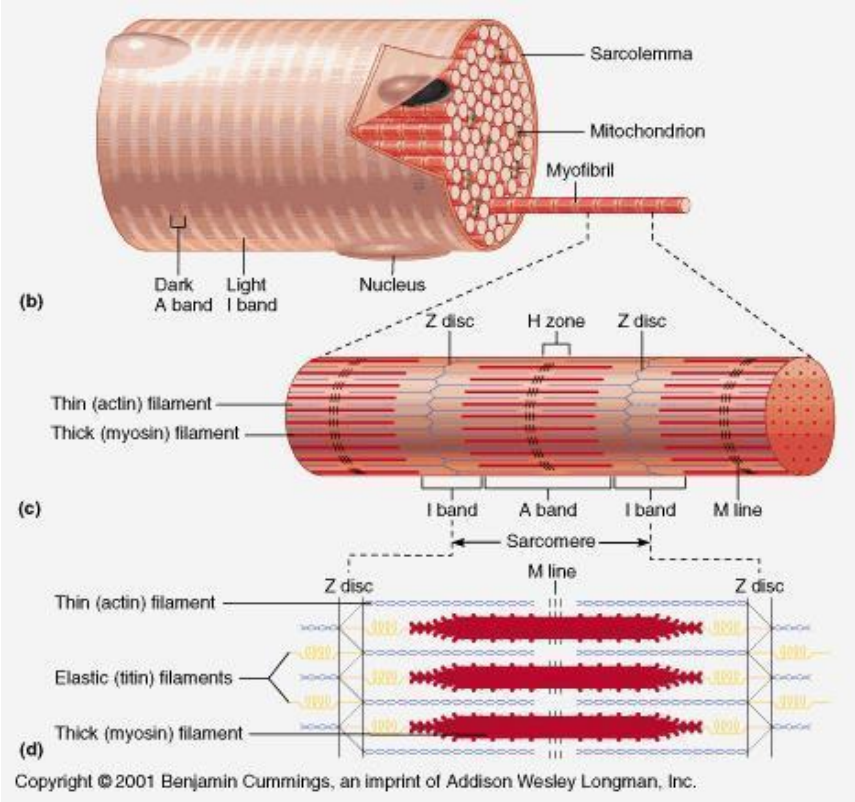
Structure of skeletal muscle fibers

1- Under light microscope the skeletal muscle showed light bands **(I-band)** and dark bands **(A-band)**.

2- Each I-band is bisected by a transverse line called **Z-line.**

3- Sarcomere: the repetitive functional sub unit extends from Z-line to Z-line, it is about 2-5 µm long in resting muscle.

4- The A-band has a lighter zone in center called **H-zone**, which bisected by **M-line**.



Characteristic of smooth muscle fibers

1- Smooth muscles are short, elongated fusiform with finely tapered ends and non-striated fibers.

2- Mono-nucleated with central location.

3- Found in vessels and visceral organs as bundles or sheets.

4- It has cell to cell junctions (gap junction).

5- Involuntary muscles.

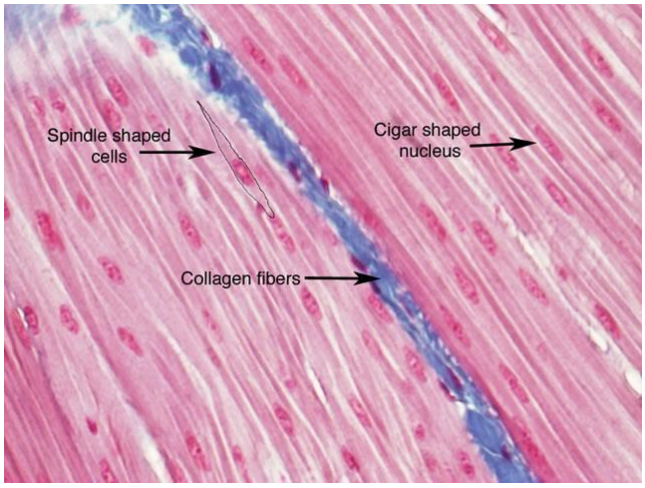
6- Endomysium sheath is present.

7- Specialized for slow and prolonged contraction.

8- The special features are the presences of the dense bodies and cytoplasmic vesicles.

9- Regeneration and mitosis are present.

10- The cross striation is none.



Skeletal muscle fibers	Smooth muscle fibers
❖ The muscle fibers are long, cylindrical in shape.	❖ The muscle fibers are spindle or fusiform in shape.
❖ Multinucleated cells with peripheral nuclei.	❖ Mono-nucleated with central location.
❖ Striated muscles	❖ Non- striated muscles.
❖ Voluntary muscles	❖ Involuntary muscles
❖ Conjunction with skeleton bone	❖ Lining of visceral hollow organs and blood vessels.

Characteristic of cardiac muscle

1- Cardiac muscles are shorter, branched and striated fibers.

2- Mono-nucleated with central location, surrounded by juxtanuclear region.

3- Found in heart wall and vessels.

4- It has cell to cell junctions (gap junction and desmosomes = intercalated discs).

5- Involuntary muscle.

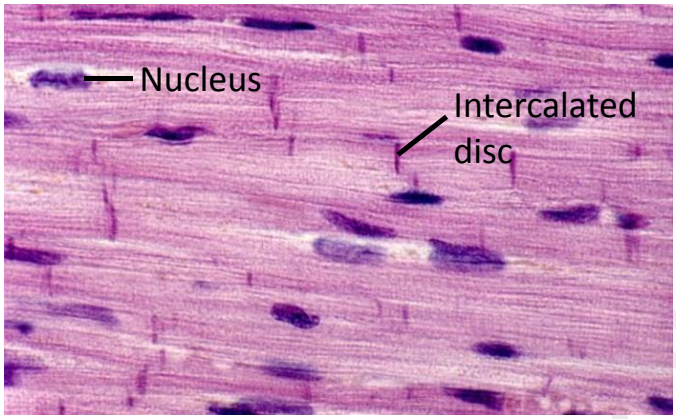
6- Endomysium sheath is present.

7- Purkinje fibers are specialized and modified cardiac muscle fibers which found in the heart. Cardiac muscle has spontaneous rhythmic contraction.

8- The special feature is the presence of the intercalated discs.

9- Regeneration and mitosis are none.

10- The cross striation is present.



Cardiac muscle fibers	**Skeletal muscle fibers**
❖ Located in the walls and septa of the heart.	❖ Conjunction with skeleton bone
❖ Shorter and branched.	❖ Longer and unbranched
❖ Striated muscles.	❖ Striated muscles.
❖ Contain one or two central nuclei	❖ Contain multinucleated cells with peripheral nuclei.
❖ Contain intercalated discs	❖ Un contain intercalated discs.
❖ Involuntary muscles.	❖ Voluntary muscles.

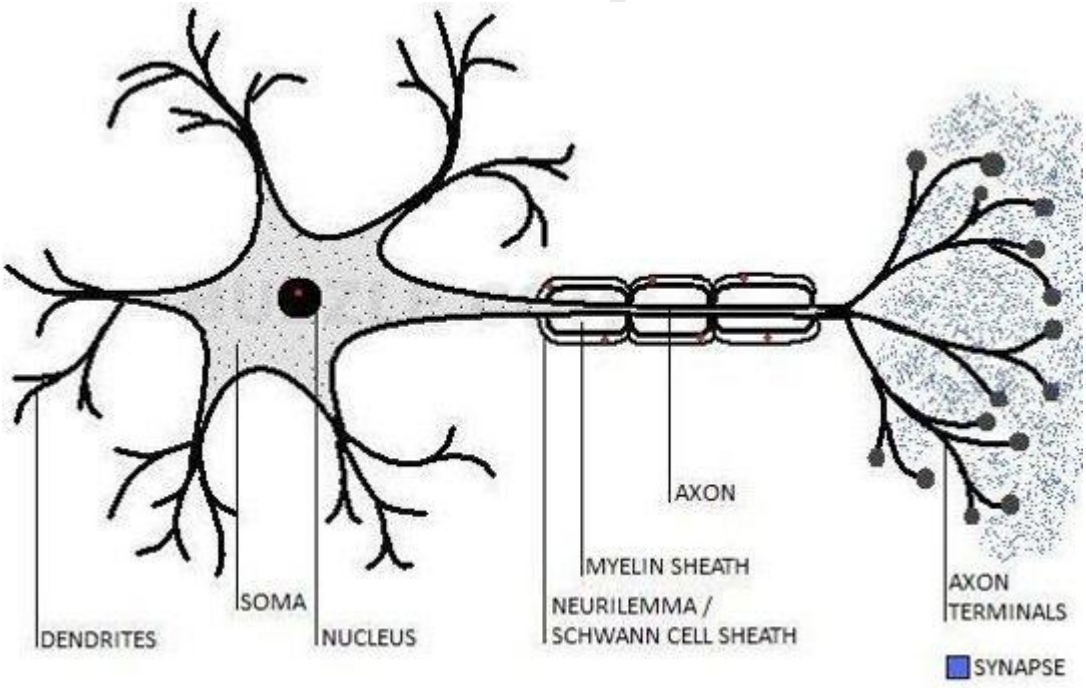
Nervous tissue

- Nervous tissue, a component of nervous system, is made up of many neurons and supportive cells, called neuroglia.
- The neuron is the structural and functional unit of the nervous tissue.
- The main function of nervous tissue is to perceive stimuli and generate nerve impulses to various organs of the body.
- The neuron is formed of a nerve cell body and its processes (an axon and dendrites).

Structure of a Neuron

In general, a neuron has three basic parts:

(1) Cell body (perikaryon); (2) Axon; and (3) Dendrites.



1- Nerve cell body or perikaryon

- The major part of the cell enclosed by a plasma membrane is the cell body, also known as the soma.
- The nucleus is central, large, single and pale basophilic.
- It has deeply basophilic prominent nucleolus.
- The cytoplasm has granules called (Nissl bodies), which are distributed in the cytoplasm of the cell body except in the region close to the axon, called axon hillock.
- Function involved reception of impulses from other neurons and conduction of the nerve impulse via the axon to another neuron or other organ.

2- Axon

- It is a single, an elongated structure of the neuron that carries impulses away from the cell body.
- The plasma membrane bounding the axon is called **axolemma**, and the cytoplasm of the axon is termed **axoplasm**.
- The axon is covered with a white fatty layer known as the **myelin sheath**. This sheath serves two major functions protecting and insulating the axon and accelerating the electrical signals during transmission.
- The myelin sheath layer has a cellular covering known as the **neurilemma** or the **Schwann cell sheath**. This sheath is essential for regeneration of nerves. It is present only in the peripheral

nervous system. In the central nervous system, neurilemma is absent, thus nerves here are incapable of regeneration.

Central nervous system	Peripheral nervous system
1- Neurilemma or the **Schwann cell sheath** is absent. 2- The nerves are incapable of regeneration.	1- The neurilemma is present. 2-The nerves are capable of regeneration.

- ❖ The medullary sheath is not a continuous layer on the axon; it has joints, or node-type interruptions known as the **nodes of Ranvier**.
- ❖ Each axon arises from a small conical area in the cell body called **axon hillock**.

3- Dendrites

- ❖ Numerous short-branched structures emerging from the soma are called dendrites. They are often covered with small, branched projections known as dendritic spines.
- ❖ The function of dendrites are the receptors of a neuron that receive electrical signals from other neurons.
- ❖ The function of dendritic spines involved to increase the surface area of the dendrite .

Classifications of neurons

A- According to the number of processes, neurons can be classified into:

1- Pseudounipolar neurons

- ❖ These neurons consist of one dendrite and one axon.

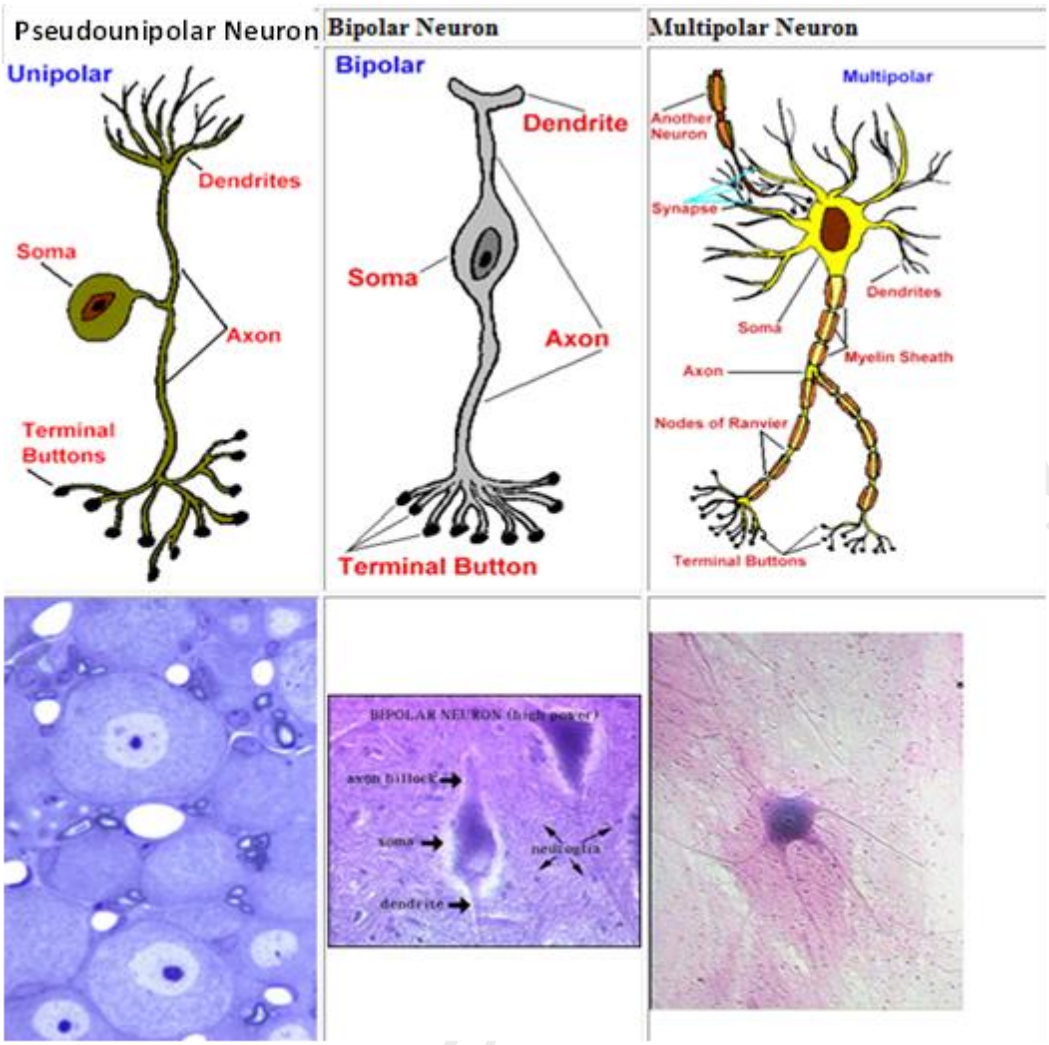
- The nerve cell body has two processes which are adherent to each other forming one pole.
- It is seen in spinal sensory ganglia.

2- Bipolar neurons

- The nerve cell body has spindle shape and has two processes from the two pols, a short dendrite and a long axon.
- It is seen in the olfactory epithelium of the nasal cavity.

3- Multipolar neurons

- The nerve cell have a single long axon and many short dendrites.
- They represented most of the neurons in the brain and spinal cord.



2- According to the function, neuron are classified into:

1- Motor (efferent) neurons

- ❖ This type carry motor impulses from central nervous system (CNS) to peripheral end organs.
- ❖ The site of this type is a motor nuclei in anterior horn cells of the spinal cord.

2- Sensory (Afferent) neurons

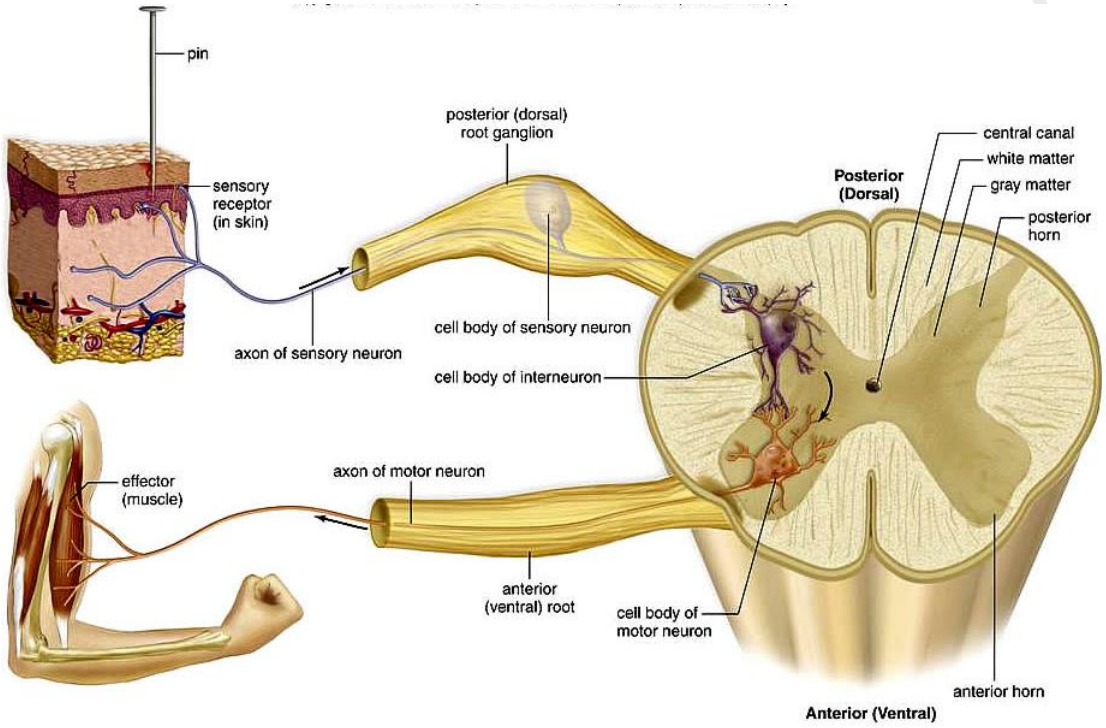
- ❖ This type receive impulses from peripheral sensory cells and organs and then carry them toward CNS.

❖ The site of this type is sensory spinal ganglia.

3- Interneurons (association)

❖ This type have short neurons that connect a sensory and a motor neuron.

❖ The site of this type is spinal –cord in reflex arc.



Neuroglia

❖ Neuroglia or glial cells are protective and supportive structures of the nervous tissue.

❖ They are found in bunches surrounding the neurons and have the ability to regenerate in case of injury.

❖ They are located in both peripheral and central nervous system.

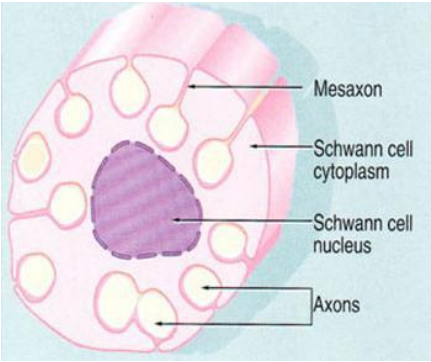
❖ Neuroglia of peripheral nervous system (PNS) include:

1- Schwann cell:

It is supporting cell of peripheral nerve. The function of this cell involved: a- Myelin production.

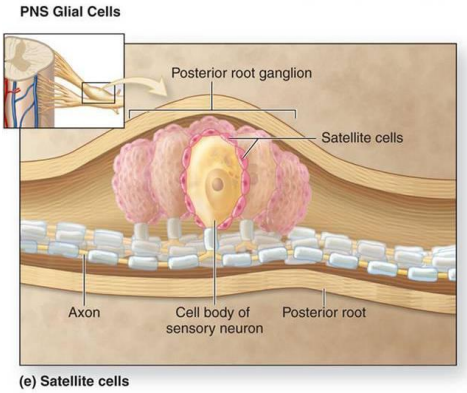
b- Electrical insulation.

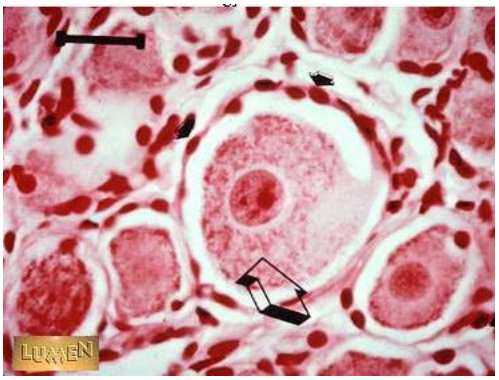
c- Removal of debris and regrowth of Injured PNS axons.



2- Satellite cell

It is specialized cell surround neuron cell bodies of ganglia in (PNS). This cell play a role in metabolic exchange.





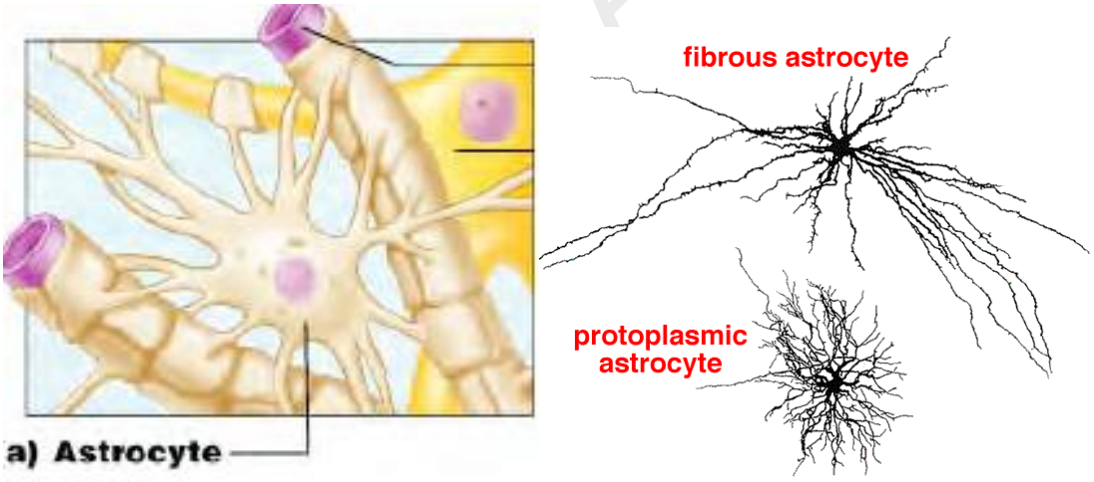
❖ Neuroglia of central nervous system (CNS)

1- Astrocytes

- They are relatively large.
- They connect and support neurons as well as blood vessels in the CNS.
- Two types of astrocytes

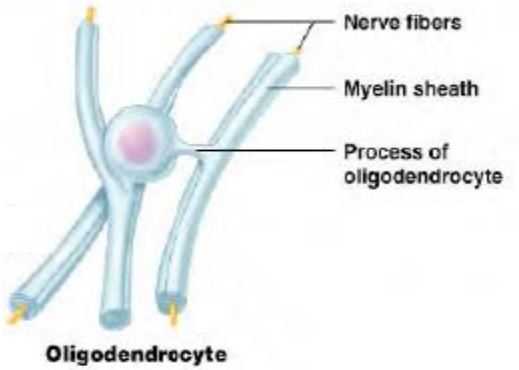
  a- Fibrous astrocytes, located in white matter, have long sparsely branched processes.

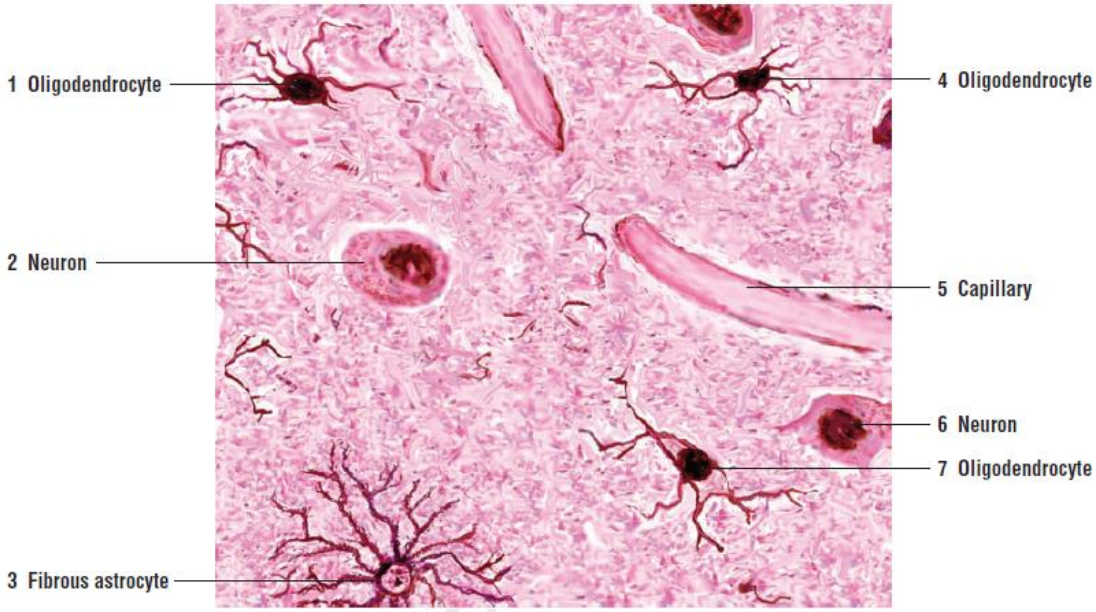
  b- Protoplasmic astrocytes, located in gray matter, have numerous short highly branched processes



2- Oligodendroglia

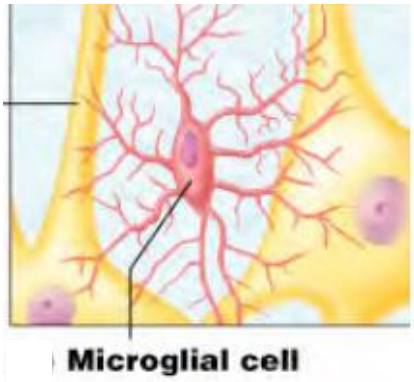
- They have small cell body and few processes.
- They form myelin sheaths in the CNS, in addition to having a metabolic role.

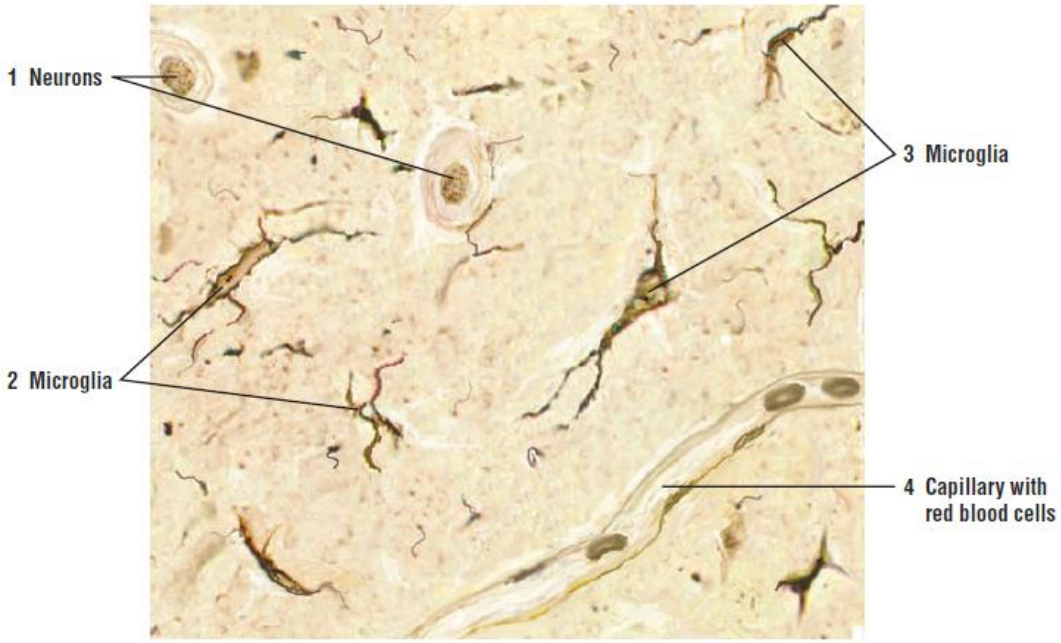




3- Microglia

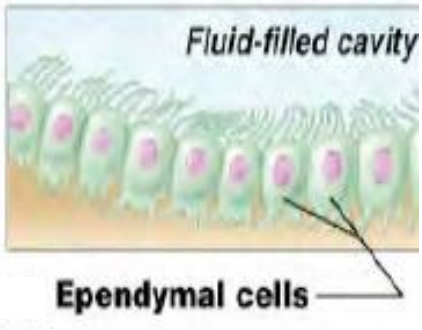
- They are small and tend to have elongate cell bodies.
- Being resident phagocytes, they are relatively rare in normal CNS tissue.
- They are found in both grey and white matter of CNS.
- They repair the damage of neurons.





4- Ependymal cells

- They line the cavities (**ventricles)** of the brain and the central canal of the spinal cord.
- Ciliated cells move the Cerebrospinal fluid (CSF) through the central canal of spinal cord.



❖ Neuroglia have several functions such as :

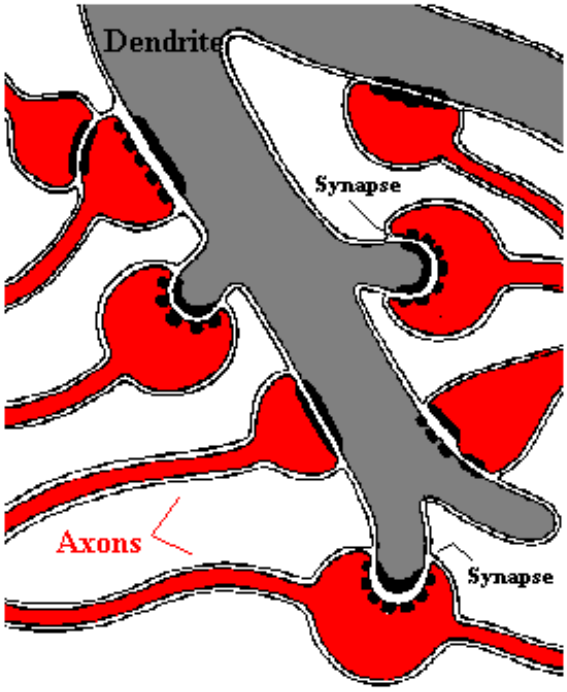
1- Provide nutrition and immune protection to the neurons.

2- They are responsible for the formation of myelin sheath and maintaining homeostasis inside the neurons.

Synapse

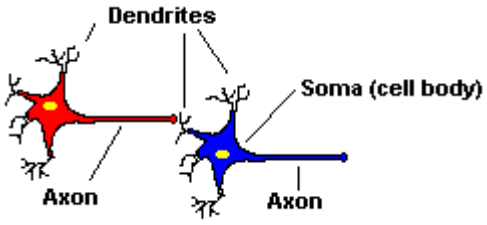
❖ Any two neurons are connected together at the site called synapse.

❖ Information from one neuron flows to another neuron across a synapse.

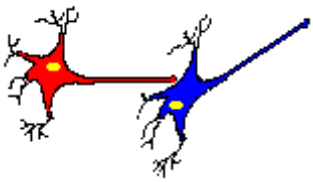


❖ According to the site, synapse are classified into:

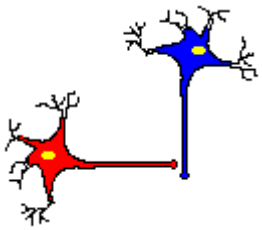
1- Axo-dendritic between axon and dendrite.



2- Axo-somatic between axon and cell body (soma).



3- Axo-axonic between axon and another axon.



❖ Synapses have 4 main functions. They are as follows:

a. They transmit information between neurons.

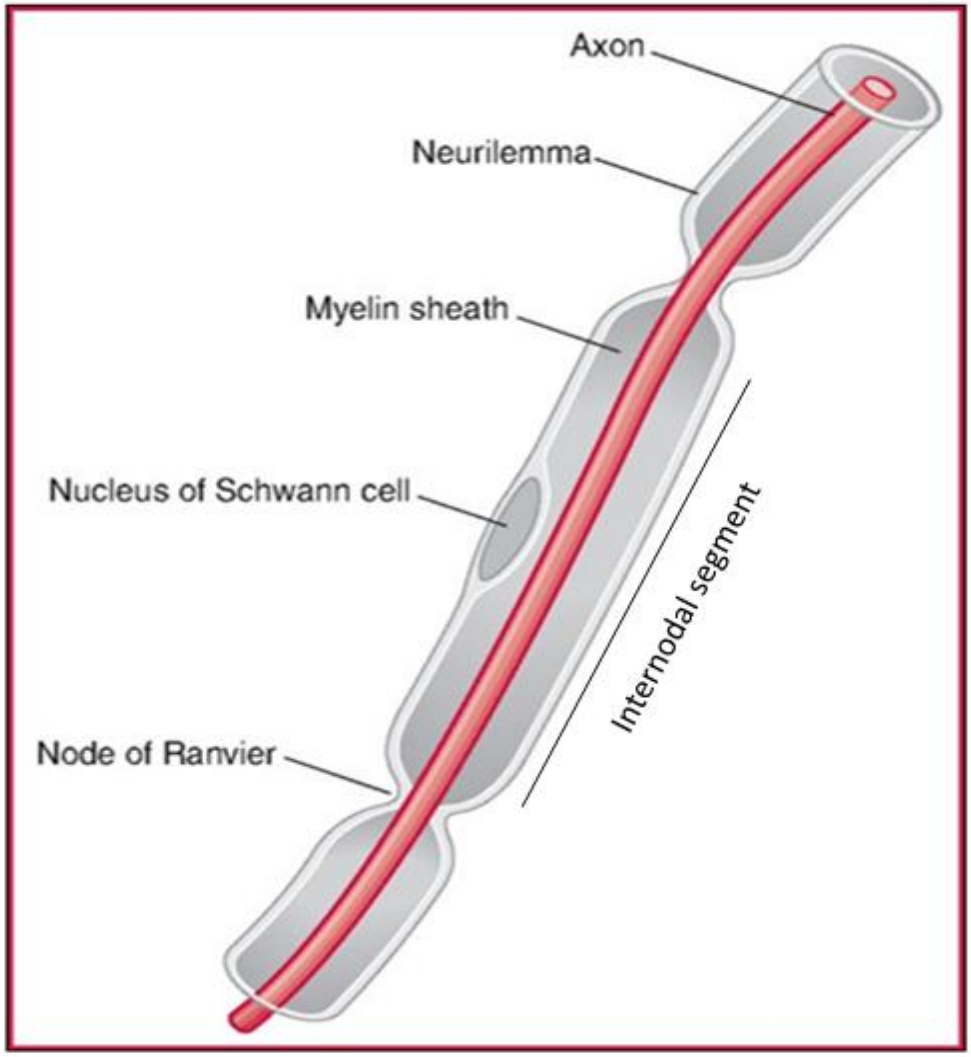
b. They filter out low frequency impulses.

c. They act as valves to ensure that impulses pass across them in one direction only.

d. They also act as junctions allowing impulses to be divided up along many neurons or merge into one.

Nerve fibers

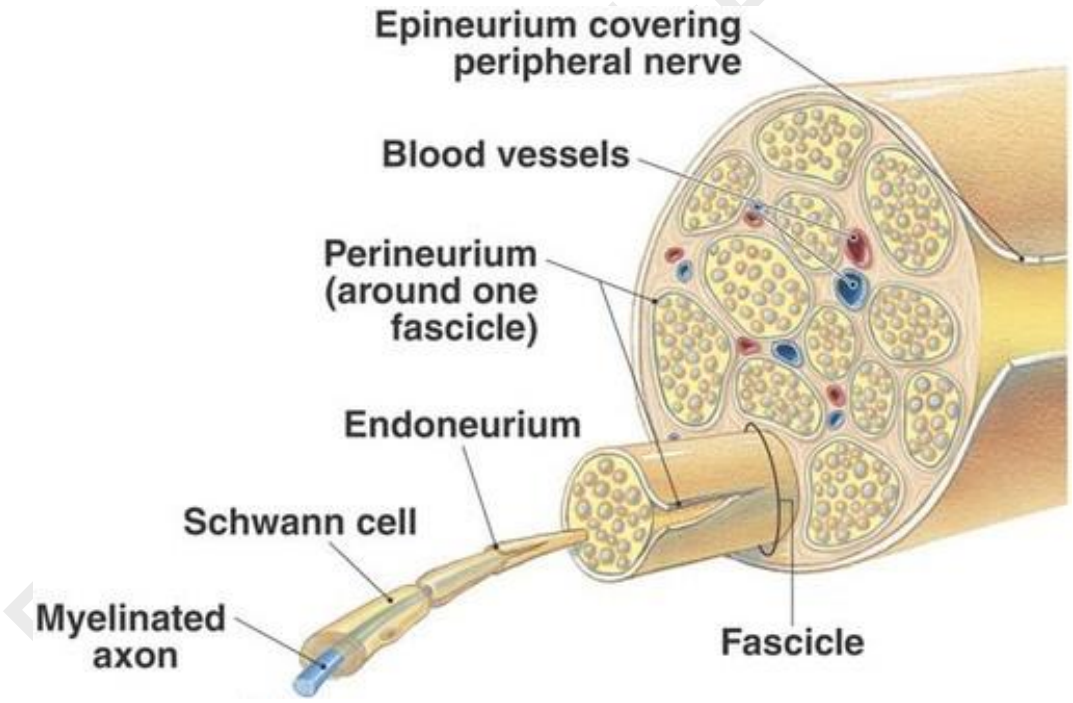
- A nerve fiber is an axon and its sheaths.
- Long, peripheral axons are surrounded by a multi-layered white, phospholipid, segmented covering called myelin sheath.
- Axons with the covering are known as myelinated fibers and those without are unmyelinated fibers.
- The function of the myelin sheath is to increase the speed of nerve impulse conduction,
- Myelin sheaths in the PNS are formed by multiple layers of wrapped Schwann cells.
- The outer surface of the Schwann cells is the neurilemma or sheath of Schwann and is located just beneath the plasma membrane of the cell.
- Between Schwann cells is an unmyelinated gap called the node of Ranvier.
- Unmyelinated fibers are also enclosed by Schwann cells, but without multiple wrappings.
- Nerve fibers of the CNS may also be myelinated or unmyelinated.
- CNS myelin sheaths also lack a neurilemma.



Peripheral nervous system

- The peripheral nervous system includes the peripheral nerves and nerve cell bodies located outside the central nervous system (CNS).
- Peripheral nerves are bundles of nerve fibers (axons), located outside the central nervous system and surrounded by several investments of connective tissue sheaths.
- Connective tissue investments of peripheral nerves include the epineurium, perineurium, and endoneurium.

- ❖ The epineurium is the outermost layer of the three connective tissue investments covering nerves. It is composed of dense, irregular, collagenous connective tissue containing thick elastic fibers that completely ensheathe the nerve.
- ❖ The perineurium is the middle layer of connective tissue investments which covers each bundle of nerve fibers (fascicle) within the nerve. It is composed of dense connective tissue but is thinner than epineurium.
- ❖ The endoneurium is the innermost layer of the three connective tissue investments of a nerve, which surrounds individual nerve fibers (axons).



Organs tissues

Brain

The basic components of the CNS include the:

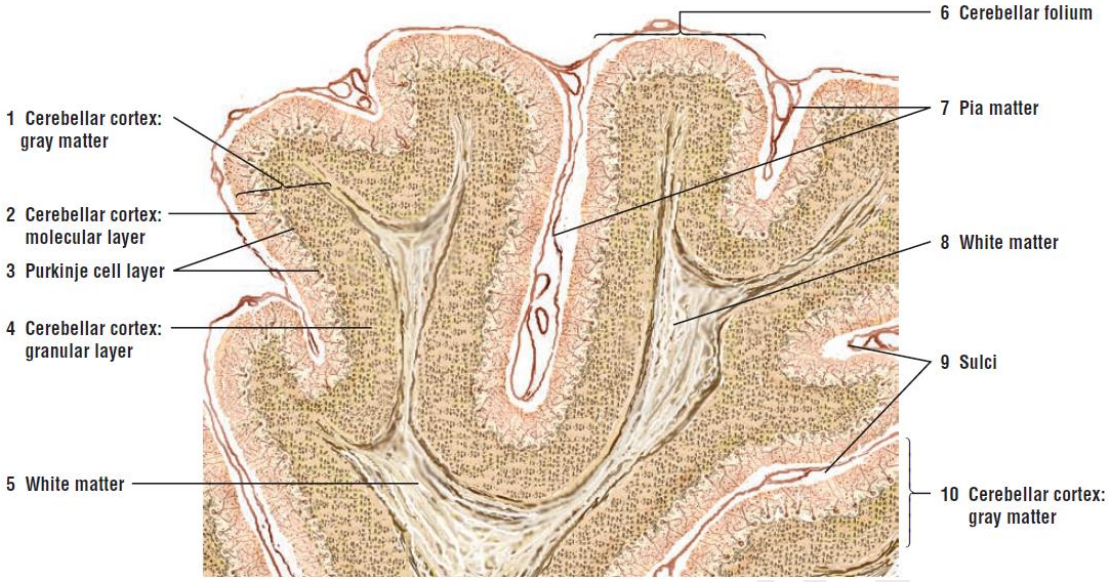
A- Cerebrum. B- Diencephalon. C- Cerebellum. D- Brain stem. E- Spinal cord.

Cerebellum

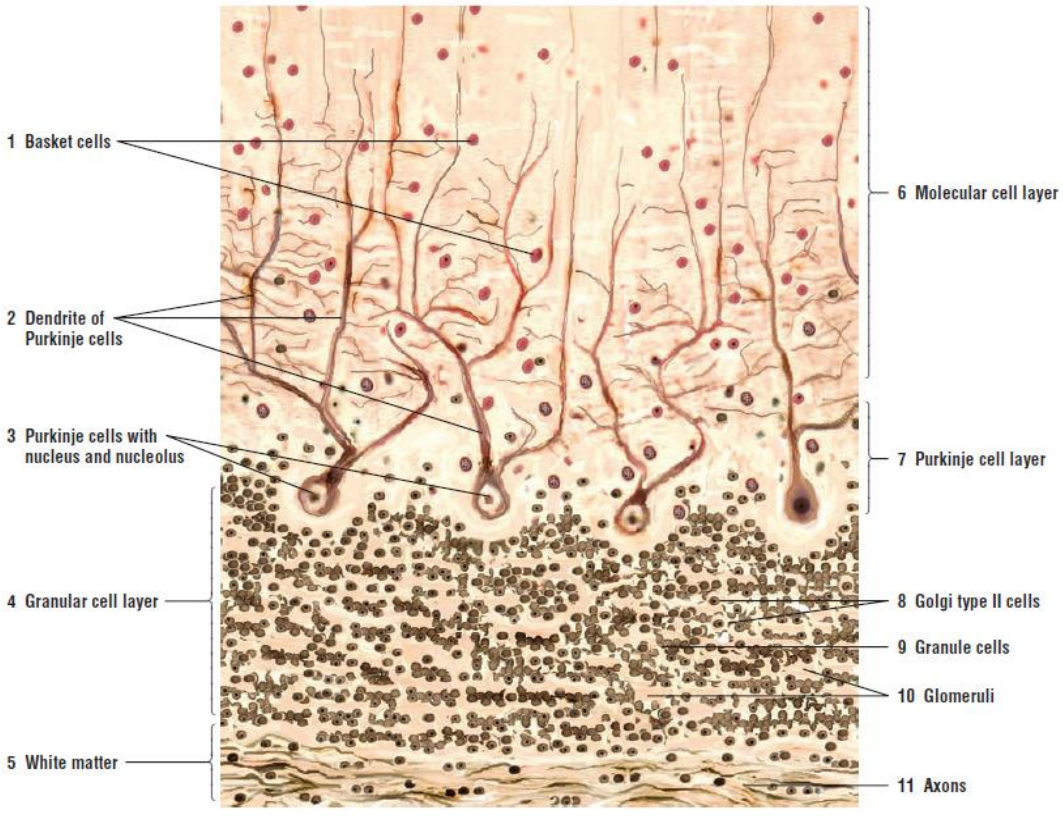
- The cerebellum is the area of the hindbrain that controls motor movement coordination, balance, equilibrium and muscle tone.
- It is comprised of white matter (medulla) and a thin, outer layer of densely folded gray matter (cortex).
- The cerebellar cortex is divided into three layers:
  - a- An outer molecular layer with relatively fewer and smaller neuronal cell bodies and many fibers that extend parallel to the length of the folium.
  - b- A central or middle Purkinje cell layer
  - c- An inner granular layer with numerous small neurons that exhibit intensely stained nuclei.

Purkinje cells are pyriform or pyramidal in shape with ramified dendrites that extend into the molecular layer.

- The white matter forms the core of each cerebellar folium and consists of myelinated nerve fibers or axons.



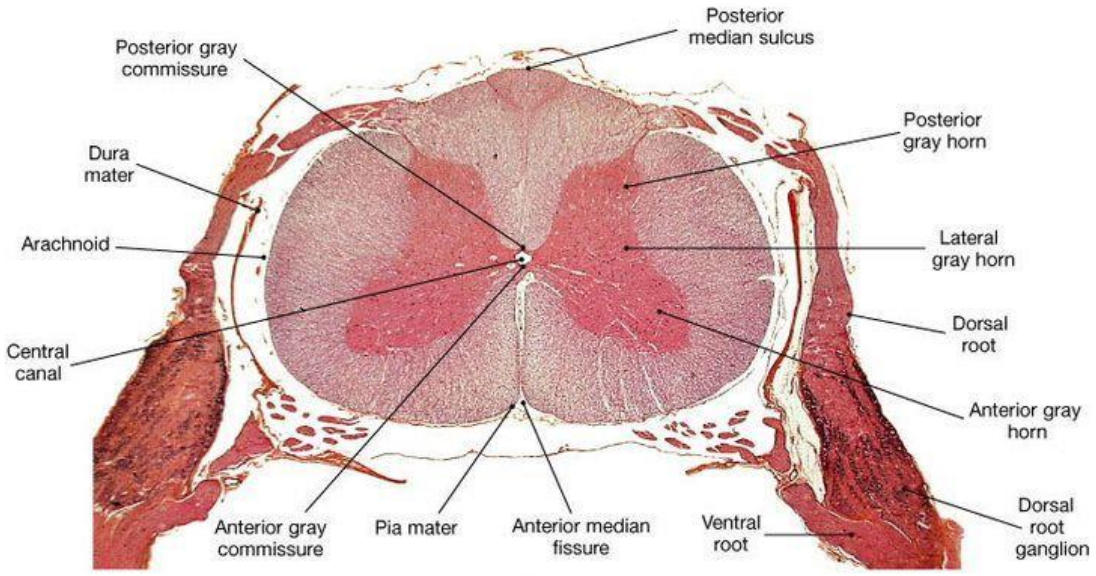
T.S. cerebellum



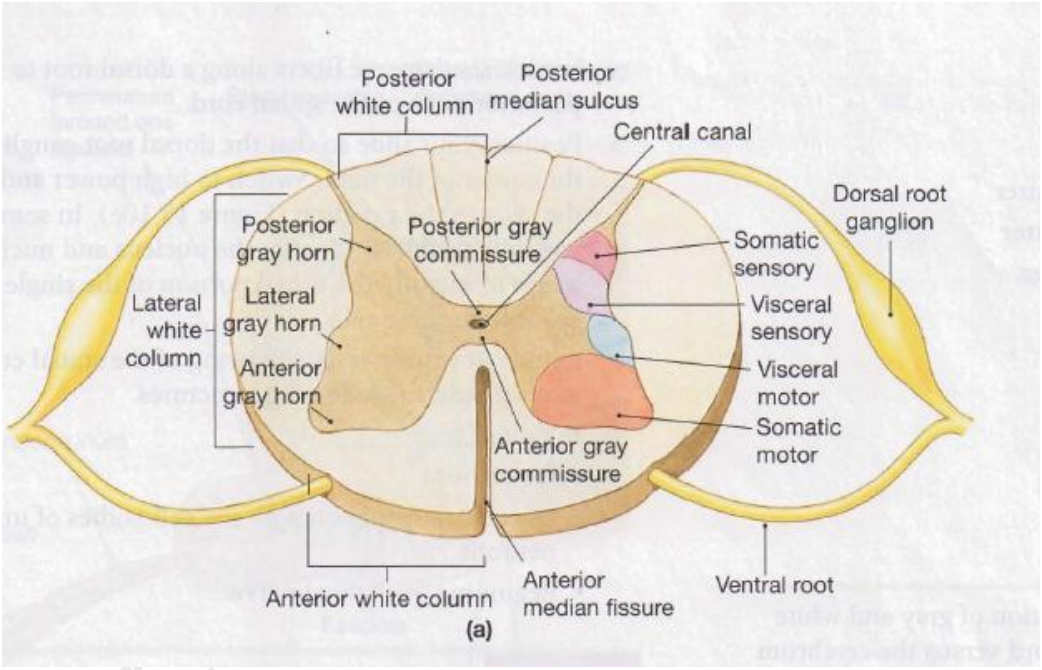
Cerebellar cortex: molecular, purkinje cell, and granular cell layers.

Spinal cord

- In cross section of the spinal cord, white matter is peripheral and gray matter is internal and has general butterfly shape (or letter H shape).
- The gray matter consists of two posterior (P) horns (sensory) and two anterior (A) (motor) horns all joined by the gray commissure around the central canal.
- The gray matter contains abundant astrocytes and large neuronal cell bodies, especially those of motor neurons in the ventral horns.
- Surrounding the grey matter is white matter containing columns of nerve fibres that carry signals to and from the brain along the length of the spinal cord.



(b)



(a)