Histolog I

First year physical therapy students

2024-2025

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Introduction

Histology: is the science of studying microscopic structures of tissues and organs of the body.

-Histology is a Greek word (Histo=tissue, logia = science) also called microscopic anatomy.

-In order to study the microscopic structure of tissue, we need to use microscope.

Microscopy

-It is an instrument that magnifies an image and allow visualization of details that can not be seen by unaided human eye.

Types of the microscope:

1-Light microscope (LM): Commonly used in teaching labs.

2- Electron microscope (EM): include Transmission EM and scanning EM.

Parts of LM: It consists of

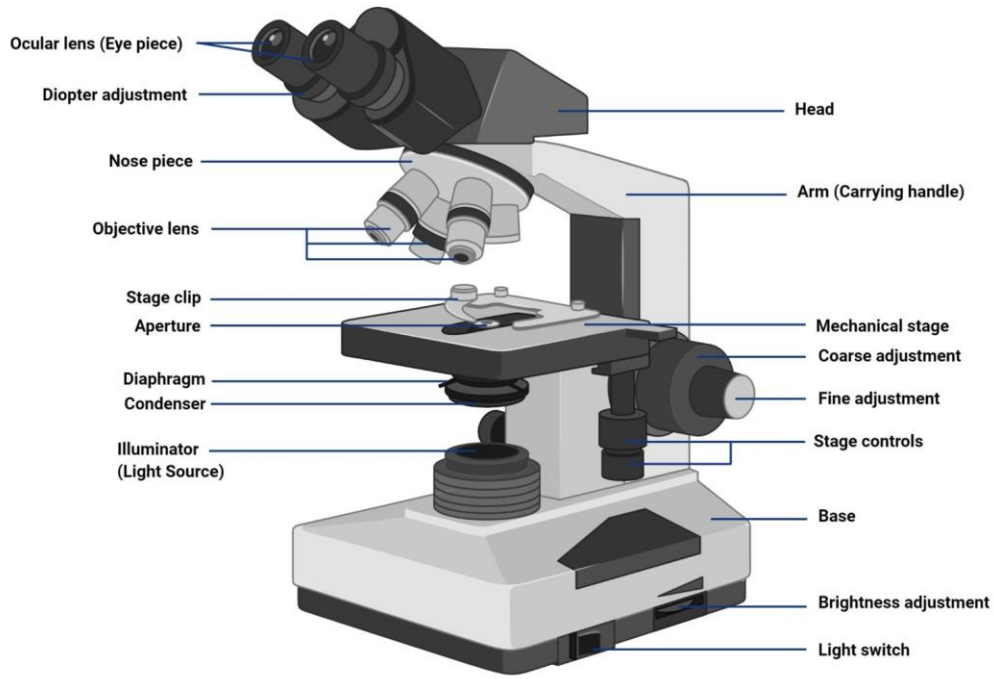
1- A light source for illumination of a specimen such as day light or lamp.

2-Acondenser to focus the beam of light at the level of specimen.

3-Astage to place the slide on it.

4-Ocular lens (eye piece) may be one in uniocular microscope or 2 lens in binocular microscope.

5-Objective lens to gather the light that has passed through the specimen. There is various magnification power of objective lens such as ×4, ×10, ×40, ×100.



Functions of microscope:

1-Magnification 2- Resolution

Magnification: -It is the increase the linear dimension of an object without optical defect.

-Final magnification of the microscope =

magnification of an objective lens× magnification of ocular lens.

-LM magnifies an object to 1000 times while EM can magnify it up to 100000 times.

Resolution: It is the ability of the microscope to produce separate images of 2 adjacent objects

-Limit of resolution: It is the shortest distance between 2 objects below which they appear as one or not seen at all.

-Limit of resolution of human eye is 0.2 mm while it is 0.2 micron for LM and 0.1 nanometer for TEM.

To examine tissue by LM,it must be thin enough to allow passage of light through it. Also, we need sufficient level of contrast of the tissue to be examined by LM. This leads to preparation of the tissue for examination.

Cytology

-It is the science of studying normal structure and function of the cell.

-Cell is the basic structural and functional unit of the living body.

-Cells and extracellular matrix forming tissues.

Organelles → Cells → Tissues → Organs → Systems → Human Body

Types of cells:

1-Prokaryotic cell **2- Eukaryotic cell**

-The prokaryotic cell has a cell wall and lack nucleus and membranous organelles. Example : bacteria and other microrganisms.

-The eukaryotic cell has * well defined cell membrane

* Well defined nucleus

* Membranous and non-membranous organelles

* Cytoskeleton

-All cells of the human body are eukaryotic.

Shape of the cell:

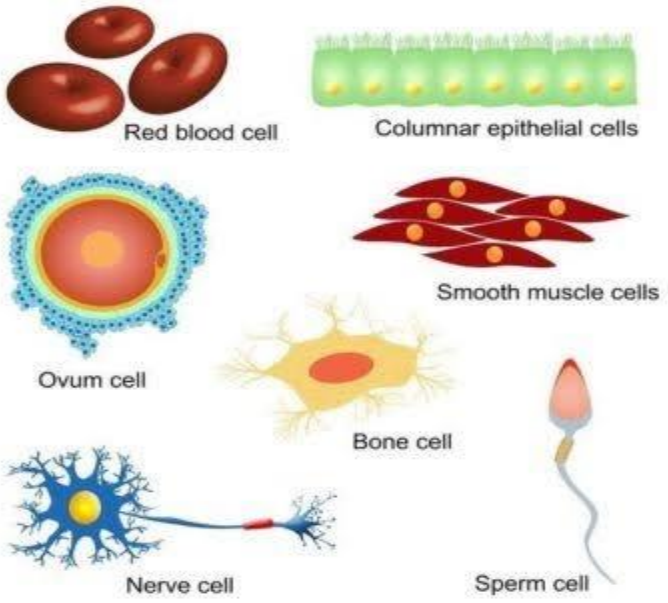
-Cells have variable shapes. Their shapes vary according to their functions.

-The cell may be squamous(flat), cuboidal, columnar, polygonal, biconcave or branched in shape.

Size of the cell:

-Human cells are generally small. Most cells are usually **10-12 micron in diameter.**

-Some cells may have a large size such as human oocyte may reach 100 micron in diameter or very small size such as red blood cell nearly 6 micron in diameter.



Components of the cell:

The cell has 2 major components:

1-**Nucleus:** contain genome (DNA) of the cell

2-Cytoplasm (cytosol): is the part of the cell that surround nucleus and include:

- Cytoplasmic organelles

- Cytoskeleton: formed of microtubules, microfilaments, and intermediate filaments.

- Cytopladmic matrix: contain variable solutes as sodium and potassium ions**.**

-Cell inclusions e.g lipid droplets and pigments.

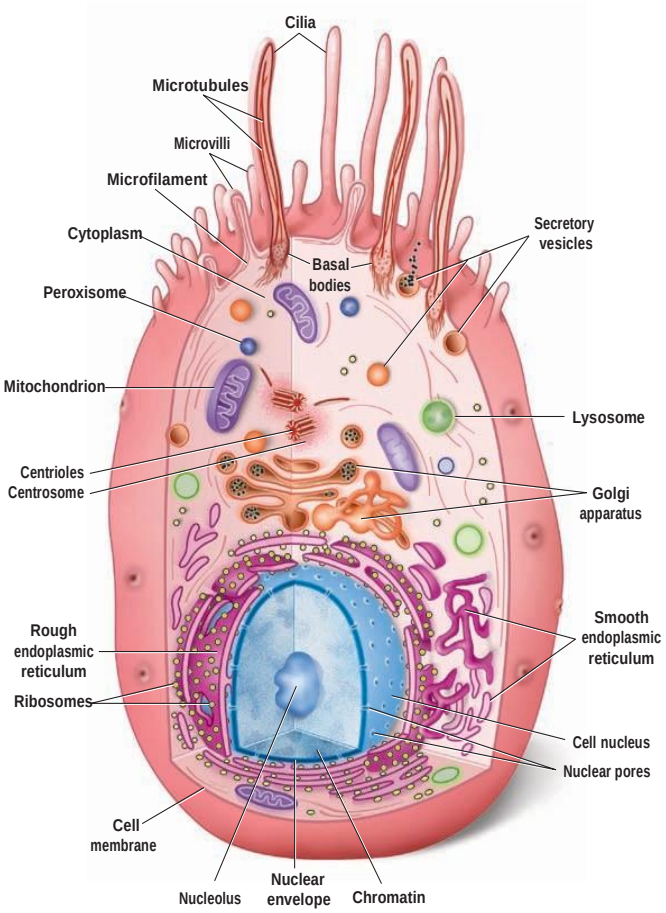


Figure I: Showing cell structure and its organelles

Cytoplasmic organelles:

-They are metabolically active structures.

-They are classified into

I-Membranous organelles (surrounded by plasma membrane) include:

-Plasma membrane (PM) **-Mitochondria**

-Golgi apparatus

-Endoplasmic reticulum (smooth endoplasmic reticulum and rough endoplasmic reticulum).

-Lysosomes **-Endosomes**

-Peroxisomes **-Transport vesicle**

II- Non-membranous organelles (not surrounded by plasma membrane) include:

-Centrioles **-Ribosomes**

- Filaments **- Microtubules**

-Proteasomes

Memberanous organelles

-They are surrounded by plasma membrane.

-This membrane separates the internal environment of the organelle from the cytoplasm.

1- Plasma membrane (also called plasmalemma or cell membrane)

-It is adynamic structure as it participates in many physiological and biochemical activities

-In living cells, it has a fluid mosaic appearance as the protein components form a mosaic that moves within the fluid lipid bilayer.

-In fixed cells, it is visible only by electron microscope(EM)

As its thickness ranges from 7.5 to 10 nm which is below the resolution limit of light microscope (LM).

-By EM it appears a trilaminar structure, inner and outer layer appear as dark band and in between the light band appears.

Components of PM :

1-Lipids: include phospholipids and cholesterol

2- Proteins **3- Carbohydrates**

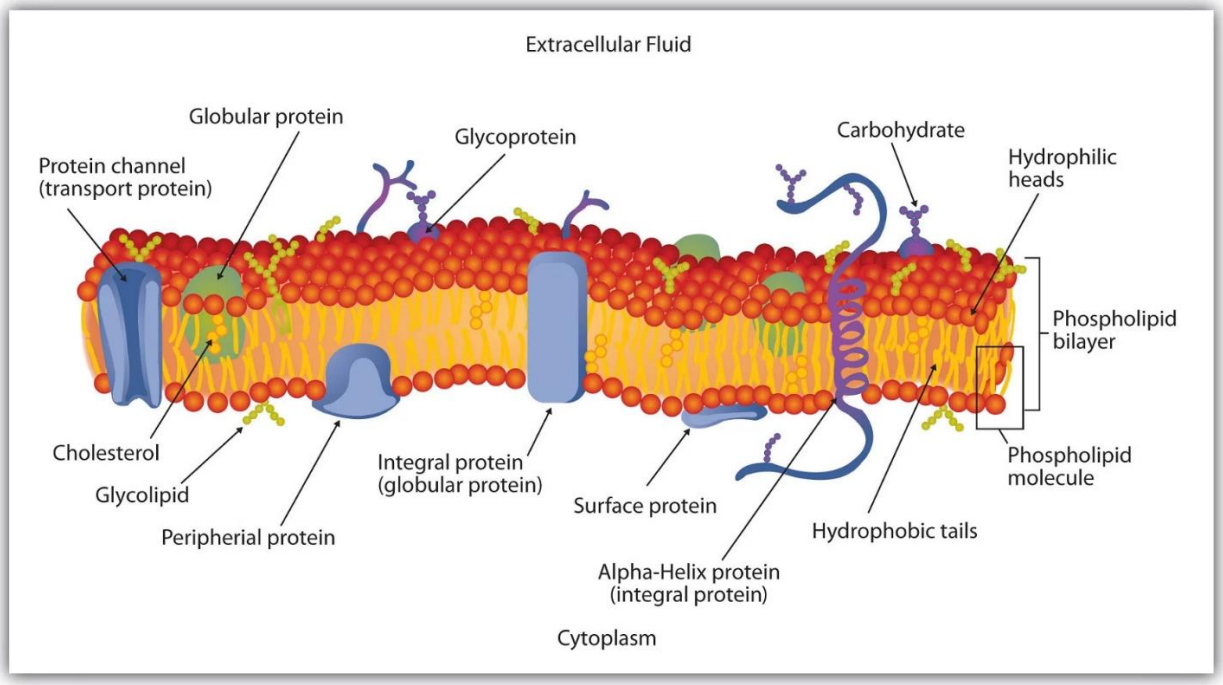


Figure II: showing the ultrastructure of PM

1-Lipids

-The phospholipids forming the bilayer of PM .The phospholipid molecule has two parts ;hydrophilic(means loving water) part directed to both surfaces of PM and hydrophilic(means hating water) part directed toward the inner part of PM.

-The phospholipids on each half of bilayer are different. Also, the composition of phospholipids of different membranes is variable.

-Some lipids of the outer layer of PM give attachment to oligosaccharides chains forming a gycolipid molecule .This glycolipid molecule shares in the formation of glycocalyx of the cell .

-Cholesterol: -It presents in patchy distribution.

-It gives stability to the plasma membrane.

-Proteins: -It forms 50% of the total membrane mass

-Present between phospholipid bilayer.

Types of proteins according to its position in the PM:

1-Integral membrane proteins:

-They are embedded in the phospholipid bilayer.

-They either pass from one side to the other (called **one pass integral protein)** or pass several times (called **multi pass integral protein**).

2-Peripheral membrane proteins:

-They are bound to one of the two surfaces of the PM.

-Carbohydrate chain may attach to the protein forming glycoprotein.

-Glycoprotein together with glycolipid form **glycocalyx (cell coat)** of the cell.

Functions of proteins of PM:

1-Pumps: actively transport ions such as sodium and potassium ions (active transport needs energy in the form of ATP).

2-Channels: Passively allow passage of small molecules, ions and water in both directions(passive transport does not require energy).

3-Receptors: recognition of the cell and binding of certain molecules such as hormones and antibodies.

4-Linker protein: anchor intracellular protein to extracellular matrix.

5- Enzymes: such as ATP synthetase enzyme in the inner mitochondrial Membrane.

2-Endoplasmic reticulum (ER):

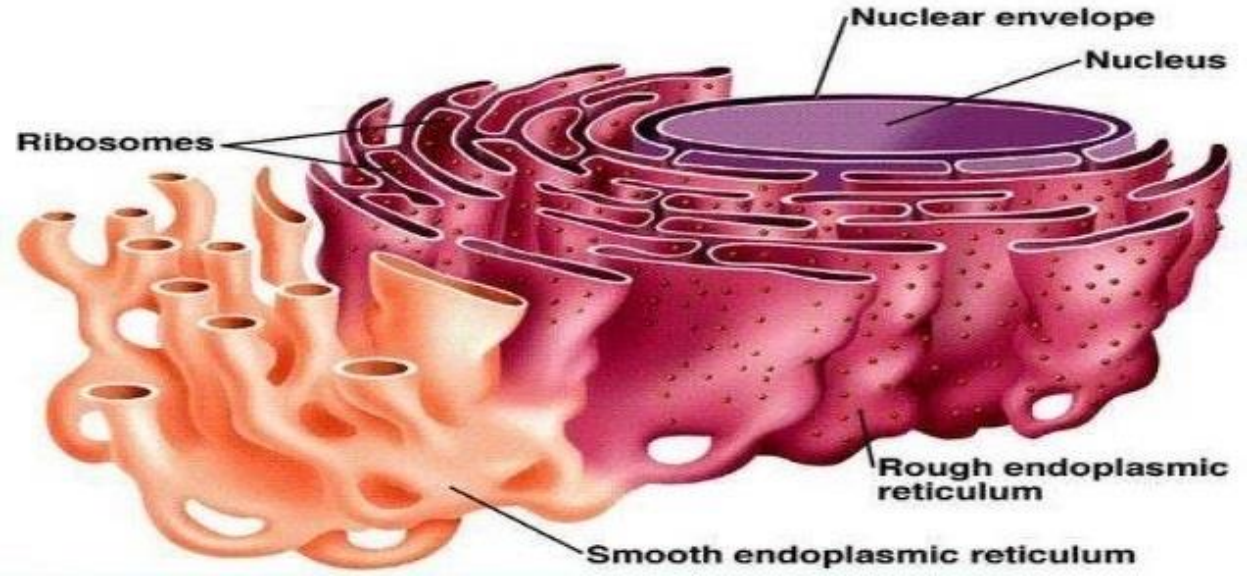
-It is a tortuous communicating network of tubules, small vesicles and flattened cisternae. Usually arranged as parallel stacks of cisternae.

-The internal environment of the ER is separated from the cytoplasm by the membrane bound it.

-Its amount, type and distribution vary according to the cell type and function.

Types of ER: I- Smooth endoplasmic reticulum (SER)

II-Rough endoplasmic reticulum(rER)



I-Smooth ER : has smooth outer surface as it lacks polyribosomes

By **LM**: Cells with large amount of smooth ER show acidophilic cytoplasm due to its protein content of membrane**.**

By EM: -best seen by EM

-smooth ER cisternae tend to be tubular connected by various channels of various shape and size.

-SER may be connected to rough ER or separate from it. SER is abundant in steroid secreting cells such as Leydig cell of testis,

Functions:

1-Synthesis of lipids .

2-Detixification of drugs.

3-Regulation of calcium ions release in muscles

4- Site of carbohydrates metabolism.

II-Rough ER:

-It has rough outer surface due to attachment of many ribosomes to its outer surface.

By LM: Cells has large amount of rough ER have basophilic cytoplasm due to ribosomes attached to it.

By EM: -formed of sac like parallel flattened cisternae with many ribosomes attached to its outer surface.

-Its cisternae are limited by membrane which to the outer membrane of the nuclear envelope.

Function: 1-Synthesis of protein.

3-Golgi complex(apparatus):

By LM: Golgi body does not stain by Hx&E so in large cells appear as clear area surrounded by cytoplasm. This area called negative Golgi image.

-It can be visualized by LM when stained by special stain such as silver stain.

By EM: appear as a complex array of flattened,slightly curved ,closely packed membrane bounded sacs called cisternae with associated vesicles and large vacuoles.

-It has 2 distinctive functional faces:

1-**The Cis face (Golgi receiving region):** it is convex and formed of flattened cisternae close to rough ER.

-It receives materials synthesized in rough ER in the form of vesicles called **transport vesicle.**

2-Trans face (maturing face): it is concave side.

-Large vacuoles accumulated and condensed to generate other vesicles that carry completed protein products to organelles away from Golgi.

3- Medial compartment of Golgi: contain flattened cisternae between Cis face and Trans face.

-Site of Golgi complex commonly located near nucleus.

-Its number and size vary according to activity of the cell**.**

Function:

1-Site of condensation and packaging of proteins.

2- Modification of protein by adding specific chemical groups.

3-Site of packaging of hydrolytic lysosomal enzymes.

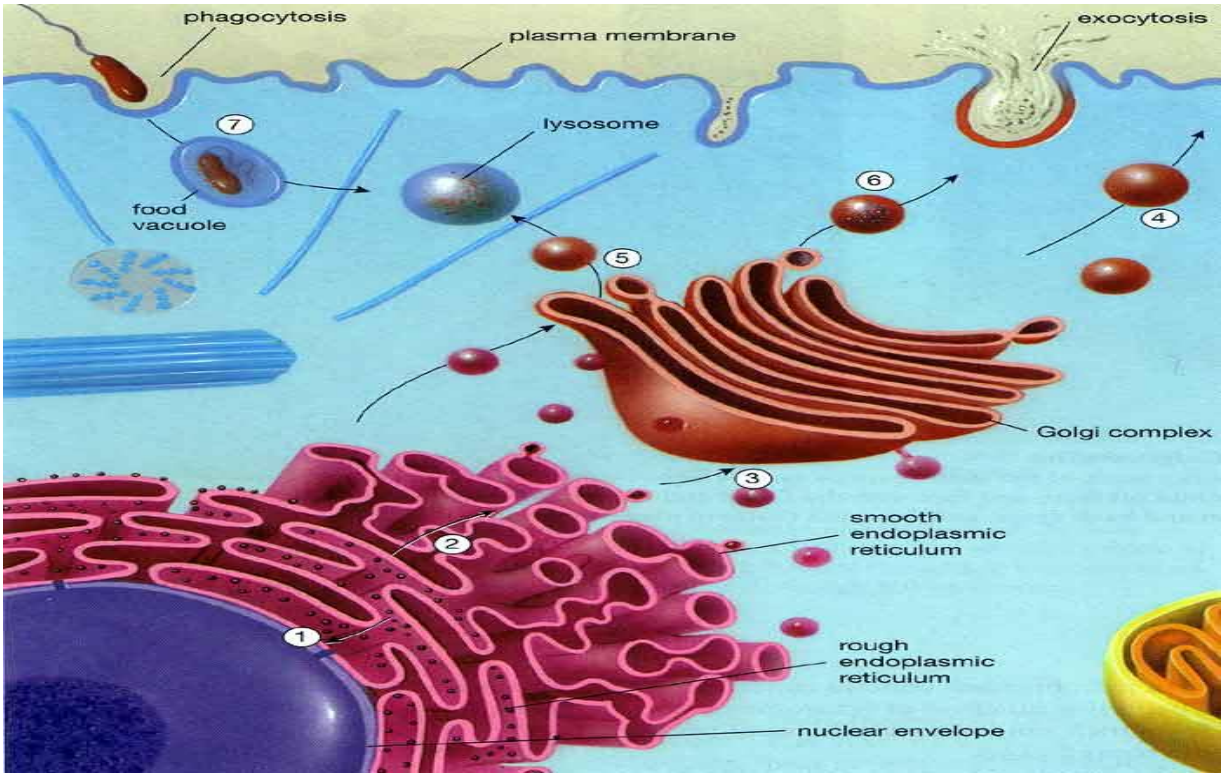


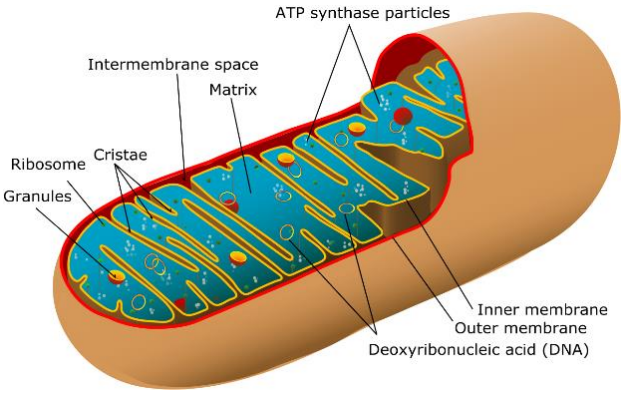
Figure illustrating functions of Golgi apparatus and vesicular transport

4- Mitochondria

-The mitochondrion is membrane bounded organelle containing specific enzymes for aerobic respiration and production of ATP.

-The only organelle can divide as it contain its own DNA.

-It undergoes dynamic change in the shape.



By LM: -appear as elongated filaments, spherical rods or pleomorphic.

-cytoplasm of cells that containing large number of mitochondria appears highly acidophilic due to the membranous component of the mitochondria.

-can be stained also by special stains such as iron Hematoxylin and Janus green B.

By EM: -It has the following components:

1-outer mitochondrial membrane.

2-inner mitochondrial membrane.

3- intermembranous space.

4-Matrix.

The outer mitochondrial membrane

-It is smooth and sieve like as it contains many channels called **porins** for transport of molecules.

-It contains many enzymes and receptors.

The inner mitochondrial membrane

-It has many long transverse or shelf like folds called cristae which project into the matrix and greatly increase the surface area.

-The number, shape and size of the cristae varies according to the activity of the cell. Tubular cristae present in the steroid secreting cells.

-The enzymes for respiratory chain are attached to the inner membrane and the heads of enzymes project into the matrix which appear as tennis -racquet shaped structure called **elementary particles.**

The intermembranous space

-It is located between inner and outer membrane.

-It contains enzymes used for generation of ATP**.**

The matrix

-It surrounded by inner mitochondrial membrane.

-It contains soluble enzymes of Krebs cycle and B oxidation of fatty acids.

-It contains dense matrix granules that store calcium.

-It contains mitochondrial DNA ,ribosomes and tRNA so it can divide.

Functions:

1-Production of energy needed by the cell.

2-share in calcium homeostasis in the body.

3-Mitochondria initiate programmed cell death(apoptosis).

5-Lysosomes:

-Site of intracellular digestion and turnover of cellular component.

-It contains more 40 hydrolytic enzymes for the digestive.

-It presents in large numbers in phagocytic cells such as macrophage and neutrophils.

-Its type and activity of lysosomal enzymes depend on the type of the cell.

-Lysosomal membrane has special phospholipids resistant to degeneration by lysosomal enzymes.

By LM: can be visible by histochemical stains such as acid phosphatase test.

By EM: appear spherical or irregular in shape limited by membrane.

Origin: Lysosomes originate from Golgi bodies or directly from rough ER.

Types of lysosomes:

1-Primary lysosome

-By EM, it has a homogenous granular content with no digestive material inside it.

2- Secondary lysosome

-It is larger and more heterogenous in appearance.

-It is formed by fusion of primary lysosomes with foreign body.

Function:

1-They aid in defense against infection by engulfing viruses and bacteria.

2-Intracellular digestive system for removal of worn-out organelles in the cell in a process called autophagy.

3-Autolysis: after death, release of lysosomes leads to self-destruction of cells.

II-Non membranous organelles

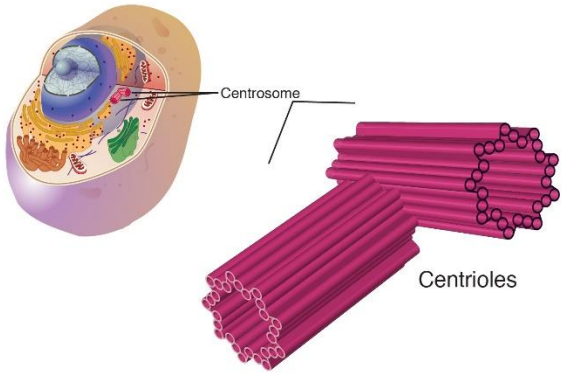
1- Centrioles

-The dominant MOTC in most cells is **the centrosome** and is the site of generation of microtubules and mitotic spindle. It usually located near the nucleus.
-The centrosome is formed around 2 **centrioles** directed perpendicular to each other.

-In transverse section centriole is formed of a ring of nine microtubule triplets.

-The 2 centrioles surrounded by pericentriolar matrix rich in proteins necessary for formation of microtubules.

-Before cell division, each centrosome duplicate itself, so each centrosome has 2 pairs of centrioles.



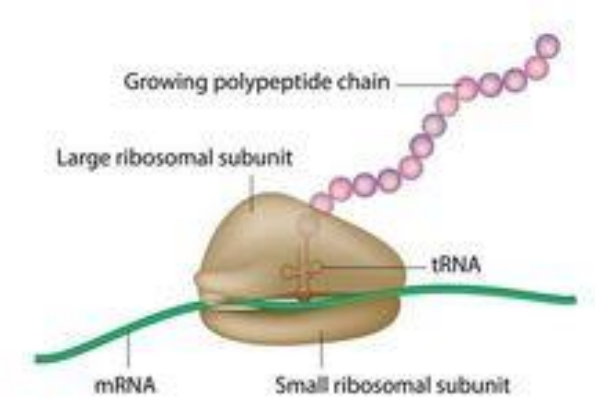
2-Ribosomes:

-They are small spherical macromolecules that synthesize proteins.

-They are uniform in size and their diameter ranges between 15-20 nm.

-They mostly consist of rRNA and proteins.

-They are synthesized in the nucleolus and reach the cytoplasm through the nuclear pores.



Types:

1- Free ribosomes: also called polysomes:

-They are scattered in the cytoplasm and have a rosette shape.

-They are consisting of several ribosomes arranged along thread of mRNA.

-They synthesize proteins used in formation of organelles inside the cell

2- Attached ribosomes:

-They are attached to outer surface of rough ER or outer nuclear.

membrane by docking proteins.

-They synthesize proteins used for secretion exported by the cell.

By LM:

-Ribosomes are below limit of resolution by LM but they stained by Hematoxylin(basic dye) i.e basophilic. Active protein secreting cell has basophilic cytoplasm due to presence of large number of ribosomes.

By EM:

-Each ribosome is formed of large subunit and small subunit that bind together during mRNA translation.

Function:

-Translation of mRNA into amino acids forming polypeptide chain.

Cell inclusions

-Unlike cytoplasmic organelles, inclusions are metabolically inactive structures.

-They vary in composition and distribution and sometimes a transient structure.

-They include 1-stored food such as glycogen mainly stored in liver and muscle and lipids mainly stored in adipose CT.

2- pigments either **endogenous** such as melanin and lipofuscin.

Or **exogenous** such as tattooing.

The Nucleus

-It is the largest structure in the cell.

-It carries the genetic material (DNA).

-Its **shape and size** depend on the cell type. It may be rounded, elongated, flattened, multilobed or bilobed.

-**The number** of nucleus

-usually single nucleus in the cell

- some cells are binucleated as liver cell and

transitional epithelial cells.

- Multinucleated cells such as osteoclast and giant cell.

-Anucleated (has no nucleus) cell is the red blood Cell.

-**Site**: usually located near the center. Some cell types have eccentric or basally located nuclei.

-Its **function** is DNA replication and synthesize of all types of RNA.

Components of the nucleus:

1- **Nuclear envelope**
2- **Chromatin**
3- **Nucleolus**

Nuclear envelope:

Forms a selective permeable barrier between the nuclear and cytoplasmic components.

By EM: It is formed of two membrane units separated by a narrow perinuclear space.

-The outer membrane and perinuclear space are continuous with the rough endoplasmic reticulum.

-Many ribosomes are attached to the outer surface of the outer nuclear membrane.

-Clumps of heterochromatin are attached to the inner surface of the inner nuclear membrane.

-Many small apertures perforate the nuclear membrane called **nuclear pores.**

-The inner and outer nuclear membranes fuse together at the edge of the pore.

-Each pore is guarded by nuclear pore complex that span the pore.

-This complex act as a sieve that allow passive diffusion of small molecules and require energy to pass large molecules.

Chromatin:

-It is formed of DNA, histone proteins, non-histone proteins and RNA that has been transcribed from DNA.

-It is responsible for basophilia of the nucleus.

-During mitosis, excessive chromatin condensation occurs forming structures called chromosomes. Each human cell contains 46 chromosomes.

Types(forms) of chromatin:

1- Heterochromatin:

- are clumps of densely staining chromatin(coiled chromatin).

- Transcriptionally inactive.

- usually located at the periphery of the nucleus.

-It predominate in metabolically inactive cells such as small lymphocytes.

- Barr body is a heterochromatin seen in the nucleus of neutrophil and cells of buccal smear of females. It is used to identify sex of the fetus.

2-Euchromatin:

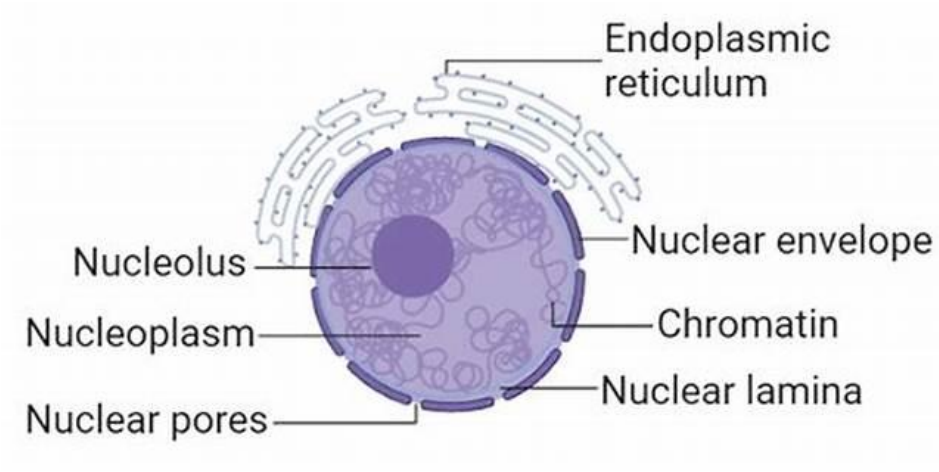
-In Hx&E stained sections, it appears as lightly stained area in

the nucleus (uncoiled).

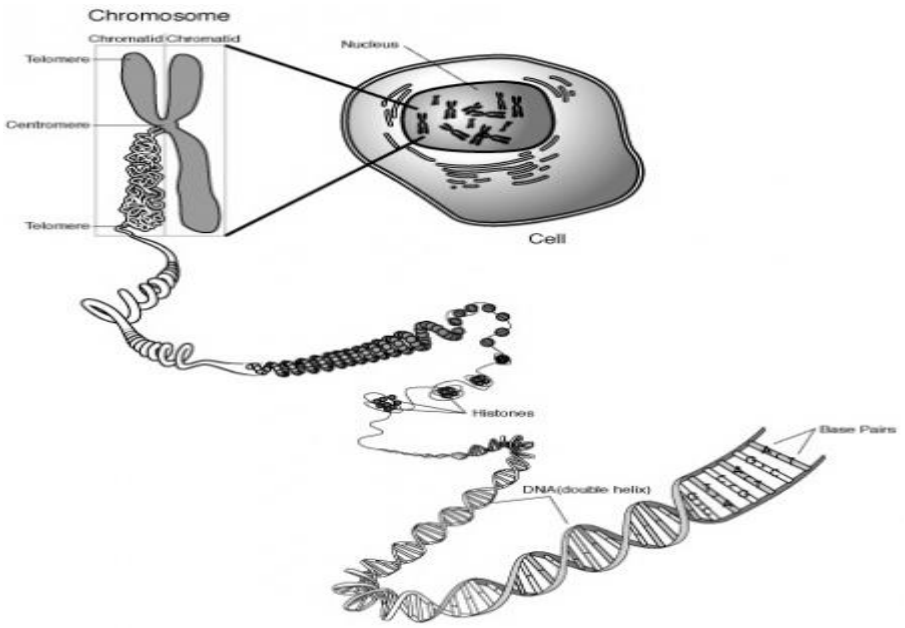
-It is transcriptionally active i.e stretched out so the DNA can undergo

reading and transcription.

-It predominates in the nuclei of the metabolically active cells such as neurons



and liver cell.



Nucleolus:

-It is a dense discrete ovoid non membranous area inside in the nucleus.

-Usually, each nucleus has one nucleolus. Some nuclei have more than one nucleolus specially in active protein secreting cells.

Function: 1-synthesis of ribosomal RNA(rRNA)

2 - production of ribosomes.

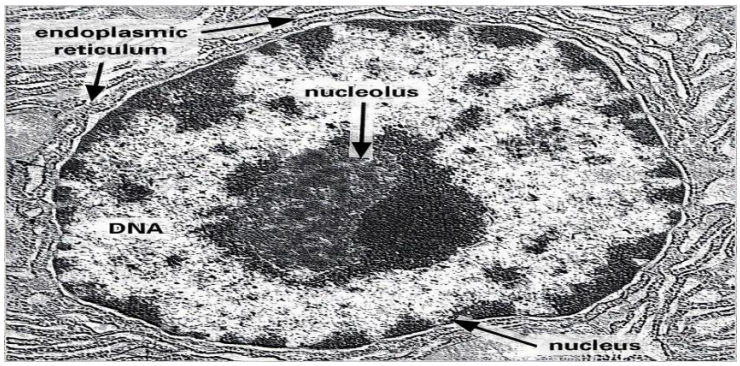
Structure:

By LM: appears highly basophilic due to its high content of RNA.

By EM: has 3 regions

1- **Fibrillar center** contain DNA loops of that contains rRNA genes.
2- **Fibrillar material** (pars fibrosa): contain genes that are actually under transcription and large amount of rRNA.

3- **Granular material** (pars granulosa) is the site of ribosomal assembly.



EM image showing nucleus and part of the cytoplasm

Types of nuclei according to their shapes:

1-Vesicular nucleus: - usually seen in active cells such as liver cell

-it contains euchromatin more than heterochromatin.

- also called open face nucleus.

2- Dense nucleus: - seen in inactive cells such as circulating lymphocyte.

-Most of its chromatin is heterochromatin

-Also called condensed nucleus.

Epithelium

Organs in the human body are consist **of four basic tissues:**

1-Epithelium (epithelial tissue) **2-Connective tissue**

3-muscule tissue **4-Nervous tissue.**

****Tissues are groups of cells organized to perform one or more specific functions.***

I-Epithelium

Characters of epithelium:

Cellularity: cells are closely adhere to one another by specialized cell to cell junctions.

Polarity: They exhibit functional and morphological polarity. In other words the cell has apical, basal and lateral parts. Each part has specific molecular structure and perform specific function.

Basal lamina (basement membrane): The basal surface of the cells lies on basement membrane.

Basement membrane is a non- cellular adhesive layer that attach epithelium to under lying connective tissue.

It secreted by epithelium and underlying connective tissue.

By LM :

-In Hx&E stained sections, It is acidophilic structure so cannot distinguished from the cytoplasm.

-It can be visualized by special stains such as PAS and silver stain. It appears a thin well-defined layer between the epithelium and connective tissue.

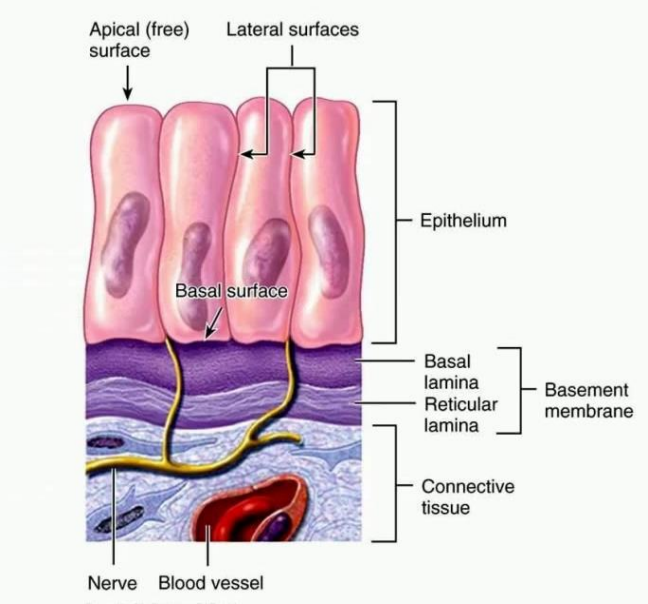
By EM: it is formed of two parts

1-Basal lamina: It lies below the epithelial cells. It appears thin dense sheet like layer of fine fibrils. It secreted from epithelial cells

2-Reticular lamina: It lies below basal lamina. It appears as a diffuse and fibrous layer. It is secreted from connective tissue cells

Function of basement membrane:

1- Provide structural support for epithelial cells.
2- Filter
3- Help to maintain cell polarity.



Vascularity: Epithelium is a vascular tissue (no blood vessels present between epithelial cells).Its nutrition depend on diffusion from the underlying connective tissue.

Regeneration: It rapidly regenerates as it is a short-lived cellsIts short life is due to avascularity of epithelium.

Functions of epithelium

1-Cover body surfaces and lines body cavities

2-Secretion such as glandular epithelium

3-Specialized epithelial cells act as a receptor such as neuroepithelium.

4-Germ cell production such as epithelial cells of the testis and ovaries.

Types of epithelia:

1-Covering and lining epithelium

2-Glandular epithelium

3-Neuroepithelium

I-Covering and lining epithelium

-It covers body surfaces and lines body cavities.

Classification: it is classified according to

1-Number of cell layers into

Simple epithelium contains one cell layer

Stratified epithelium contains two or more cell layers

2-Shape of the surface cells

Squamous (flat cell), Cuboidal cells or columnar cells.

Types of simple epithelia:

I-Simple squamous epithelium: formed of one layer of squamous (thin) cells

Site: Bowman's capsule of the renal glomerulus, blood vessel wall(endothelium)and lung alveoli.

II-Simple cuboidal epithelium: formed of one layer of cuboidal cells (width and height is roughly similar.

Site: collecting renal tubules and follicles of thyroid gland.

III-Simple columnar epithelium: formed of one layer of columnar cells(height is more than width).

Site: Stomach, intestine, and gall bladder.

Function: Simple epithelia mainly involved in absorption or secretion.

IIII-Pseudostratified columnar ciliated epithelium: it appears stratified (as the nuclei appears at dufferent levels)while it is actually simple formed of short cells do not reach the surface and tall cells reach the surface all rest on the basement membrane.

-Pseudostratified columnar ciliated epithelium with goblet cells(respiratory epithelium) found in trachea and bronchi.

-Pseudostratified columnar ciliated epithelium found in epididymis.

Types of stratified epithelia

I-Stratified squamous epithelium

-Formed of many layers of cells.

-Basal layer formed of cuboidal or columnar cells

-Middle layers formed of many polyhydral cells.

-Superficial layer formed of squamous cells

-Superficial surface may be keratinized or non keratinized

- Stratified squamous epithelium non keratinized line esophagus, oral cavity and anal canal.

- Stratified squamous epithelium keratinized found in epidermis of skin

-Function of stratified epithelium is mainly protection.

II-Stratified cuboidal epithelium

-Formed of many layers of cells

-Superficial layer formed of cuboidal cells.

-Site: lining the duct of sweat gland.

III-Stratified columnar epithelium

-Formed of many layers of cells

-Superficial layer formed of columnar cells.

-Site: Conjunctiva of the eye.

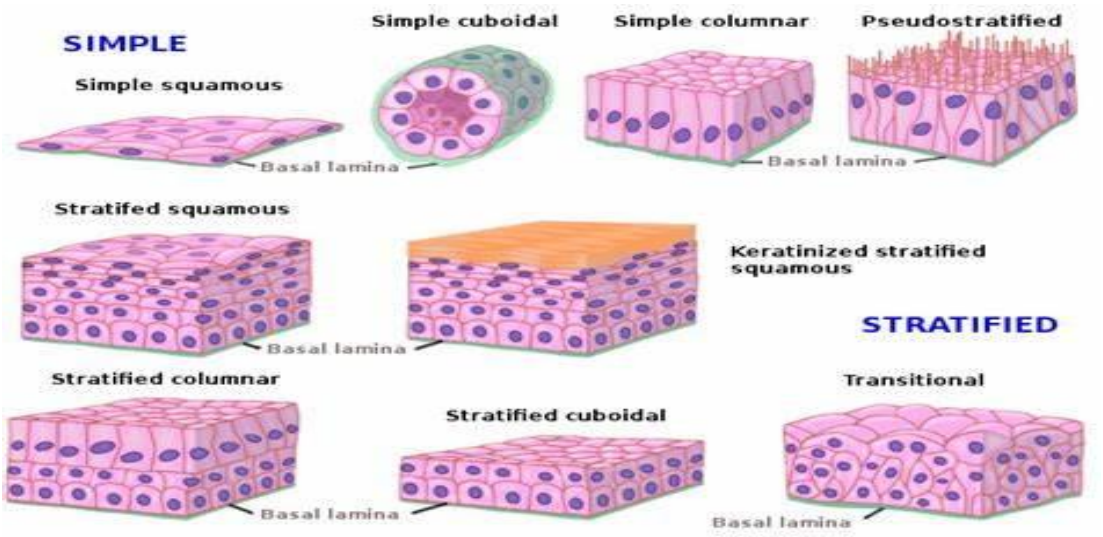
IV-Transitional epithelium(urothelium)

-formed of many layers of cells.

-Superficial layer formed of rounded or dome-shaped cells.

-The shape of the cells transformed from rounded and polyhedral cells(in empty bladder) to flat cells(in full distended bladder) hence the name Transitional epithelium.

-It lines the lower urinary tract (ureter & urinary bladder).



II-Glandular epithelium

-Epithelial cells may produce and secrete macromolecules. For example, enzymes from pancreatic acini and lipids from sebaceous glands.

Classification of glandular epithelium according to:

I-The presence or absence of ducts into:

A-Exocrine gland:

-Secrete their product through ducts.

-Example: salivary glands and pancreatic acini.

Exocrine gland can be further classified according to nature of secretion into:

1-Serous gland:

-Its secretion is watery rich in proteins

-Cells are high pyramidal in shape have rounded vesicular nucleus, well developed RER and Golgi complex and their apical part filled with secretory granules.

Example: Parotid gland.

2-Mucus gland:

-Its secretion is viscid and called mucus.

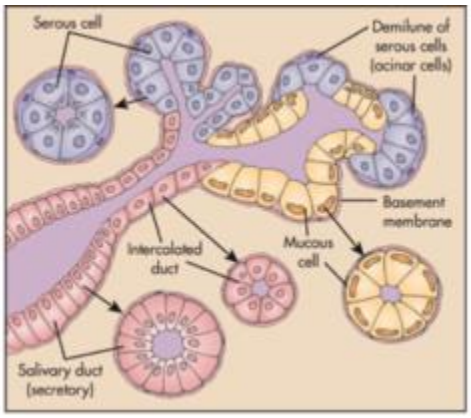
-Cells are low columnar cells have flattened basal nucleus, well developed RER and Golgi apparatus. Its cytoplasm appears foamy as the mucus is dissolved during staining by Hx&E.

-**Example**: esophageal gland and Brunner's gland in the duodenum.

3-Mixed (seromucous) gland:

-Formed of both mucus and serous acini.

-**Example**: Submandibular and sublingual salivary glands.



Exocrine glands can be further classified according to the shape of the secretory part and branching of the duct into:

B-Endocrine glands:

- Secrete their product directly to the blood capillaries.

-Example: pituitary gland, thyroid gland and adrenal gland.

-Their secretion is called Hormones.

II-The number of cells forming the gland into:

A-Unicellular gland:

-It is scattered secretory cells commonly seen in simple epithelium.

-Example: Goblet cell (secretes mucus) present in the lining of intestinal epithelium and in respiratory epithelium.

B-Multicellular gland:

-The gland is formed of many cells.

-Example: All exocrine glands.

III- according to mode of secretion into:

A-Merocrine gland:

-Secretion is released through exocytosis(secretory vesicle fused with plasma membrane to release the secretory product to outside of the cell).

-Most common type of protein secretion.

-Example: salivary gland

B-Holocrine gland:

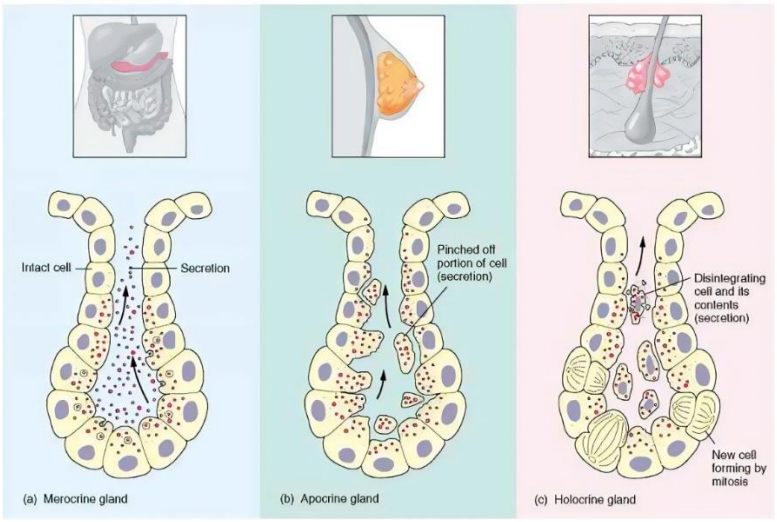
-Cells accumulate the secretion and enlarge until undergo complete disruption (complete loss of the cell).

-Example: sebaceous gland.

C-Apocrine gland:

-Secretory product accumulate at the apical pole of the cell then released through pinch out of small amount of cytoplasm and portion of plasma membrane(loss of part of PM).

-Example: Mammary gland.



III-Neuroepithelium:

-It is highly specialized type of epithelium-

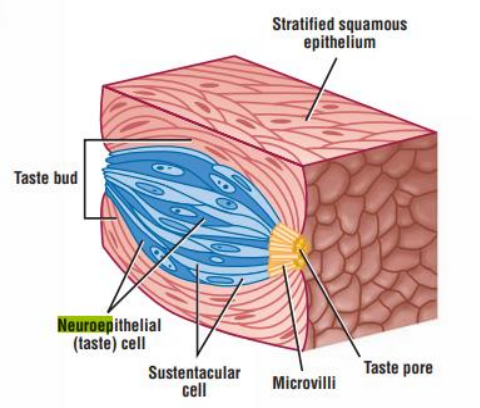
formed of neuroepithelial(gustatory) cell, supporting(sustentacular) cell and stem cell

-Function: perception of stimuli

-Sites: 1-Taste buds in the oral cavity responsible for taste sensation

2-Organ of Corti in the inner ear responsible for hearing

3-Macula utriculi and macula sacculi in the semi-circular canals and vestibuli in the inner ear responsible for equilibrium.



Connective tissue

Connective tissue consists of

1-Cells **2- Fibers** **3- Ground substance**

Fibers and ground substance are collectively described as **Extracellular matrix.**

Functions of CT:

1-Binds structures.

2-Support and protection

3-Serve as a framework of organs.

4-Form capsules of organs.

5-Synthesis and storage of fat

6-Repair wound.

A-Connective tissue cells

Are classified into:

1-Fixed cells **2-Free cells**

1-Fixed (resident) cells:

-They are resident in the connective tissue.

-They include:

- Undifferentiated mesenchymal cells

-Fibroblast -Fibrocytes

-Macrophage -Mast cell.

-Adipocyte

2-Free(wondering) cells:

-They migrate from blood to connective tissue in response to certain stimuli.

-They include:

-Lymphocyte -Monocyte

-Eosinophils -Basophils

-Neutrophils -Plasma cell

1-Undifferentiated mesenchymal cell(UMSC):

-The mother cell of connective tissue(can differentiate into other types of CT cells.

-It is a stem cell.

-It is spindle shaped cells with few cytoplasmic processes. It has scanty cytoplasm and large nucleus with prominent nucleoli. Its cytoplasm has free ribosomes.

2-Fibroblast (active cell):

-The most common CT cell.

-Produce and maintain the extracellular matrix of connective tissue.

-By LM : it has basophilic cytoplasm and vesicular nucleus.

-The active fibroblast has abundant cytoplasm, many cytoplasmic processes, vesicular nucleus with prominent nucleolus, many rough

reticulum and well developed Golgi apparatus (criteria of protein secreting cell).

-Fibroblast is responsible for repair of wound and damaged tissue.

3-Fibrocyte (Quiescent cell):

-It is smaller than fibroblast.

-Spindle shape with few processes.

-Contains less Rough endoplasmic reticulum and darker more heterochromatic nucleus.

4-Macrophage:

-It is derived from blood monocyte.

-Shape and size of macrophage vary according its activity.

-It measures 10-30 micron in diameter.

-It has a characteristic irregular outer surface showing protrusions and indentations(pseudopodia).

-Its nucleus is oval or kidney shape and in eccentric in position.

-Its cytoplasm contains large number of lysosomes in addition to many rough endoplasmic reticulum and well developed Golgi apparatus.

-Its function is phagocytosis of tissue debris, foreign body, viruses and bacteria.

5-Adipocyte(fat cells)

-present in many connective tissues .

-Aggregation of adipocytes form adipose connective tissue.

- Its function is storage of fat.

Types of adipocyte:

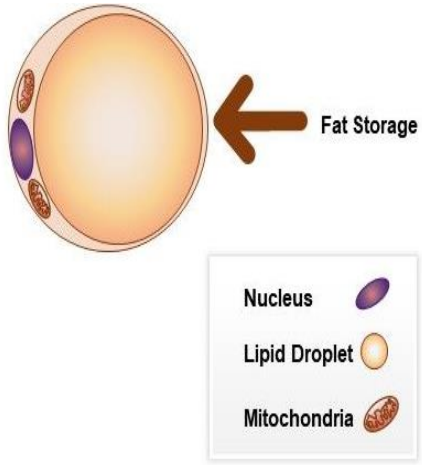
1-Unilocular (white) fat cell

-large cell with eccentric flat nucleus.

-the cytoplasm is occupied by a single large fat droplet.

-By Hx&E staininng the cell has a signet ring appearance as the lipid droplet is dissolved during staining.

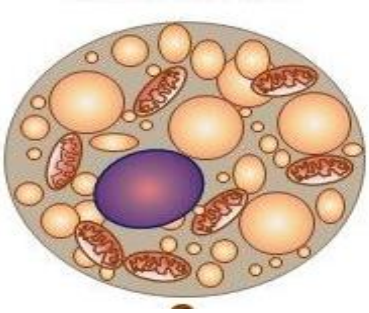
-Fat can be stained by special stain called sudan III or black and by osmic acid.



2-Multilocular(brown) fat cell

-It has rounded nucleus and many small fat droplets in its cytoplasm.

-It contains large number of mitochondria.



6-Mast cell

-It originates from progenitor cell in the bone marrow.

-It is a large ovoid cell filled with basophilic granules that often obscure the central nucleus.

-Its cytoplasmic granules show metachromasia which means that they change the color of some basic dyes such as toluidine blue to red or purple color.

-Its cytoplasm has many rough endoplasmic reticulum and well developed Golgi apparatus.

-Function: secretion of heparin and histamine(mediators of inflammation).

Free cells

1-Plasma cell

-It arises from activated B lymphocyte.

-Its function is production of antibodies.

-It is large ovoid cell has basophilic cytoplasm rich in rough endoplasmic nucleus and well-developed Golgi apparatus(criteria of protein secreting cell).

-The nucleus is spherical, eccentric with characteristic cartwheel or clock face appearance as heterochromatin resembling the spokes of the wheel or numbers on a clock.

2-Baophils

-It is one of the granular leucocytes.

-It migrates from blood stream to the connective tissue to perform its function.

-Its nucleus is into two irregular lobes but large specific granules overlying the nucleus usually obscure its shape.

-The cytoplasm is studded with basophilic granules. These granules show show metachromasia which means that they change the color of some basic dyes such as toluidine blue to red or purple color.

-**Function:** Secretion of heparin and histamine (chemical mediator of inflammation).

-It shares many features with mast cells.

3-Esinophils

-It is a granular leucocyte. It migrates from the blood stream to the connective tissue to perform its function.

-It has bilobed nucleus.

-Its cytoplasm is studded with large acidophilic specific granules.

Function: - It plays an important role in allergic reaction and parasitic infections.

4-Neutrophils

-It is a granular leucocyte. It migrates from the blood stream to the connective tissue to perform its function.

-Its nucleus has two to three lobes linked by fine chromatin threads.

Function: Neutrophil is the first leucocytes to arrive at sites of infection.

5-Lymphocyte

-It is a non-granular leucocyte.

-It has a thin rim of cytoplasm surrounding a deeply stained heterochromatic nucleus.

-lymphocyte can be classified according to function into:

1) B lymphocyte: play a role in antibody mediated immunity

2) T lymphocyte: play a role in cell mediated immunity

3) Natural killer cell: play a role in cell mediated immunity.

Connective tissue fibers

-Fibers are elongated structures formed of proteins produced by fibroblasts.

-Types:

1- Collagen fibers 2- Reticular fibers 3-Elastic fibers

1-Collagen fibers

-The most common structural components of CTA.

-They are flexible and highly tensile strength.

-In the LM : appear as wavy non branching bundles.

-They stain by eosin and appear red in color also can stained by Masson trichrome stain and appear light green in color.

In EM :Collagen fibers appear as bundles of fine thread like subunits of collagen fibrils. Collagen fibrils formed of collagen molecules.Each molecule is formed of 3 polypeptide chains.

-There are many types of collagen fibers.

2-Reticular fibers

-Formed of collagen type III

-Form extensive network of thin fibers that support most of tissue cells.

-In LM: They are fine branched fibers never form bundles.

-They can be visualized by special stain such as silver stain and PAS (periodic acid Schiff).

-In EM appear as fine threads forming a network with other types of fibers.

3-Elastic fibers

-They allow tissue to respond to stretch and distension.

-In fresh state they have a yellow color.

-They are branching fibers

-They are poorly stained by eosin. They are best stained by Orcien stain where thay appear brown in color.

Connective tissue ground substance:

-It is a highly hydrated, transparent, complex mixture of three major kinds of macromolecules (namely, glycosaminoglycans, proteoglycans and multiadhesive glycoprotein).

Function:

1-It fills the spaces between cells and fibers.

2-It allows diffusion of small molecules.

3-also act as a lubricant.

Types of connective tissue

*Classification of CT based on the composition and organization of its extracellular composition and on its function.

A-Embryonic connective tissue include:

1- Mesenchyme 2- Mucoid CT

B-Connective tissue proper include:

1-loose (areolar)CT 2- Dense regular CT 3-Dense irregular CT

C-Specialized CT include:

1-Reticular CT 2-Adipose CT 3-Cartilage

4-Bone 5- Blood.

Cartilage (Chondrium)

-It is a tough form of supporting CT.

-It is avascular tissue and receive nutrients by diffusion from underlying connective tissue.

-Function: 1-it allows the tissue to bear mechanical stresses without distortion.

2- it forms a framework supporting soft tissue such as larynx and trachea.

3-Act as a cushion with skeletal joints.

4-act as a frame for bone growth.

-Cartilage in every sites in the body is surrounded by a sheath of dense connective tissue called perichondrium except in articular joints.

Perichondrium

-It is responsible for nutrition of the cartilage.

-it is essential for growth and maintenance of the cartilage.

-Perichondrium is formed of:

1-outer fibrous layer consists of collagen type I fibers and fibroblast.

2-inner cellular layer joined to the cartilage contains mesenchymal stem cells which provide a source of new chondroblast that differentiate into chondrocytes.

Structure:

Formed of cells, fibers, and ground substance.

Cartilage cells:

1-Undifferentiated mesenchymal stem cell: is the mother cell of the cartilage.

2-Chondroblast (young cell): arise from undifferentiated mesenchymal stem cell.

-present at the periphery of the cartilage.

-It is elliptical in shape with its long axes parallel to the surface.

-It is responsible for formation of extracellular matrix so it has the criteria of protein secreting cell(vesicular nucleus, many rough endoplasmic reticulum and well developed Golgi apparatus).

3-Chondrocytes: -chondroblast differentiates into chondrocyte.

-located deep in the cartilage.

-more rounded in shape and surrounded by lacuna.

-may present in groups up to eight cells within the same lacuna

called **isogenous groups.**

-cartilage cells and matrix may shrink slightly during histologic preparation resulting in both irregular shape of the chondrocyte and its retraction from the lacuna.

Types of cartilage (based on the characteristics of their matrix):

1-Hyaline cartilage

-The matrix of hyaline cartiage appears glassy in fresh state hence the name(hyalo=glassy).

-Through out the cartilage matrix there are spaces called Lacunae.

-Chondrocytes located inside these lacunae.

-Chondrocytes are distributed either singularly or in groups.

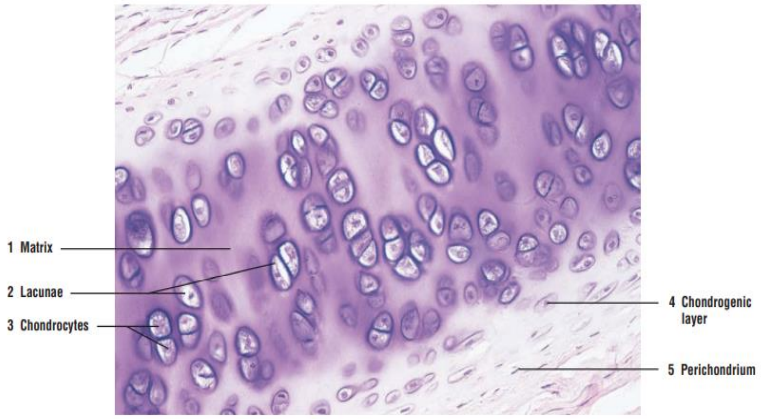
-It characterized by matrix containing type II collagen fibers, GAGs, proteoglycans and multiadhesive glycoprotein secreted by chondrocytes.

-In Hx&E stained sections the matrix appears basophilic.It is also homogenous as the refractive index of fibers is the same for the refractive index of the ground substance.

-The matrix is condensed around lacuna forming territorial matrix which is strongly basophilic. Between lacunae, the matrix is less basophilic and called interterritorial matrix.

-Its matrix is highly hydrated to provide resilience and diffusion of small molecules.

-It is found in skeleton of neonates, costal cartilage and form tracheal rings.



Growth of cartilage: There are 2 types

I-interstitial growth: the process that form new cartilage within an exciting cartilage.

-It involves mitotic division of preexisting chondrocytes.

II-appositional growth: the process that forms new cartilage at the surface of an exciting cartilage.

-Cells in the cellular layer of perichondrium is differentiated into new chondroblast.

-It occurs more in postnatal life.

2-Elastic cartilage:

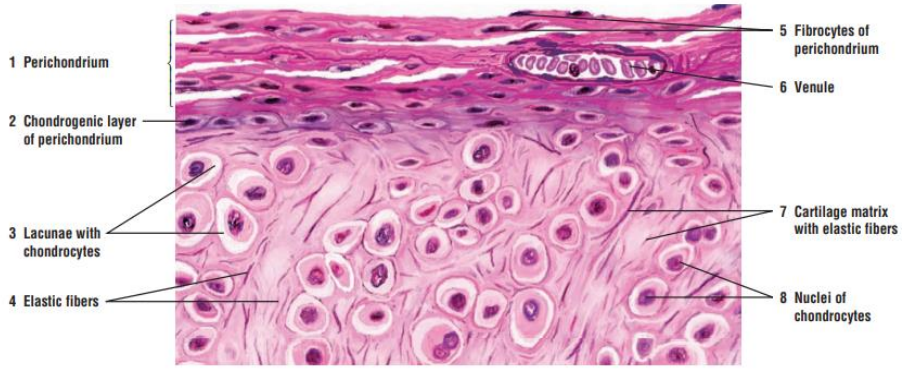
-It has the same components of hyaline cartilage but in addition its matrix contains branching and anastomosing elastic fibers.

-These fibers are best demonstrated by orcein stain which take brown color.

-These fibers add an elastic property to the cartilage in addition to resilience.

-It is surrounded by a perichondrium

-It is found in ear pinna, external auditory meatus and epiglottis of the larynx.



3-White fibrocartilage:

-It is a combination of dense regular connective tissue and hyaline cartilage.

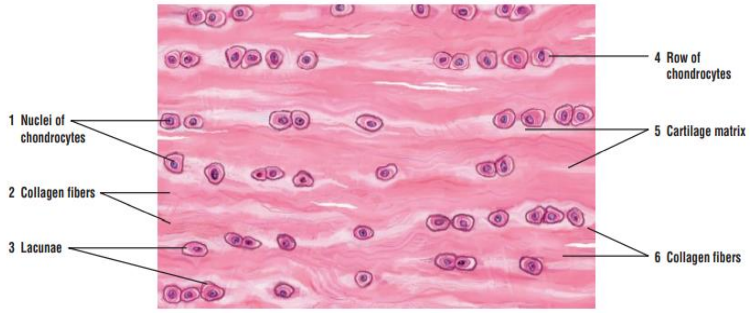
-It is not surrounded by a perichondrium.

-It appears as areas of chondrocytes and hyaline matrix separated by areas of dense bundles of collagen type I and fibroblast.

-So, its matrix contains collagen type I and collagen type II fibers.

- It is resistance to compression and shearing forces also act as a shoch absorbent.

-found in intervertebral disc, symphysis pubis and meniscus of knee joint.



Regeneration of cartilage:

-Cartilage has limited ability to repair due to 1) avascularity of cartilage 2) the immobility of the chondrocytes and 3) limited ability of chondrocytes to repair.

-Some repair may occur if injury involves perichondrium as it contains stem cells.

Bone tissue (Ostium)

-It is a specialized type of connective tissue characterized by a mineralized extracellular matrix.

-It is supporting connective tissue.

-Unlike cartilage, bone is highly vascular.

-Bone consists of cells, fibers and ground substance.

A- Bone cells

1-Osteoprogenitor cells (osteoblast precursor cell)

-It is derived from the UDMCs

-It is a resting cell that can differentiate into an osteoblast.

-It is found on the internaland external surfaces of bones.

-By LM: appears as flattened(squamous) cell with vesicular elongated nucleus and basophilic cytoplasm.

-By EM: reveals vesicular nucleus, rER, free ribosomes and small Golgi apparatus.

2-Osteoblast

-It is the differentiated bone cell that secretes the bone matrix

-By LM: appear cuboidal in shape and aggregated in one layer in apposition to the forming bone. Its cytoplasm is deeply basophilic.

-It is active protein secreting cell having thin cytoplasmic processes.It is characterized vesicular nucleus, many rER, well developed Golgi apparatus and secretory vesicles.

3-Osteocyte

-The osteocyte is the mature bone cell enclosed by bone matrix.

-When the osteoblast completely surrounded by bone matrix is called osteocyte.

-Each osteocyte occupies a space or Lacuna.

-Osteocyte has many cytoplasmic processes are enclosed by canaliculi within the matrix.

-Osteocyte is connected to the neighboring osteocyte by gap junction.

-In Hx &E stained sections, the cell processes and canaliculi are not visualized clearly.

-Osteocyte has more heterochromatic nucleus, less rough endoplasmic reticulum, smaller Golgi apparatus than osteoblast.

Function: Maintenance of bone matrix.

4-Osteoclast

-It is formed by fusion of bone marrow derived monocytes.

-It is a large motile multinucleated cell.

-It lies directly on the bone surface where resorption occur.

-The osteoclast is polarized cell has three distinctive regions:

1-The ruffled border is the part of the cell in direct contact with bone.It contains deep plasma membrane infoldings to increase the surface area.

2-The clear zone(sealing zone) is a ring like area of cytoplasm adjacent to the ruffled border. It contains abundant actin filaments and lacks other organelles. It binds the cell tightly to the bone the bone matrix.

3-The basolateral region is responsible for exocytosis of degraded material.

-The cell is deeply acidophilic contains multiple vesicular nuclei,Rer,multiple Golgi complexes, many vesicles and large number of lysosomes.

Function: bone resorption during bone growth and remodeling.

Bone matrix

Composed of organic and inorganic materials

I-inorganic material:

-It represents 50% of dry weight of bone matrix. Calcium hydroxyapatite is most abundant form of calcium present in the matrix.

II-organic material

-Collagen type I forms 90% organic material. It binds to calcium to provide hardness and resistance to the bone tissue.

-Small amount of proteoglycans and multiadhesive glycoproteins are also present.

-Bone matrix is highly acidophilic.

Bone covering

1-Periostium: covers the outer surface of the bone

-It is formed of connective tissue.

-It is organized into 1) outer fibrous layer and inner cellular layer.The outer fibrous layer contains bundles of collagen typeI. Bundles of periosteal collagen called perforating (or sharpey) fiber binds the periosteum to the bone matrix.

2)Inner cellular layer includes osteoblasts and mesenchymal stem cells.

2-Endostium: is less organized than periosteum.

-It covers the internal surface of the bone

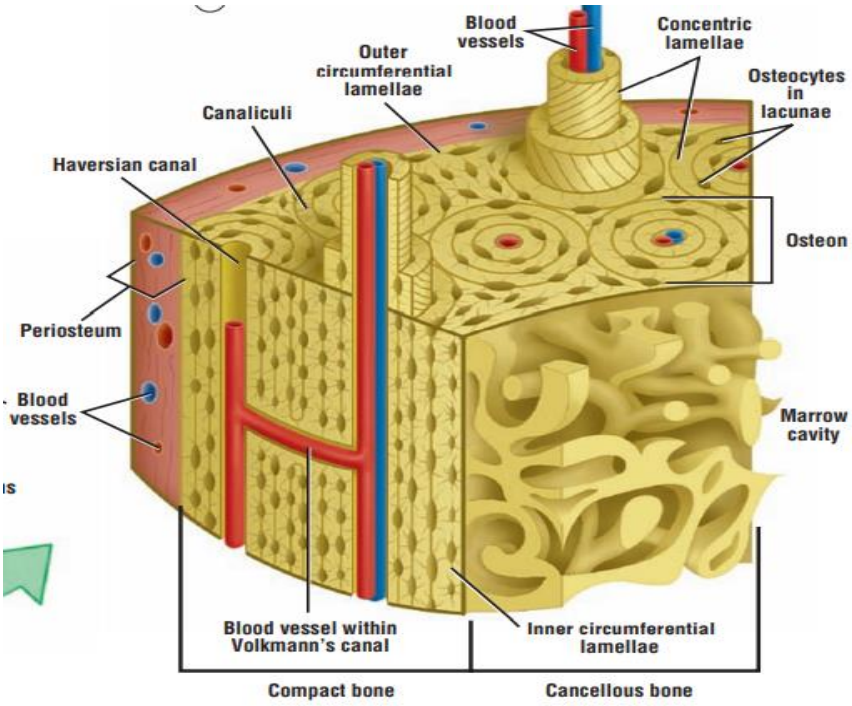
-It contains sparse fibers, osteoprogenitor cell and osteoblast.

Types of bones

There are two types of bone:

I-Compact bone

II-Cancellous bone



I-Compact bone

-It is formed of structural unit called Osteon (Haversian system)-

The osteon is formed of concentric lamellae of bone matrix surrounding central Haversian canal. Osteocytes are present in these lamellae.

Haversian canal carries the vascular and nerve supply of the bone.

-The long axis of an osteon is parallel to the long axis of the bone.

-Perforating (Volkman's canal) are channels which carry blood vessels and nerves from the periosteal and endosteal surface to reach the Haversian canal, also connect Haversian canals to one another. They are at right angles to the osteon and the bone.

Sites: Shaft of long bones.

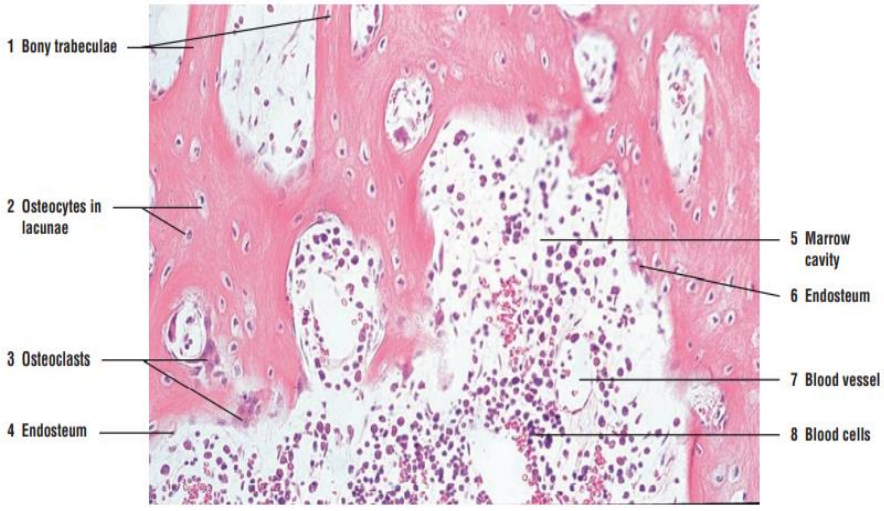
II-Cancellous bone

-Unlike compact bone, it does not contain an osteon.

-It is formed of bone trabeculae separated by bone marrow cavities.

-Bone trabeculae contain bone matrix and osteocytes arranged randomly inside it.

Site: Skull and ribs.



Osteogenesis (Bone development)

It occurs by one of two methods:

1-Iintramemranous ossification, in which osteoblast differentiate directly from the mesenchyme and to form new bone tissue.

2-Endochondral ossification, in which a preexisting cartilage is invaded by osteoblast . Then, osteoblast starts new bone formation.

Blood

-It is a specialized type of connective tissue consists of cells and fluid extracellular matrix called plasma.

-The blood volume is about 5-6 liters in adults.

Blood cells

- Blood cells can be studied via tissue sections, but a blood film or smear is preferred for routine microscopic evaluation. The procedure for a blood film involves placing a drop of blood on a glass slide, spreading it thinly and evenly over the surface to make a blood film and then stained by Hx&E or Giemsa stain.

- Blood consists of three major cell types: erythrocytes (red blood cells), leukocytes (white blood cells), and platelets (thrombocytes). These cells, also called the formed elements of blood.All cells are suspended in plasma.

Blood cells have a limited life span, and, as a result, they are continuously replaced in the body by a process called hemopoiesis. In this process, all blood cells are derived from a common stem cell in red bone marrow.

-Function: Blood cells transport gases, nutrients, waste products, hormones, antibodies, various chemicals, ions, and other substances in the plasma to and from different cells in the body.

Erythrocytes:

-RBCs are anucleate(has no nucleus) biconcave discs that are highly flexible and malleable as they travel in narrow lumen of the capillary.

-They make up 99% of the formed elements of blood and have a lifespan in circulation of about 120 days.

-Numbers of RBCs per liter of blood usually average 4.5 – 6.0 million / ul in adults.

-During hemopoiesis, RBCs lose the nucleus and almost all organelles except the cytoskeleton and then enter the circulation so it called Corpuscle. Its cytoplasm is completely filled with hemoglobin.

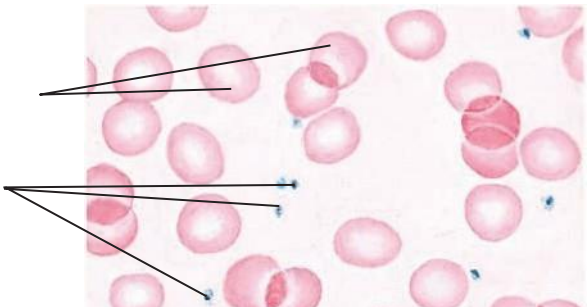
-In blood films stained by Hx&E, the RBC appear as biconcave disc with a pale area in the center surrounded by a thicker, eosinophilic peripheral zone. The RBCs are uniform in size.

-A biconcave shape provides a large surface area for transporting O2 from lungs to tissues and returning CO2 from tissues to lungs for elimination.

-RBCs has a sticky surface so they adhere to each other in circulating blood and form loose rows known as rouleaux.

-Human erythrocyte is 7.5 um in diameter.

-Old RBCs are removed from the circulation by macrophages in the spleen, liver and bone marrow.



White blood cells (Leucocytes)

WBCs are classified according to the density of cytoplasmic granules into:

I-Granular leucocytes include neutrophils, eosinophils and basophils
II-Non-granular leucocytes include lymphocytes and monocytes.

-All are motile cells circulate in the blood for a short time and migrate across small blood vessel walls to perform functions in the connective tissue.

-Normal total leucocytic count ranges from 4000-11000/L.

Granulocytes

-They are a terminally differentiated cell so have a short life span.

1-Neutrophils:

-Neutrophils are the most numerous leukocytes and constitute 60%-70% of the leukocyte count.

-Neutrophils are 12-15um in diameter.

-The nucleus has a distinctive segmented (multilobed) shape and many forms (thus the name polymorphonuclear leukocytes). Nucleus formed three to five lobes connected by fine chromatin strands.

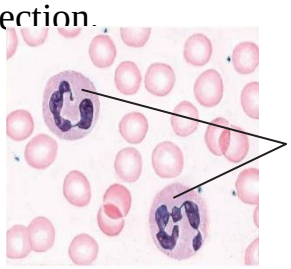
-Neutrophil cytoplasm is lightly eosinophilic(acidophilic) and contains **two types of granules.**

1) specific granules are many small, membrane-bound not acidophilic or basophilic but stain faintly with neutral dyes.

2) large azurophilic granules that stain reddish purple. They are primary lysosomes containing peroxidase and hydrolytic enzymes.

-The cytoplasm also includes small Golgi complex, a few scattered mitochondria, and some glycogen deposits.

Function: The first leucocyte reaches the site of infection as it can kills bacteria.so the number of neutrophils increases in bacterial infection.



Neutrophils

2-Eosinophils:

-Eosinophils represent small proportion of leukocytes in peripheral blood nearly 1%-4% of the leukocyte count.

-The diameter of eosinophils is12-15 um the same as neutrophils or they are slightly larger.

-Their nucleus is typically bilobed.

-Its cytoplasm includes two types of granules:

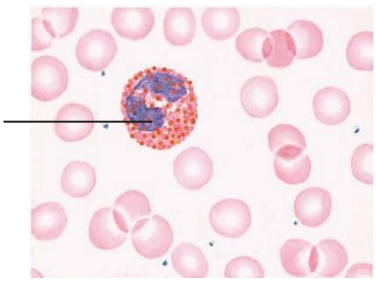
1)Primary azurophilic granules (as described above).

2)Specific granules are large, acidophilic granules. These specific granules are uniform in size and highly refractile. These granules contain various hydrolytic enzymes and secrete histaminase, which inactivates histamine produced by basophils and mast cells. The eosinophils are identified by the abundance of these large acidophilic granules.

- Electron microscopy shows the membrane-bound specific granules to have an irregular shape with flattened crystalloid core.

- Eosinophils are common in mucosal connective tissues in the respiratory and gastrointestinal tracts.

-Function: The cells phagocytose antigen-antibody complexes and parasites so their numbers increase in parasitic infections and allergic responses.



Esinophil

3-Basophils

-Basophils, the least numerous leukocytes, account for less than 1% of the leukocyte count.

-They are 12-15 um in diameter.

-Its cytoplasm has 2 types of granules :

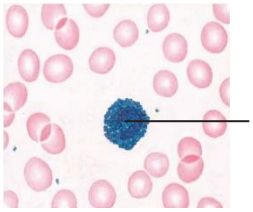
1) Primary azurophilic granules.

2) specific granules they are large, distinctive granules, intensely basophilic and fill the cytoplasm.

-The nucleus formed of two irregular lobes but the nucleus is usually obscured by many closely packed basophilic specific granules, which often stain more deeply than nuclear chromatin.

- Basophils closely resemble mast cells of connective tissue; their granules, like those of mast cells but larger and fewer, have metachromatic staining properties and contain histamine and heparin.

-Function: basophils involved in allergic reactions and increase in number(basophilia) in urticaria and some leukemias.



basophils

II-Agranulocytes

1-Lymphocytes

- lymphocytes are the most numerous agranular leukocyte representing 20%-40% of the total leukocyte count.

-They are spherical cells with a densely stained nucleus and a thin rim of basophilic cytoplasm.

- By electron microscopy, many free ribosomes and rough endoplasmic reticulum (RER) are dominant in the cytoplasm. A small Golgi complex, small numbers of mitochondria, and occasional lysosomes are also present.

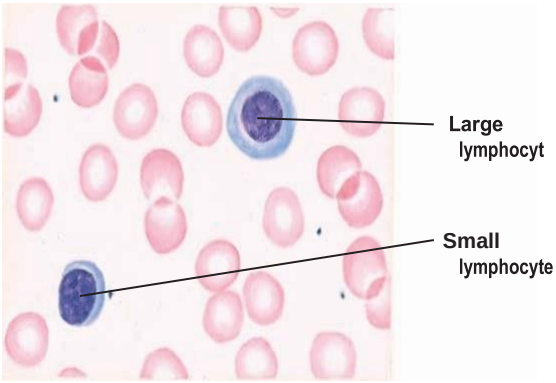
Types of lymphocytes

1-According to their size, they can be classified into **small** (6- 10 um) and **medium to large** (11-16 um). Most of circulating lymphocytes in normal blood are small.

2-According to their site of differentiation into **T cells** and **B cells.**

-B cells are differentiated in the bursa. B lymphocytes when activated it differentiated into plasm cells. Plasma cell secretes antibodies, so B lymphocytes are responsible for humoral immunity.

-T cells are differentiated in the thymus. T lymphocytes are responsible for cellular immunity.



2-Monocytes

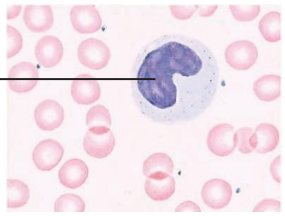
-It is the largest leucocytes with a diameter of 12- 20 mm.

-They constitute 3%-10% of the total leukocyte.

-Each cell has an oval or kidney shape, pale stained, and indented nucleus. Monocyte cytoplasm is pale basophilic and contains a moderate number of small, scattered azurophilic granules but no specific granules. the cytoplasm also contains scattered elements of RER, free ribosomes, small Golgi complex and a few small mitochondria.

-Function:

monocyte migrates to the connective tissue and transformed into macrophage. Number of monocytes increase in inflammation.

monocyte 

Platelets

-Platelets are motile cytoplasmic fragments enveloped by a plasma membrane.

-They arise from megakaryocytes in bone marrow.

-They are the smallest formed elements in peripheral blood, with a diameter of 2-4 um.They appear as plate-like structures without nuclei.

-They normally range from 150 to 400 × 10^9/L.

Muscular tissue

-There are three types of muscle tissues in the body: skeletal muscle, cardiac muscle, and smooth muscle.

-All muscle tissues consist of elongated cells called **fibers.** The cytoplasm of muscle cells is called **sarcoplasm** and the surrounding cell membrane or plasmalemma is called **sarcolemma.**

-Each muscle fiber sarcoplasm contains numerous myofibrils, which contain two types of contractile protein filaments called actin and myosin.

I-Skeletal muscle

-voluntary striated muscle attached to the skeleton.

-skeletal muscle contains elongated, thread-like multinucleated cells called muscle fibers.

-Individual muscle fibers vary considerably in diameter from 10 to 100 µm and may extend throughout the whole length of a muscle and, in some sites, may be many centimeters in length.

Organization and covering of the skeletal muscle:

-The individual muscle cells (muscle fibers) are grouped together into elongated bundles called **fasciculi or fascicles** with delicate supporting tissue called **endomysium** occupying the spaces between individual muscle fibers. Each fascicle is surrounded by loose collagenous tissue called **perimysium**. Most **muscles** are made up of many fasciculi, and the whole muscle mass is invested in a dense collagenous sheath called **the epimysium**. Large blood vessels and nerves enter the epimysium and divide to ramify throughout the muscle in the perimysium and endomysium.

Organization within the muscle fiber(cell) :

-Longitudinal section of skeletal muscle shows transverse striations of alternating light and dark band.

-The sarcoplasm containing long filaments called myofibrils run parallel to the long axis of the fiber.

-The myofibrils contain alternating dark band called A band and light band called I band.

-Each I band is bisected by a dark transverse line, called Z line.

-The functional and structural unit of the muscle is called sarcomere.

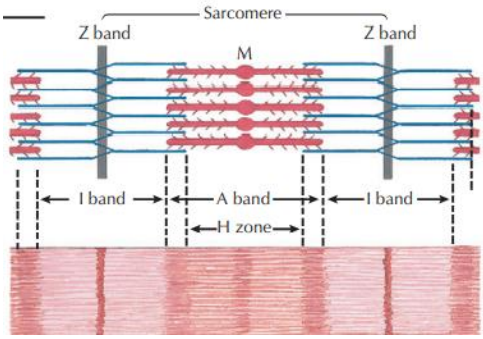
-The sarcomere extends from the Z line to Z line.

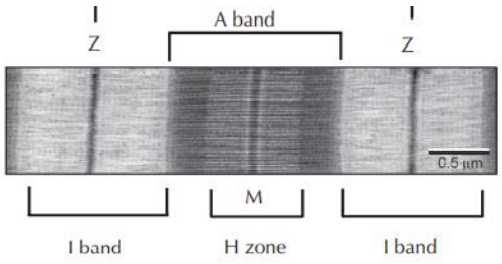
Components of the sarcomere:

1)Thick myosin filaments are present in the center of sarcomere.It is 1.6 um length and 15 nm wide. They occupy the A or dark band.

2)Thin actin filaments extend from the Z line on both sides and run between the thick filaments forming the I band. The actin filaments are 1.0 um long and 8 nm width.

-So, the **I band** is formed of thin filaments only. While the **A band** is formed of overlapping actin and myosin filaments. At the center of A band there is a lighter region occupied only by thick filaments called H zone. **The H zone** is bisected by **M line**. The M line contains the myosin binding proteins which bind myosin in place.



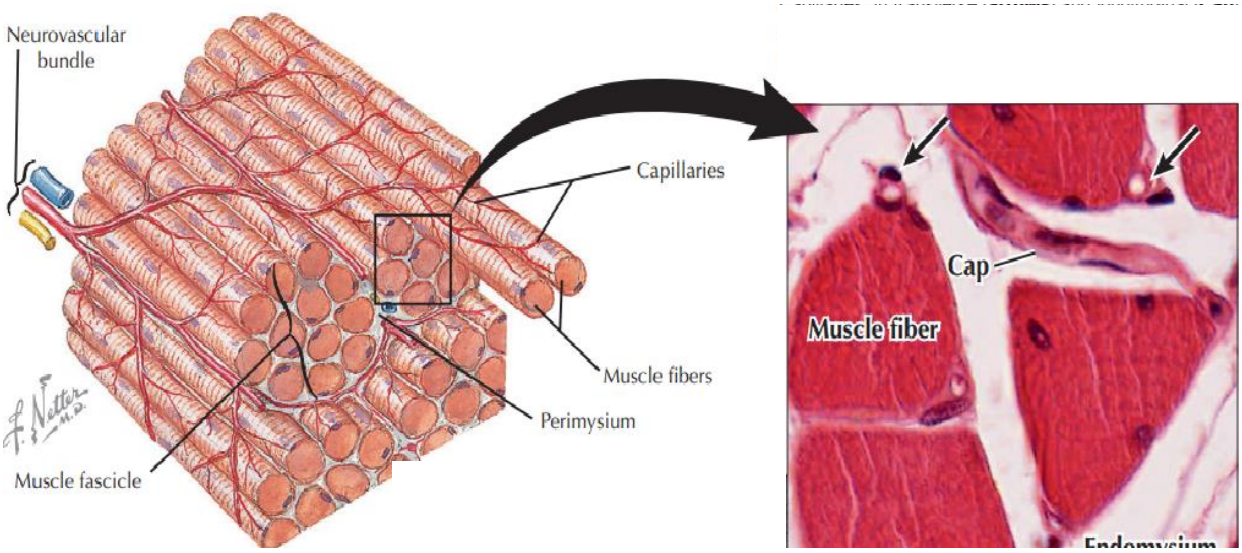


Skeletal muscle by LM :

-Skeletal muscle fibers are non-branching, long, cylindrical, multinucleated cells, with peripheral nuclei in longitudinal section.

-The cytoplasm is deeply acidophilic and showing transverse striations.

-In transverse section: Muscle fiber appear rounded or polygonal. They have acidophilic cytoplasm showing dots(myofibrils).



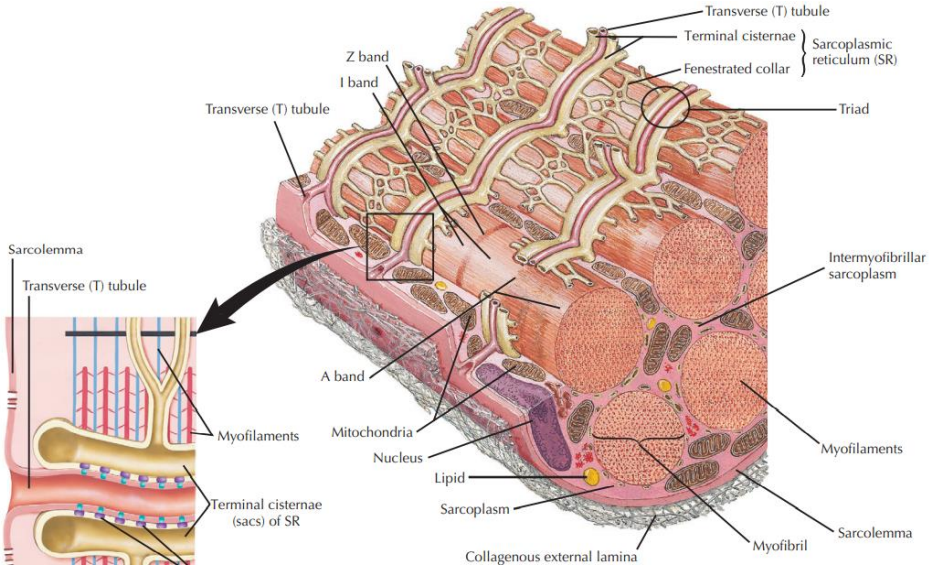
By EM:

-The sarcolemma has a specialized invagination penetrate deeply in the sarcoplasm and encircle each myofibril. This invagination is called transverse or T tubule

- Smooth endoplasmic (sarcoplasmic) reticulum expanded forming terminal cisterna adjacent to each T tubule.

-The complex formed of two terminal cisternae and T tubule is called **Triad.** The triad complex allows depolarization of the sarcolemma in the T tubule to affect the sarcoplasmic reticulum and trigger release of calcium ions into the cytoplasm around thin and thick filaments to initiate contraction.

-Large number of mitochondria, Golgi apparatus and glycogen granules are also present in the cytoplasm.



Cardiac muscle

-It is striated involuntary muscles forming the wall of the heart.

By LM:

-The cytoplasm is acidophilic showing transverse striations (less than in skeletal muscle).

-Cardiac muscle fiber is shorter than skeletal muscle fiber and branched.

-It has a single oval centrally located nucleus.

-Cardiac muscle fibers are joined together by intercalated discs.

By EM

-Intercalated disc consists of many types of junctional complexes namely;

1-zonula adherents act as anchoring site for actin filaments of the sarcomere.

2-Desmosomes prevent pulling apart under constant contractile activity.

3-Gap junction provide ionic continuity between adjacent cells.

-Each T tubule contact with only one terminal cisterna forming **diad** no triad.

-Many mitochondria and Golgi complex are present in the cytoplasm.

Smooth muscle

-Non striated involuntary muscles present in the wall of blood vessels and visceral organs such as the ureter, esophagus, and stomach.

-By LM:

-Smooth muscles present in sheets of spindle shaped cells

(Broad in the middle and tapering at the two ends).

By EM:

-The organelles are mainly small area on both sides of the nucleus. They are mitochondria, Golgi complex, RER and free ribosomes.

-The remainder of the cytoplasm is occupied by filaments. There are 3 types of filaments present in smooth muscle; thin(actin) filament, thick(myosin) filament and intermediate (desmin and vimentin) filaments.

-Some filaments are inserted into dense bodies.