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INTRODUCTION TO HISTOLOGY



ILOs

Upon successful completion of this course student will be able to:

- Define histology.
- Know the common types of microscopes & their applications in medical research.
- Define magnification & resolution power of different microscopes.
- Know the different types of stains
- Know the mostly commonly used stain & their applications in medical field.

Histology: is the subject dealing with the microscopical structure of normal tissue.

The aim of histology course is:

- To help the student to understand the microanatomy of cells, tissues & organs.
- To make correlation structure with function.

The study of histology is carried out by using **microscopes** of different types.

The commonly used types of microscopes are:

- 1- Light microscope (L.M.)
- 2- Electron microscope (E.M.)
- 3- Light microscope & electron microscope differ in their optical resolution & magnification (enlargement).

Resolution power: means the least distance at which two points appear separate from one another, if the distance is less the two points will appear as one point.

Resolution power of the eye = **0.2 mm**

Resolution power of the LM. = **0.2 μ m**

Resolution power of the EM. = **0.2nm**

Maximum magnification power in case of L.M. is about X1000 while in case of EM. magnification power is about X100,000.

Common stains used for Light microscopy

Cells are colorless and usually indistinguishable by LM unless stained.

- 1) **Acidic stain:** e.g. eosin, it can stain basic structures, so these structures are acidophilic.
- 2) **Basic stain:** e.g. hematoxylin which stains acidic structures, so these structures are basophilic.
- 3) **Neutral stain:** e.g. Leishman's stain. It is a combination of an acidic & a basic stain for staining of blood cells.
- 4) **Vital stain:** It is used to stain a living structure inside a living animal such as staining of phagocytic cells using trypan blue or India ink.

- 5) **Supravital stain**: It can stain a living cell outside a living person e.g. Brilliant Cresyl blue which stains reticulocytes (immature RBCs) in a blood film.
 - 6) **Metachromatic stain**: It will give a new color after staining which is different from its original color. The new color develops as result of a chemical combination between the stain & certain structures within the cell e.g. toluidine blue stains granules within mast cell with a violet color. Changing the original color of the stain at the end of staining process is called **metachromasia**.
 - 7) **Orcein stain** for elastic fibers, they take brown color.
 - 8) **Silver stain**: It can stain reticular fibers with brown or black color, it is also used to demonstrate Golgi apparatus in the cell.
 - 9) **Osmic acid**: It stains myelin sheath with black colour.
 - 10) **Histochemical & cytochemical stains**: These stains localize & demonstrate certain substances within a tissue or a cell depending on a biochemical reaction e.g.
 - I. **Glycogen** can be stained red by Best's carmine.
 - II. **Lipids (fat)** can be stained black with Sudan black & orange with Sudan III.
 - III. **Enzymes** can also be stained using special methods e.g. acid & alkaline phosphatase enzymes
-

2-The cell

- The cell is the functional & structural unit of all living tissues.
- The cell is the smallest living structure which has vital properties such as growth, secretion, excretion, digestion, contraction, respiration & reproduction.
- The cells of the body are variable in shape, size & functions but they are similar in composition:

I- Cytoplasm.

II- Nucleus.

I. Cytoplasm: It is formed of:

1) Cytoplasmic matrix:

It is a colloidal solution containing proteins, carbohydrates, lipids, minerals & enzymes.

2) Cytoplasmic organelles:

They are permanent minute living structures that are essential for the vital processes of all cells e.g., respiration, secretion, digestion.

3) Cytoplasmic inclusions:

They are non- living temporary structures, not essential for the vitality of the cell. They are no more than substances stored within some cells e.g. glycogen, fat & pigments.

Cytoplasmic Organelles

They are classified according to presence or absence of surrounding membranes into:

A) Membranous cell organelles

1. Cell membrane.
2. Mitochondria.
3. Endoplasmic reticulum (rough & smooth).
4. Golgi apparatus.

5. Lysosomes.
6. Peroxisomes.

B) Non membranous cell organelles

1. Ribosomes
2. Cytoskeleton:
 - a. Microtubules (centrioles & cilia)
 - b. Filaments (Thin, intermediate & thick)

A-Membranous cell organelles

1-Cell membrane

Definition:

It is an ultra- thin membrane that surrounds the cell i.e. it forms an envelope or a cover for the cell.

L.M.:

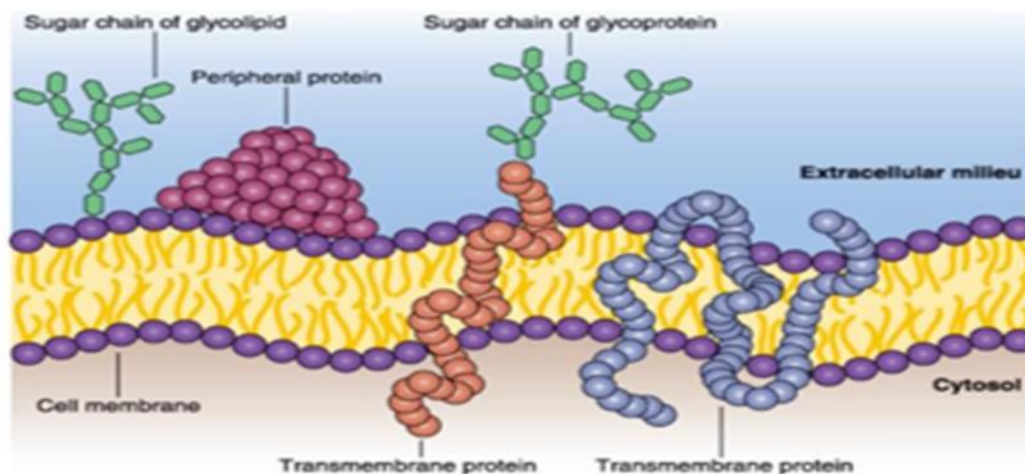
It is invisible by L.M as it is very thin (8-10 nm) but can be stained by **Ag** or **PAS**.

E.M.:

It appears as three parallel lines, two dark layers separated by a light one i.e. it is a Trilamellar membrane. The cell membrane has an outer covering rich in carbohydrates called cell coat.

Molecular structure of the cell membrane: (Fig1)

Fig 1|



The cell membrane is composed of lipids, protein & carbohydrate:

1. Lipids component:

Cell membrane has two types of lipids:

- a) Phospholipid molecules b) Cholesterol molecules.

The lipid component of the cell membrane allows passage of fat-soluble substances through it.

2. Protein component:

Cell membrane contains two types of protein:

a) Intrinsic protein (integral protein):

Intrinsic protein is present in the form of:

- Small particles
- A large globule which extends along the whole thickness of the cell membrane & acts as a pathway for water soluble substances.

b) Extrinsic protein:

It is represented by small molecules which are loosely attached to both surfaces of the cell membrane forming a non-continuous layer.

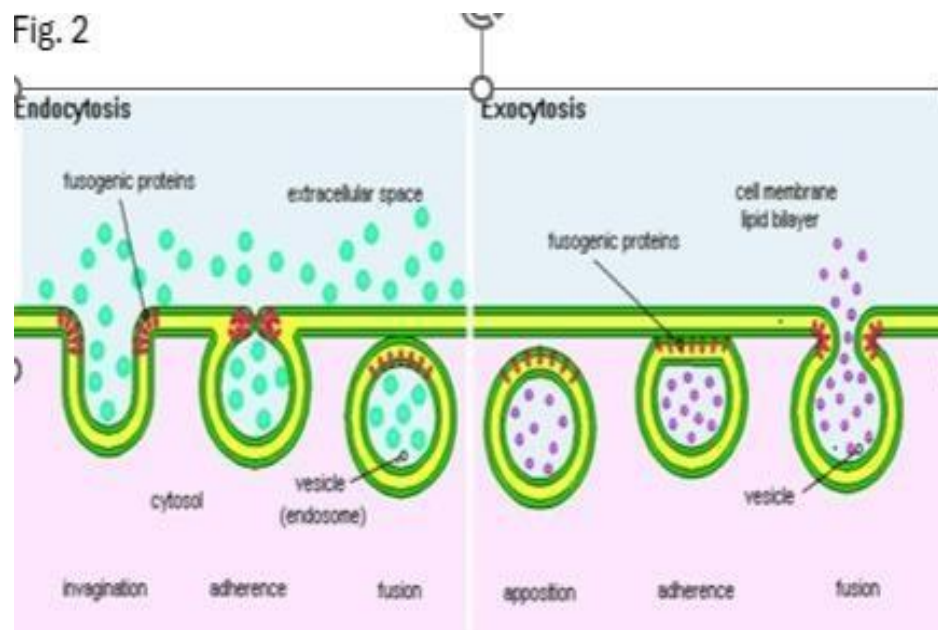
3. Carbohydrate component:

- They are oligosaccharides .
- They are either attached to protein molecule & form glycoprotein
- OR to lipid and form glycolipid.
- Glycolipid & glycoprotein are known as the cell coat or glycocalyx.
- Cell receptors are present among the cell coat; they are responsible for entrance of drugs, hormones & bacteria to the cell.

Functions of cell membrane:

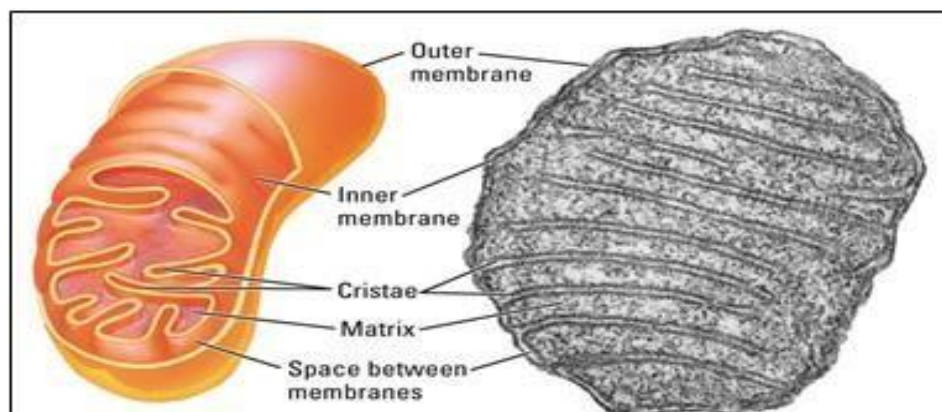
- a- It keeps the internal composition of the cell.
- b- Cell coat as a part of the cell membrane is responsible for cell adhesion, cell recognition, cell protection & cell immunity (functions of cell coat).
- c- It allows passage of substance through it by:-
- 1) Passive diffusion: (e.g. gases & water)
 - 2) Facilitated diffusion: e.g. glucose.
 - 3) Active transport: e.g. Na pumps outside the cell.

- 4) Selective permeability: By presence of receptors
- 5) Bulk transport (vesicular transport): Macromolecules enter & leave the cell by vesicular transport that involves changes in plasma membrane at a localized site & formation of vesicles from the cell membrane or fusion of vesicles with the cell membrane. Vesicular transport may be one of two processes:
 - * Exocytosis: in which substances leave the cell to outside.
 - * Endocytosis: in which substances enter the cell. If the substance that enters the cell is solid the process is called phagocytosis. Entrance of fluid is called pinocytosis. (Fig.2)



2- Mitochondria (Fig.3)

Fig 3



Definition:

- It is a membranous cell organelle.
- It is the powerhouse of the cell.
- It is responsible for cell respiration & energy production.

Number: varies according to cell activity e.g. liver cells contain 1000- 2000/ cell

N.B. They are present in all cells except RBCs.

Site: at site of the most activity e.g. apical part in ciliated cells.

L.M.:

- Mitochondria appear as granules, rods or filaments.
- They can be stained dark blue by iron hematoxylin & green by Janus green stain.

EM:

- Mitochondrion appears as a vesicle rounded or oval in shape.
- It is covered with double membranes, separated by an inter-membranous space.
- Outer membrane is smooth while the inner one shows incomplete folds, shelves or cristae.
- Mitochondrial matrix fills the internal cavity of mitochondria.
- The matrix contains lipids, protein, carbohydrates, Ca & Mg as well as DNA & RNA.
- Oxidative enzymes are attached by heads to the cristae.

Functions:

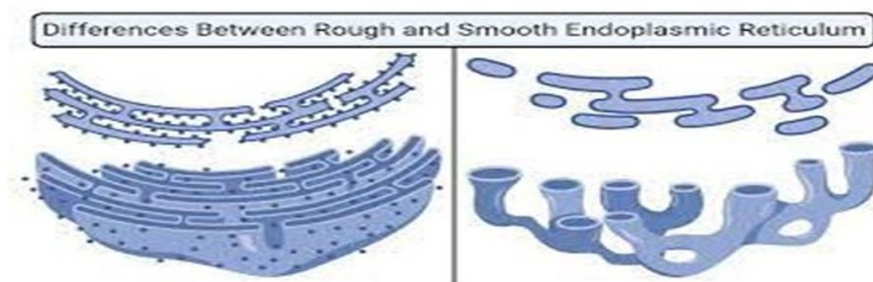
1. Mitochondria are the Powerhouse of the cell. They produce energy stored in the form of ATP & released at time of need.
2. They can form their own protein & can divide, as they contain DNA & RNA.

3- Endoplasmic Reticulum (Fig.4)

Definition:

- It is a membranous organelle formed of flattened communicating vesicles & tubules that form reticulum [network] inside the cytoplasm.
- It is classified according to presence or absence of ribosomes into two types:
 - a. Rough (granular) E.R.
 - b. Smooth (agranular) E.R.

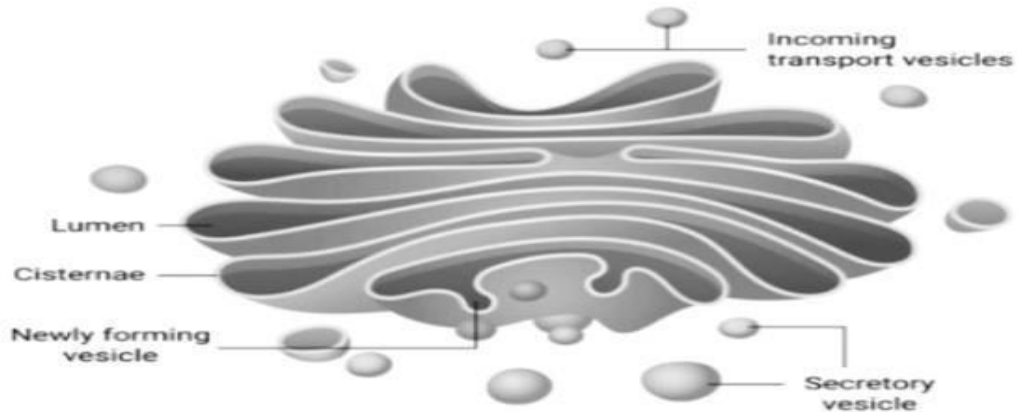
Fig 4



	Rough endoplasmic reticulum r ER	Smooth endoplasmic reticulum s ER
Site	Protein forming cells e.g. pancreas, plasma cells, fibroblasts	Lipid forming cells e.g. liver & cells of some endocrine glands.
LM	A basophilic (blue) structure due to presence of ribosomes	It cannot be seen. If it is abundant the cytoplasm becomes <u>acidophilic</u>
EM	-A network of parallel flattened communicating vesicles & tubules called cisternae. It is covered with ribosomes.	-Branching & anastomosing tubules & vesicles. -It has no ribosomes. -It is continuous with r ER
Functions	1-Synthesis of protein by the help of the ribosomes 2-Condensation & packing of the protein 3-Budding of the packed protein in the form of transfer vesicles. 4- It acts as intracellular pathway 5 - It shares in the formation of Lysosomes, by formation & segregation of their hydrolytic enzymes.	1-Lipid synthesis. 2-Steroid hormones synthesis. 3-Formation & storage of glycogen. e.g. in liver & muscles. 4-It helps muscle contraction by Ca pump. 5-Detoxification of drugs & hormones in liver. 6-Acts as intracellular pathway.

4-Golgi Apparatus (Fig.5)

Fig 5



Definition:

- It is a membranous organelle.
- It is considered as the secretory system of the cell.
- It is well developed in protein forming cells and secretory cells.

LM:

It is demonstrated by (Ag) stain. It appears as a dark brown network & fibrils around the nucleus (perinuclear) in nerve cell or between the nucleus & secretory pole (supranuclear) in secretory cell. e.g. pancreas.

N.B. In sections stained with H&E. the area occupied by Golgi apparatus appears as unstained, area & so it is called **negative Golgi Image**. (Fig6)

Negative Golgi Image

fig 6



EM: It is formed of saucer-shaped flattened saccules stacked over each other forming a stack. Each stack has two faces:-

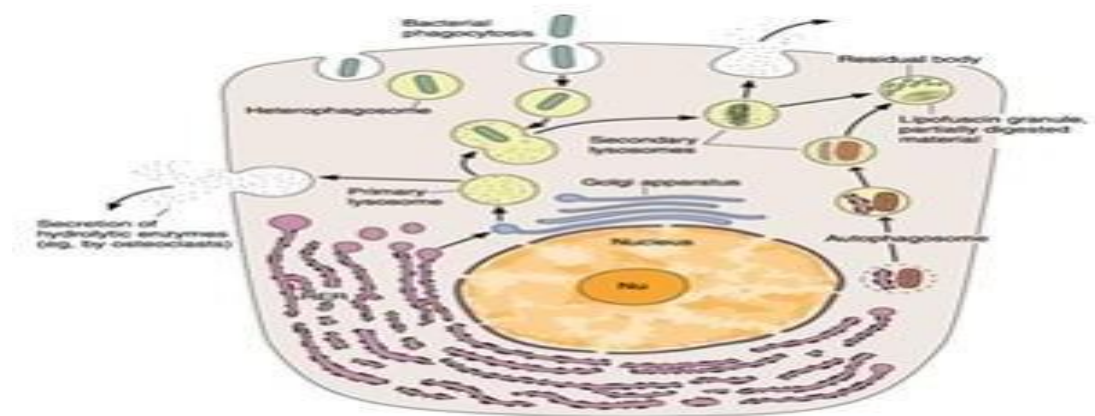
- 1- **Immature convex surface**, which is the forming surface (cis surface) that receives the transfer vesicles which carry protein from r E.R.
- 2- **Mature concave surface** from which secretory vesicles come *out* carrying condensed & modified protein. Also, other vesicles containing hydrolytic enzymes will come out & these are called Lysosomes

Functions:

- 1- Concentration of protein formed by r E.R.
- 2- Modification of protein by adding sulphates or carbohydrates.
- 3- Discharge of secretion in the form of secretory vesicles
- 4- Isolation and packaging of hydrolytic enzymes in the form of lysosomes.
- 5- Formation & maintenance of cell membrane & cell coat.

5-Lysosomes (Fig.7)

Fig 7



Definition:

- Membranous organelles rich in hydrolytic enzymes
- They are considered as the digestive system of the cell.

Number: They are numerous in phagocytic cells e.g. white blood cells.

Origin: The hydrolytic enzymes are formed in rER & carried in transfer vesicles to Golgi apparatus & come out as primary lysosomes

LM: They can be demonstrated by using a special stain for the enzymes present within them, e.g. acid phosphates enzyme.

EM: E.M picture of Lysosomes depends on their types.

1- Primary Lysosomes:

- These are the newly formed lysosomes coming from Golgi apparatus.
- They appear as small rounded homogenous vesicles.

2- Secondary Lysosomes:

- They result from fusion of primary Lysosome with phagocytic vesicle.
- They appear as heterogenous vesicles.
- They are of different types:

a) **Heterolysosomes:** They result from fusion of a primary lysosome with a phagocytic vesicle containing food or bacteria.

b) **Multivesicular bodies:** They result from fusion of primary lysosomes with

pinocytic vesicle containing fluid droplets.

c) **Autolysosomes:** They result from fusion of primary lysosomes with vacuoles containing old organelles.

d) **Residual bodies:** These are no more than secondary lysosomes containing the undigested remnants. They are either discharged outside the cell or accumulated within the cell as lipofuscin granules as in long lived cells e.g. cardiac muscle or nerve cell.

Functions:

- 1- Digestion of nutrients within the cell.
- 2- Defensive function, destruction of any bacteria or virus.
- 3- Removal of any degenerated old organelles.
- 4- Lysis of the cells & all the body after death.
- 5- Change of inactive hormone into active one. e.g. in thyroid gland.
- 6- Help the sperm to penetrate the ovum.

B-non-membranous cell organelles

1- Ribosomes

Definition:

- Ribosomes are non-membranous cell organelles.
- They are formed within the nucleolus.
- Their chemical composition is ribonucleoprotein=rRNA +protein.

LM: (Fig 8)

- They are very minute structures (15-20nm) difficult to be seen by L.M.
- They appear as basophilic structures by H&E when they are numerous, due to presence of ribosomes

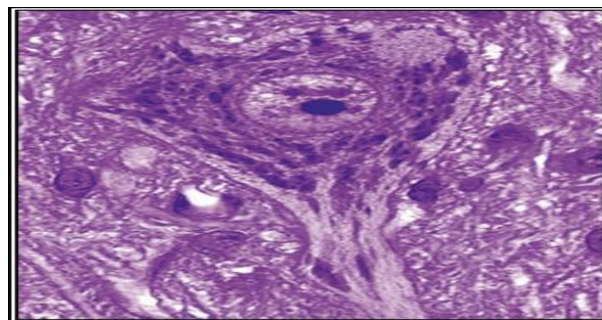
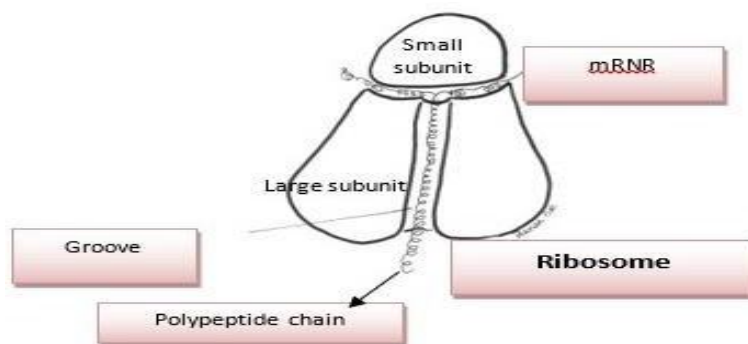


Fig 8

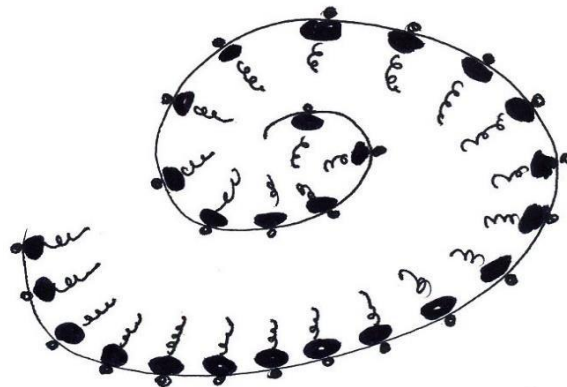
EM: Fig 9

- Ribosomes are small electron dense particle
- It is formed of two subunits, a large one & a small one. Both are connected by m RNA.
- The large subunit has a central groove which is occupied by the newly formed polypeptide chain.

**Fig 9**

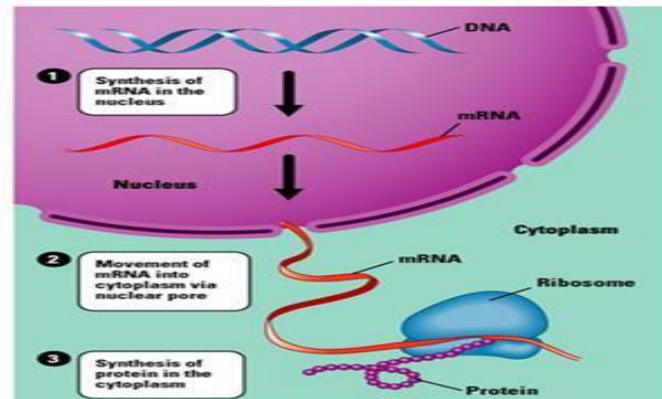
There are three forms of ribosomes:

- I- Free ribosomes** are diffusely scattered in the cytoplasm. It is common in immature cells e.g. stem cells.
- II- Polyribosomes:** the ribosomes are connected by m- RNA in a spiral or rosette form. (Fig 10)
- III- Attached ribosomes:** The ribosomes are attached by means of their large subunits to rER.

**Fig 10: Polyribosomes**

Functions of Ribosomes:(Fig 11)

- * Ribosomes act as intracellular site where amino acids join forming polypeptide chains i.e., they are the site for protein synthesis.
- * Protein formed by free ribosomes is used within the cell while that formed by rER is used outside the cell (transfer vesicle→ Golgi →secretory vesicle → cell membrane → outside the cell).

**Fig: 11****2- Cytoskeleton****A- Microtubules**

Definition: Non- branching & rigid hollow fine tubes formed of a protein called tubulin.

LM: They are difficult to be seen by L.M. except by using special stains.

EM:

- They appear as fine tubules that measure about 20-25nm in diameter.
- The length of microtubules can be changed by adding or removal of tubulin molecules at their end.

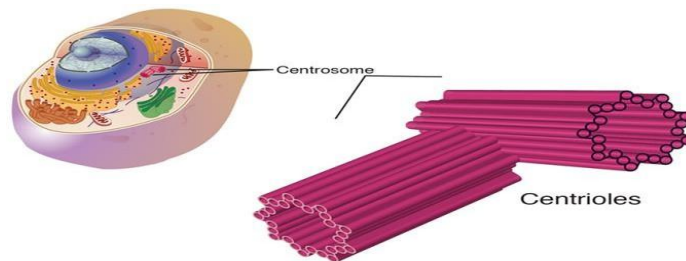
Functions:

- 1- Maintenance of the cell shape e.g. platelets.
- 2- Intracellular vesicular transport.
- 3- Formation of mitotic spindle during cell division.
- 4- Elongation & movement of the cell.
- 5- Formation of centrioles, cilia & flagella.

B- Centriole: (Fig:12)

Definition:

- They are derived from the microtubules.
- They are responsible for cell division.
- They are absent in non-dividing cells e.g. RBCs & nerve cells.

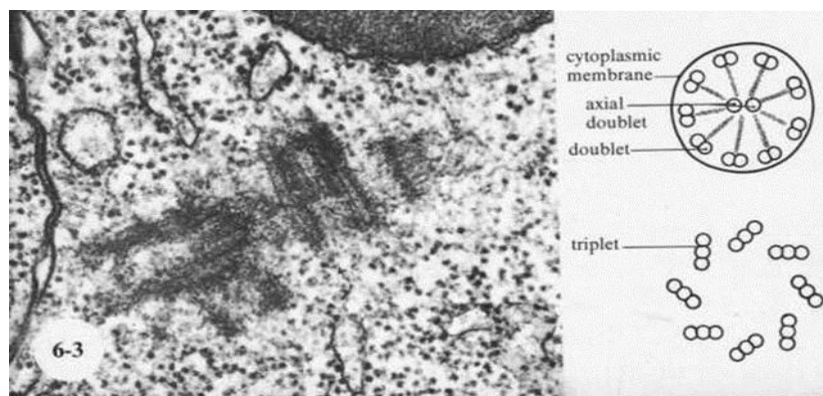
**Fig:12**

Site: They are usually present near the nucleus in an area called centrosome.

LM: They are visible by light microscope as dark paired short rods or dots after staining with iron hematoxylin.

EM:(Fig 13)

- They appear as two short hollow cylinders ($0.5 \times 0.2 \mu\text{m}$) perpendicular to each other.
- The wall of each centriole is formed of nine bundles.
- Each bundle consists of three microtubules (triplet).

**Fig:13**

Functions:

1. Share in formation of mitotic spindle during cell division.
2. They are responsible for the formation of cilia & flagella.

C- Cilia

Definition: Cilia are motile hair-like processes projecting over the cell surface, capable of moving fluids & particles along the surface.

LM: The cilia appear as short, fine, hair-like structures arising from the free surface of the cell giving it a brush border.

Development of cilia:

- Cilia develop from centriole, first by replication of it to give baby centrioles, one for each cilium. Each baby centriole moves toward the surface of the cell to become the basal body from which a cilium can grow.
- The **basal body** is similar to centriole in structure nine triplets microtubules.
- Two inner microtubules (doublet) grow upwards from each triplet pushing in front of them the free surface of the cell membrane. At the same time two single microtubules grow in the center ($9 \times 2 + 2 = 20$), this part is called the shaft of the cilium.
- The third outer microtubule of each triplet of the basal body grows downwards forming the rootlets of the cilium that fix it ($9 \times 1 = 9$).

EM: Each cilium consists of three parts: (Fig 14)

1- Shaft of Cilium:

- It is a finger like projection over the cell surface covered by cell membrane.
- It contains nine doublets & two single microtubules ($9 \times 2 + 2 = 20$).

2- Basal body:

- It is similar to centriole in structure formed of nine triplets ($9 \times 3 = 27$).

3- Rootlets of Cilium: It is formed of nine single microtubules ($9 \times 1 = 9$) which are present below the basal body.

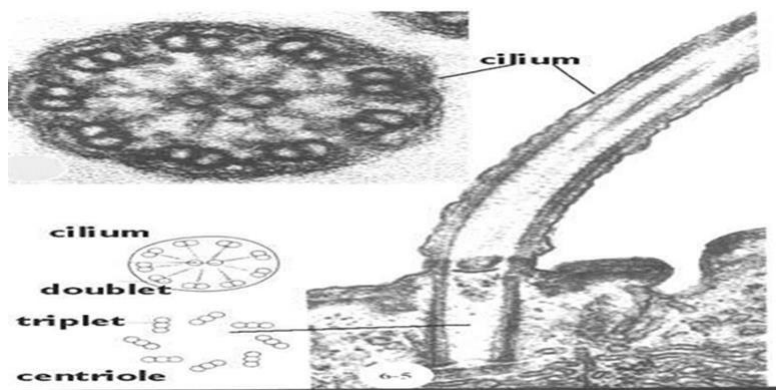


Fig:14 Cilia

Functions:

- 1- Cilia move in a wave like manner to move secretions or particles over the tissue surface e.g. in respiratory system & female genital system.
- 2- Cilia can modify & act as receptors for a stimulus e.g. in rods & cones in retina where they receive light.
- 3- Flagellum: it is a long cilium forming the tail of the sperm -----> motility.

d- Filaments:

Definition: They are minute threads that act as a part of the cytoskeleton which maintains the shape of the cell.

LM: They are difficult to see except by using a special stain.

EM: They are classified according to their diameter into:

1- Microfilaments (thin filaments): [actin]

- They are very fine strands about 6nm in diameter formed of a protein called actin.
- They are found in muscle & microvilli.
- They form a supporting network within the cell that helps to maintain its shape.

2- Intermediate filaments:

- They have a diameter of about 8-10nm.
- There are about 50 different types of intermediate, filaments in humans, e.g.
 - a- Cytokeratin filaments are present in epithelial cells.
 - b- Vimentin filaments are present in connective tissue & muscle.
 - c- Desmin filaments are present in muscle.
 - d- Neurofilaments are present in nerve cells.
 - e- Glial filaments are present in glial cells.

3- Thick filaments:

- Their diameter is about 15 nm.
- They are formed of a protein called myosin & they are found in skeletal muscle.

Cell Inclusions

They are classified into two groups:

- a- Stored food. b- Pigments.

A-Stored food: The cell may store carbohydrates or lipids:

1. **Carbohydrates:** stored in the form of glycogen as in liver & muscles.

LM: Glycogen cannot be demonstrated by (H&E) as it is water soluble, it can be seen if stained by special stain as Best's Carmine (**red**) or PAS (**purple**).

2. **Lipids:** Lipids are stored in the form of small droplets or large globules. Fat cells are the main site for storage of lipids, other cells like liver cells may contain fat.

LM: Lipids cannot be demonstrated by (H&E) as it dissolves in xylol. Lipid can be stained **orange** by Sudan III & black by Sudan black.

B-Pigments : either

- 1- **Endogenous** which are produced by the cell,

- i- Hemoglobin which is present in RBCs to carry gases.
- ii- Melanin which give the skin & hair their color.
- iii- Lipofuscin granules are accumulated residual bodies in long lived cells e.g. nerve cells & cardiac muscles.

- 2- **Exogenous:** enter the cell from outside as:

Carotene pigments in carrots -----> color fats in cells

Dust& carbon particles in air -----> blacken lungs.

3- Tissues of the Body

❖ **There are four main tissues in the body**, these are:

- 1- Epithelial tissue
- 2- Connective tissue
- 3- Muscular tissue
- 4- Nervous tissue

I-Epithelial Tissue

This tissue is called epithelial tissue because it can cover surfaces or line cavities all over the body.

○ **General characters of epithelial tissue:**

- 1- It may develop from ectoderm, mesoderm or endoderm.
- 2- The epithelial cells rest on a basement membrane (B.M.) which may be clear or not clear.
- 3- No blood vessels can enter in between epithelial cells, but nerves can, so epithelial tissue is avascular tissue.
- 4- Epithelial tissue receives nutrition by diffusion from the underlying connective tissue.
- 5- Epithelial tissue consists of numerous crowded cells with minimal intercellular substance between the cells that form continuous sheets, which cover surfaces or line cavities & is called surface epithelium.
- 6- Epithelial tissue may be modified to give secretion & is called glandular epithelium.
- 7- Epithelial tissue may modify to receive sensation & is called neuroepithelium & may acquire a contractile function & is called myoepithelium.
- 8- Epithelium can regenerate in a short time i.e. there is a continuous process of regeneration.

○ **Epithelial tissue is classified into:**

- I- Surface epithelium.
- II- Glandular epithelium.
- III- Neuro-epithelium
- IV- Myo-epithelium.

I- Surface epithelium

Surface epithelium is classified according to its **number of layers** into:

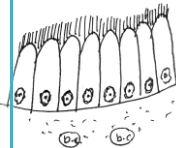
- a) Simple epithelium.
- b) Stratified epithelium.

a- Simple Epithelium**Definition:**

It is formed of one layer of cells resting on basement membrane.

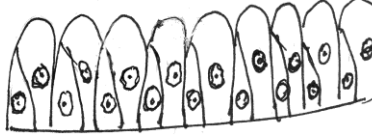
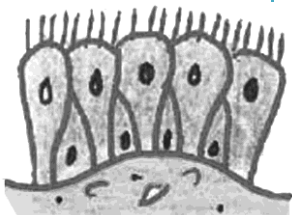
It is divided according to shape of cells into:

- 1- Simple squamous epithelium
- 2- Simple cubical epithelium
- 3- Simple columnar epithelium
- 4- Simple columnar ciliated epithelium
- 5- Pseudo-stratified columnar epithelium

	1-Simple squamous epithelium	2-Simple cubical	3-Simple columnar	4-Simple columnar ciliated
• Shape of cells	- Flat - Flat nucleus	- Cube-like - Central rounded nucleus	-Tall cells -Basal oval nucleus	Tall cells carry cilia -Basal oval nucleus
• Functions	- Smooth surface (easy movement) - Thin surface (gas & fluid exchange)	- Secretion - Reabsorption	Secretion Absorption (microvilli e.g. intestine)	Movement of particles or fluids over the surface
• Sites	- Mesothelium[pleura, pericardium & peritoneum] - Endothelium[heart & blood vessels] - Lung alveoli - Bowman's capsule of kidney	- Thyroid follicle - Small ducts of salivary g. - Renal convoluted tubules	-Stomach -Intestine -Goblet cells [secrete mucous which accumulates in its apex]	-Lung bronchioles -Uterus -Fallopian tubes
Hanaa.AK				

5- Pseudostratified Columnar Epithelium:

- It is actually a simple epithelium as all the cells rest on the B.M.
- It is formed of crowded cells.
- Nuclei are present at more than one level; this gives the epithelium a false appearance of being stratified.

POC	a-Pseudostratified columnar non-ciliated	b-Pseudostratified columnar ciliated with motile cilia & goblet cells	c-Pseudostratified columnar ciliated with non-motile cilia
• Sites	1- male genital system (vas deferens). 2- Membranous part of male urethra	Respiratory epithelium • Nose • Larynx • Trachea • Bronchi	• Epididymis
	 Pseudostratified columnar epith		

b- Stratified Epithelium:**Definition:**

Epithelium is formed of more than one layer, the basal layer resting on the B.M. It is classified according to shape of the top layer into:-

- 1- Stratified squamous epithelium.
- 2- Transitional epithelium [stratified cuboidal].
- 3- Stratified columnar epithelium.
- 4- Stratified cubical epithelium.

Function:

The main function of stratified epithelium is protection.

	1- Stratified Squamous Epithelium	2- Transitional Epithelium	
• Number of layers	5-30	6-8 [empty bladder] 3-4 [full bladder]	
• Basement membrane	Clear & wavy	Non-clear, non-wavy	
• Basal cell layer	Columnar with basal oval nuclei	High cuboidal cells with rounded	
• <u>Intermediate layers</u>	• Crowded <u>polygonal</u> cells with <u>central rounded nuclei</u> • <u>Minimal intercellular</u> substance. • Cells are held together with <u>desmosomes</u>. • They gradually decrease in size	• <u>polyhedral</u> with <u>rounded nuclei</u> • <u>wide intercellular</u> spaces containing <u>mucous</u> like substance which helps gliding of the cells over each other. • <u>NO</u> desmosomes • Cells become <u>flat</u> in <u>full bladder</u>	
• Top layer	Flat cells with flat nuclei. 	• Cells are <u>dome shape</u> with upper convex, lower concave surface & have <u>rounded nuclei</u>, • Some cells are binucleated. • <u>The top layer</u> is covered with <u>mucous</u> to protect against the action of urine.	
• Types	<u>Non-Keratinized</u> <u>Keratinized</u> cells of the top layer gradually die& change into keratin scales.	One type: In <u>full bladder</u> the change in number of layers is due to gliding of cells help of mucus present between the cells so the number of layers decrease & the surface area increase.	
• Sites	Line any <u>wet surface</u> opening over the skin 1-Oral cavity 2-Oesophagus 3- Cornea.	<u>Skin & dry</u> opening over it 1-Epidermis of skin. 2- External ear. 3- Nasal orifices.	Urinary bladder, ureters, some parts of urethra, renal calyces and renal pelvis
• Functions	Protection	Protection &accommodation (distensibility)	

3- Stratified Columnar Epithelium:

Like stratified squamous epithelium, but the number of layers is fewer & the top layer is formed of columnar cells which may be ciliated or not ciliated: -

a- Stratified columnar ciliated epithelium:(Fig15)

Sites: Fetal esophagus (a rare type).

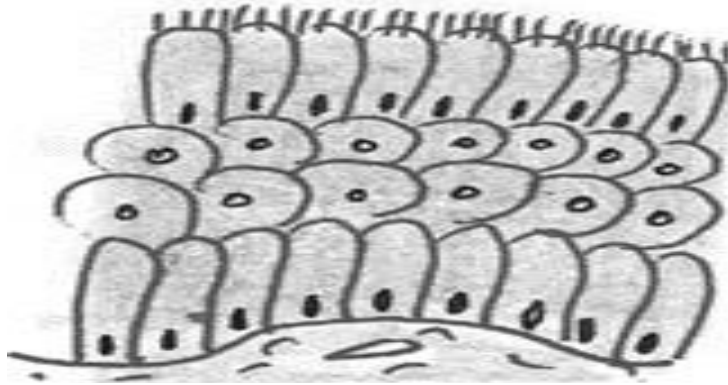


Fig:15- Stratified columnar ciliated epithelium

b- Stratified columnar non ciliated epithelium:(Fig 16)

Sites: 1- Recto-anal junction.

2- Large ducts of glands.

3- Male urethra (penile part).

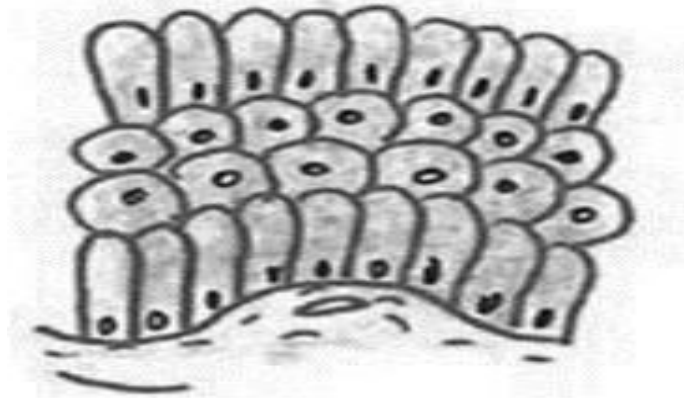


Fig16: Stratified columnar non ciliated epithelium:

4- Stratified Cubical Epithelium: (Fig17)

It is a rare type of epithelium which is formed of few layers of cells, may be only two layers of cubical cells as in ducts of sweat glands

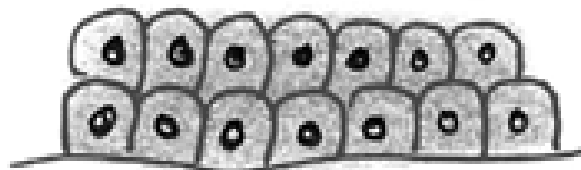


Fig17 Stratified cubical

Definition:

It is a type of epithelium which modifies to act as a gland & give secretion.

Classification of glandular epithelium according to:**1-Presence or absence of duct:****a) Exocrine gland (salivary glands):**

The exocrine gland is formed of secretory portion & duct system

b) Endocrine gland, ductless gland,(thyroid gland):

- NO duct system.
- Their secretion is called hormones.
- Secretion is carried by blood.

c) Mixed gland (pancreas):

The gland is formed of two parts exocrine part & endocrine part

2-Number of cells forming the gland:

- a) **Unicellular** gland, formed of one cell (goblet cell)
- b) **Multicellular** glands formed of many cells (all glands)

3-Type of secretion:

- a) **Watery** secretion (Sweat gland)
- b) **Serous** secretion: The secretion is watery but contains enzymes e.g. parotid gland & pancreas.
- c) **Mucous** secretion: e.g. Salivary gland & goblet cells.
- d) **Muco-serous** secretion e.g. sublingual & submandibular gland.
- e) **Fatty** secretion e.g. sebaceous gland.
- f) **Waxy** secretion e.g. glands of external ear.
- h) **Cellular** secretion e.g. ovary (ova) & testis (sperms).

4-Mode (mechanism) of secretion:**a) Merocrine secretion:**

- The most common mechanism
- Secretion come out by exocytosis
- No changes in the cell e.g. pancreas.

b) Apocrine secretion:

- The secretion is released surrounded by a part of cytoplasm & the cell membrane usually the apex of the cell

- e.g. mammary gland & some sweat glands.

c) Holocrine secretion:

- The secretion accumulates within the cell.
- The swollen cell ruptures & secretions come out with the cell components e.g. sebaceous glands.

5-Branching of the duct:

- a) Simple gland: The gland has a single non branching duct.
- b) Simple branched gland: The gland has a single non branching duct & a **branched secretory portion**.
- c) Compound gland: The gland has a branching duct system.

6-Shape of secretory part:

- a) **Tubular**: Secretory part is in the form of a long tube
- b) **Alveolar (acinar):-** Secretory part is rounded or ball shape.
- c) **Tubuloalveolar:-** Secretory part is flask shape.

N.B. Since all exocrine glands consist of a secretory part & a duct system so they are classified into:

i) Tubular :

- Simple tubular glands e.g. intestinal glands.
- Simple branched tubular glands e.g. fundic glands of stomach
- Simple coiled tubular e.g. sweat glands.
- Compound tubular glands e.g. kidney, liver

ii) Alveolar:

- Simple alveolar glands e.g. sebaceous glands.
- Simple branched alveolar glands e.g. sebaceous glands.
- Compound alveolar glands e.g. mammary gland

iii) Tubulo-alveolar:

- Simple tubulo-alveolar gland, not present in man.
- Simple branched tubulo-alveolar glands e.g. lingual, labial glands (minor salivary glands).
- Compound tubulo-alveolar glands e.g. major salivary glands (parotid) & pancreas.

III-NEURO-EPITHELIUM

Definition:

- It is a specialized type of epithelium.
- It acts as a receptor.
- It consists of three types of cells
- **Hair cells** which receive sensation.
- **Supporting cells** for support
- **Basal cells** act as stem cells for regeneration.

1- Taste buds (Fig 17) in the tongue for taste sensation.

2- Organ of Corti in the ear for hearing.



Fig17 Tast buds

IV-MYO-EPITHELIUM

Definition:

It is a special type of epithelium, which has a contractile function

- The myo-epithelial cells are present around the base of secretory cells
- Between the cells & the basement membrane
- When they contract, they squeeze the secretory cells
- Help them to evacuate their secretion inducts of glands e.g. around **salivary glands, mammary gland & sweat glands.**

Cell polarity [Specializations] Cell modifications

I. Apical Modifications

1- Microvilli :(Fig 18)

- Finger like projections from the cell Membrane.
- L.M: apical brush border.
- EM: have a core of actin filaments which maintain its shape & help shortening & elongation of microvilli.
- Site & function: Increase the apical surface area for absorption e.g., in small intestine

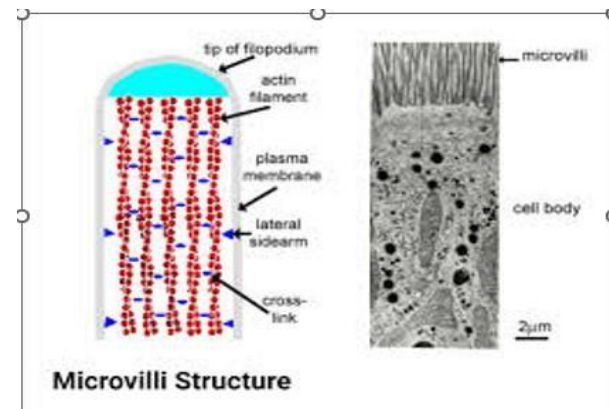


Fig.18

2- Stereocilia: (solid= non- motile): (Fig:19)

- Not true cilia but long microvilli.
- L.M: hairlike processes from the free surface of some cells.
- E.M: Have a core of actin filaments.
- Function & Site: help absorption e.g. epididymis.

Epididymis

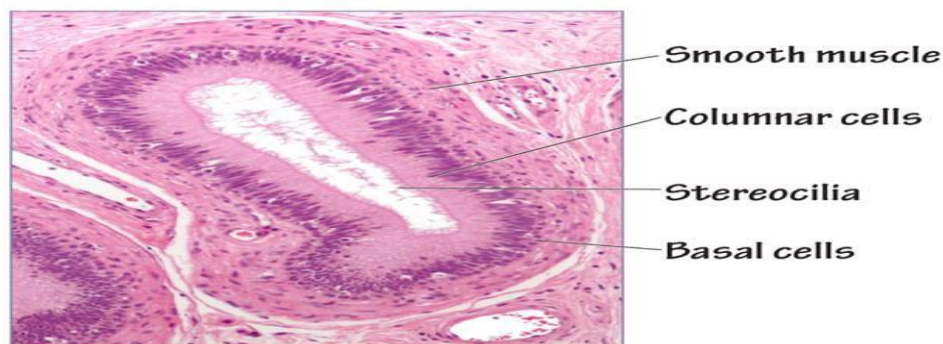


Fig19: showing stereocilia of epididymis

3- Cilia:

- L.M: hairlike processes which arise from the free surface of some cells.
- E.M: have a core of 20 microtubules arranged as 9 peripheral doublets & 2 central singlets covered with cell membrane.

- Function & sites:

Their rhythmic beating propels fluids or particles in one direction e.g. trachea, bronchi & Fallopian tube.

4- Flagella: (Fig:20)

The flagellum is an extra-long cilium that forms the tail of sperm & helps its movements.

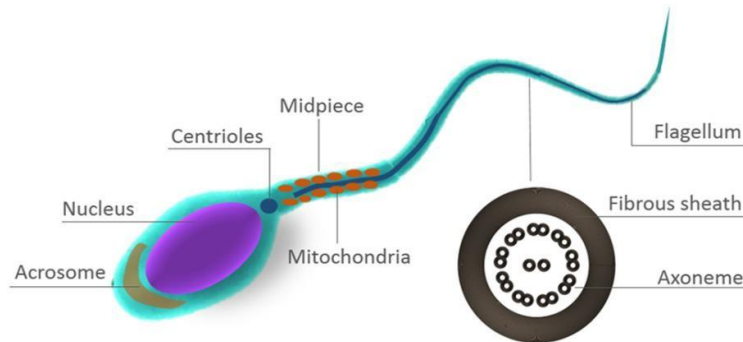


Fig:20 Flagella

II. Lateral specializations= Cell junctions

1] Tight junction:

a- Zonula Occludens: (Fig 21)

The 2 adjacent cell Membranes fuse completely at certain points to prevent passage of any substance between cells.

It surrounds the apex of the cell like a belt.

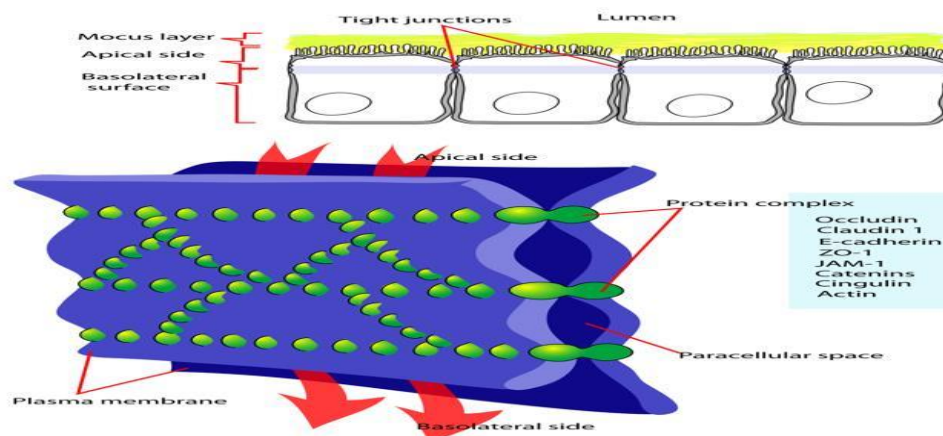


Fig:21

b- Fascia Occludens: It is patchy fusion of the 2 cell membranes (not like a belt) e.g. between endothelial cells.

2] Adherens junction= zonula adherens:

- The 2 adjacent cell membranes are separated by a wide space (20nm) filled with adhesive cell coat material with condensed actin filaments at the cytoplasmic side. It surrounds the cell like a belt

Function: It fixes adjacent cells & prevents their separation.

3] Macula Adherens= Desmosome Fig:22

- The 2 adjacent cell membranes are separated by a very wide space (30 nm) filled with adhesive substance. The cytoplasmic side is thickened forming attachment plates in which tonofilaments are inserted forming hair pin- like loops. It does not encircle the cell but appears as spot.

Function: Strongest type fixes epithelial cells e.g. in skin.

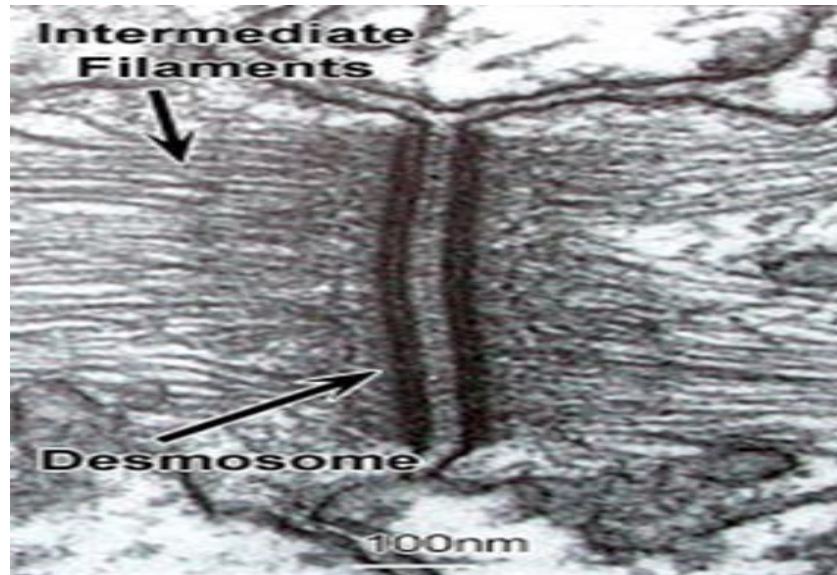


Fig:22 Desmosomes

4] Gap junction: [Communicating J.] = nexus.(Fig:23)

- The 2 adjacent cell membranes are separated by a very narrow gap (2nm) but connected by narrow channels.
- Function: allows passage of ions or impulses from one cell to the other e.g. cardiac & smooth muscles.

N.B. If more than one junction is present between adjacent cells e.g. cells of small intestine it is called junctional complex.

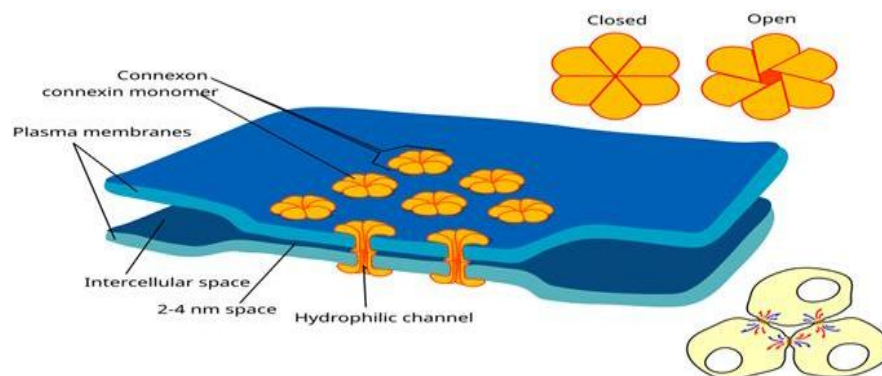


Fig:23 Gap junction

III. Basal specializations

1] Hemidesmosome

- 1/2 a desmosome at the basal part of basal cells.
- It fixes epithelium to basement membrane & connective tissue

2] Basement membrane:

- The membrane that connects epithelium to connective tissue.
- L.M: Red line (by PAS) or brown (by AG).
- It is either clear (thick) as in skin
- OR non- clear (thin) as in transitional epithelium.
- E.M: 2 components
- 1-Basal lamina formed mainly by the cell coat of epithelium (glycoprotein) & collagen fibers (IV)
- 2-Reticular lamina : consists of reticular fibers (type III collagen) & glycoprotein.

- Functions:

- 1- Supports epithelium.
- 2- Fixes epithelium to connective tissue.
- 3- Controls passage of ions & nutrients e.g. kidney & lung.

3] Basal Infoldings: (Fig:24)

- The basal cell membrane shows invaginations
- Dividing the base of the cell into compartments
- Contain mitochondria to give energy for active transport of ions e.g. in kidney tubules.

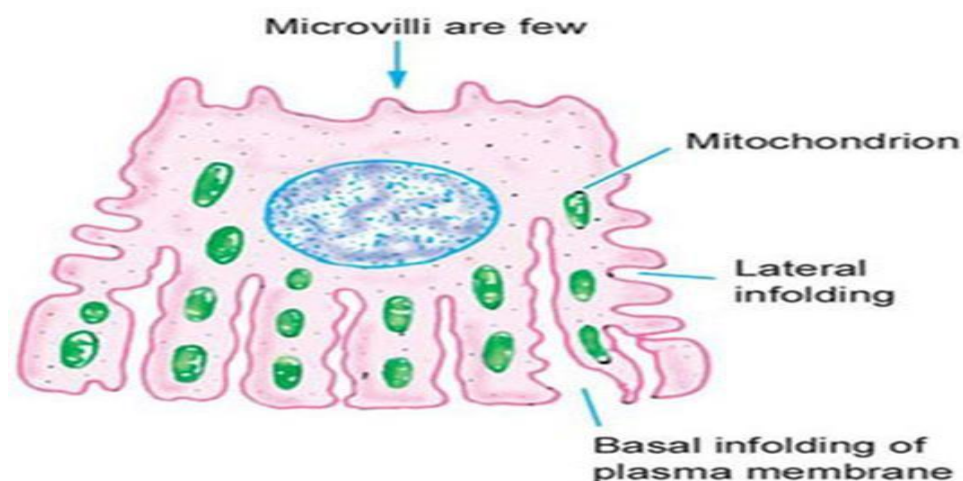


Fig:24 Basal infoldings

II-CONNECTIVE TISSUE

➤ The connective tissue is formed of 3 components:

A. Cells.

B. B. Fibres.

C. Extracellular matrix in which cells and fibres are embedded.

Origin of connective tissue: Mesodermal origin

Characteristics of connective tissue:

1. Formed of widely separated cells with large amount of matrix.
2. Rich in blood vessels, nerves and lymphatics.

Types of connective tissue: according to matrix

- Soft -----connective tissue proper.
- Rubbery ----- cartilage.
- Hard ----- bone.
- Fluid ----- blood.

1-Connective Tissue Proper

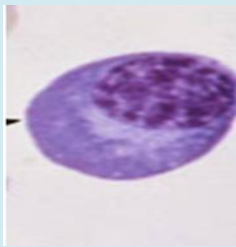
Components of C.T. proper: A. Cells. B. Fibres. C. Extracellular matrix

A- Connective Tissue Cells

They are 2 types of cells:

<i>Fixed (stable, long lived)</i>	<i>Free (transient, short lived)</i>
1. Fibroblast.	1. Plasma cell.
2. Fat cell.	2. Mast cell.
3. Mesenchymal cell.	3. Leukocytes.
4. Reticular cell.	4. Free macrophage.
5. Pericyte.	
6. Fixed macrophage.	
7. Pigment cell.	

POC	UMC	Pericyte	Fibroblast	Fibrocytes	Reticular cell	Pigment cell
Origin	----	UMC	UMC & Pericyte	UMC	UMC	Macrophages
Sites	Mesenchymal tissue in embryo	Around blood vessels	Commonest cell	C.T.	Stroma of organs	Dermis of skin
Shape	Branched cells with many processes			Spindle	Small & branched	
Cytoplasm	Pale basophilic	Pale basophilic	Dark Basophilic	Pale basophilic	Pale basophilic	Shows Granules
Nucleus	Oval, pale & + nucleolus	Oval, pale & + nucleolus	Oval, pale & + nucleolus	Oval, <u>dark</u>	Rounded & pale	Rounded & pale
EM	Few organelles Many ribosomes	Few organelles Gap junctions	Rich in rER & Golgi app	Less rER & Golgi app	Depends on activity	Melanosomes
Functions	Differentiate to 1- C.T. cells 2- Blood cells 3- Smooth m. 4- Endothelium	a- After injury it can differentiate to 1- fibroblast 2- Endothelium 3- Smooth m. b- It can contract & cause vasoconstriction	1- Form C.T. <u>matrix</u> & <u>fibres</u> 2- Produce <u>growth factor</u> which stimulates formation of C.T. especially <u>after injury</u>	Change to active fibroblasts during healing & after wound	1- Form reticular fibres 2- Act as phagocytic cell 3- Act as antigen presenting cell	1- Store melanin 2- Give colour 3- Protection from ultra violet rays

POC	Adipocyte Unilocular	Adipocyte Multilocular	Mast cell	Plasma cell	Macrophage [Fixed & free]
Origin	UMC	UMC	UMC	Active B-Lymphocyte	Blood monocyte
Sites	white adipose C.T	Brown adipose C.T.	Around blood vessels in respiratory & digestive system	In lymphatic tissue	Fixed in CT. called histiocyte Free in liver, skin, lung & nervous tissue
Shape	Large oval	Small oval or rounded	Large oval	Large oval	Large with irregular outline
Nucleus	Flat perip heral	Central- rounded	Small central nucleus	Eccentric ,nucleus cartwheel or clock-face appearance	Dark eccentric kidney shape nucleus
Cytoplas m	- Minimal cytoplas m - Large fat droplet - Signet ring appearance by H&E	- Much cytoplas m - Many fat droplets - No signet ring appearance	- Basophilic - Granular (coarse granules)	- Basophilic - No granules - Negative Golgi - Metachromatic staining with Toluidine blue	- Pale basophilic - Special stain [vital stain [trypan blue]]
E.M.	- Many ribosomes - Few mitochondria	- Few ribosomes - Many mitochondria - Rich in cytochrome enzymes	Well developed Golgi apparatus	- Rich in r ER - Well developed Golgi apparatus	Rich in lysosomes
Function s	Fat storage Support Heat insulation Energy production 	- Break down of fat - Release of heat	- Secretion of Heparin - Secretion of Histamine - Secretion of ECF (Eosinophil Chemotactic Factor)	Formation & secretion of antibodies 	- Phagocytosis of foreign bodies - Formation of multinucleated giant cell - Acts as antigen presenting cell - Secretion of cytokines & collagenase enzyme

- All types of leukocytes can be found in CT
- Cells responsible for immunological reaction are macrophage, mast cells, leukocytes & plasma cells.

B- Connective Tissue Fibres

➤ Three types:

I. Collagenous fibres. II. Elastic fibres. III. Reticular fibres.

	<i>White collagenous</i>	<i>Yellow elastic fibers</i>	<i>Reticular fibers</i>
Structural protein	collagen	Elastin	Type III collagen
Fibers forming cells	• Fibroblasts • Chondroblasts • Osteoblasts	• Fibroblasts • Chondroblasts • Smooth muscle	• Fibroblasts • Reticular cells • Smooth muscle
Shape LM.	Wavy branching bundles –non branching fibers	Single, thin & branching	Delicate, thin & branching
Staining /fresh	Eosin Acidophilic- pink. Mallory's blue. Van Geison Red. Fresh: colorless - white	• Eosin: PINK. • Orcein: brown. • Van Geison: yellow. • Fresh yellow	Ag black PAS purple
Functions	Resists stretch strength	Elasticity [stretchable]	Support with flexibility & allow movement of cells

C- Extracellular Matrix

➤ Structure: Extracellular matrix is formed of

- 1) Ground substance 2) Tissue fluid.

1- Ground substance:

- It is the major 'packing' component of connective tissue
- It surrounds the cells and fibres
- It is colourless, gel-like substance which is highly hydrated.
- Secreted mainly by fibroblasts.
- It consists of glycoproteins, glycosaminoglycan, and hyaluronic acid

2- Tissue fluid:

- Derived from capillaries through its pores.
- It is similar to blood plasma except for the absence of plasma proteins.
- Functions:
 - 1- Acts as a medium for the transfer of nutrients & waste materials between connective tissue cells and blood.
 - 2- Acts as physical barrier prevents the spread of microorganisms.
- Staining: Ground substance can be stained by:
 - Ag (brown).
 - Toluidine blue [purple -metachromatic stain]

Types of Connective Tissue Proper

Types:

1) Loose (Areolar) Connective Tissue:

i. Structure:

- All types of connective tissue cells mainly fibroblasts, macrophages, fat cells, and mast cells.
- All types of fibres mainly white collagenous fibres.

- Matrix is most abundant with potential cavities (areolae) which can be filled with fluids or gasses.

ii. Sites:

- Under epithelium; subserous, dermis of skin, submucosa.
- Around blood vessels.
- Fills spaces between other tissues.

iii. Functions: Support epithelium, blood vessels and nerves.

2) Adipose connective tissue:

i. Structure:

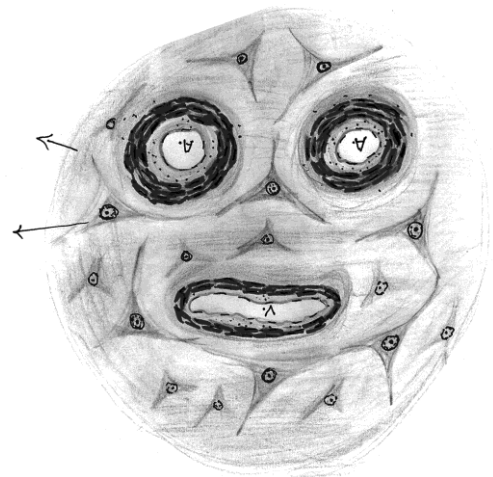
- Large number of fat cells forming lobules separated by connective tissue septa of collagen and elastic fibres.

ii. Types: white and brown adipose CT.

Fat cells	• Large. • One droplet of lipid. • Few mitochondria. • Flat peripheral nucleus.	• Small. • Many droplets of lipids. • Many mitochondria. • Spherical central nucleus
Colour Nucleus of fat cell	White	Brown due to: 1. Rich in blood vessels. 2. Cells are rich in mitochondria full of cytochrome pigment.
Sites	1. Under skin. 2. Around kidney and blood vessels. 3. Mesentery.	In foetus and newborn: 1. Interscapular region. 2. Axilla. 3. Mediastinum. In adults: only around thoracic aorta.
Functions	1. Synthesis & storage of fat. 2. Support of kidney and blood vessels. 3. Heat insulator.	1. Heat generation.

3) Reticular connective tissue:

- i. Structure: formed of.
 - Reticular cells which are
 - They are specialized fibroblasts
 - connected by desmosomes,
 - Reticular fibres forming a network, so it is stained brown by Ag.
- ii. Sites: in the stroma of:
 - Lymphatic organs as spleen and lymph nodes.
 - Bone marrow.
 - Glands as liver.
- iii. Function: support cells in its sites.



4) Mucoid connective tissue (Fig:25)

- i. Structure: formed of
 - Mesenchymal cells & fibroblasts that communicate with their processes.
 - Jelly like ground substance huge in amount, rich in mucus, hyaluronic acid and glycoprotein called Wharton's jelly.
- ii. Sites:
 - Umbilical cord.
 - Pulp of growing tooth.
 - Vitreous humour of eye.
- iii. Function: protects nearby structures from pressure.

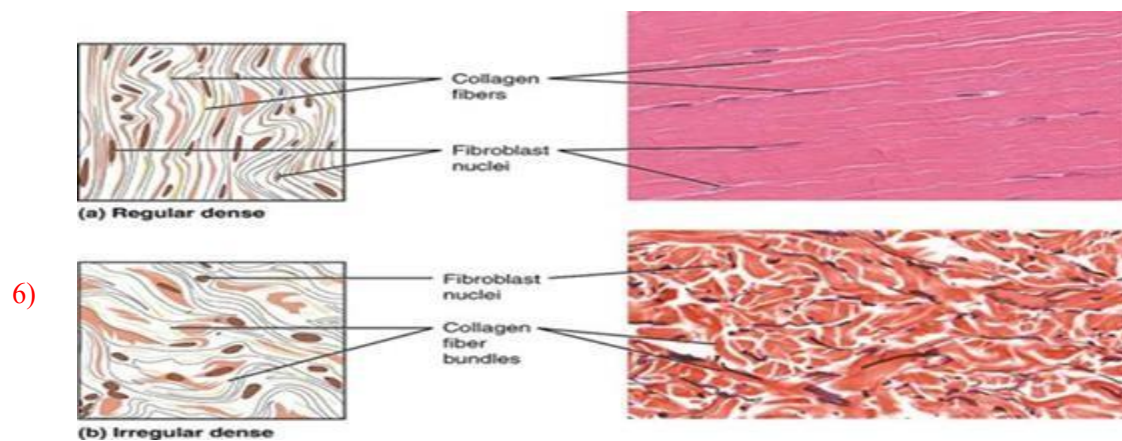
Fig:25 Mucoid CT

5) White fibrous connective tissue: (Fig 26)

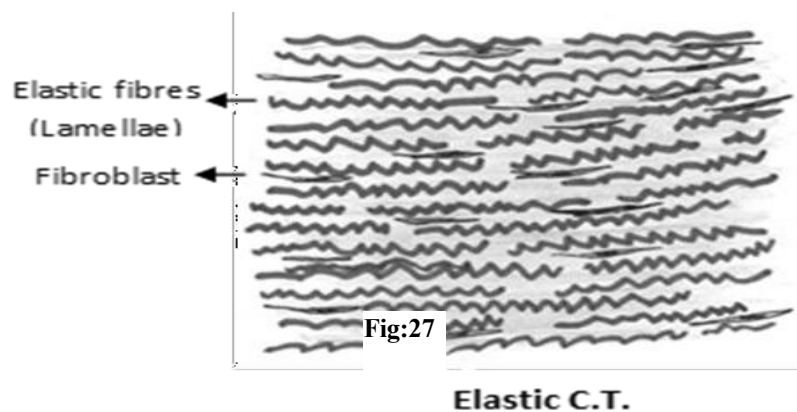
- i. Structure: Mainly formed of fibroblasts and collagen fibres with very minimal ground substance.

ii. Types:

Structure	Collagen bundles are parallel to each other and to the fibroblasts in between.	Collagen bundles are irregularly arranged forming network with fibroblasts in between.
Sites	• Tendons. • Cornea.	• Periosteum, perichondrium. • Sclera.
Functions	Resists stretch in one direction.	Resists stretch in different directions.

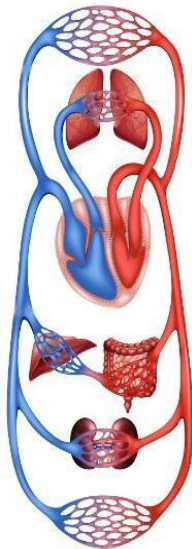
**Fig 26: diagram showing types of white fibrous C.T****Yellow elastic connective tissue: (Fig:27)**

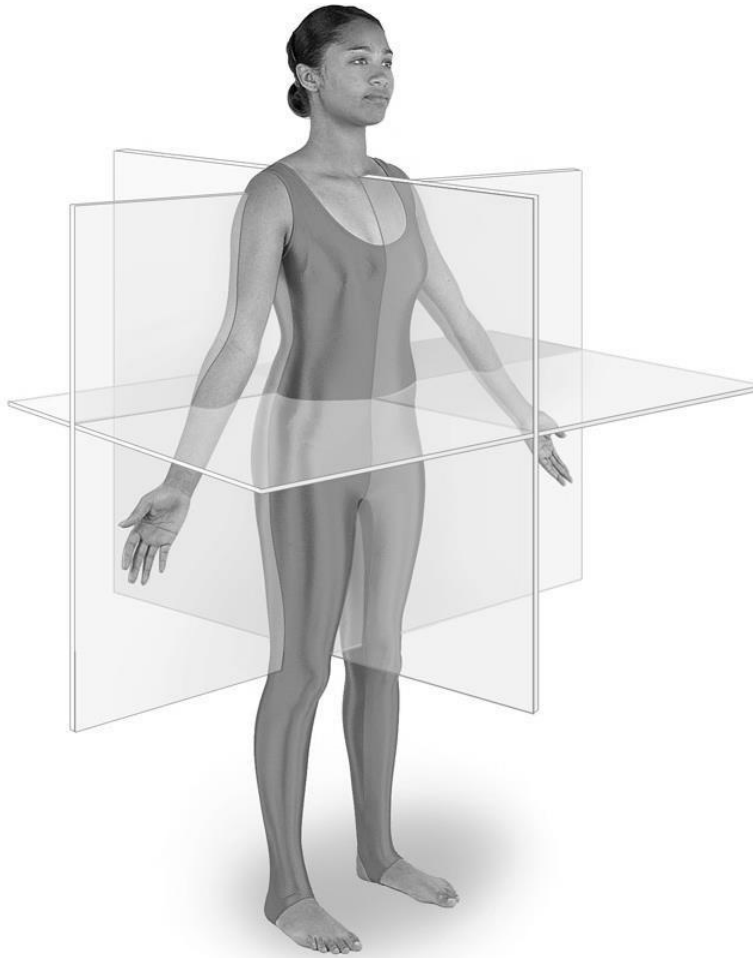
- i. Structure:** formed of connective tissue cells mainly fibroblasts and connective tissue fibres mainly elastic fibres so it appears yellow in fresh state and can be stained brown with orcein.
- ii. Sites:**
 - Aorta and large vessels.
 - Bronchi and bronchioles.
 - Ligamentum nuchae and ligamentum flavum.
- iii. Function:** gives flexible support.



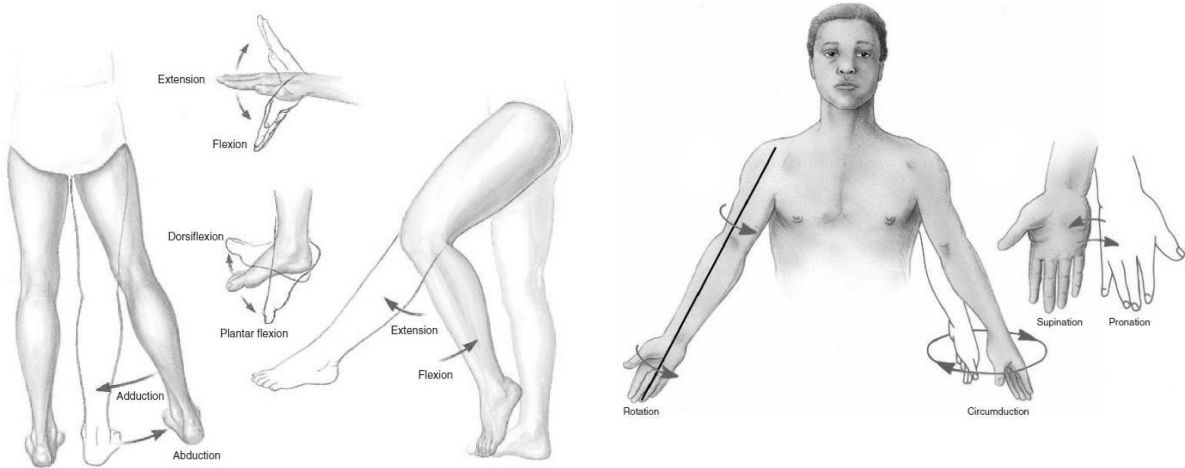
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INTRODUCTION





Planes



Movements

TERMINOLOGY

Anatomical position: all the anatomical descriptions are based on a position in which the man is standing, with his face & palms of hands directed forward & the feet are close to each other.

Anatomical planes & directions:

Median (sagittal) plane: a vertical plane which divides the body at the midline into Rt & Lt equal halves. According to this plane & the planes parallel to it (paramedian or parasagittal planes) the body is divided into *medial* (near the midline) & *lateral* (away from midline).

Coronal plane: a vertical plane which divides the body into *anterior* (in front of the plane) & *posterior* (behind the plane).

Transverse (horizontal) plane: which divides the body into *superior* (upper) & *inferior* (lower) parts.

Anatomical descriptions:

- In addition to the previous terms, others could be used as:

Superficial & deep: near or away from the surface.

External & internal: outside or inside.

Proximal & distal: near or away from the trunk.

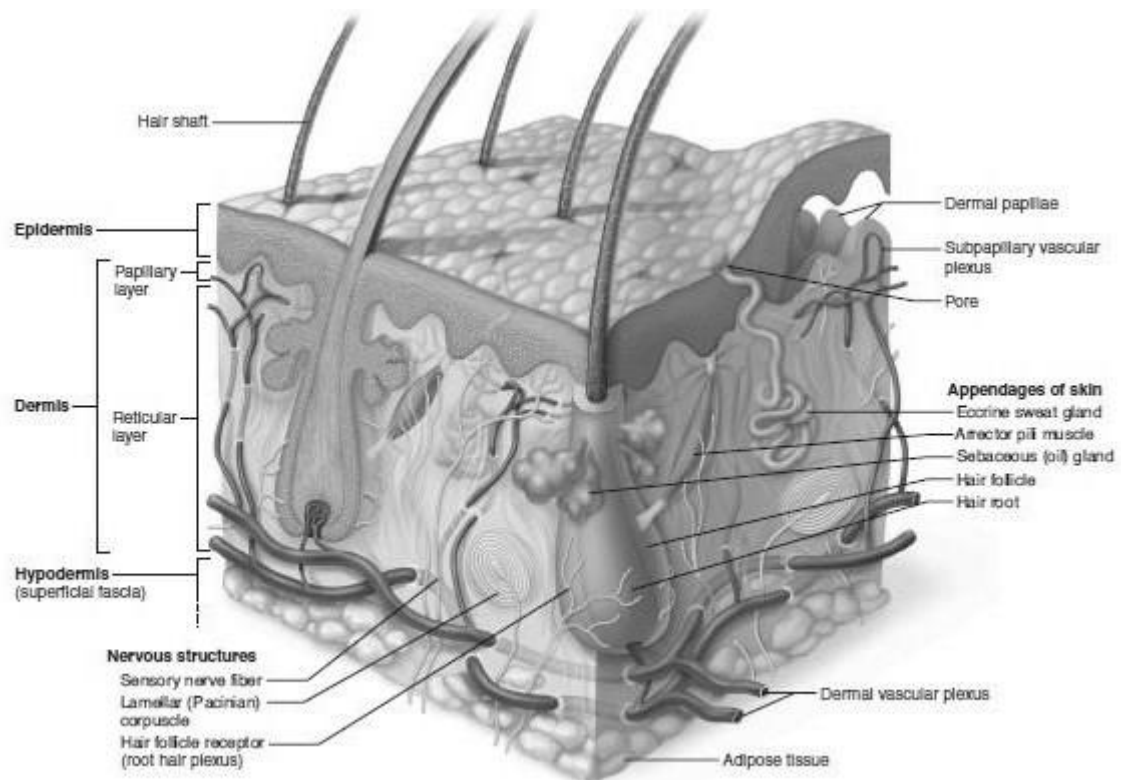
Terms of movements:

Flexion & extension: moving 2 ventral surfaces towards or away from each other.

Adduction & abduction: movement towards or away from midline.

Medial & lateral rotations: moving the anterior side towards or away from the midline.

N.B.: other terms of movements may be used in specific sites.



Skin and fascia

Marieb

SKIN & FASCIA

SKIN

Layers: it is formed of 2 layers:

Epidermis: outer tough layer.

Dermis: inner layer containing hair follicles, sweat glands, nerves, blood vessels & lymphatics.

Functions:

- Protection from external environment.
- Sensations.
- Regulation of body temperature.

SUPERFICIAL FASCIA

- ❖ Formed of loose connective tissue & fat.
- ❖ It also contains nerves, blood vessels & lymphatics, transmitting it to skin.
- ❖ It is absent in specific sites, e.g.: eye lids & scrotum.

Functions:

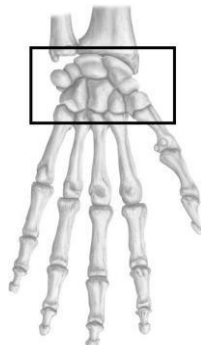
- Fat store.
- Regulation of body temperature (fat prevent heat loss).
- In females, it contains the mammary gland forming the breast.

DEEP FASCIA

- ❖ It is formed of dense connective tissue, to surround the deeper structures.
- ❖ It is well developed in limbs, especially around the joints (to grasp the different structures passing) & in the palm of hand & sole of foot (for protection).
- ❖ It is poorly developed in sites which need expansion, e.g.: face and thoracic and abdominal walls.



long



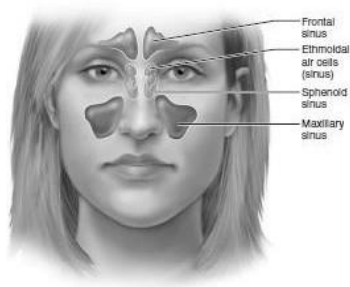
short



flat



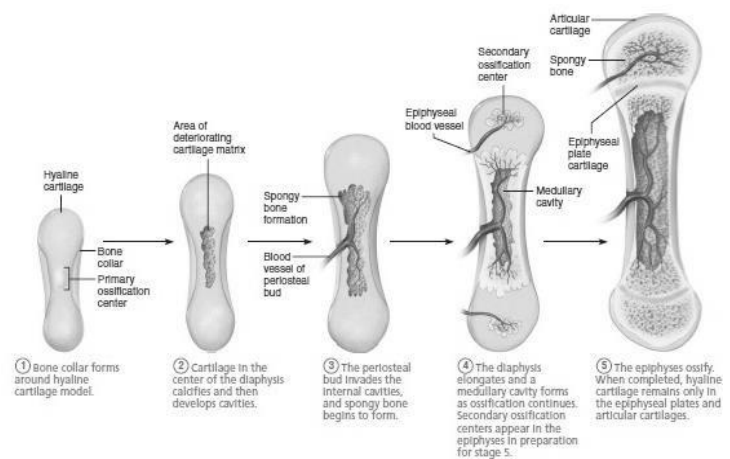
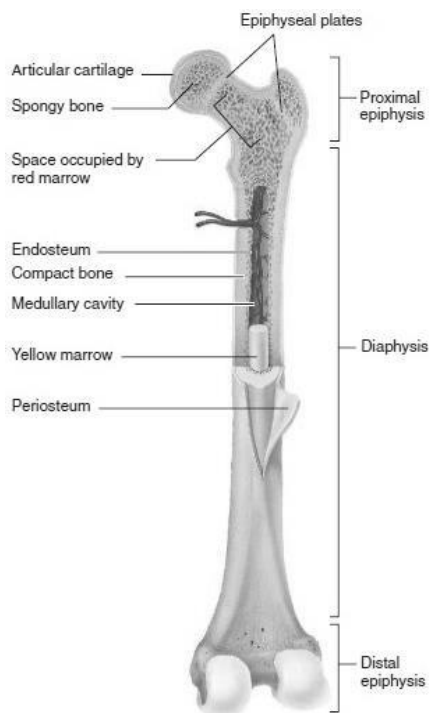
irregular



pneumatic



Sesamoid



Growing long bone

BONES

Types of bones:

Type	Description	Example
Long	A bone with a shaft (diaphysis) & 2 ends (epiphysis)	Humerus & femur
Short	Small bone	Carpal bones
Flat	A bone with 2 surfaces	Scapula
Irregular	A bone which does not fit the previous 3 types	Vertebrae
Pneumatic	Special type, which is filled with air	Maxilla
Sesamoid	Special type, which is found in a tendon of a muscle	Patella

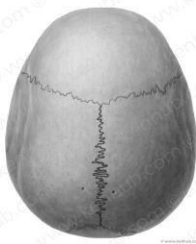
Ossification of bones:

Membranous: a connective tissue membrane will ossify into bone (e.g.: clavicle).

Cartilaginous: a membrane will be transformed into cartilage model which will ossify into bone (e.g.: all bones of the limbs except clavicle).

Growing long bone

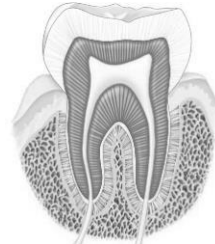
- During development of long bones, it is formed of a membranous model, which mostly changes to a cartilage.
- Before birth, the shaft is transformed into bone, it begins by a **primary center of ossification**.
- After birth, each end is transformed into bone, it begins by a **secondary center of ossification**.
- A disc of cartilage persists between the shaft and each end, it is called **epiphyseal plate of cartilage**.
- The epiphyseal plate of cartilage add new cells to the shaft, this will increase bone **length**.
- The newly formed part of the shaft (near epiphyseal plate of cartilage) is called **metaphysis**.
- Later, the epiphyseal plate of cartilage ossifies, this will stop bone lengthening.
- Usually the 2 epiphyseal plates of the same bone do not ossify at the same time. One (**non growing**) end ossifies around the age of 19 years in males (17 years in females). The other (**growing**) end will ossify around the age of 21 years in males (19 years in females) with variations.
- The bone is covered by a **periosteum**. Periosteum add new cells deep to it, causing an increase in bone **width**.
- The bone shows a cavity. This cavity is lined with **endosteum** and contains bone marrow, which is responsible for formation of blood cells.



Suture



Syndesmosis



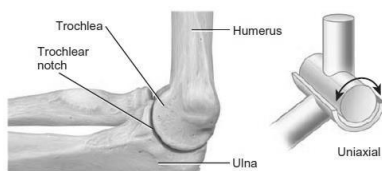
gomphosis



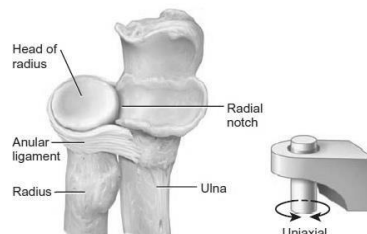
Primary cartilaginous



Secondary cartilaginous



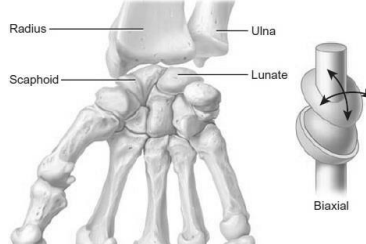
Hinge



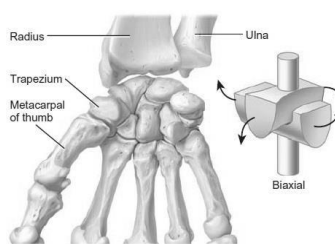
Pivot



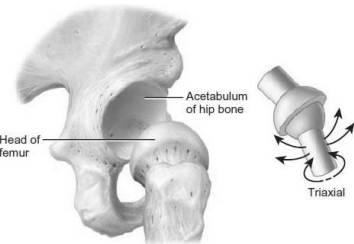
Modified hinge



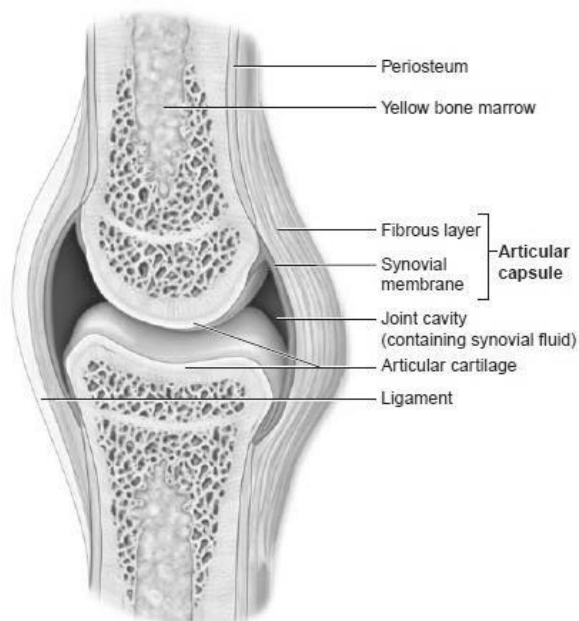
ellipsoid



Saddle



Ball & socket



Synovial Joint features

Ken Hub / McKinley & O'Loughlin / Shier / Marieb / Tortora & Nielsen

JOINTS

Definition: meeting between 2 or more bones (or cartilages).

Types: according to the tissue between the bones the joints is classified into:

Fibrous: a fibrous tissue connect the 2 bones, further divided into:

Type	Features	Example
<i>Syndesmosis</i>	- Allows minimal movement - Does not ossify with age	Inf tibiofibular joint
<i>Suture</i>	- Allows minimal movement - Ossify with age	Sagittal suture (in skull)
<i>Gomphosis</i>	- Allows no movement - Does not ossify with age	Between teeth & gums

Cartilaginous: a cartilage connects the 2 bones, further divided into:

Type	Features	Example
<i>Primary cartilaginous</i>	- Formed of hyaline cartilage - Allows no movement - Ossifies with age - Usually found away from midline	Epiphyseal plate of cartilage
<i>Secondary cartilaginous</i>	- Formed of fibrocartilage - Allows minimal movement - Usually does not ossify with age - Usually found in midline	Intervertebral disc

Synovial: the 2 bones are connected with a capsule filled with synovial fluid, further divided into:

Type	Features	Example
<i>Plane</i>	Allows only gliding movement	Acromioclavicular
<i>Hinge</i>	Uniaxial: allows only flexion & extension	Elbow
<i>Pivot</i>	Uniaxial: allows only rotation	Sup & inf radioulnar
<i>Modified hinge</i>	Biaxial: allows flexion & extension + minimal rotation	Knee
<i>Ellipsoid</i>	Biaxial: allows flexion & extension + adduction & abduction	Wrist
<i>saddle</i>	Multiaxial: allows flexion & extension + adduction & abduction + minimal rotation	Carpometacarpal of thumb
<i>Ball & socket</i>	Multiaxial: allows flexion & extension + adduction & abduction + rotation	Shoulder Hip

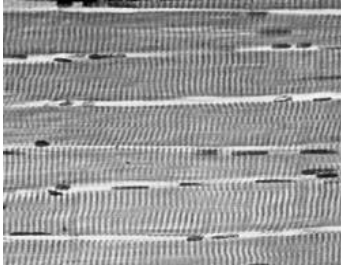
Synovial Joint features:

Articular cartilages: a layer of hyaline cartilage, covering the articular surfaces, for smooth movement.

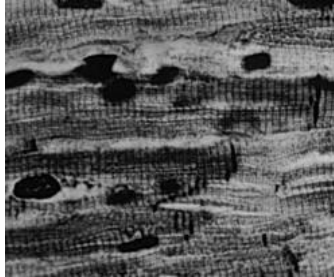
Capsule: it is formed of fibrous tissue, which connect the articular surfaces

Synovial membrane: lines the capsule & covers intracapsular non articular structures. It makes the joint space closed & secretes synovial fluid, which is responsible for joint lubrication.

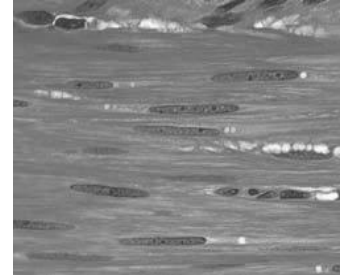
Ligaments: strong fibrous tissue, for joint stability. These ligaments may be capsular (thickened part of capsule), intracapsular or extracapsular.



Skeletal



Cardiac



Smooth

PARALLEL

Fascicles parallel to longitudinal axis of muscle; terminate at either end in flat tendons.



Example: Sternohyoid muscle

FUSIFORM

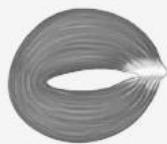
Fascicles nearly parallel to longitudinal axis of muscle; terminate in flat tendons; muscle tapers toward tendons, where diameter is less than at belly.



Example: Digastric muscle

CIRCULAR

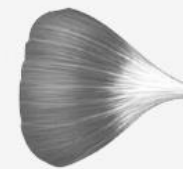
Fascicles in concentric circular arrangements form sphincter muscles that enclose an orifice (opening).



Example: Orbicularis oculi muscle

TRIANGULAR

Fascicles spread over broad area converge at thick central tendon; gives muscle a triangular appearance.



Example: Pectoralis major muscle

PENNATE

Short fascicles in relation to total muscle length; tendon extends nearly entire length of muscle.

Unipennate

Fascicles are arranged on only one side of tendon.



Example: Extensor digitorum longus muscle

Bipennate

Fascicles are arranged on both sides of centrally positioned tendons.



Example: Rectus femoris muscle

Multipennate

Fascicles attach obliquely from many directions to several tendons.



Example: Deltoid muscle

Types of skeletal muscles

McKinley & O'Loughlin / Whitaker & Borley

CARTILAGE

❖ It is avascular dense connective tissue, with intercellular matrix.

Types:

Type	Features	Example
Hyaline	Large amount of matrix	• Epiphyseal plate of cartilage • Articular cartilages
Fibrocartilage (white)	• Little matrix • Rich in collagen fibers • firm	• Intervertebral discs • Intraarticular cartilages
Elastic (yellow)	• Rich in elastic fibers • malleable	• Auricle of ear • Epiglottis

MUSCLES**Types:**

	Skeletal	Smooth	Cardiac
Site	Attached to skeleton	Viscera except heart	Heart
Muscle fibers	Striated	Smooth	Striated
Innervation	Somatic nerves	Autonomic nerves	Autonomic nerves
Action	voluntary	Involuntary	Involuntary

SKELETAL MUSCLES**Attachment of skeletal muscle:**

Origin: it is the beginning of the muscle, it is usually proximal & fixed.

Insertion: it is the end of the muscle, it is usually distal & movable.

Forms of attachments:

Fleshy: the regular fleshy nature of the muscle.

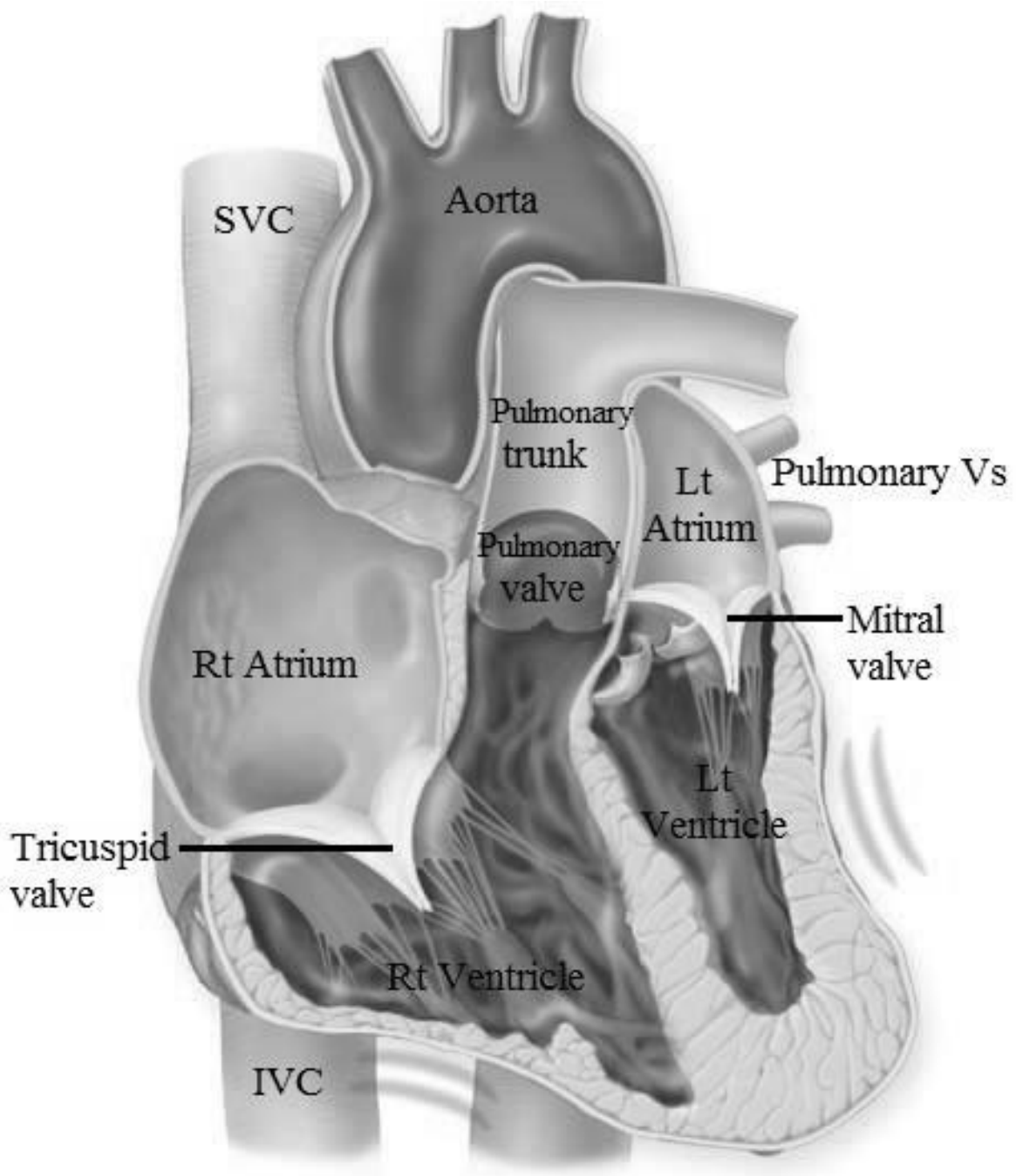
Tendon: cylindrical cord like fibrous tissue.

Aponeurosis: flat sheet like fibrous tissue.

Raphe: meeting of 2 muscles (usually in midline), in the form of a mixture of fleshy & tendinous fibers.

Types of skeletal muscles:

Type	Features
Parallel	The muscle fibers are parallel from origin to insertion
Fusiform	Parallel muscle fibers with central dilatation
Triangular	The fibers attach by a wide origin & narrow insertion
Circular	The fibers form a circle
Pennate	<i>Unipennate</i> The fibers attach obliquely to the tendon from one side
	<i>Bipennate</i> The fibers attach to the tendon from 2 sides
	<i>Multipennate</i> Union of many bipennate parts
	<i>Circumpennate</i> Circular arrangement of multipennate



Heart

Mckinley

CARDIOVASCULAR SYSTEM**HEART**

- ❖ It is a muscular organ which pumps blood to different parts of the body.
- ❖ It has 4 chambers (Rt & Lt atria & Rt & Lt ventricles).
- ❖ It is supplied by coronary arteries. Occlusion of a coronary artery may lead to angina.

Parts:**RT atrium**

- It receives non oxygenated blood from different parts of the body (except the lungs) through SVC and IVC.
- It transmits it through Rt A-V opening (guarded by tricuspid valve) to Rt ventricle.

Rt ventricle

- It receives non oxygenated blood from RT atrium.
- It pumps it through pulmonary artery (guarded by pulmonary valve) to the lungs where it is oxygenated.

Lt atrium

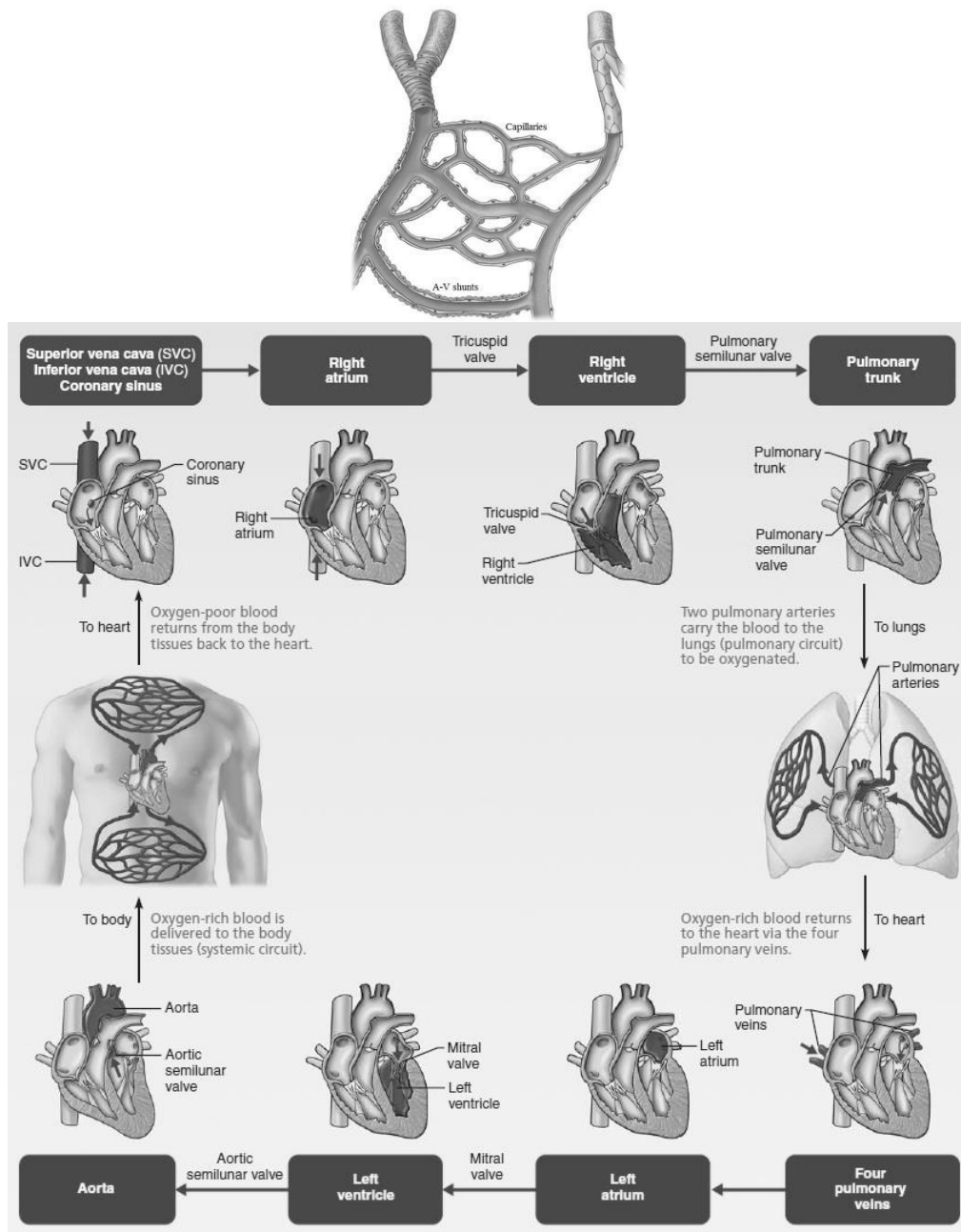
- It receives oxygenated blood from lungs through pulmonary veins.
- It transmits it through Lt A-V opening (guarded by mitral valve) to Lt ventricle.

Lt ventricle

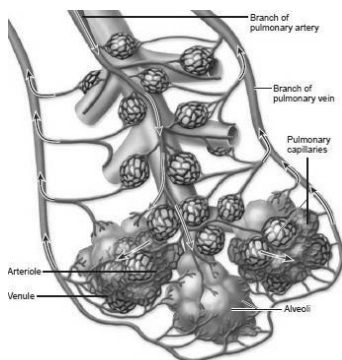
- It receives oxygenated blood from Lt atrium.
- It pumps it through aorta (guarded by aortic valve) to different parts of body.

BLOOD VESSELS**Arteries:**

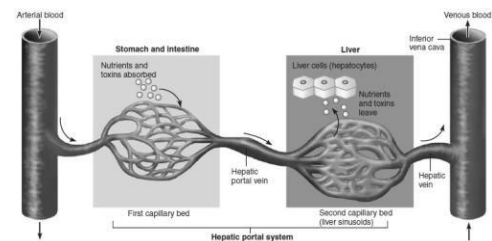
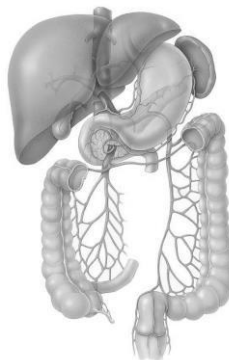
- It is blood vessels transmitting blood away from the heart.
- It has an elastic wall, helping in its dilatation and constriction to regulate blood pressure.
- All the arteries carry oxygenated blood except pulmonary arteries which carry non oxygenated blood.
- The arteries divide into smaller arteries → arterioles → capillaries.
- Usually, the arteries anastomose with each other. Those who don't anastomose are called end arteries. Occlusion of an end artery will lead to death of the part supplied by it. E.g.: in heart, lungs, kidneys, spleen, retina and CNS.



Circulations



Pulmonary capillaries



Portal circulation

Tortora & Nielsen / McKinley & O'Loughlin / Martini / Marieb

Veins:

- It is blood vessels transmitting blood to the heart.
- It has less elastic wall.
- All the veins carry non oxygenated blood except pulmonary veins which carry oxygenated blood.
- The capillaries unite → venule → vein → larger vein.

Capillaries:

- Small thin walled blood vessels.
- It allows the movement of oxygen & nutrients from blood to intercellular tissues & CO₂ & waste products in the opposite direction.

Sinusoids:

- Wider than capillaries.
- It allows slow circulation.
- E.g.: liver, spleen, suprarenals and bone marrow.

A-V shunts:

- Direct channels between arterioles and venules.
- It allows rapid circulation (as in temperature regulation) and not concerned with material exchange.
- E.g.: hands, feet and nose.

CIRCULATIONS

Systemic circulation:

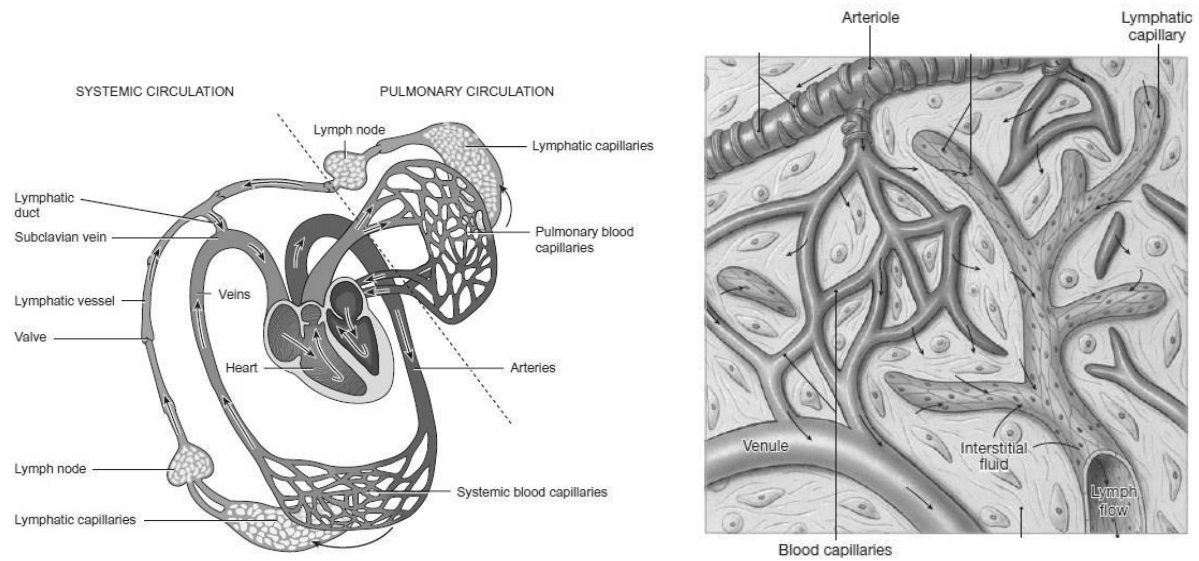
- It is between the heart and different tissues of the body.
- Lt ventricle pumps oxygenated blood → aorta → arteries → arterioles → capillaries (material exchange with cells) → venules → veins → SVC & IVC → Rt atrium.

Pulmonary circulation:

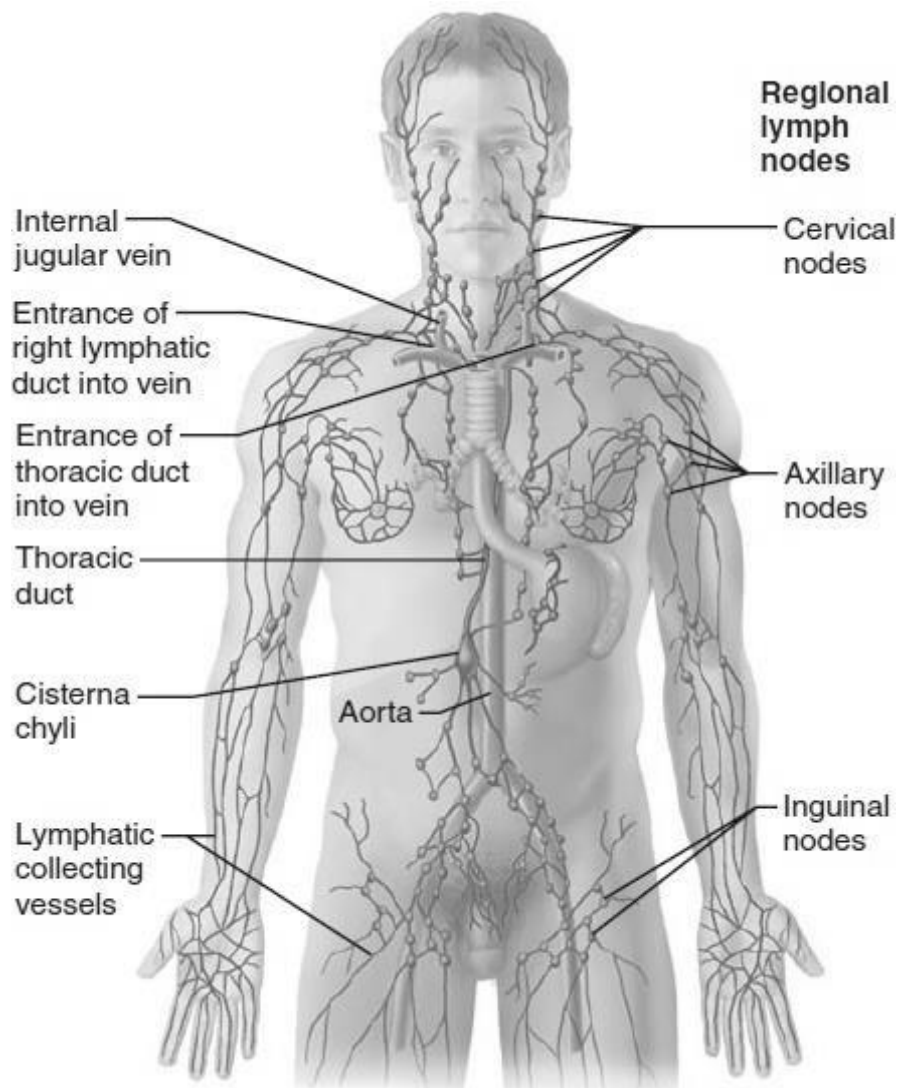
- It is between the heart and lungs.
- Rt ventricle pumps non oxygenated blood → pulmonary arteries → arterioles → capillaries (gas exchange with lung alveoli) → venules → pulmonary veins → Lt atrium.

Portal circulation:

- Between the GIT & liver (interrupting GIT systemic circulation).
- Capillaries of GIT (carrying absorbed nutrients) → venules → veins → portal vein → divides → liver sinusoids (adjustment of nutrient levels and detoxication).
- So, the portal vein begins like a vein (union of smaller veins) and ends like an artery (giving divisions).



Lymph vessels



Lymph nodes

LYMPHATIC SYSTEM

- ❖ In organs, the exchange occurs between capillaries and intercellular fluid. Part of the fluid is not drained back to the capillaries. Instead, it is collected in lymphatic vessels as lymph, which is filtered during its course in lymph nodes. Finally, it drains into the venous system.

Lymph:

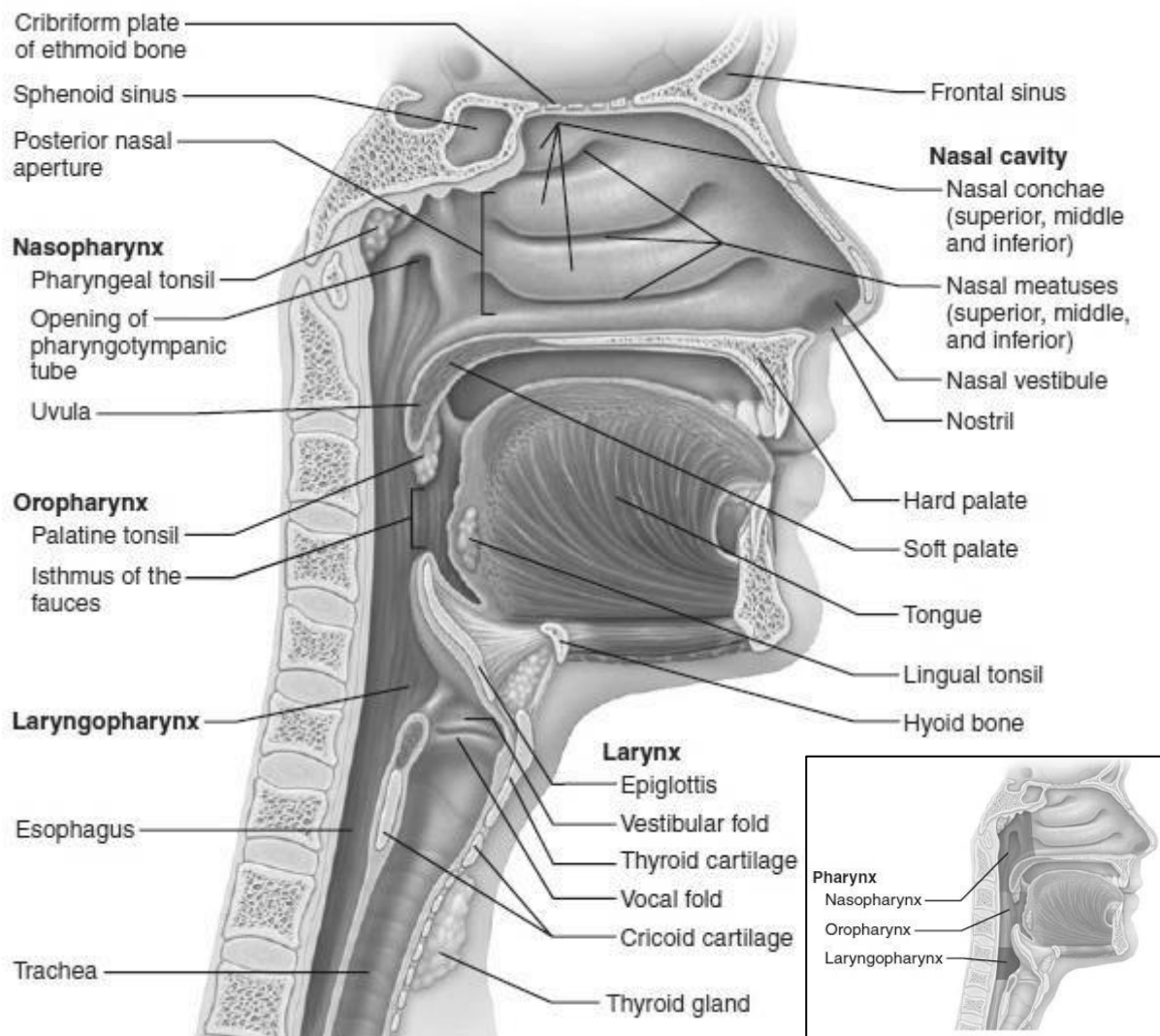
- It is the intercellular fluid drained with lymph vessels. It is clear and rich in lymphocytes.

Lymph vessels (lymphatics):

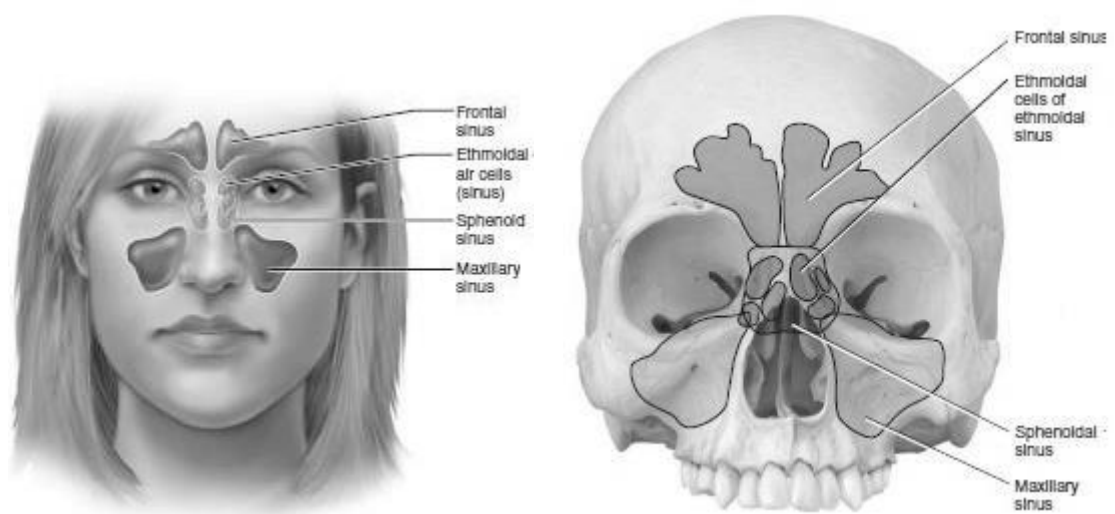
- Larger than blood capillaries.
- The lymph capillaries unite → larger lymph vessels, which pass through the lymph nodes.
- Some organs are rich in lymphatics. E.g.: dermis and mucous membranes.
- Some organs are devoid of lymphatics. E.g.: CNS, bone marrow, cornea and epidermis.

Lymph nodes:

- It is a collection of lymph tissues interrupting the lymph vessels course and filtering the lymph.
- They are usually found in entrance sites of body parts. E.g.: axillary lymph nodes for upper limbs, inguinal lymph nodes for lower limbs and cervical lymph nodes for head and neck.
- Some organs are considered modified lymph nodes, as they don't have afferent lymphatics. They have a protective function against external threats. E.g.: tonsils and adenoids.



Nose & pharynx



Paranasal sinuses

RESPIRATORY SYSTEM**NOSE****Parts:**

Roof: narrow and separated from cranial cavity by thin perforated bone.

Floor: wide and formed by the palate.

Median septum: formed of post bony and ant cartilaginous parts.

2 lateral walls: show 3 shelf projections called conchae (sup, middle & inf), below each concha a meatus is found (sup, middle & inf). These meatuses receive the openings of paranasal sinuses.

Ant nasal openings: in the face.

Post nasal openings: to the pharynx.

- ❖ The nose is lined with respiratory epithelium (vascular and mucoid) for modification of inspired air. Except near the roof where it is lined with olfactory epithelium (smell receptors).

PARANASAL SINUSES

- ❖ It is air filled spaces within some skull bones, connected to the nose and lined with respiratory epithelium.
- ❖ It is found in frontal, maxillary, sphenoid and ethmoid bones.
- ❖ It allows the enlargement of the skull bones without increase in weight
- ❖ Inflammation of these sinuses is called sinusitis, which may be a result of inadequate connection to the nose.

PHARYNX

- ❖ It is a muscular tube posterior to nose (nasopharynx), oral cavity (oropharynx) and larynx (laryngopharynx).
- ❖ It extends from the base of skull to C6 vertebra.

Parts:**Nasopharynx:**

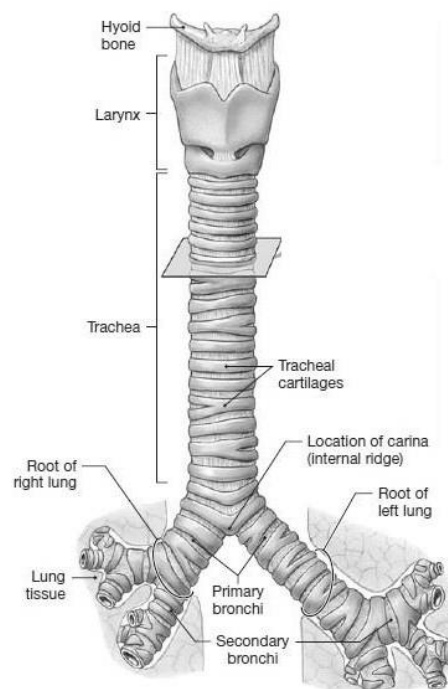
- Lies behind the nose.
- It transmits air from the nose (anterior) to oropharynx (inferior).
- It communicates with the middle ear through Eustachian tube.
- It has a collection of lymphoid tissue called adenoids.

Oropharynx:

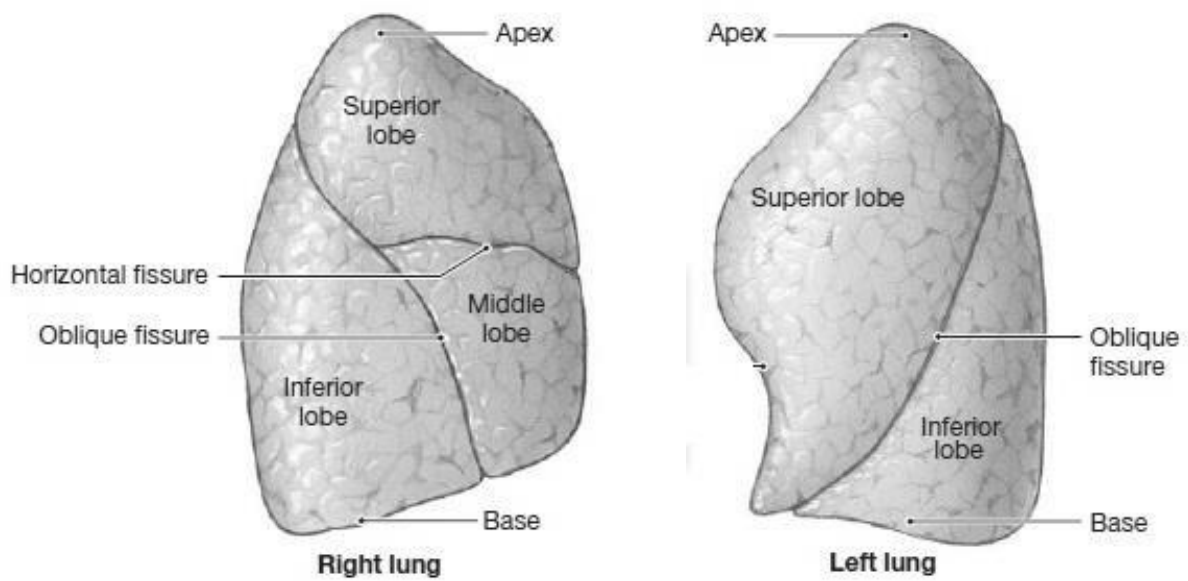
- Lies behind the oral cavity.
- It transmits air from nasopharynx (superior) to larynx (anteroinferior) and transmits food from oral cavity (anterior) to laryngopharynx (posteroinferior).

Laryngopharynx:

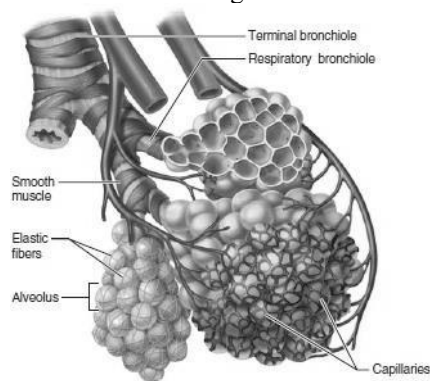
- Lies behind the larynx.
- It transmits food from oropharynx (superior) to esophagus (inferior).
- It has a collection of lymphoid tissue called tonsils.



Larynx, trachea and bronchi



Lungs



Alveoli

LARYNX

- ❖ It is formed of cartilages, membranes and muscles.
- ❖ It begins at C3 vertebra, as a continuation of oropharynx. It ends at C6 vertebra to continue as trachea.
- ❖ It shows 2 vocal cords which allow air passage, its vibration against expired air produces voice.

TRACHEA

- ❖ It is 12 cm long and 12 mm in diameter.
- ❖ It shows C shaped cartilages in its wall to keep it open.
- ❖ It begins at C6 vertebra and ends at T4 vertebra by dividing into 2 bronchi (Rt & Lt).

BRONCHI

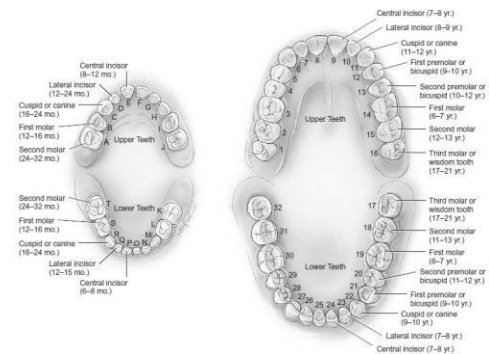
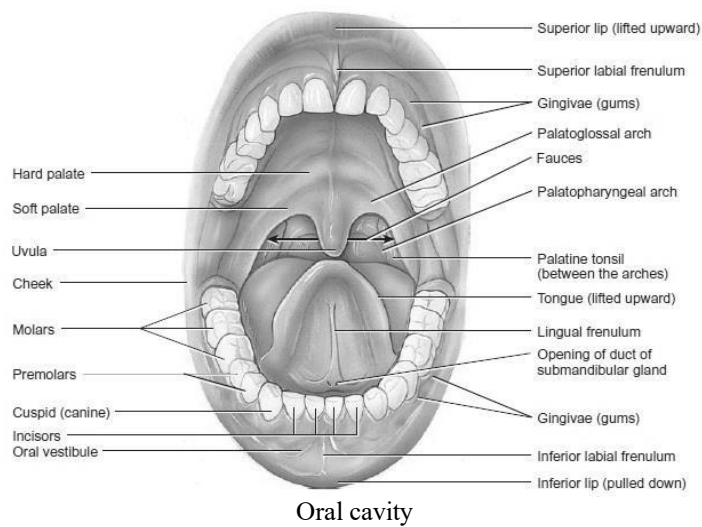
Rt bronchus	Lt bronchus
Short (2.5 cm)	Long (5 cm)
Wide	Narrow
More vertical	More horizontal
Divides into 2 bronchi before entering the lung	Divide inside the lung

Accordingly, foreign body is more commonly lodged in Rt than Lt bronchus.

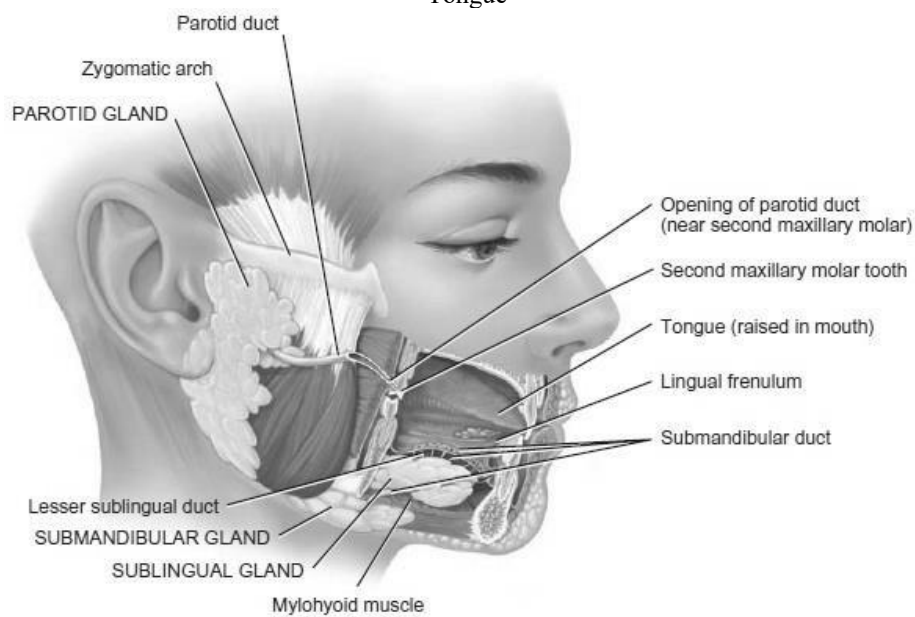
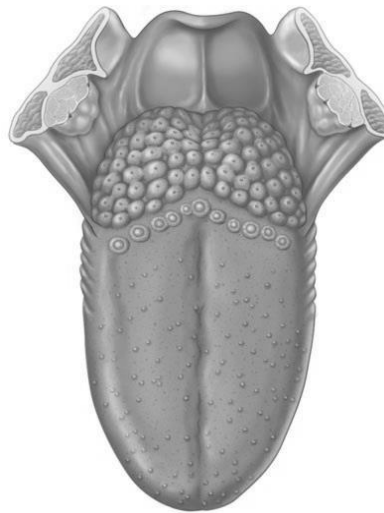
LUNGS

- ❖ 2 (Rt and Lt).
- ❖ Each is $\frac{1}{2}$ cone shaped with an apex (sup) and base (inf).
- ❖ Each bronchus enters the lung divides into smaller bronchi → bronchioles → many divisions → alveoli (filled with air and surrounded by pulmonary capillaries for gas exchange).
- ❖ Structures entering the lungs:
 - Pulmonary vessels for oxygenation: the artery carries non oxygenated blood and the vein carries oxygenated blood.
 - Bronchus (or two).
 - Bronchial vessels to supply the lung itself.
- ❖ Each lung is covered with pleura, which is a double layer of serous sac with thin film of fluid in between, for lubrication of the lung movement.

Rt lung	Lt lung
Short	Long
Wide	Narrow
Larger	smaller
Shows 2 fissures	Shows 1 fissure
Formed of 3 lobes (sup, middle and inf)	Formed of 2 lobes (sup and inf)
Has a deeply concave base due to the presence of the liver inf to it	Has a shallow concave base



Teeth



Salivary glands

DIGESTIVE SYSTEM**MOUTH**

- ❖ Its roof is formed of palate (ant: hard palate formed of bones and post: soft palate formed of muscles); both are covered with mucous membrane.
- ❖ Its floor is formed of muscles of oral diaphragm and covered with mucous membrane.
- ❖ It is continuous posteriorly with the oropharynx.
- ❖ It contains 2 U shaped gums (sup and inf), each is formed of fibrous tissue covered with mucous membrane.
- ❖ Each ¼ of gum contains 8 teeth in adults (2 incisors, 1 canine, 2 premolars and 3 molars).
- ❖ The vestibule: is the space between the gums and the cheeks.

TONGUE

- ❖ It is a muscular organ covered by mucous membrane, with a tip (ant) and a root (post).
- ❖ The muscles are either extrinsic (attached from bones to tongue and moving it) or intrinsic (not attached to bones and changing tongue shape).
- ❖ The mucous membrane covering the tongue can feel general sensations (pain, temperature... etc). The dorsal surface shows taste buds (receptors) which can also feel taste sensations (salty, bitter... etc).
- ❖ The mucous membrane covering the inf (ventral) surface shows a fold connecting it to the floor of mouth called frenulum.

SALIVARY GLANDS**3 pairs:**

Parotid: at the side of face, below the ear.

Submandibular: deep to the mandible.

Sublingual: in the floor of mouth.

- ❖ They are exocrine glands, secreting saliva by ducts into the oral cavity.
- ❖ Their secretion is stimulated by parasympathetic & inhibited by sympathetic innervation.

PHARYNX

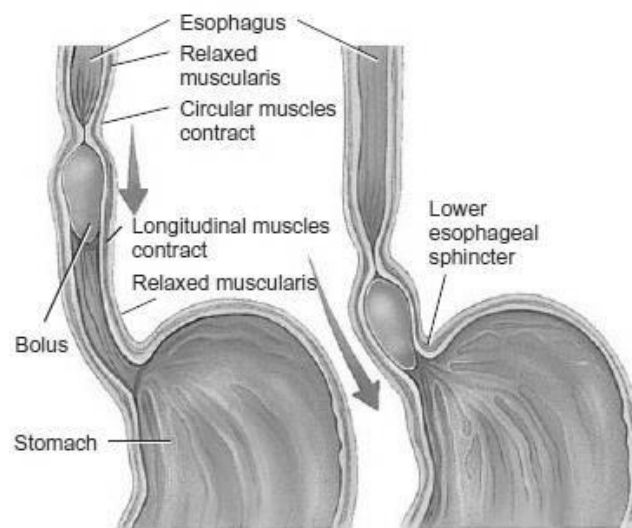
- ❖ See respiratory system.

ESOPHAGUS

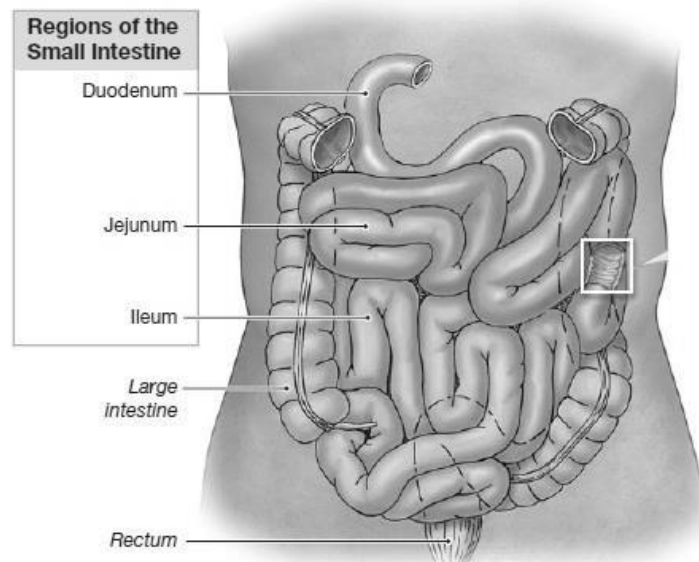
- ❖ It is a muscular tube (25 cm) extending from the laryngopharynx (at the level of C6 vertebra) to the stomach.
- ❖ It pushes the food by peristaltic movements.

STOMACH

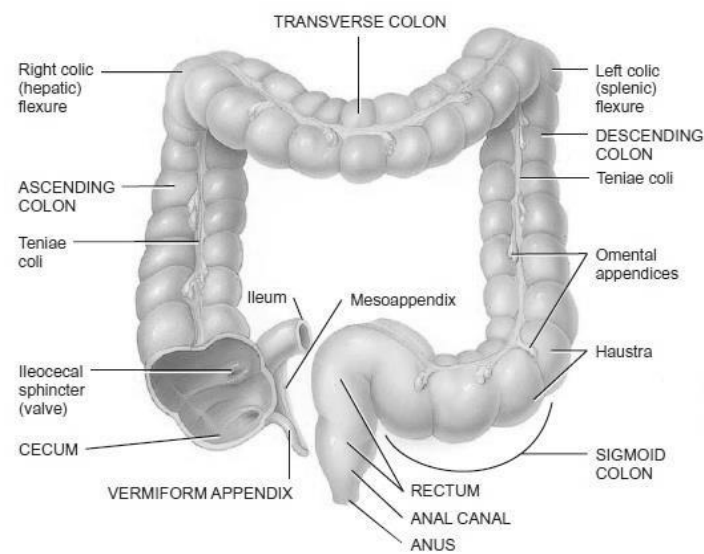
- ❖ It is the most dilatable part of GIT.
- ❖ It is usually J shaped.
- ❖ It has 2 openings; cardiac (connecting it to the esophagus and guarded by a physiological sphincter) and pyloric (connecting it to the duodenum and guarded by powerful anatomical sphincter), these sphincters allow the food passage from the esophagus → stomach → duodenum and not the reverse.
- ❖ It has 2 borders; right (*lesser curvature*) and left (*greater curvature*).
- ❖ It has 2 surfaces; anterior (facing liver and anterior abdominal wall) and posterior.



Esophagus and stomach



Small intestines



Large intestines

SMALL INTESTINES

- ❖ It is about 6 meters, and divided into duodenum, jejunum and ileum.

Duodenum

- It is C shaped (10 inches, 25 cm long).
- It begins after the pyloric sphincter and ends by becoming jejunum.
- It is mostly fixed to the posterior abdominal wall.

Parts:

1st part: 2 inches long, horizontal (extending from Lt to Rt).

2nd part: 3 inches, vertical (directed downwards).

3rd part: 4 inches, horizontal (extending from Rt to Lt).

4th part: 1 inch, vertical (directed upwards).

- It has an opening in the 2nd part (***major duodenal papilla***), which receive the liver and pancreatic secretions through ***hepatopancreatic ampulla***, this opening is guarded by ***sphincter of Oddi***.

Jejunum

- It is about 2.5 meters long.
- It has a thick wall and a wide diameter (4 cm).
- It has many mucosal folds showing villi (for absorption of food) and rich vascularity.

Ileum

- It is about 3.5 meters long.
- It has a thin wall and a narrow diameter (3,5 cm).
- It has less mucosal folds and less vascularity, but it has more lymphatics and surrounding fat.

LARGE INTESTINES

- ❖ It is about 60 inches (1.5 meters).
- ❖ It has a 3 longitudinal muscle straps (***Taenia coli***), which is shorter than the large intestines causing it to form (***sacculaton***), it also has a small fat pockets at its outer wall (***appendices epiploicae***).
- ❖ It has mucosal folds, which disappears in distension and has no villi.

Parts:

Cecum: 3 inches, rounded sac.

Appendix: narrowest part of the GIT, extends from cecum for 1-7 inches.

Ascending colon: 5 inches, on the RT side, directed upwards.

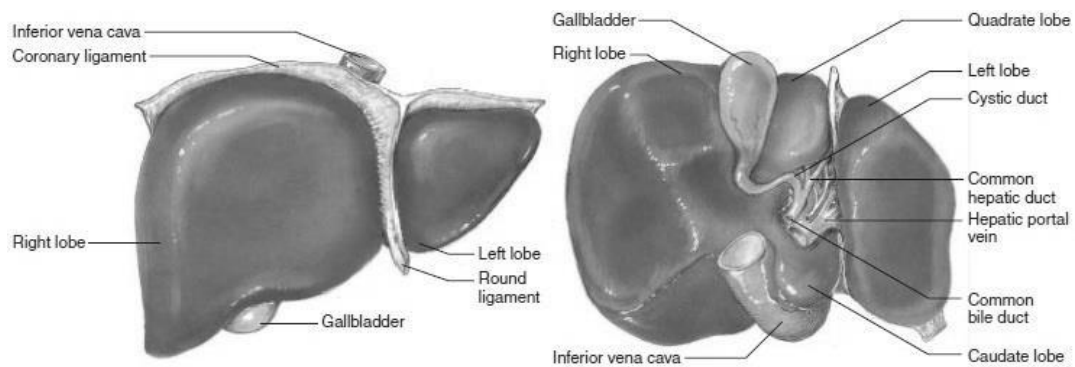
Transverse colon: 20 inches, extending from Rt to Lt.

Descending colon: 10 inches, on the Lt side, directed downwards.

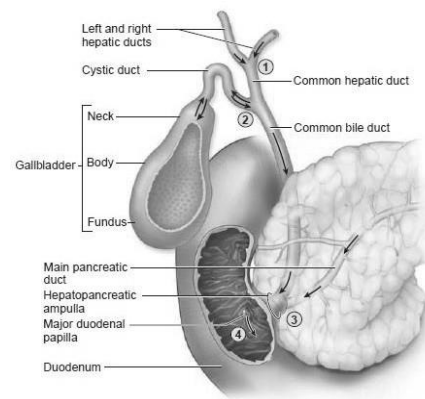
Sigmoid colon: 15 inches, lies in the pelvis.

Rectum: 5 inches.

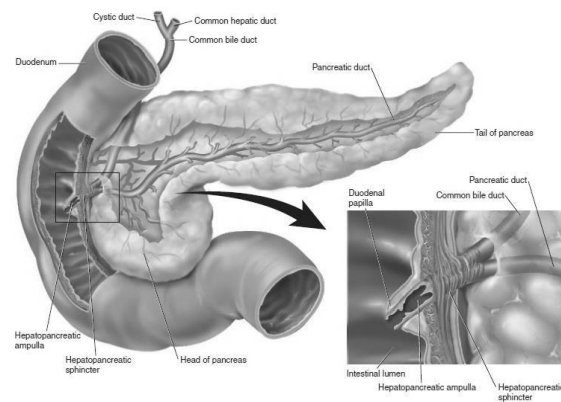
Anal canal: 2 inches and guarded by internal (involuntary) and external (voluntary) sphincters.



Liver

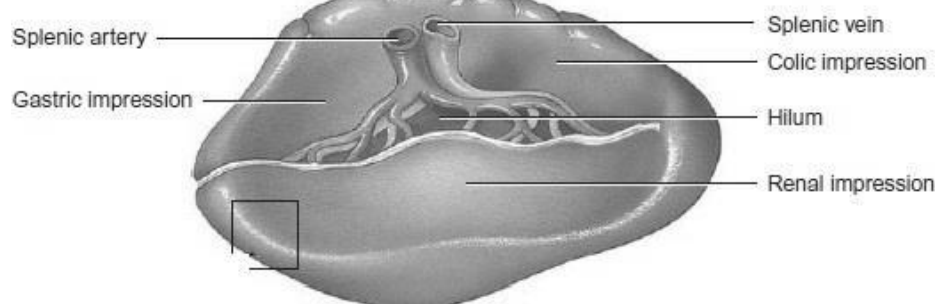


Biliary system



Pancreas

SUPERIOR



Spleen

LIVER

- ❖ It is the largest gland in the body (about 1.5 kg in adults).
- ❖ It is pyramidal in shape, with the base directed to Rt and the apex directed to the Lt.
- ❖ It is formed of large Rt and small Lt lobes.
- ❖ It is supplied by hepatic vessels. It also receives portal vein transmitting blood rich in nutrients absorbed from GIT.
- ❖ The liver has an important function in managing the level of nutrients in blood, breaking toxins and it also secretes bile for digestion.

BILIARY SYSTEM

- ❖ The bile is secreted from the liver in 2 (Rt & Lt) hepatic ducts.
- ❖ Both unite to form common hepatic duct.
- ❖ The hepatic duct meets the cystic duct.
- ❖ The cystic duct transmits bile from common hepatic duct to gall bladder for storage and concentration. It then transmits the concentrated bile in reversed direction to the common bile duct.
- ❖ The gall bladder is a cyst found below the inferior surface of the liver, it is formed of fundus (related to the anterior abdominal wall), body and neck which is continuous with the cystic duct.
- ❖ The common bile duct is formed by union of common hepatic duct and cystic duct. It descends to unite with the main pancreatic duct to form *hepatopancreatic ampulla* which opens in the duodenum.

PANCREAS

- ❖ It is a mixed gland; endocrine (islets of Langerhans) secreting insulin directly in the blood, and exocrine secreting enzymes through ducts into the duodenum.

Parts:

Head: discoid, in the concavity of duodenum.

Neck: narrow part.

Body: extending from Rt to Lt.

Tail: reaching the spleen.

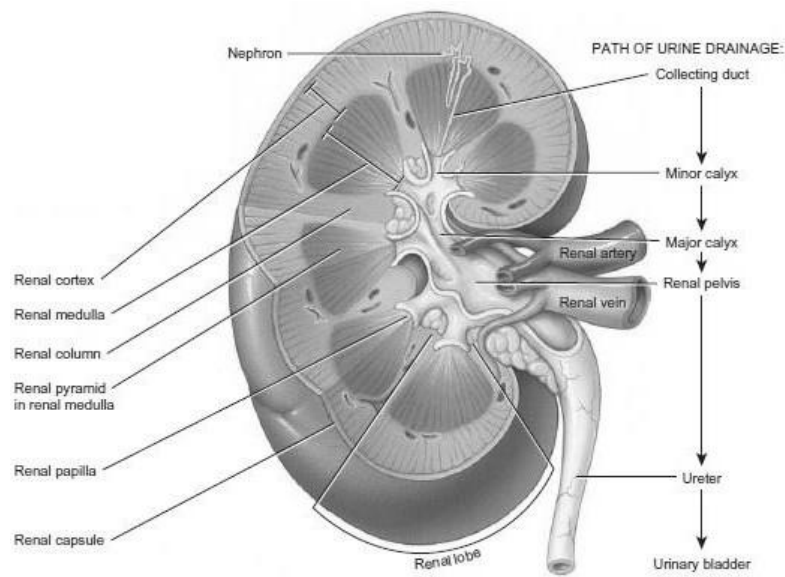
Ducts:

Main pancreatic duct: It extends along the whole length of pancreas. It ends by uniting with common bile duct forming *hepatopancreatic ampulla*, which open in the duodenum.

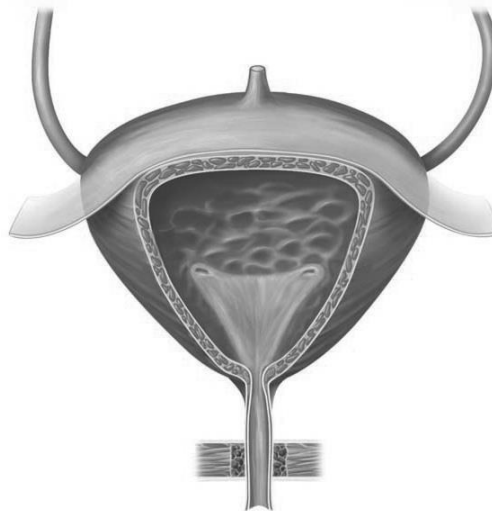
Accessory pancreatic duct: It drains part of the head of pancreas and open in the duodenum.

SPLEEN

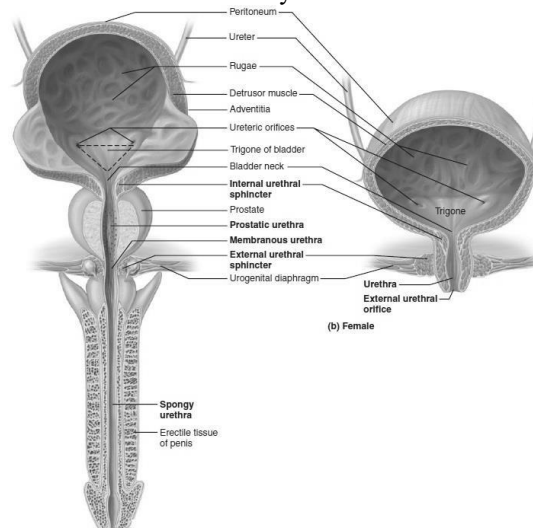
- ❖ It is a lymphoid organ related anatomically to the GIT.
- ❖ It is 12X6X3 cm.
- ❖ It has 2 surfaces (outer related to the diaphragm and 9-11 Lt ribs and inner related to abdominal viscera), 2 ends (ant and post) and 2 borders (sup and inf).



Kidney



Urinary bladder



Urethra

URINARY SYSTEM**KIDNEY**

- ❖ It is 12X6X3 cm.
- ❖ It has 2 ends (sup & inf), 2 borders (med & lat) & 2 surfaces (ant & post).
- ❖ Its function is to filter blood from waste products and excess water and secretes it as urine.
- ❖ It is formed of an outer part (cortex) and inner part (medulla).
- ❖ The unit of filtration is called nephron. It secretes urine in a collecting duct → minor calyces (8-12/ kidney) → major calyces (2-4/ kidney) → pelvis → ureter.

URETER

- ❖ It is 25 cm long.
- ❖ It extends from the kidney to the urinary bladder.
- ❖ Part of it passes on the posterior abdominal wall, the other part passes on the pelvic wall.
- ❖ It has narrow sites, in which stone formation may occur.

URINARY BLADDER

- ❖ It is pyramidal in shape with 4 surfaces (sup, post & 2 inferolateral).
- ❖ Its function is a urine reservoir. It usually gives an impulse for urination if filled with 300 cc, reaching 500 cc may lead to involuntary urination.
- ❖ It has a muscular wall lined with mucosa, to push the urine outwards.
- ❖ Its mucosa is sensitive to distension. The most sensitive part is the trigone (lining the post surface) which is richly innervated by autonomic nerves.
- ❖ It shows 3 openings; one for each ureter, and a 3rd opening for the urethra (neck of urinary bladder).

Male urethra

- ❖ It is 15-20 cm long.

Parts**Prostatic**

- 3 cm.
- Surrounded by prostate.
- This part receives ducts of the prostate & the 2 ejaculatory ducts
- Its upper part is surrounded by internal urethral sphincter (formed of involuntary muscles and innervated by autonomic nerves).

Membranous

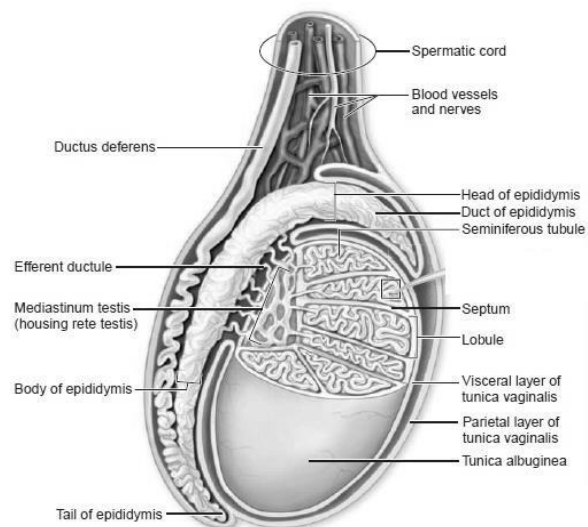
- 2 cm.
- Passes in perineum (superficial part of pelvis).
- It is surrounded by external urethral sphincter (formed of voluntary muscles and innervated by somatic nerves).

Penile

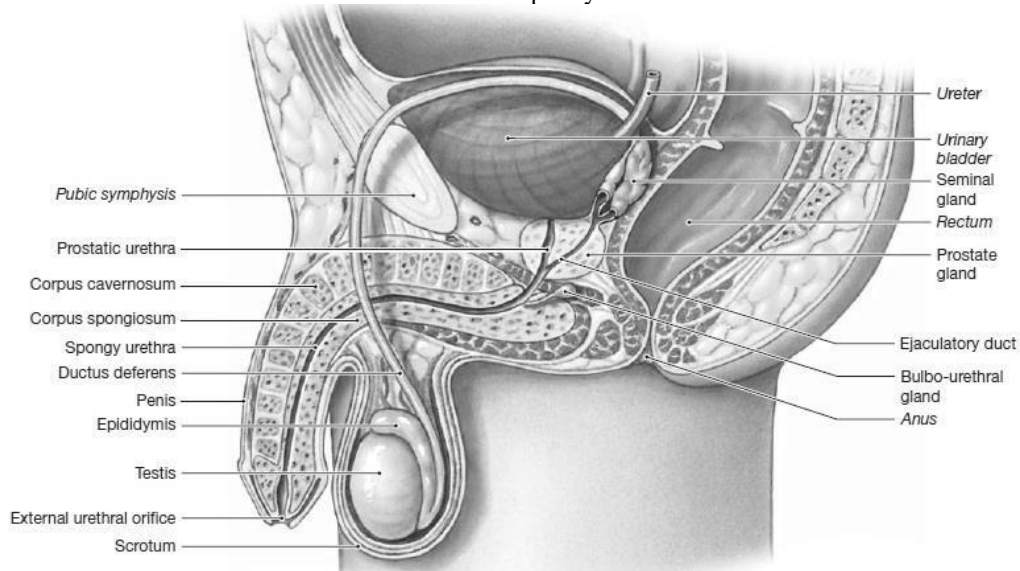
- 10-15 cm.
- Passes in the corpus spongiosum of the penis.

Female urethra

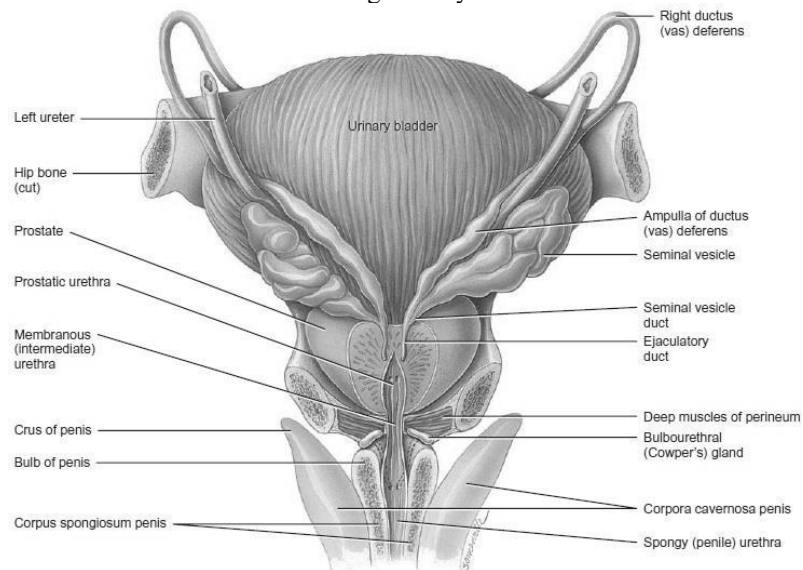
- ❖ 4 cm.
- ❖ It is wider than male urethra.
- ❖ Passes from the neck of urinary bladder to the vulva.



Testis and epididymis



Male genital system



Vas deference, seminal vesicles, ejaculatory ducts and prostate (post view)

McKinley & O'Loughlin / Martini / Tortora & Nielsen

MALE GENITAL SYSTEM**SCROTUM**

- ❖ It is a skin pocket containing the testis.
- ❖ It is considered as an extension of anterior abdominal wall.
- ❖ It is suspended from the trunk to regulate the temperature of testis, so it does not contain any fat.

TESTIS

- ❖ It is 4X2X1 cm.
- ❖ It lies in the scrotum.
- ❖ It is divided into about 200 compartments.
- ❖ Each compartment contains about 2 seminiferous tubules.
- ❖ Each seminiferous tubule is about 2 feet (60 cm) long.
- ❖ The seminiferous tubules are concerned with sperm formation.
- ❖ The sperm formation lasts about 2 months.

EPIDIDYMIS

- ❖ It is 6 meter single coiled duct.
- ❖ It lies in the scrotum.
- ❖ The sperms pass through epididymis in about 2 weeks, where it starts to have its own movements.
- ❖ The epididymis takes a comma shape, where it has a head, body and tail.

VAS DEFERENCE

- ❖ It is 45 cm long duct.
- ❖ It has a thick muscular wall which can be felt by examination.
- ❖ It starts as a continuation of tail of epididymis.
- ❖ Part of it is found in scrotum, it then passes in spermatic cord, inguinal canal and pelvis, where it ends by forming ampulla (dilatation) of the vas for sperms storage.
- ❖ The ampulla unites with seminal vesicle forming ejaculatory duct.

SPERMATIC CORD

- ❖ It is a sheath formed of extensions of anterior abdominal wall.
- ❖ It contains the vas deference, arteries, veins, lymphatics and nerves of the testis.

SEMINAL VESICLES

- ❖ It is a male sexual gland.
- ❖ It is responsible for about 70% of semen volume.
- ❖ The seminal vesicles secrete fructose which is the nutrient for the sperms.

EJACULATORY DUCT

- ❖ It is formed by union of ampulla of vas and seminal vesicle.
- ❖ It opens in prostatic urethra.

PROSTATE

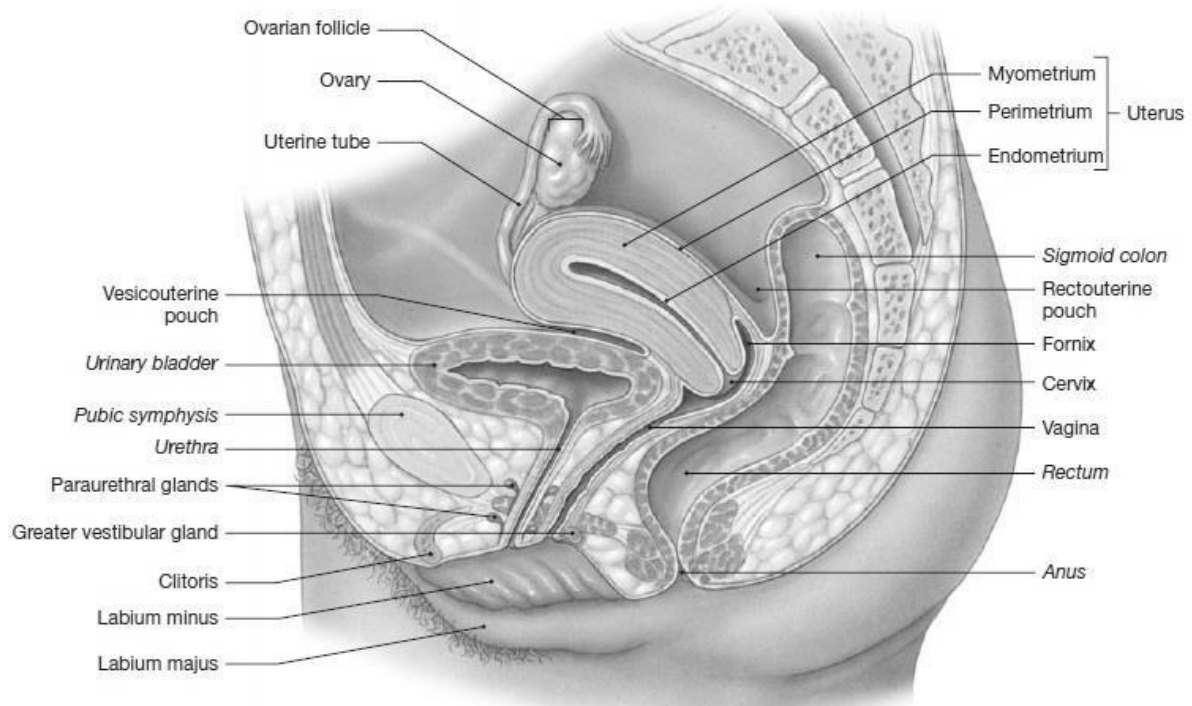
- ❖ It is a male sexual gland.
- ❖ It surrounds the upper part of the urethra below the urinary bladder.
- ❖ It secretes its product directly in the prostatic urethra.
- ❖ Usually, it enlarges in old males leading to senile enlargement of prostate.

BULBOURETHRAL GLANDS

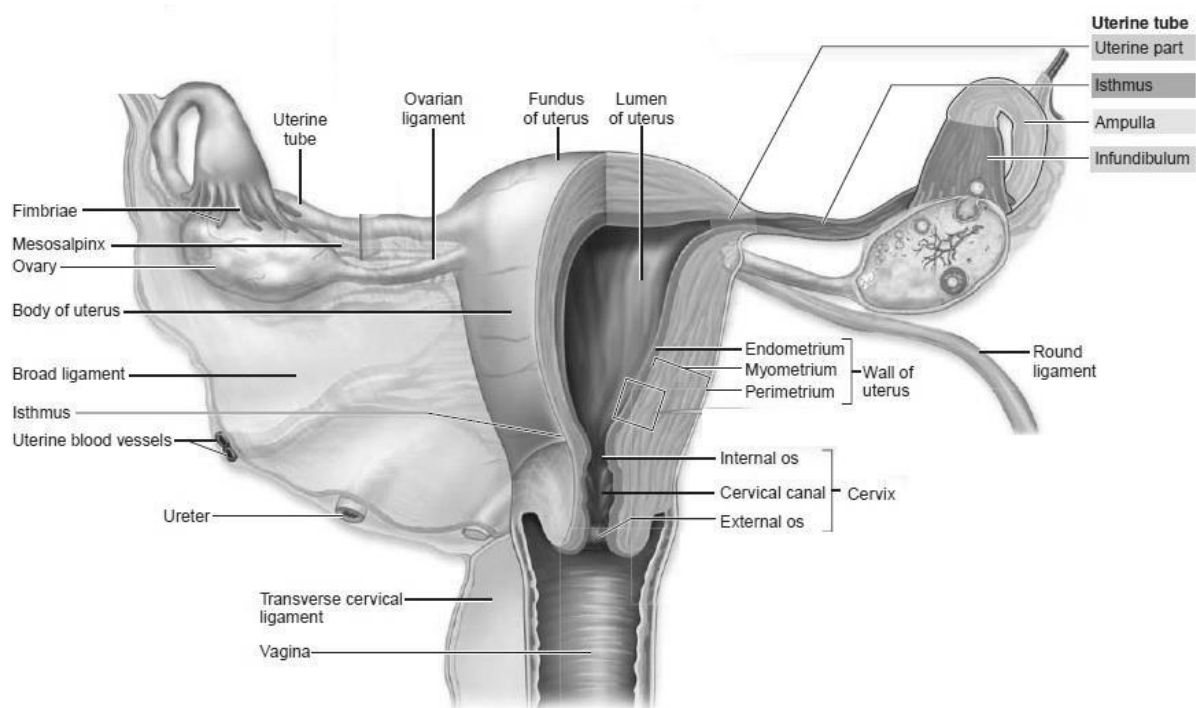
- ❖ It is found at the sides of urethra inferior to prostate.
- ❖ It secretes mucoid secretion in the urethra.

PENIS

- ❖ It is the male organ of copulation.
- ❖ It is formed of 3 cylindrical bodies; 2 corpora cavernosa formed of erectile tissue and a corpus spongiosum formed of spongy tissue & contains urethra.



Female genital system (lat view)



Female genital system (ant view)

FEMALE GENITAL SYSTEM

OVARY

- ❖ It is 3X2X1 cm.
- ❖ It lies in the pelvis.
- ❖ It is concerned with ova formation.

UTERINE (FALLOPIAN) TUBES

- ❖ It is about 10 cm.
- ❖ It receives the ovum from the ovary, the ovum remains for 1 day for fertilization.
- ❖ If fertilization occurs, the cilia in the fallopian tube move the fertilized ovum to the uterus.

Parts:

Infundibulum: guiding the ova and showing fimbriae (finger like processes).

Ampulla: dilated part. It is the site of fertilization.

Isthmus: narrow part.

Intrauterine part: narrowest part.

UTERUS

- ❖ It is a hollow muscular organ 3X2X1 inches.

Parts:

Fundus: above the level of fallopian tubes.

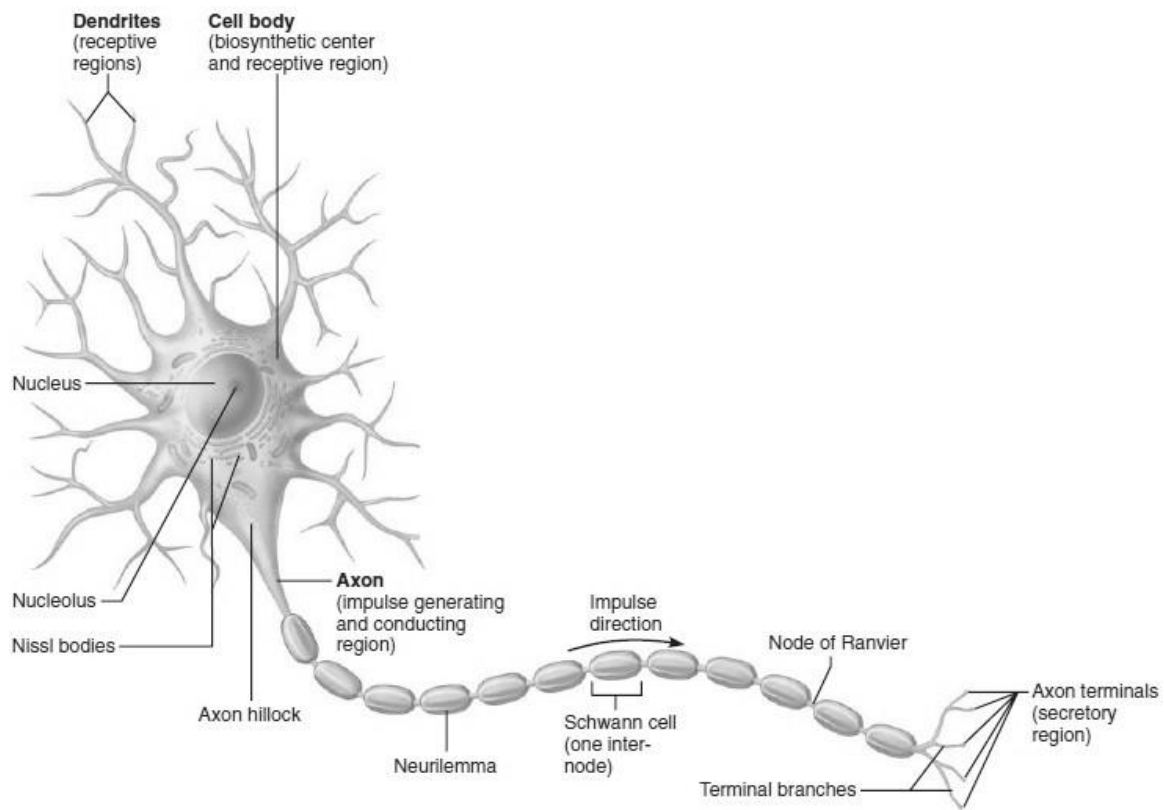
Body: main part.

Cervix: connecting the body with the vagina.

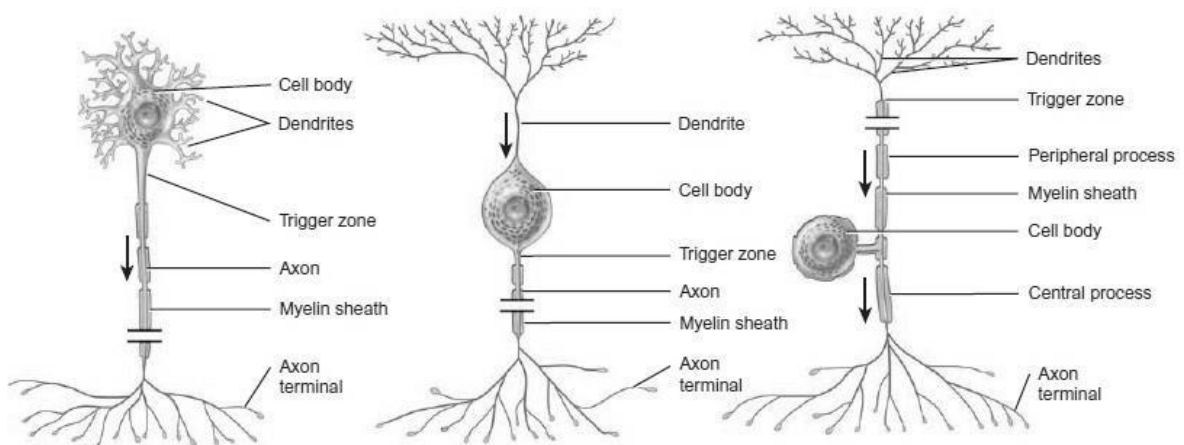
- ❖ It is lined with endometrium which is the site of implantation.
- ❖ It is mainly supported by a transverse cervical ligament.

VAGINA

- ❖ It is the female organ of copulation.
- ❖ It is a sheath which transmit the sperms to the uterus and deliver the baby.
- ❖ It lies post to urethra and urinary bladder and ant to anal canal and rectum.



Neuron



Different types of neurons

NERVOUS SYSTEM

Neuron: the single unit of the nervous system is the nerve cell (neuron). It consists of:

1) **The cell body:**

- Collection of nerve cell bodies may be :
 - a) **Ganglion:** outside the CNS.
 - b) **Nucleus:** inside the CNS.

2) **The nerve fibers:**

- It may be:
 - a) **Dendrites:** usually short, numerous & carry nerve impulses towards the cell body.
 - b) **Axon:** usually single, long & carries nerve impulses away from the cell body.
- The collection of nerve fibers may be:
 - a) **Nerve trunk:** collection of nerve fibers outside the CNS.
 - b) **Tract:** collection of nerve fibers inside the CNS. Further divided into:
 - 1) **Associated:** connecting different areas at the same half of CNS.
 - 2) **Commisural:** connecting similar areas in the 2 halves.
 - 3) **Projecting:** connecting different parts of CNS (e.g. between spinal cord & cerebrum).

Synapse: a meeting between 2 neurons.

Parts of nervous system: the nervous system is divided into:

A) **Central nervous system (CNS):** protected by bones & covered with meninges containing cerebrospinal fluid (CSF). Further divided into:

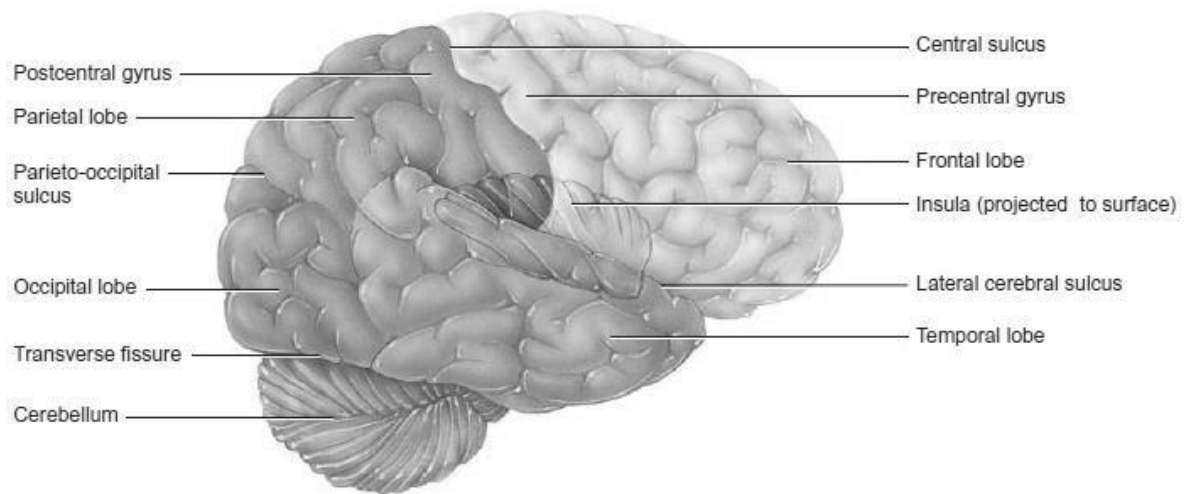
1) **Brain:**

- a) **Cerebrum.**
- b) **Cerebellum.**
- c) **Brain stem,** further divided into:
 - 1) **Midbrain.**
 - 2) **Pons.**
 - 3) **Medulla.**

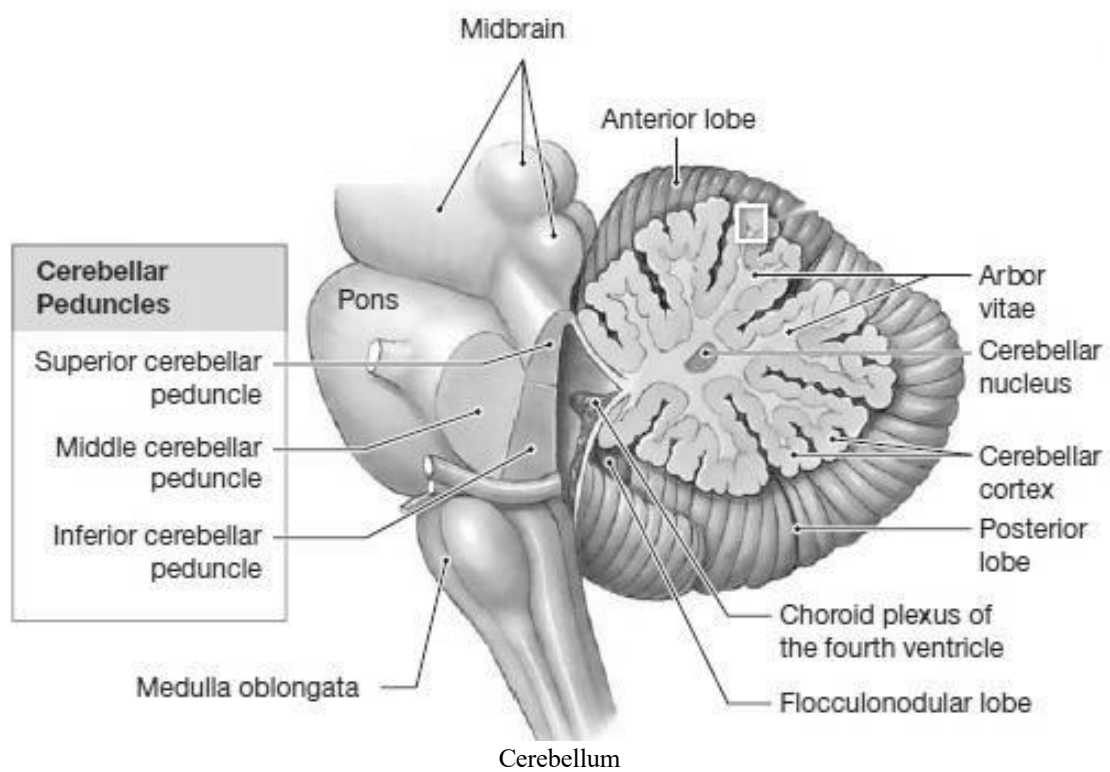
2) **Spinal cord.**

B) **Peripheral nervous system:**

- 1) **Cranial nerves.**
- 2) **Spinal nerves.**
- 3) **Autonomic nervous system.**



Lobes of cerebrum



CENTRAL NERVOUS SYSTEM

Cerebrum:

- Formed of 2 cerebral hemisphere.
- It is formed of gray matter (nerve cell bodies), which is found at the surface (cerebral cortex) and as deeper collections (nuclei) and white matter (nerve fibers).
- Shows cavities called ventricles which contain CSF.
- Shows the attachment of 2 pairs of cranial nerves (I & II).

Lobes: it shows 4 lobes:

Frontal: concerned with motor functions, speech & higher mental functions (personality, behavior, will...etc).

Parietal: concerned with general sensory functions & taste.

Temporal: concerned with hearing & olfaction.

Occipital: concerned with vision.

Cerebellum:

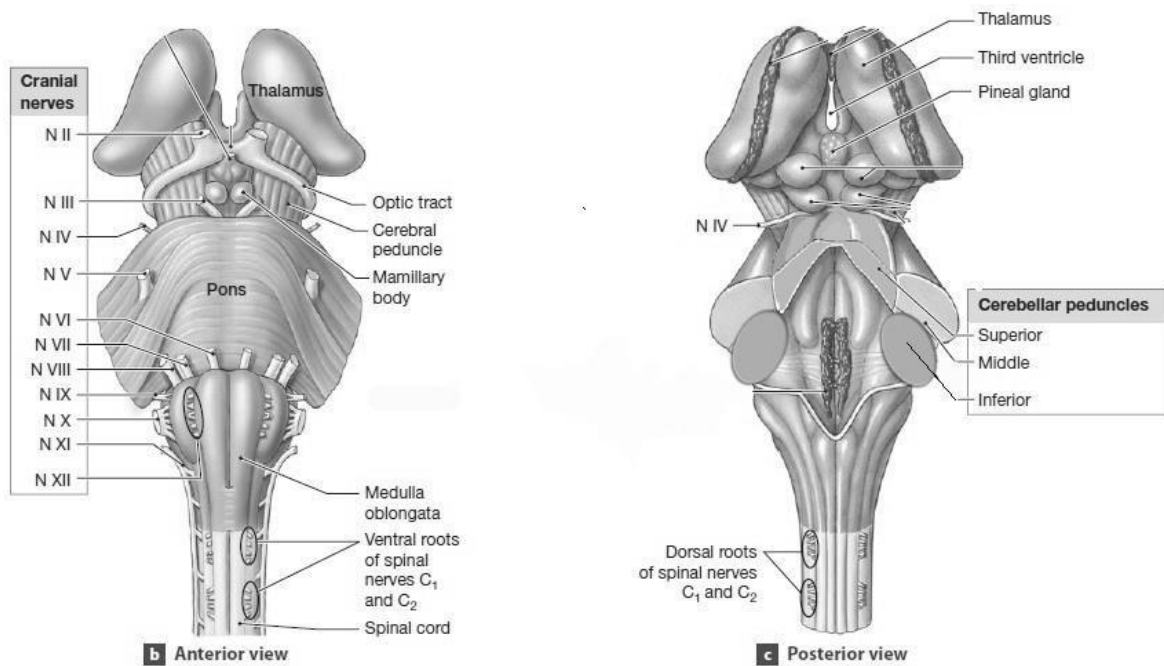
- Butterfly shaped, formed of 2 cerebellar hemispheres connected with a vermis.
- It is formed of gray matter at the surface (cerebellar cortex) and deep nuclei and white matter (nerve fibers).
- Shows no attachment of cranial nerves.
- It is connected to the brain stem by 3 pairs of peduncles; sup (to midbrain), middle (to pons) and inf (to medulla).

Functional lobes:

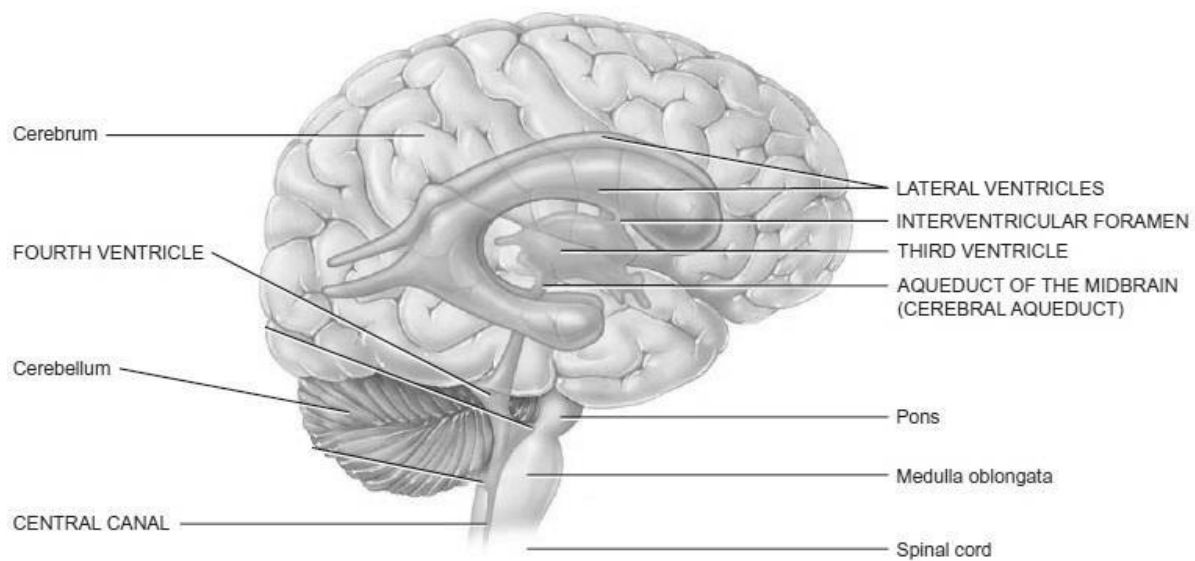
Vestibulocerebellum (archicerebellum): concerned with equilibrium.

Spinocerebellum (paleocerebellum): concerned with regulation of muscle tone.

Cerebrocerebellum (neocerebellum): concerned with planning & control of movements.



Brain stem



Ventricles of brain

Brain stem:

Mid brain:

- Shows narrow cavity called cerebral aqueduct which contain CSF.
- Shows the attachment of 2 pairs of cranial nerves (III & IV).
- Connected to cerebellum by sup cerebellar peduncle.

Pons:

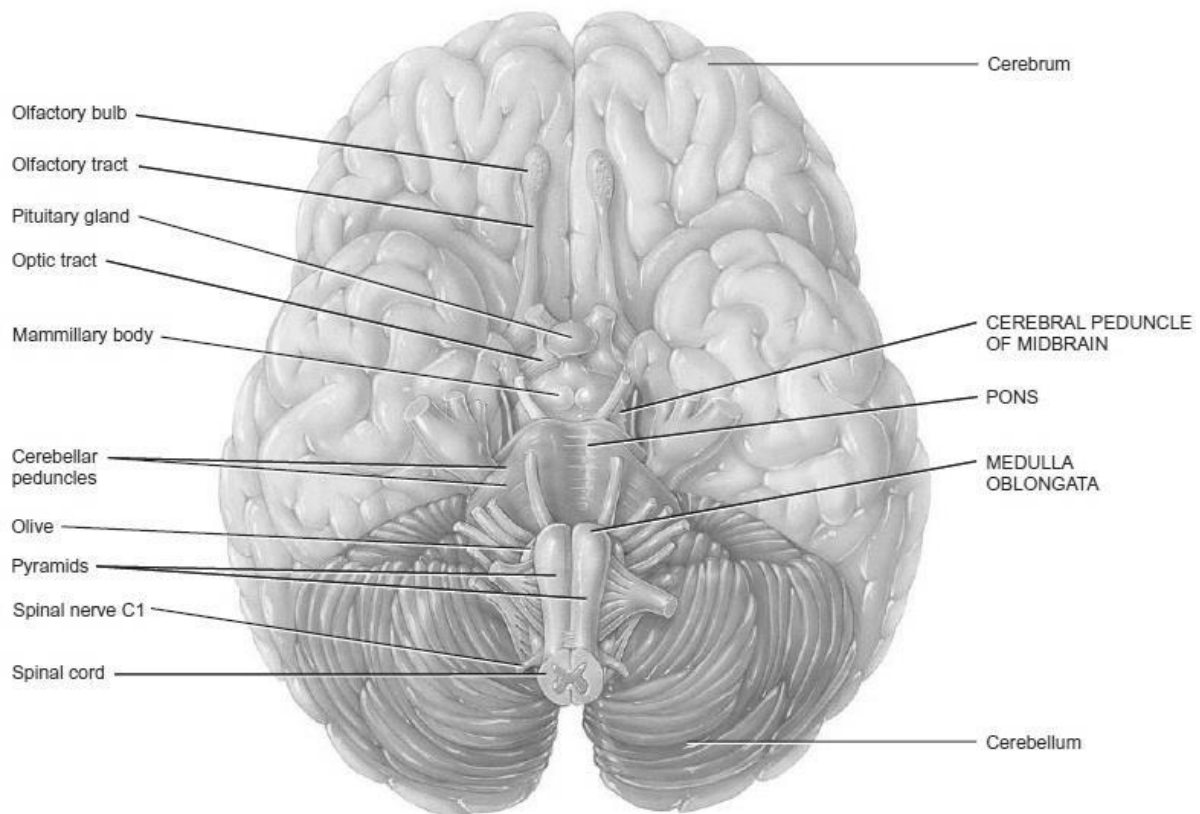
- Bounded posteriorly by a ventricle separating it from cerebellum and containing CSF.
- Shows the attachment of 4 pairs of cranial nerves (V-VIII).
- Connected to cerebellum by middle cerebellar peduncle.

Medulla:

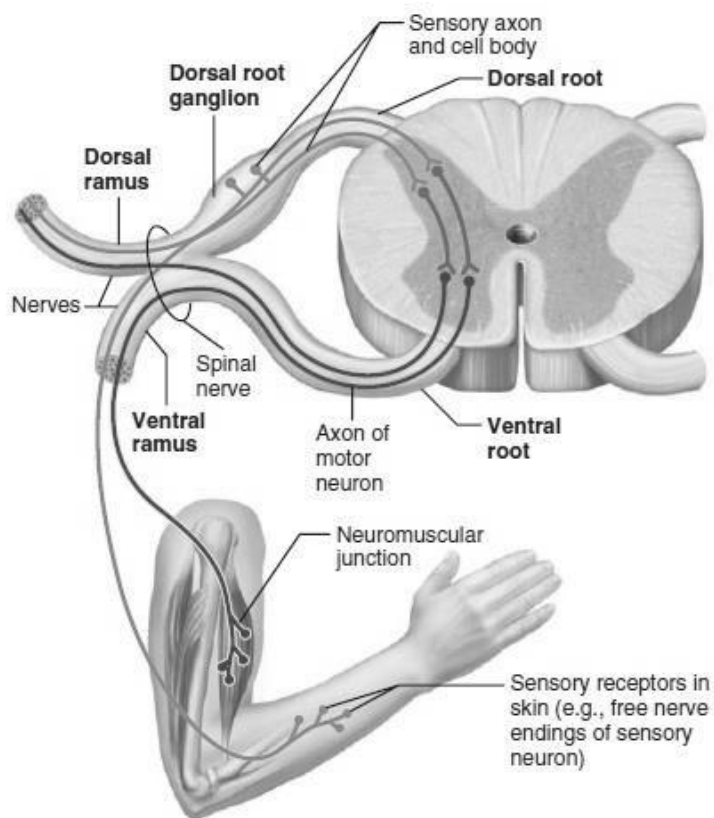
- The upper part is bounded posteriorly by a ventricle separating it from cerebellum. Its lower part shows a narrow canal. Both contain CSF.
- Shows the attachment of 4 pairs of cranial nerves (IX-XII).
- Connected to cerebellum by inf cerebellar peduncle.

Spinal cord:

- Protected by vertebral column, surrounded by meninges & CSF.
- Shows a tubular internal cavity (central canal) which contains CSF.
- Shows 31 segments, each of them gives an attachment for a pairs of spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral & 1 coccygeal).
- Formed of inner H shaped gray matter (nerve cell bodies) and outer white matter (nerve fibers).
- The gray matter shows:
 - 2 post horns: sensory.
 - 2 Lateral horns: autonomic (some segments).
 - 2 Ant horns: motor.



Cranial nerves



Spinal nerve

PERIPHERAL NERVOUS SYSTEM**Cranial nerves**

<i>Nerve</i>		<i>Function</i>
I	Olfactory	Smell
II	Optic	Vision
III	Oculomotor	• Motor to the muscles of the eye • Parasympathetic to the eye
IV	Trochlear	Motor to 1 eye muscle
V	Trigeminal	• Motor to the muscle of mastication • Sensory to the face
VI	Abducent	Motor to 1 eye muscle
VII	Facial	• Motor to the muscles of the face • Taste to ant 2/3 of tongue • Parasympathetic to submandibular & sublingual salivary glands & lacrimal gland
VIII	Vestibulocochlear	Hearing & equilibrium
IX	Glossopharyngeal	• Motor to 1 muscle of pharynx • Sensory to pharynx • Sensory & taste to post 1/3 of tongue • Parasympathetic to parotid gland
X	Vagus	• Motor to 1 muscle of larynx • Sensory & taste to root of tongue • Parasympathetic to thoracic & abdominal viscera
XI	Cranial accessory	Motor to most of the muscles of palate, pharynx & larynx
XII	Hypoglossal	Motor to most of muscles of tongue

Spinal nerves

- 31 pairs (8 C, 12 T, 5 L, 5 S & 1 Cc).
- It has 2 roots: Post (dorsal) root (sensory) & ant (ventral) root (motor).
- The 2 roots unite to form the spinal nerve (mixed).
- The spinal nerve divides into 2 rami:

Ant (ventral) ramus:

- Mixed.
- Form plexuses (except in thoracic region).
- Supplies muscles & skin of anterolateral sides of trunk & limbs.

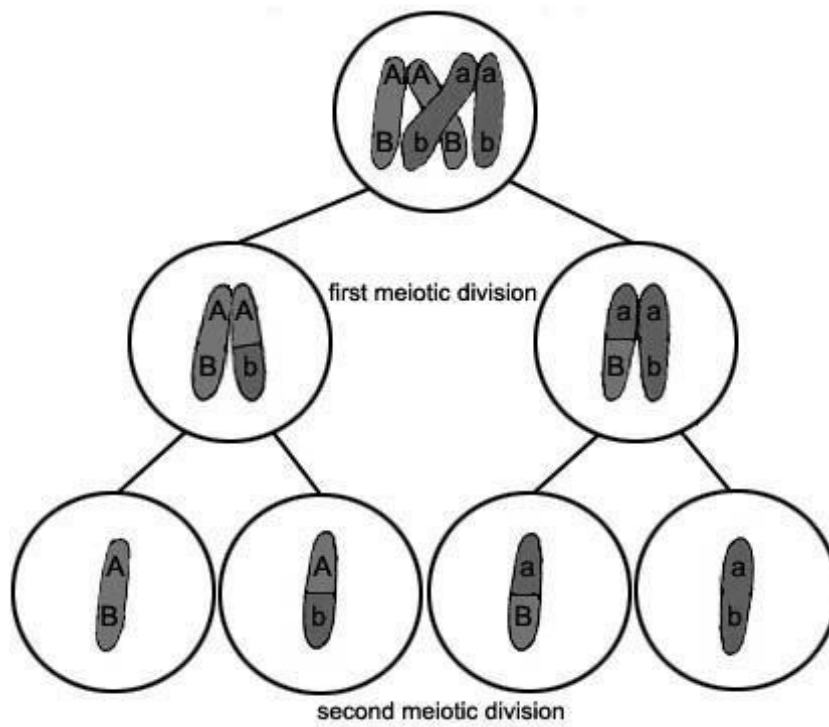
Post (dorsal) ramus:

- Mixed.
- Does not form plexuses.
- supplies muscles & skin of the back (post to vertebral column).

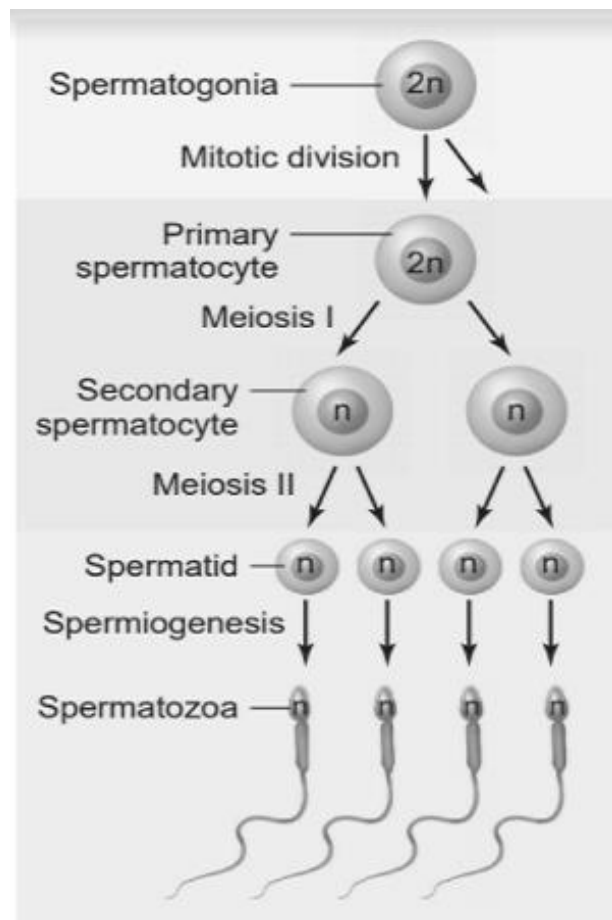
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GENERAL EMBRYOLOGY





Meiotic divisions and crossing over



Spermatogenesis

GAMETOGENESIS

Definitions

Primary sexual organ: it is the organ containing the cells capable of forming a gamete (half of the future human being). They are the testis in males and the ovaries in females.

Primary sex cells: The cells which are capable of forming a gamete. They are the spermatogonium in males and oogonium in females.

Gametogenesis: it is formation of a gamete (sperms in males and ova in females).

Mitotic division: is the division of a cell leading to two daughter cells similar to each other and to the mother cell.

Meiotic division: is the division of a cell leading to two daughter cells not similar to each other or the mother cell. It shows a decrease in the number or the amount of chromosomes and DNA. In gametogenesis there are two meiotic divisions:

First meiotic division:

- The 46 chromosomes in the nucleus of a cell arrange into two columns (each contains 23 chromosomes).
- Each chromosome incompletely splits into two chromatids.
- **Crossing over:** each chromosome exchanges a segment with its neighboring chromosome (this leads to uncounted number of chromosomal variations).
- The cell divides into 2 cells (each containing 23 chromosomes).

Second Meiotic division:

- Each of the 23 chromosomes splits completely into two chromatids.
- Each chromatid develops into complete chromosome (note that the two chromatids are not identical, So, the newly formed chromosomes are not similar).
- The cell divides into 2 cells (each containing 23 chromosomes).

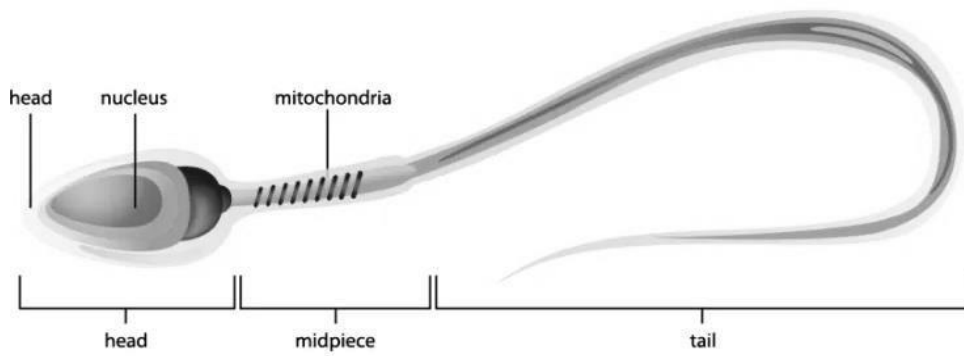
SPERMATOGENESIS

Definition: formation of a sperm from spermatogonium.

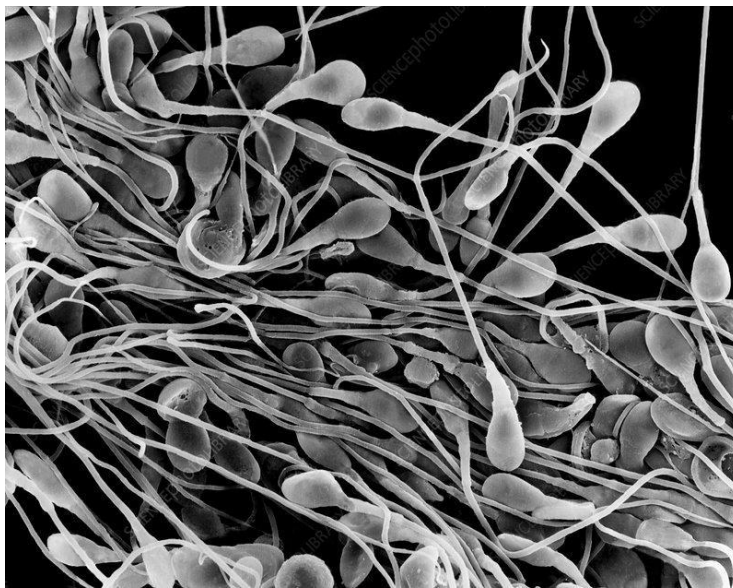
Site: in seminiferous tubules of the testis.

Process:

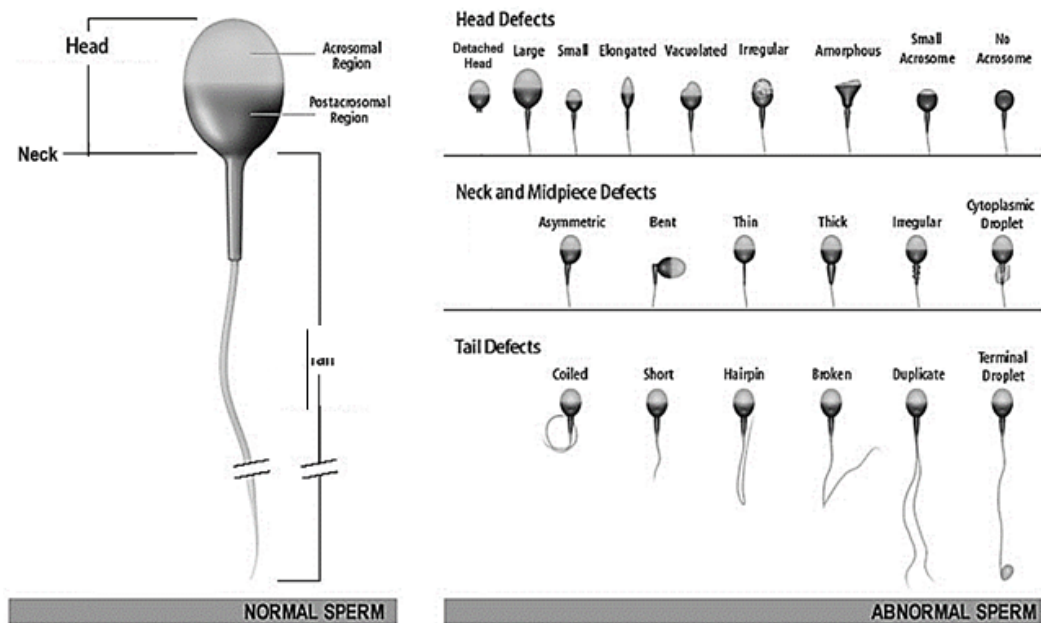
- **Spermatogonia** lies on the basement membrane of the seminiferous tubules. It contains **46 chromosomes (44+X+Y)**.
- Each **spermatogonium** divides by **mitosis** forming 2 daughter spermatogonia (each contains **46 chromosomes (44+X+Y)**).
- One of the daughter spermatogonia (**spermatogonia A**) remains in contact with basement membrane while the other (**spermatogonia B**) starts to mature.
- **Spermatogonia B** enlarges in size and transforms into **primary spermatocyte (44+X+Y chromosomes)**. Primary spermatocyte is the largest germ cell.
- **Primary spermatocyte** divides by **1st meiotic division** forming two **secondary spermatocytes (22+X and 22+Y chromosomes)**. This division decreases the number of chromosomes.
- Each **secondary spermatocyte** divides by **2nd meiotic division** forming two **spermatids (22+X or 22+Y)**. This division decreases the amount of DNA in each chromosome.



Sperm



Scanning EM of sperms



Abnormal forms of sperms

- **Spermiogenesis:** is the transformation of spermatid into sperm:
- The nucleus of the spermatid becomes the head of the sperm.
 - The Golgi apparatus of the spermatid becomes the head (acrosome) cap of the sperm (containing enzymes to facilitate the penetration of ova).
 - One of the centrioles of the spermatid elongates forming the axial filament of the sperm (middle piece and tail).
 - The mitochondria of the spermatid surrounds the upper part of the axial filament forming the middle piece.
 - The rest of the axial filament forms the tail of the sperm.
 - The neck is a narrow junction between the head and the middle piece.
 - The sperm is about 55 μm (0.055 mm) long where the head is 5 μm and the tail is 50 μm (1/10).

Characteristics of spermatogenesis:

- The process from the mitotic division of spermatogonia to the formation of the sperm lasts for about 2 months.
- The spermatogenesis results in formation of 4 sperms from each spermatogonium with a preservation of a copy for further spermatogenesis (that's why spermatogenesis does not stop by age).
- The sperms passing from testis are immotile, they acquire motility during passage in epididymis (2 weeks).
- Each testis is divided into 200 compartments, each contains 2 seminiferous tubules, each of them is 2 feet long. A large number of sperms are continuously formed.

SEMINAL FLUID (SEMEN)

- ❖ It consists of sperms (formed in testis and transported through epididymis, vas deference and ejaculatory duct) and secretions from male genital glands (mainly seminal vesicles and prostate).

Normal parameters of semen:

Amount: 2-6 ml/ ejaculate. Lower volume is called hypospermia (hypo = below), the absence of semen with ejaculation is known as aspermia (a = no).

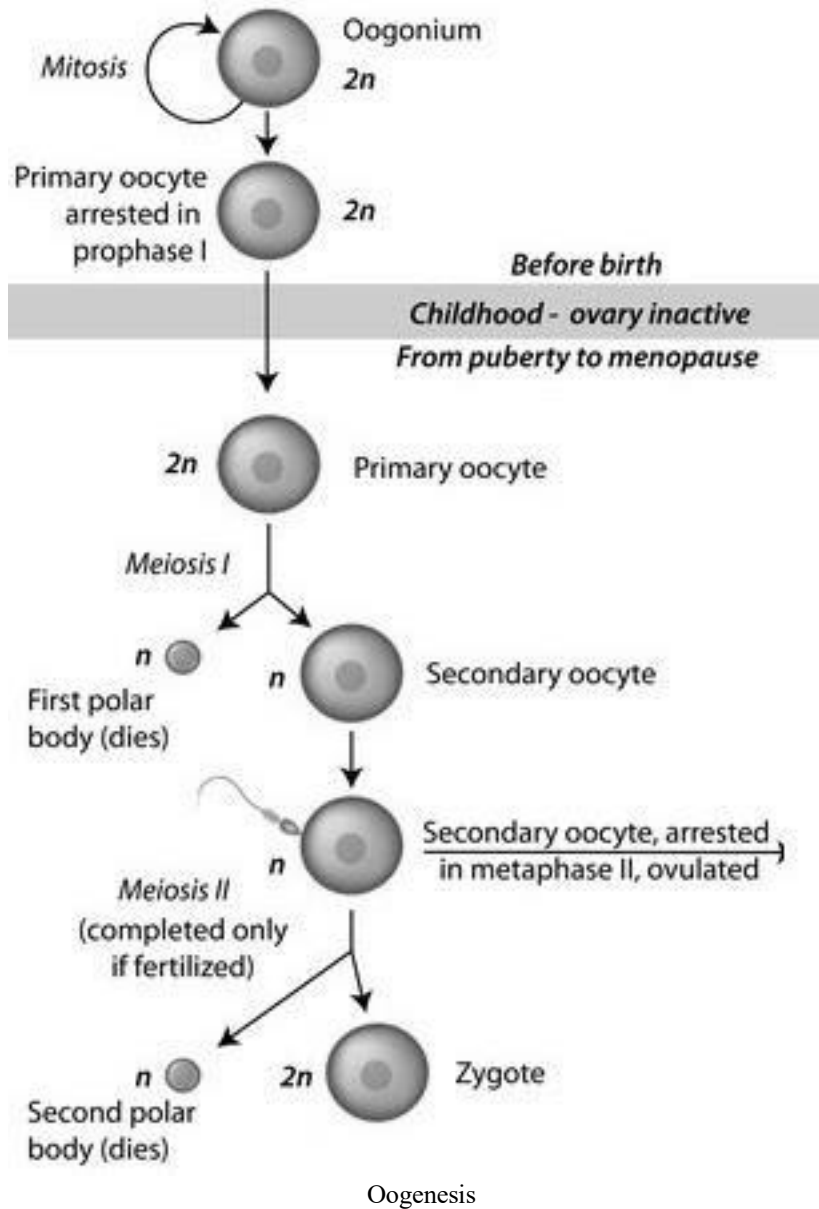
Sperms count: 20-200 million sperm/ ml (40-1200 million sperms/ ejaculate). Lower values are called oligozoospermia (oligo = few).

Vital sperms: $\geq 60\%$. Lower values are called necrozoospermia (necro = dead).

Normal sperm forms: ($\geq 4\%$), Some abnormal forms are capable of fertilization. Lower values are called teratozoospermia (terato = malformed).

Sperm motility: $\geq 40\%$ and $\geq 30\%$ with aggressive motility. Lower values are called asthenozoospermia (asthen = weak).

- ❖ Out of the ejaculated sperms, only 500 sperms reach the ampulla of Fallopian tubes (site of fertilization). This process lasts 2 hours after ejaculation.
- ❖ Sperms survives for 2 days in female genital tract.



OOGENESIS

Definition: formation of a ova from oogonium.

Site: in the cortex of ovaries.

Process:

- **Oogonia** contains **46 chromosomes (44 + X + X)**.
- Oogonium enlarges in size and transform into **primary oocyte (44+X+X chromosomes)**.
- **Primary oocyte** divides by **1st meiotic** division forming two cells; one **secondary oocytes (22+X)** and the other degenerates forming **1st polar body (22+X)**.
- **Secondary oocyte** divides by **2nd meiotic division** forming two cells; **mature ova (22+X)** and the other degenerate forming **2nd polar body (22+X)**.

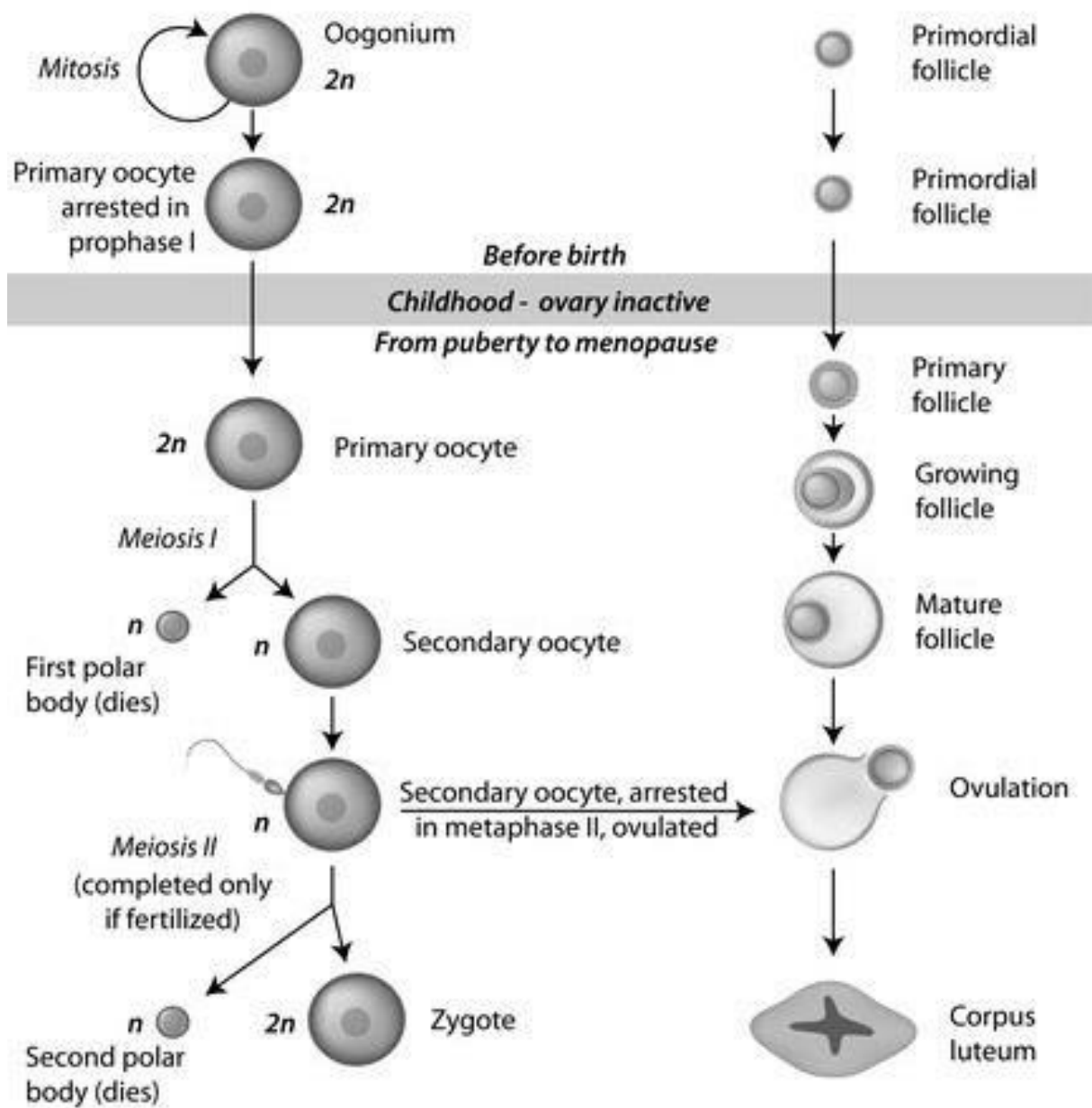
Characteristics of Oogenesis:

Oogenesis timing:

- During female *intrauterine life*, all *oogonia* are transformed to *primary oocytes*, which starts *1st meiotic division* but does not complete it.
- With *each ovarian cycle*, primary oocyte *completes the first meiotic division* forming *secondary oocyte* and *1st polar body*, the secondary oocyte *starts the 2nd meiotic division* but does not complete it, this is the cell which is ovulated.
- If *fertilization* occurs, secondary oocyte *completes the 2nd meiotic division* forming *mature ova* and *2nd polar body*.

Oogenesis population

- During *intrauterine life*, the *oogonia* undergoes several mitotic divisions reaching **5 million**, most of them degenerate and only **1 million** are transformed into primary oocytes (*at birth*), only **40.000 primary oocytes** survive to the age of *puberty*.
- Starting from puberty, *each ovarian cycle* **20-100 primary oocytes** start the process of ova formation, only **one** of them succeeds. The large consumed number are necessary for hormonal production to complete the process.
- The oogenesis results in formation of 1 ovum from 20-100 oocyte (that's why oogenesis stops by age leading to *menopause*).
- Only one ovum is produced each month. It lasts for **12-24 hours** only.



Follicle development

Pinterest

OVARIAN FOLLICLES AND OVULATION

Primary follicle: during intrauterine development, each primary oocytes is surrounded by a single layer of flat follicular cells.

Secondary follicle: at puberty, and parallel to the development of primary oocyte into secondary oocyte, the follicular cells become **granulosa cells** (multilayers of cubical cells containing granules (hence the name).

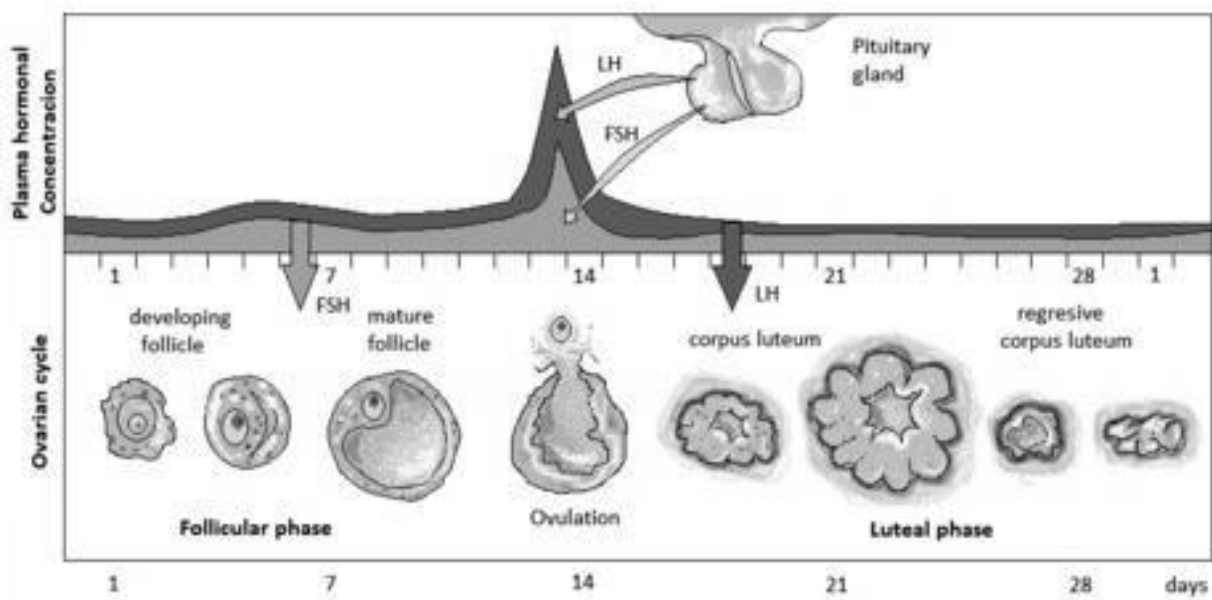
Tertiary follicle: cavities start to appear between granulosa cells.

Mature Graafian follicle:

- The cavities enlarge and unite forming an **antrum** (= chamber).
- The outer layer of the follicle is called **stratum granulosum** (= granular layer).
- The secondary oocyte with its surrounding cells is called **cumulus oophorous** (= ovarian elevation) and is formed of:
 - **Secondary oocyte.**
 - **Zona pellucida** (= transparent zone): a membrane surrounding the secondary oocyte.
 - **Corona radiata** (= radiating crown): the granulosa cells around the zona pellucida.
- The ovarian tissue due to the compression of enlarging follicle becomes compact and form a capsule called **theca folliculi** which is further divided into:
 - **Theca interna:** formed of connective tissue cells which secrete estrogen.
 - **Theca externa:** formed of fibrous tissue.

Ovulation: due to the enlargement of the follicle and pressure on the ovarian cortex, the overlying cortex becomes ischemic and rupture leading to:

- The secondary oocyte with the surrounding zona pellucida and corona radiata leaves the ovary and enters the Fallopian tube.
- The rest of the granulosa cells and surrounding theca interna cells start to accumulate yellow pigments forming **corpus luteum** (= yellow body) and secrete progesterone and small amount of estrogen.
 - If fertilization occurs, the dividing cells secrete HCG which stimulates the corpus luteum to enlarge and continue secreting progesterone during the first half of pregnancy (**corpus luteum of pregnancy**) till it is replaced by placenta.
 - If no fertilization occurs the corpus luteum gradually degenerates within ten days (**corpus luteum of menstruation** → **corpus albicans**).



Ovarian cycle

Pinterest

OVARIAN CYCLE

- ❖ It is cyclic changes which occur in the ovarian follicles under the effects of the pituitary hormones.
- ❖ This cycle occurs monthly from puberty to menopause.

Phases of ovarian cycle:

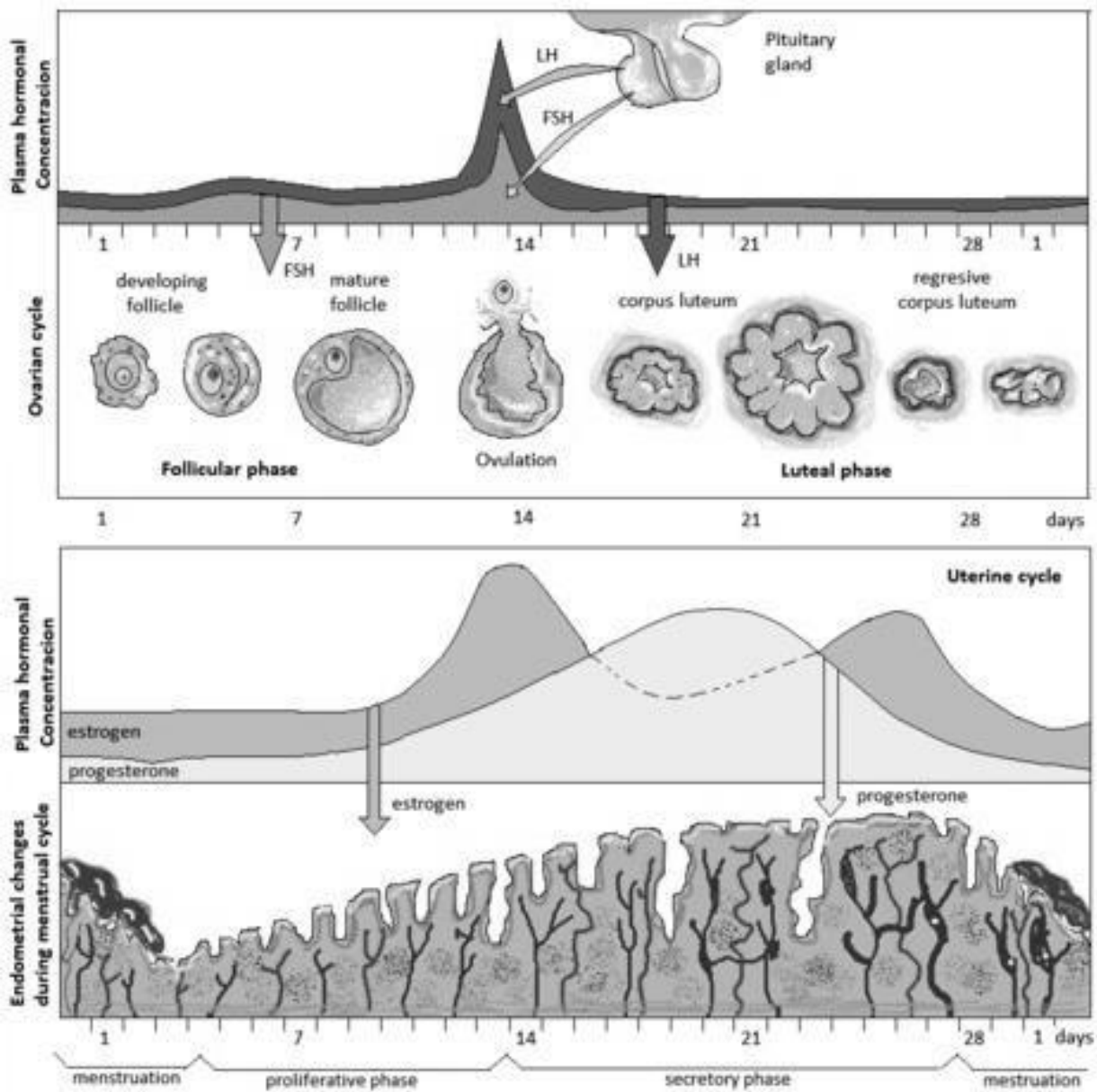
Follicular phase: the pituitary gland starts to secrete **FSH** which leads to:

- **Primary oocyte** completes the **1st meiotic** division forming **secondary oocyte** and 1st polar body.
- Maturation of **primary follicle** to **mature Graafian follicle**. The granulosa cells secrete **estrogen** which at certain level has negative feedback on FSH (decreases its secretion) and stimulates **LH** secretion (also from pituitary gland).
- The high estrogen level of this phase is responsible for the proliferative phase of uterine cycle.

Ovulation: caused by **LH surge** leading to liberation of secondary oocyte with its surroundings from the ovary.

Luteal phase:

- **LH** secreted from pituitary gland causes corpus luteum to secrete **progesterone** and small amount of estrogen (both suppress FSH stopping crossing cycles).
- If fertilization occurs, the corpus luteum enlarges and continues secreting progesterone leading to inhibition of FSH → stopping new cycles.
- If fertilization does not occur, corpus luteum gradually degenerates, and **progesterone level decreases** leading to an increase in **FSH** hormone causing initiation of a **new cycle**.
- The high progesterone level of this phase is responsible for the secretory phase of uterine cycle.



Ovarian and uterine cycles

Pinterest

UTERINE (MENSTRUAL) CYCLE

- ❖ The uterus is a muscular organ lined with endometrium formed of basal, compact and spongy layers.
- ❖ The uterine cycle is a monthly changes which occurs in the uterine endometrium under the effect of the ovarian hormones.
- ❖ This cycle occurs monthly (21-35 days) from puberty to menopause.

Phases of Uterine cycle:

Proliferative (estrogenic – follicular) phase :

- Under the effect of estrogen (secreted by the granulosa cells during the follicular phase of ovarian cycle).
- The estrogen stimulates the basal layer to develop leading to construction of compact and spongy layers (the cells increase in number, the glands and the arteries increase in number and size).
- It lasts for 10 days.

Secretory (progestational – luteal) phase :

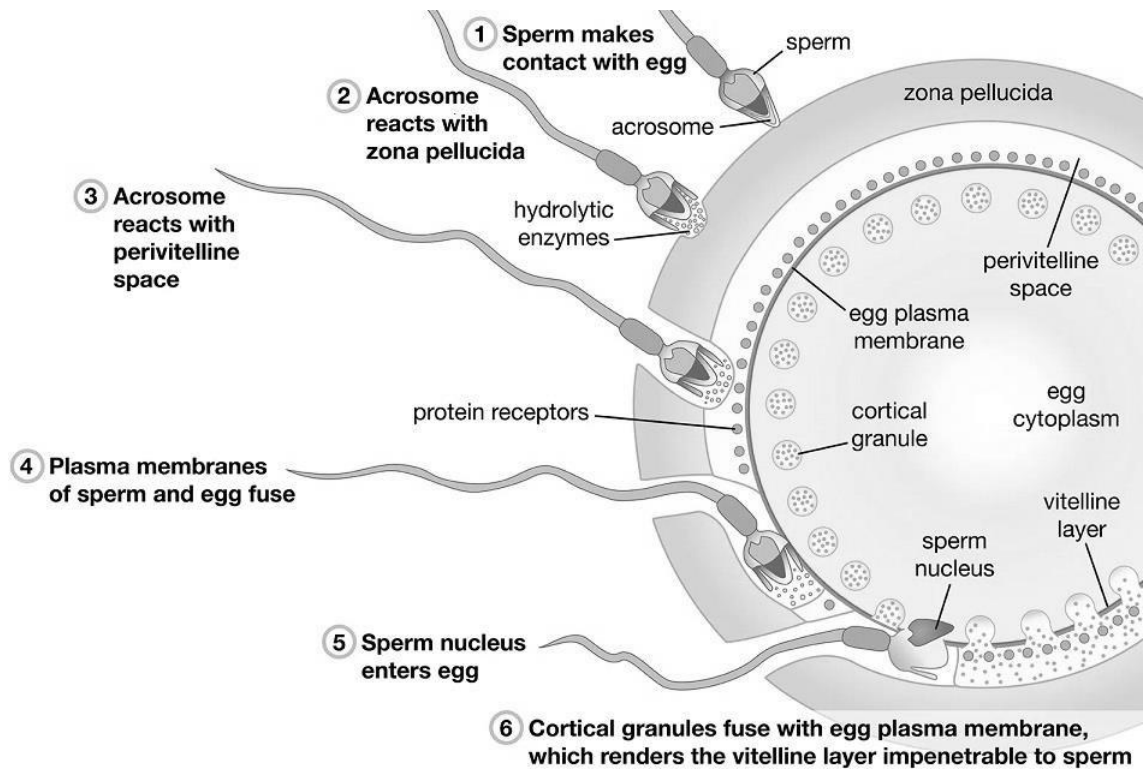
- The endometrium proliferates under the effects of progesterone (mainly) and estrogen secreted by corpus luteum in the luteal phase of the ovarian cycle.
- The cells enlarge and accumulate nutrients, the glands dilate and are filled with glycogen and the arteries dilate and become spiral.
- It lasts for 14 days.
- If fertilization occurs, corpus luteum of pregnancy continues to secrete progesterone keeping the enlarged endometrium with the dividing cells implanted into it (the endometrium will be called decidua).
- If fertilization does not occur, the corpus luteum degenerates with decreased progesterone level leading to vasoconstriction of the uterine arteries causing ischemia followed by shedding and bleeding.

Menstrual phase:

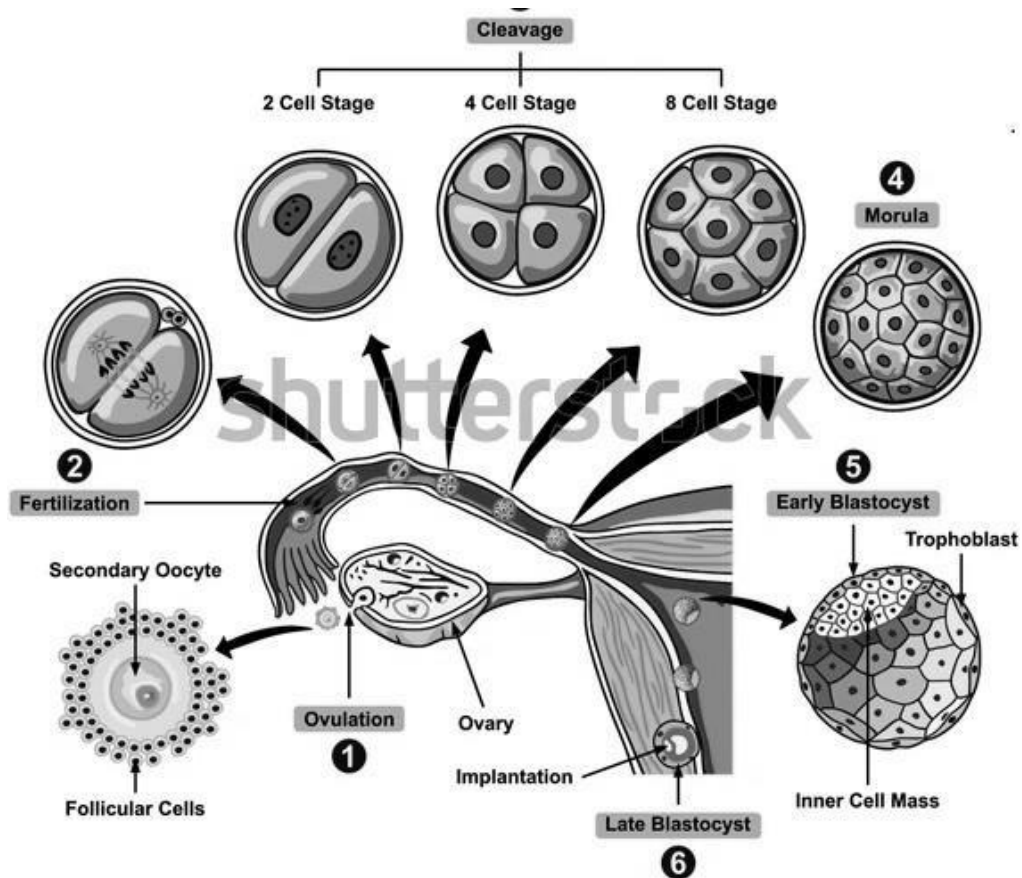
- It occurs due to decreased estrogen and progesterone levels due to degeneration of corpus luteum.
- Shedding of the compact and spongy layers of endometrium occurs leaving only the basal layer.
- It lasts for 3-7 days.

MENOPAUSE

- ❖ It is cessation of ovarian cycle due to exhaustion of primary follicles during previous cycles → little number of follicular cells is present to be stimulated by FSH → decreased estrogen and progesterone levels → cessation of uterine cycle.



Fertilization



Cleavage, morula and blastocyst

FERTILIZATION

Definition: fusion between a single sperm and an ovum to form a fertilized ova (zygote).

Steps:

Capacitation:

- It occurs during the passage of the sperm into the female genital tract due to exposure to its enzymes.
- It is chemical changes affecting the acrosomal cap and increased activity.

Acrosome reaction:

- It occurs in Fallopian tube due to exposure to secondary oocyte.
- It is perforations in the acrosomal cap leading to the release of its enzymes.

Penetration of corona radiata: by many sperms.

Penetration of zona pellucida: it occurs by a single sperm. However, many sperms are needed to pore their enzymes.

Zonal reaction: chemical changes in zona pellucida so that it is not affected by acrosomal enzymes anymore.

Fusion of cell membranes of the sperm and the secondary oocyte.

Completion of 2nd meiotic division and formation of mature ova and 2nd polar body.

Fusion of pronuclei: the head of the sperm (male pronucleus) and the nucleus of the ova (female pronucleus) fuse together, leading to restoration of diploid number of chromosomes (46) and detection of sex (44+XX is a female and 44+XY is a male).

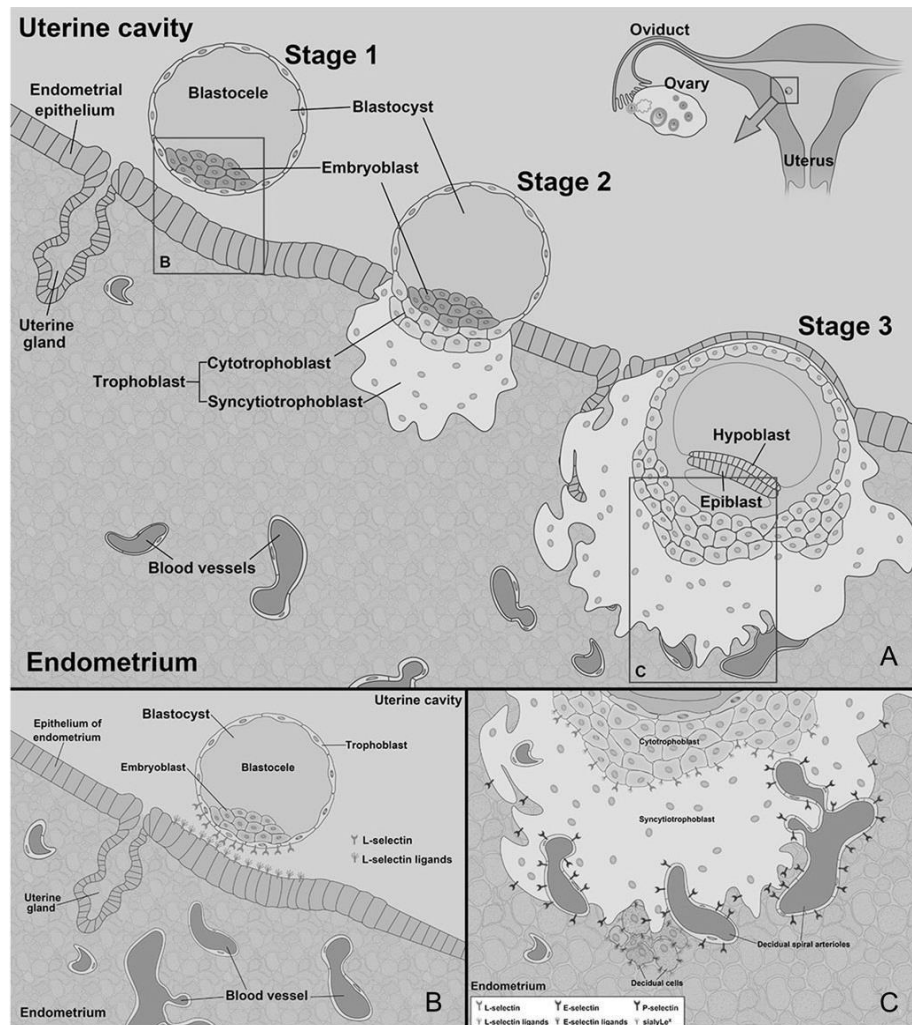
The zygote starts cleavage (division of cells).

Hormonal effect: the dividing cells produce HCG which stimulates corpus luteum growth (corpus luteum of pregnancy) → high progesterone and estrogen levels → maintenance of secretory phase of uterine cycle and inhibition of FSH and LH leading to ovarian cycle pause.

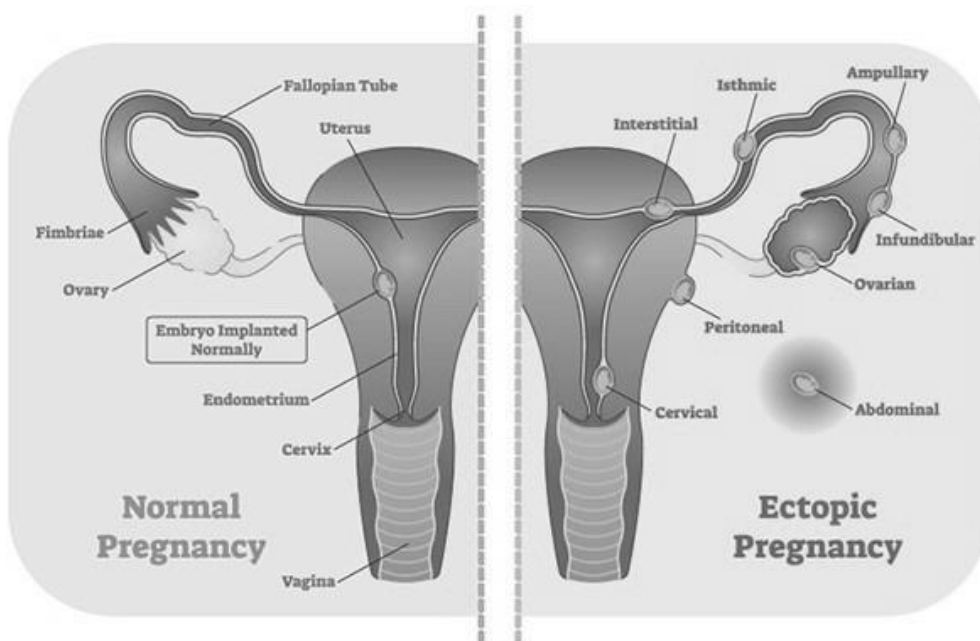
CLEAVAGE, MORULA AND BLASTOCYST

Definition of cleavage (segmentation): is repeated mitotic division of the zygote.

- During cleavage the zygote moves by cilia of Fallopian tube towards the uterus.
- The cells divide into 2-4-8-16-32 cells.
- 16-32 cells mass is called Morula (= mulberry).
- The morula is still surrounded by zona pellucida and reaches the uterus on the 4th day after fertilization.
- During the 5th and 6th days, the uterine enzymes dissolve the zona pellucida and the dividing cells shows a cavity between them. The cell mass is called **blastocyst**, the cavity is called **blastocoele** and the cells are called **blastomeres** (nearly 64 cells) and divides into:
 - **Outer cell mass (trophoblast):** nutrient cells.
 - **Inner cell mass (embryoblasts):** embryo forming cells.
- On the 7th day of fertilization, the blastocyst implants inside the wall of uterus.



Implantation



Normal and abnormal implantation

IMPLANTATION

Definition: it is the invasion of the blastocyst to the endometrium of the uterus.

Duration: between 7th and 14th day after fertilization.

Site: usually in the endometrium of the upper 1/3 of the uterus (post wall).

Mechanism:

- The trophoblast over the embryoblast (embryonic pole) projects forming finger like processes and produces enzyme to invade the endometrium (which is prepared forming nutrient filled cells, glycogen rich glands and spiral arteries).
- The last part of blastocyst sinks into the uterus (ab-embryonic pole), the site of implantation is closed by fibrinous tissue followed by regeneration of the epithelium. Accordingly, the whole trophoblasts are inside the endometrium (and not just attached to it).

Changes of blastocyst during implantation (2nd week after fertilization):

The trophoblasts divide into:

Outer syncytiotrophoblasts: loose its cell walls for easier penetration

Inner cytotrophoblasts.

- Both layers secrete HCG maintaining corpus luteum (of pregnancy).

The embryoblasts arrange into a bilaminar disc with two layers of cells:

Ectoderm: columnar cells.

Endoderm: cubical cells.

The blastocoele is divided by the disc into two cavities:

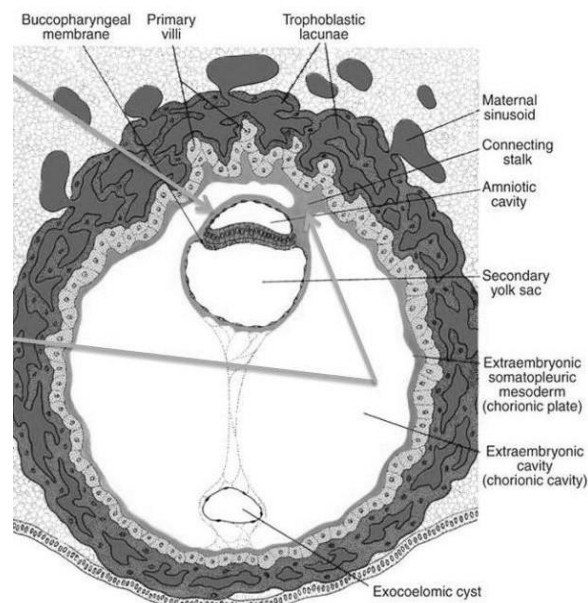
Amniotic cavity: dorsal to ectoderm. Its roof is called amnion (amniotic membrane) and is formed from cells derived from trophoblasts.

Primary yolk sac: ventral to endoderm. Endodermal cells migrate to line it forming (Heuser's membrane).

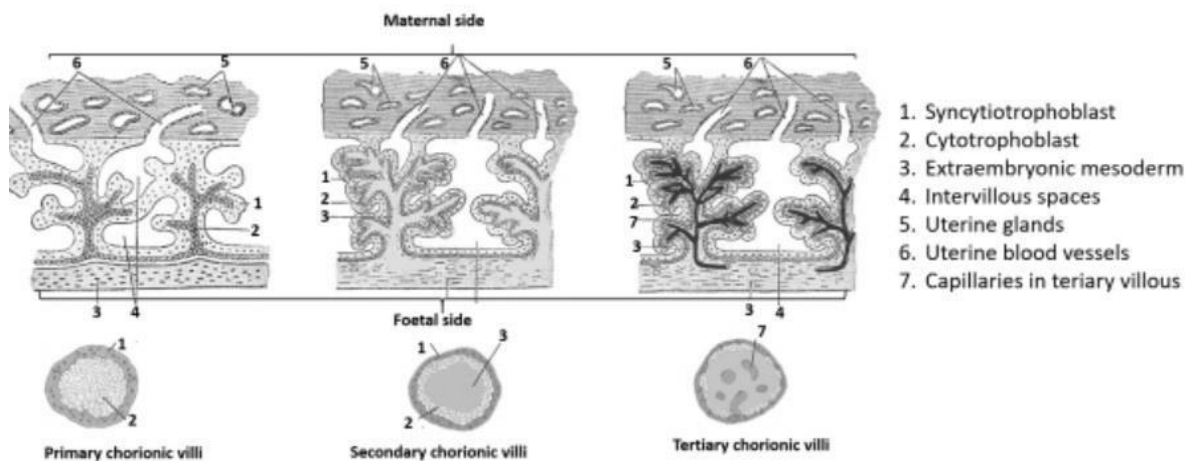
Abnormal sites of implantation:

- 1) **Placenta Previa:** implantation in the lower part of the uterus. The developing placenta will be under the fetus (previa = exceeding).
- 2) **Ectopic pregnancy:**
 - a) **Tubal pregnancy:** in the uterine tube.
 - b) **Ovarian pregnancy:** in the ovary.
 - c) **Abdominal pregnancy:** in the abdominal cavity.

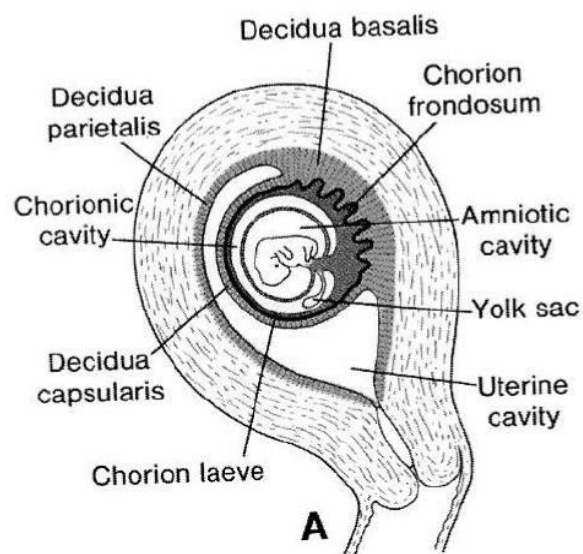
— Ectopic pregnancy does not complete due to lack of adequate uterine nutrition. It invades the organ implanted at and causes its rupture or bleeding.



Chorionic vesicle



Chorionic villi



Parts of chorion and decidua

CHORIONIC VESICLE

Formation:

- Cytotrophoblast cells form a new layer inner to it called **extraembryonic mesoderm (EEM)**.
- spaces appear inside EEM forming **extraembryonic coelom (EEC)** which divides EEM into outer layer lining the cytotrophoblast & inner layer surrounding the amniotic cavity and yolk sac.
- Part of the EEM will still connect the outer and inner layers (**connecting stalk or future umbilical cord**) dorsal to amniotic cavity.
- Now the blastocyst is called **chorionic vesicle**.
- The outer wall of the chorionic vesicle is called **chorion**, and is formed of (syncytiotrophoblast, cytotrophoblast and EEM lining the trophoblast).
- The chorion gives finger like processes called **chorionic villi** which invades the uterine wall. The spaces between the chorionic villi (**intervillous spaces**) are filled with maternal blood.
- The chorionic villi surround the whole chorionic vesicle, then the villi will enlarge deep in uterine wall (chorion frondosum), and atrophies towards the uterine cavity (chorion leave).

Stages of chorionic villi:

- 1) **Primary villi:** formed of syncytiotrophoblast + cytotrophoblast.
- 2) **Secondary villi:** formed of syncytiotrophoblast + cytotrophoblast and extraembryonic mesoderm.
- 3) **Tertiary villi:** formed of syncytiotrophoblast + cytotrophoblast and extraembryonic mesoderm invaded by fetal blood vessels. It is further divided into:
 - a) **Stem (anchoring) villi:** each extends from the base of the chorion (chorionic plate) towards the uterine wall.
 - b) **Branching (free absorbing) villi:** small villi branching from the stem villi and surrounded by maternal blood. They are the sites of exchange of nutrients and gases between the maternal and fetal blood .

Parts of chorion

- 1) **Chorion frondosum:** the part of the chorion invading the uterine wall. It shows numerous branching tertiary villi.
- 2) **Chorion leave:** The part of the chorion facing the uterine cavity. It is less developed.

DECIDUA

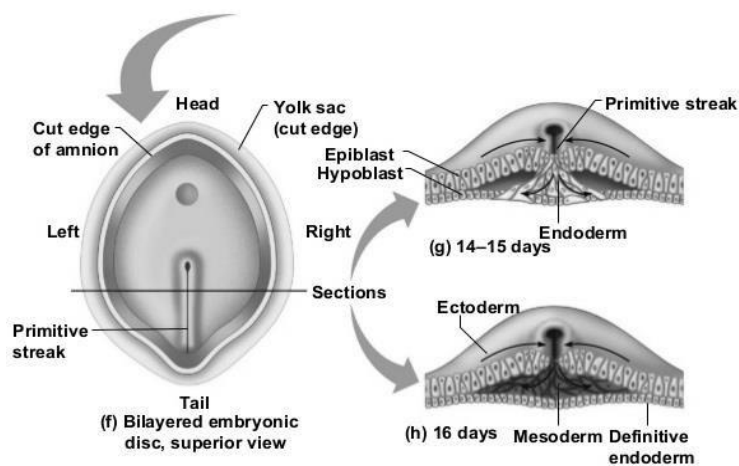
Definition: it is the endometrium after implantation. It maintains its secretory phase under the effect of progesterone (of corpus luteum and placenta). The stromal endometrial cells are called **decidua cells**. The decidua falls as a single mass during labor (decidua = fall).

Features:

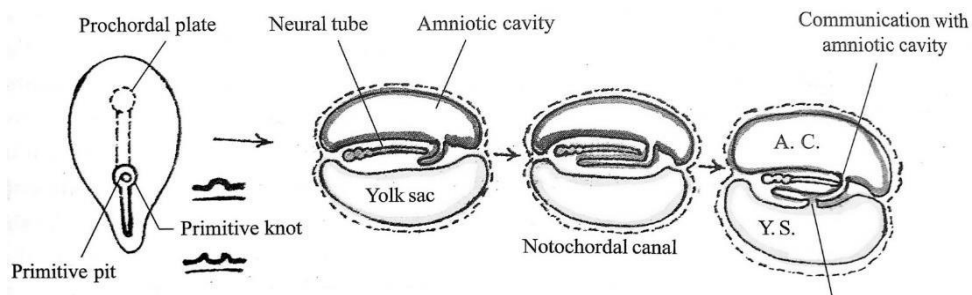
- 1) **The endometrial stromal cells (decidua cells):** enlarge and filled with nutrients.
- 2) **The endometrial glands:** becomes larger, tortuous and filled with glycogen and mucin.
- 3) **The blood vessels:** engorged, spiral. They are invaded by chorionic villi pouring maternal blood between them.

Parts of decidua:

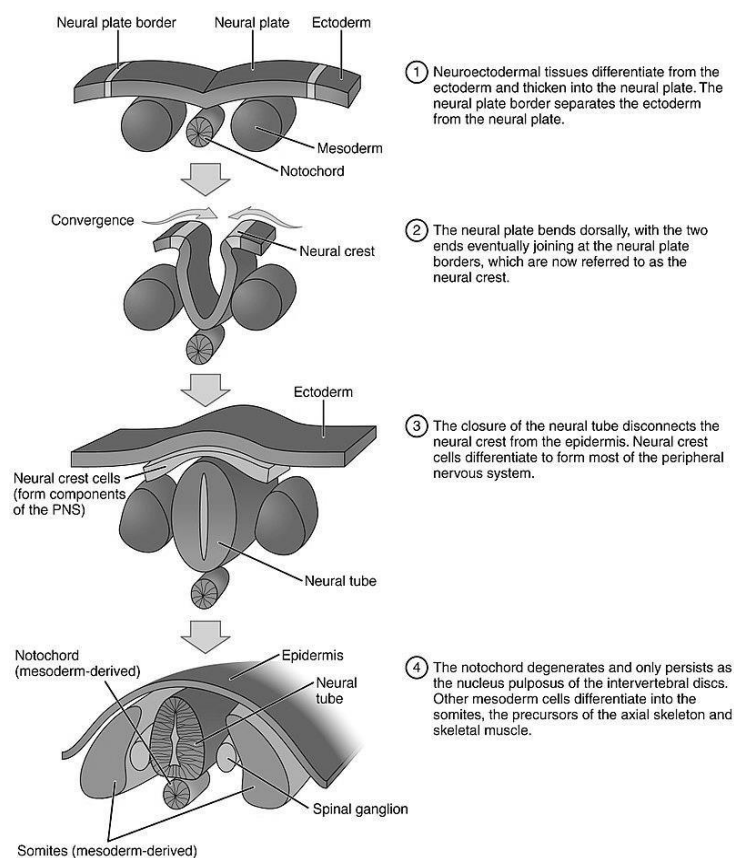
- 1) **Decidua basalis:** deep to the blastocyst.
- 2) **Decidua capsularis:** superficial to blastocyst (separating it from uterine cavity).
- 3) **Decidua parietalis:** the rest of the endometrium.



Primitive streak & primitive node



Notochord



Neural tube

CHANGES IN THE EMBRYOBLASTS

- ❖ At the stage of blastocyst, the embryoblasts are the inner cell mass. During implantation the embryoblasts arrange into a bilaminar disc (ectoderm and endoderm).
- ❖ The disc is at first rounded, then oval, then pear shaped with a wide cranial end and narrow caudal end.

PRIMITIVE STREAK & PRIMITIVE NODE**Formation:**

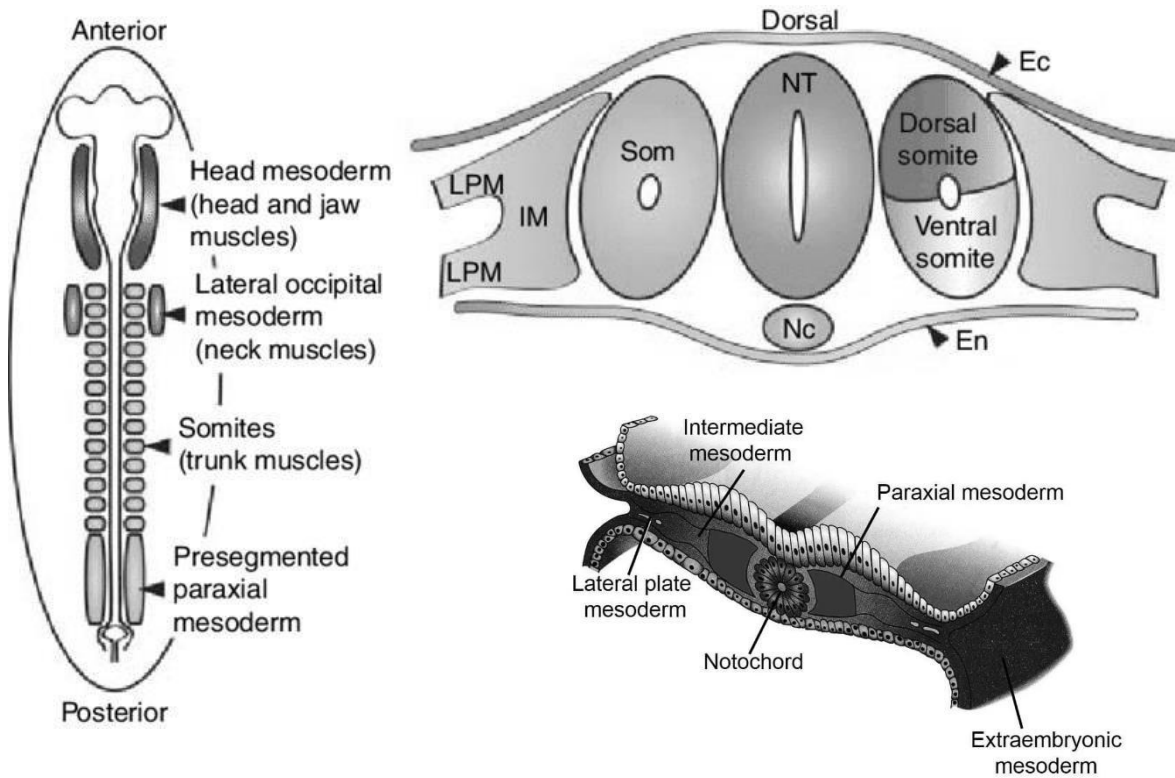
- Some midline caudal ectodermal cells proliferate to form a thick rod like structure called **primitive streak**.
- The cells at the cranial end of the primitive streak proliferate to form the **primitive node**.
- A depression occurs in the primitive node called **primitive pit**.

NOTOCHORD**Formation:**

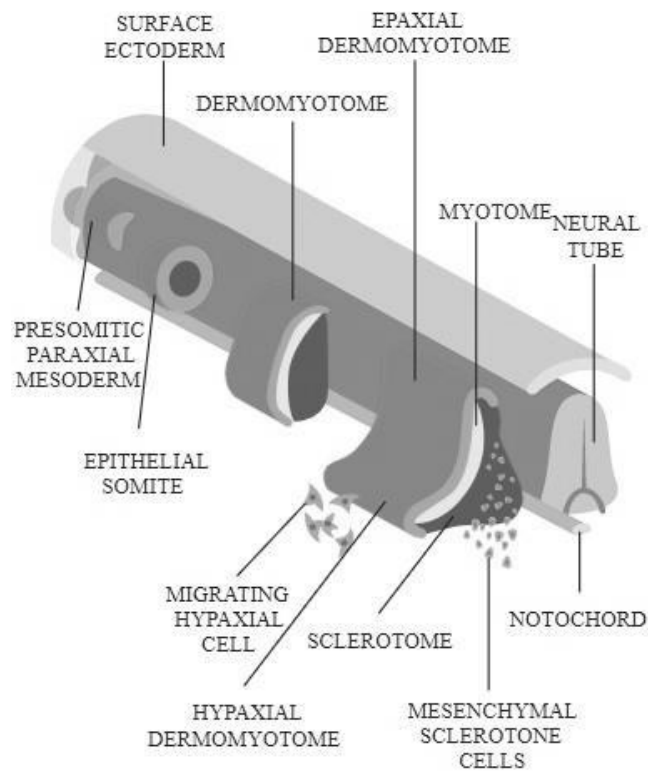
- Some cells of the primitive node proliferate and form a median solid cord called **notochordal process**, between the ectoderm and endoderm. It extends cranially to prechordal plate (prechordal = before the cord).
- The primitive pit deepens inside the notochordal process transforming it into **notochordal canal**.
- The floor of the notochordal canal degenerates with the underlying endoderm. So, a connection is formed between the amniotic cavity and the yolk sac (**neuroenteric canal**).
- The remaining roof and sides of the notochordal process form the **notochordal plate**, then enfolds to form solid **definitive notochord** (notochord = cord of the back) which is the primitive axis of the embryo.

NEURAL TUBE**Formation:**

- The central part of the ectoderm between primitive node and prechordal plate thickens to form **neural plate**.
- The neural plate invaginates to form **neural groove**, which has two **neural folds** on its sides. The junction between the ectoderm and the neural groove on each side shows a longitudinal strip called **neural crest**.
- The neural folds fuse with each other to form the **neural tube**.
- The neural tube separates from the surface ectoderm and sinks down below it but above the notochord. The neural crest becomes dorsolateral to the neural tube.
- The neural tube has two openings at its ends called the cranial and caudal **neuropores**, which close by the end of the 4th week.
- The neural tube differentiates forming the central nervous system. While the neural crest differentiates forming dorsal root ganglion and other structures.



Intraembryonic mesoderm



Somites

INTRAEMBRYONIC MESODERM (IEM)**Formation:**

- Cells from primitive streak and primitive node migrate between ectoderm and endoderm and form intraembryonic mesoderm (IEM).
- IEM separates ectoderm from endoderm except at:
 - Prechordal plate (Buccopharyngeal membrane):** it is the future mouth, lies cranial to notochord, here, the endodermal cells become columnar and fuse tightly with the overlying ectoderm.
 - Cloacal membrane:** it is the future anal canal and urethra, it lies caudal to primitive streak.
- The IEM of both sides meet ant to prechordal plate (the most cranial part is called **septum transversum** (future diaphragm) followed caudally by **cardiogenic area** (future heart). It also crosses midline post to cloacal membrane (here it is connected to connecting stalk (future umbilical cord).

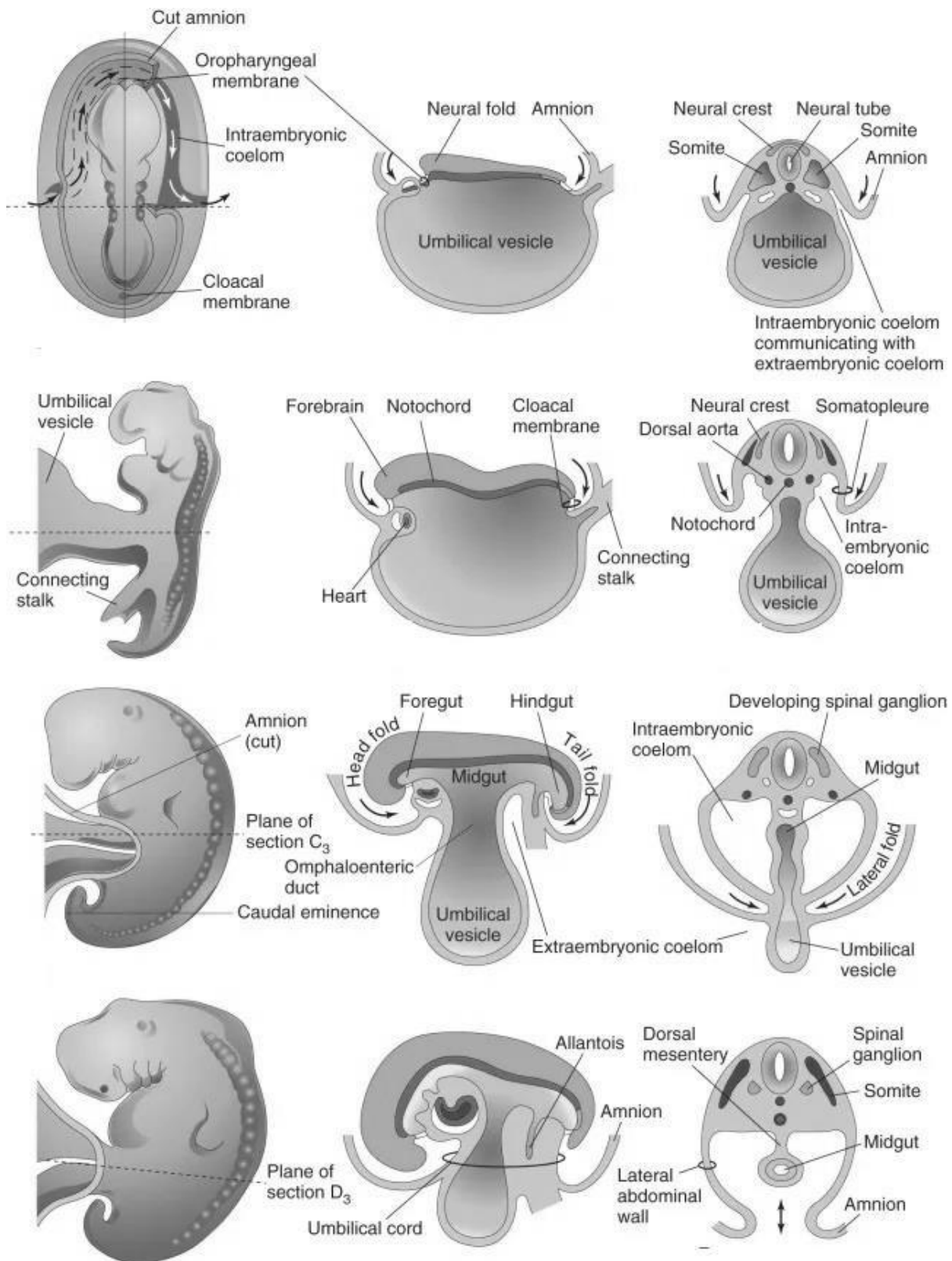
Derivatives of IEM: on each side of the notochord, the IEM is divided into three parallel craniocaudal masses (from medial to lateral):

1) Paraxial mesoderm:

- It is divided into cubical masses called somites, which appear in a craniocaudal sequence. The first pair of somites appear on the 20th day of development and the last one in the 5th week.
- There are 42–44 pairs of somites; 4 occipital, 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 8–10 coccygeal.
- Each **somite** is divided into three parts:
 - a) **Sclerotome:** ventromedial, it surrounds the notochord and differentiates into vertebral column and ribs.
 - b) **Myotome:** intermediate, it differentiates into the muscles of the back.
 - c) **Dermatome:** dorsolateral, it differentiates into the dermis of the skin, which cover the muscles of the back. (both the skin and the muscles of the back are supplied by dorsal rami of the spinal nerves).

2) Intermediate cell mass: it is the nephrogenic area, it differentiates into most of the urogenital system.**3) Lateral plate mesoderm:**

- Many small cavities appear in that plate. These cavities fuse together to form a u shaped cavity called intraembryonic coelom (IEC) whose base is cranial to the oropharyngeal membrane. The IEC divides the lateral plate mesoderm into:
 - a) **Somatic (parietal) layer:** dorsal layer in contact with ectoderm, differentiates into the dermis, bones, joints, muscles and vessels of the limbs and ventral part of the trunk.
 - b) **Splanchnic (visceral) layer:** ventral layer in contact with endoderm, differentiates into the connective tissue, smooth muscles and vessels of the viscera (gastrointestinal, respiratory and urogenital systems).



Folding

FOLDING

Timing: 4th week of pregnancy.

Causes:

- Rapid growth of the cranial part of the neural tube.
- Expansion of amniotic cavity.

Results of folding:

Formation of folds:

- 1) Head fold (cranial).
- 2) Tail fold (caudal).
- 3) Two lateral folds.

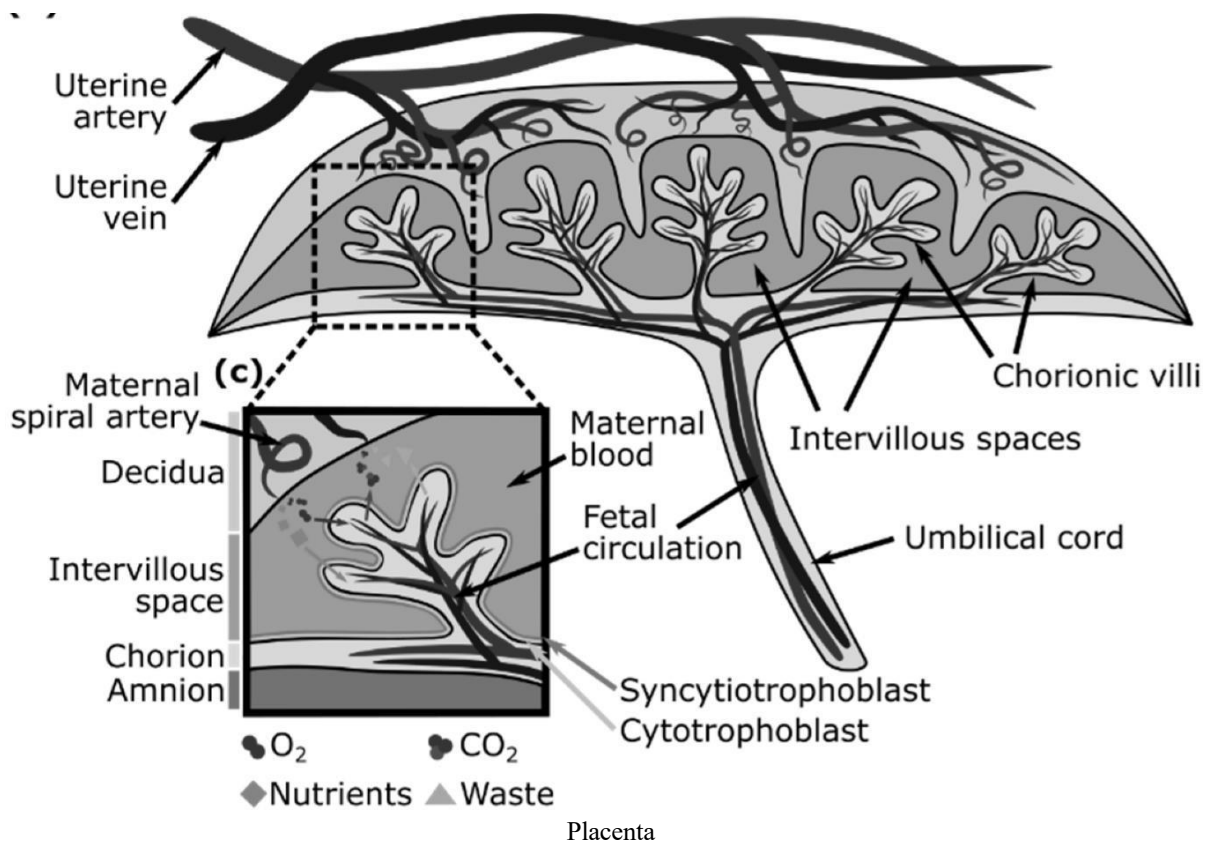
Fusion of similar germ layers: the three layers of the embryonic disc fold together. After complete folding each layer unites with the similar one of the opposite side, all around the connecting stalk (future umbilical cord). The ectoderm becomes the outer layer surrounding the embryo (future epidermis).

Formation of the gut and definitive yolk sac:

- The endoderm and most of the yolk sac invaginates within the folds.
- The endoderm will form a tube inside the folds (gut) which is further divided into:
 - a) **Foregut:** in the head fold.
 - b) **Midgut:** between the lateral folds.
 - c) **Hindgut:** in the tail fold.
- A small part of the yolk sac becomes outside the fold but still connected to the midgut by vitelline (vitello intestinal) duct (vitellus = Yolk sac). This part is called definitive Yolk sac.

Rearrangement of positions:

- The cranial part of neural tube (future brain) becomes the most cranial structure and forms a large forebrain bulge.
- The prechordal plate (future mouth) lies caudal to the developing brain.
- The cardiogenic area (future heart) becomes caudal to the prechordal plate and forms a large Pericardial bulge.
- Septum transversum (future diaphragm) becomes caudal to the cardiogenic area.
- The connecting stalk (future umbilical cord) becomes ventral near the definitive yolk sac.
- The cloacal membrane (future anal canal and urethra) becomes caudal to connecting stalk.
- The amniotic cavity surrounds the whole embryo.



CHANGES IN THE TROPHOBLASTS

PLACENTA

Formation: formed of chorion frondosum and decidua basalis.

Microscopic features:

- The chorion projects chorionic villi invading decidua basalis.
- The part of the chorion forming the base of chorionic villi is called **chorionic plate**.
- The chorionic villi deepen inside the decidua but does not reach the muscular layer of the uterus, to prevent that, the cytotrophoblasts of the stem villi pierce their overlying syncytiotrophoblasts and join each other deep to the chorionic vesicle, forming **cytotrophoblastic shell** separating it from the deeper layers of decidua.

Placental barrier: it is the layers separating the fetal blood (inside the fetal blood vessels of chorionic villi) from the maternal blood between the villi.

- At the first 20 weeks of pregnancy, the barrier is formed of syncytiotrophoblast, cytotrophoblast, extraembryonic mesoderm and endothelium of the fetal vessels.
- After 20 weeks of development, the barrier is formed of syncytiotrophoblast and endothelium of fetal vessels, to facilitate material exchange between maternal and fetal blood.

Macroscopic features (at birth):

- Discoid in shape.
- 500 gm in weight.
- 15 – 20 cm in diameter. Occupying 20-30% of the endometrium.
- It is about 3 cm thick in the center, and gradually thins towards the periphery (1 cm).

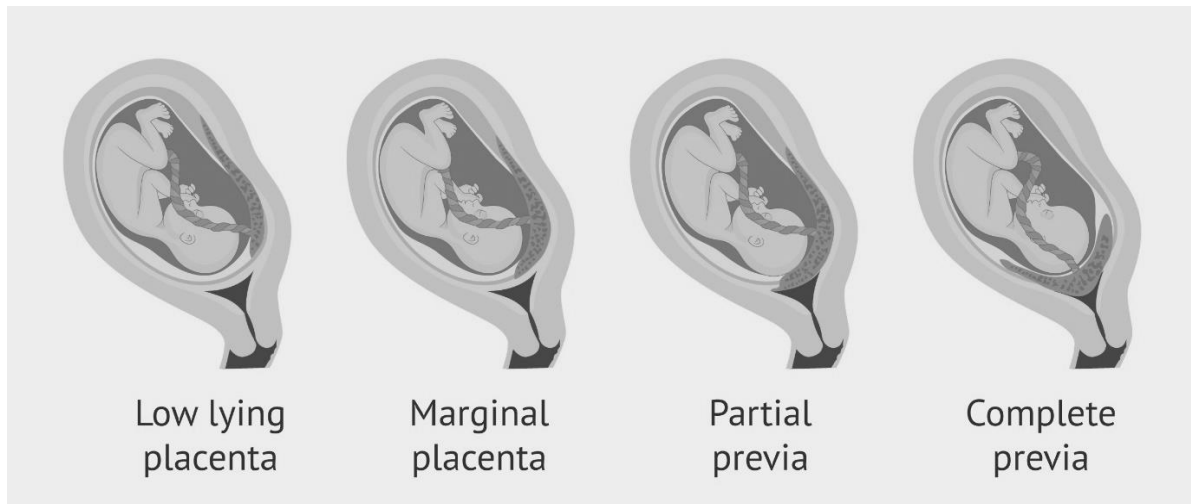
Surfaces:

Maternal: irregular, formed of 15–20 irregular projections called **cotyledons**. The cotyledons are separated by placental septa, arising from the decidua basalis.

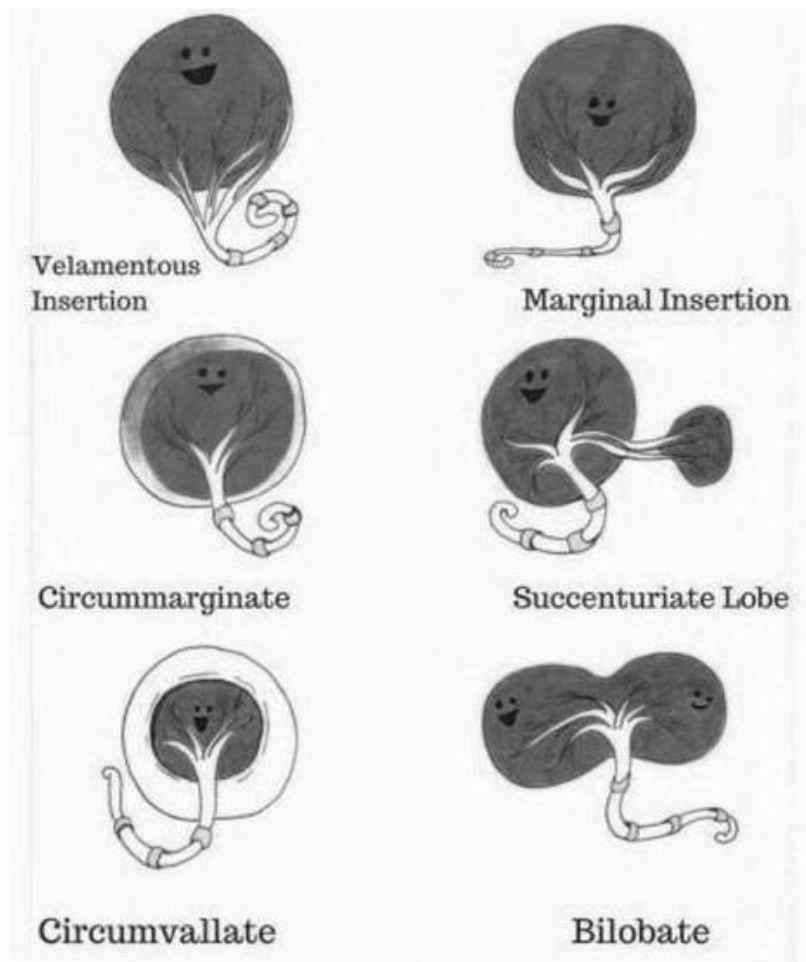
Fetal: smooth, covered by amniotic membrane, the umbilical cord is attached near the center.

Functions of the placenta:

- 1) **Respiratory:** O₂ passes from maternal to fetal blood and CO₂ passes from fetal to maternal blood (replacing lungs function).
- 2) **Nutritive:** nutrients pass from maternal to fetal blood (replacing GIT function).
- 3) **Excretory:** waste products pass from fetal to maternal blood (replacing kidneys function).
- 4) **Endocrinal (secretory):** the placenta secretes:
 - a) **Human chorionic gonadotrophins (HCG):** which maintains the corpus luteum for the 1st half of pregnancy.
 - b) **Estrogen and progesterone.**
 - c) Lactogen, relaxin and other hormones.
- 5) **Immunological:** Some antibodies pass from maternal to fetal blood.
- 6) **Protective:** The placental barrier prevents passage of some infective agents and harmful drugs from maternal to fetal blood. However, some bacteria (e.g., syphilis), viruses (e.g., German measles), parasites (e.g., toxoplasma) and drugs (e.g., morphine) may pass the placental barrier causing harmful effects on fetus.



Placenta previa



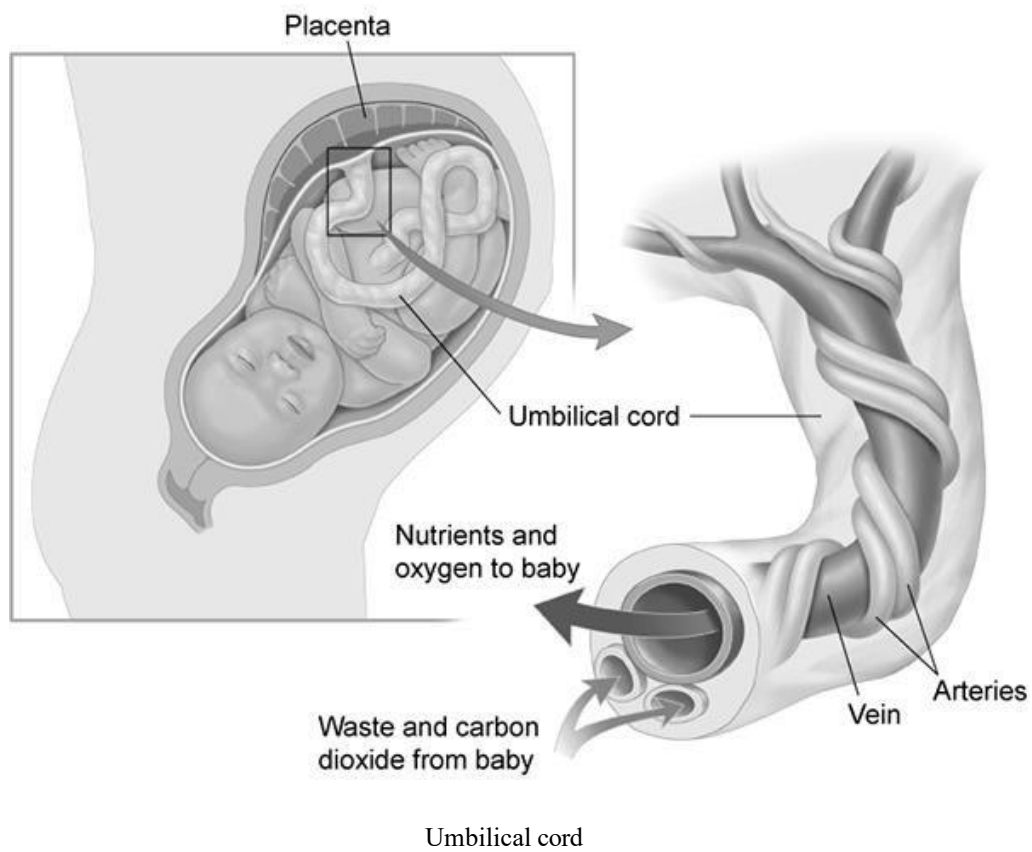
Placental anomalies

Anomalies of the placenta:

- 1) **Position anomalies (placenta previa):** the placenta is lower than the fetus due to implantation in the lower part of the uterus. Further divided into:
 - a) **lateral placenta previa:** the placenta is attached to the lower uterine segment but above the cervix.
 - b) **Marginal placenta previa:** the placenta is attached to the margin of the uterine cervix.
 - c) **Central placenta previa:** the placenta is covering the internal os of cervix.

N.B.: the lower uterine segment is the most growing and stretched part of the uterus. This may cause repeated tears in the placenta and repeated hemorrhages during pregnancy. It is completely forbidden to perform a PV (per vaginal) examination in that case as it may cause placental injury and fatal bleeding.
- 2) **Shape anomalies:**
 - a) **Bilobed (bipartite - bidiscoid) placenta:** the placenta is formed of two discoid equal parts.
 - b) **Trilobed (tripartite - tridiscoid) placenta:** the placenta is formed of three discoid equal parts.
 - c) **Accessory (succenturiate) placenta:** small part of the placenta is separated from the main part.

N.B.: in these cases, a part of the placenta may remain in the uterus after delivery, leading to postpartum hemorrhage.
 - d) **Diffuse (membranous) placenta:** placenta occupying a wide area of endometrium, due to spreaded chorion frondosum.
- 3) **Umbilical cord attachment anomalies**
 - a) **Battledore placenta:** the umbilical cord is attached to the periphery of the placenta.
 - b) **Velamentous attachment of umbilical cord:** the umbilical cord is attached to fetal membranes away from placenta. However, the umbilical vessels are still connected to the placenta.
- 4) **Placenta accreta (= adherent):** abnormally fixed placenta to the uterus, due to deep invasion of chorionic villi reaching the muscle layer of the uterus.



UMBILICAL CORD**Formation and progress:**

- At the stage of chorionic vesicle, the extraembryonic mesoderm lines the trophoblasts and covers the amniotic cavity and yolk sac. The two layers are separated by extraembryonic coelom except a part dorsocaudal to amniotic cavity called the **connecting stalk**.
- After folding, the connecting stalk moves to the ventral aspect of the embryo. It elongates gradually with the growth of the fetus allowing free movements.

Contents:

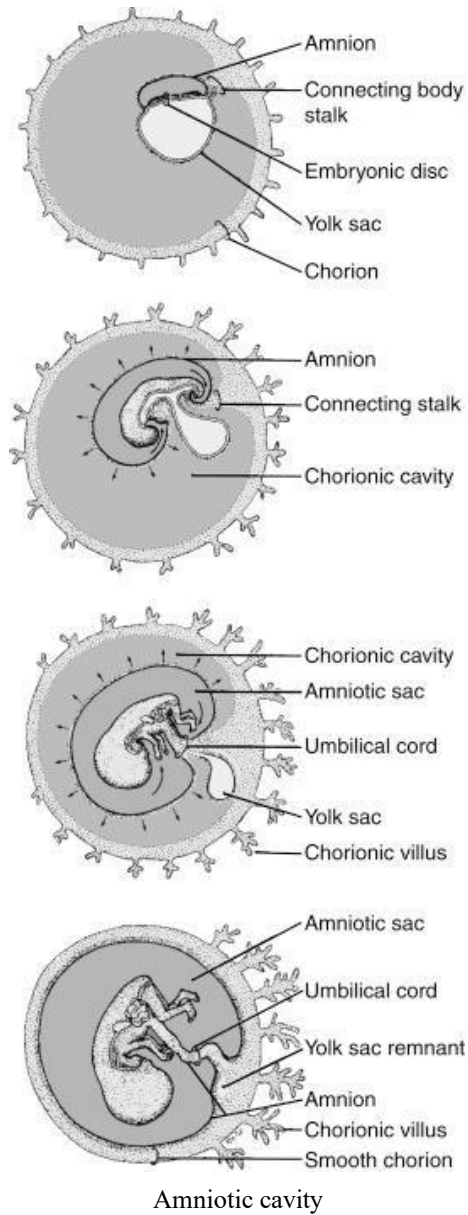
- 1) **Warton's jelly:** the EEM of the connecting stalk.
- 2) **Umbilical vessels:**
 - a) **Two (Rt & Lt) umbilical arteries:** carries non oxygenated blood from the fetus to the placenta.
 - b) **Two (Rt & Lt) umbilical veins:** the Rt rapidly disappears. The **Lt vein** carries oxygenated blood from the placenta to the fetus.
- 3) **Vitelline duct:** which connects the midgut to the definitive yolk sac. Later this duct disappears.
- 4) **Urachus** (distal part of allantois).

Macroscopic features (at birth):

- 50–60 cm in length.
- 1–2 cm in diameter.
- Covered by amniotic membrane.

Anomalies of umbilical cord:

- 1) **Very long cord:** may wind around the neck of the fetus causing hypoxia and may cause true knots.
- 2) **Very short cord:** may cause early separation of the placenta.
- 3) **Knots of the cord:**
 - a) **True knots:** usually accompanied by long cord and excessive movement of the fetus. It is a fatal condition.
 - b) **False knots:** localized collections of Wharton's jelly.
- 4) **Abnormal attachment of the cord to the placenta** (battledore placenta and velamentous attachment of umbilical cord).



AMNIOTIC CAVITY, AMNION AND AMNIOTIC FLUID**Formation and progress:**

- At the stage of blastocyst, the amniotic cavity is dorsal to embryonic disc. Its roof is formed of amnioblasts (cells derived from cytotrophoblasts) and the floor is formed by ectoderm.
- At the stage of chorionic vesicle, the EEM separates the amniotic cavity from the cytotrophoblasts.
- After folding, the amniotic cavity surrounds the whole embryo. And reflects at the umbilical ring to cover the umbilical cord.
- The amnion is the membrane enclosing the amniotic cavity.

Sources of amniotic fluid:

Maternal: diffusion through the chorion.

Fetal: amniotic cells and fetal urine.

Circulation of the amniotic fluid: the fetus swallow the amniotic fluid → the fluid is absorbed through fetal GIT → circulating in fetal circulation → secreted through fetal kidney as urine to the amniotic fluid → swallowed again.

Functions of the amniotic fluid :

- 1) Protection against external trauma (water cushion).
- 2) Symmetrically distributes the pressure on the embryo preventing asymmetrical growth.
- 3) Prevents adherence between embryoblasts and its derivatives and trophoblasts and its derivatives.
- 4) Keeps aseptic environment around the embryo.
- 5) Keeps constant temperature of the embryo.
- 6) Allows free movement of the fetus encouraging muscular development.
- 7) Development of vital mechanisms before birth:
 - a) Swallowing.
 - b) GIT absorption.
 - c) Circulation.
 - d) Kidney functions and urine formation.
 - e) Urination.
- 8) During labor, the amniotic sac enters the cervix of the uterus helping its dilatation.
- 9) Before birth, the amniotic cavity ruptures and its sterile fluid cleans the birth canal.

Anomalies of amniotic fluid:

- The normal amount of amniotic fluid is 750-1500 ml (at full term).

Oligohydramnios: it is less than 400 ml amniotic fluid.

Causes:

- Renal agenesis.
- Urinary tract obstruction.

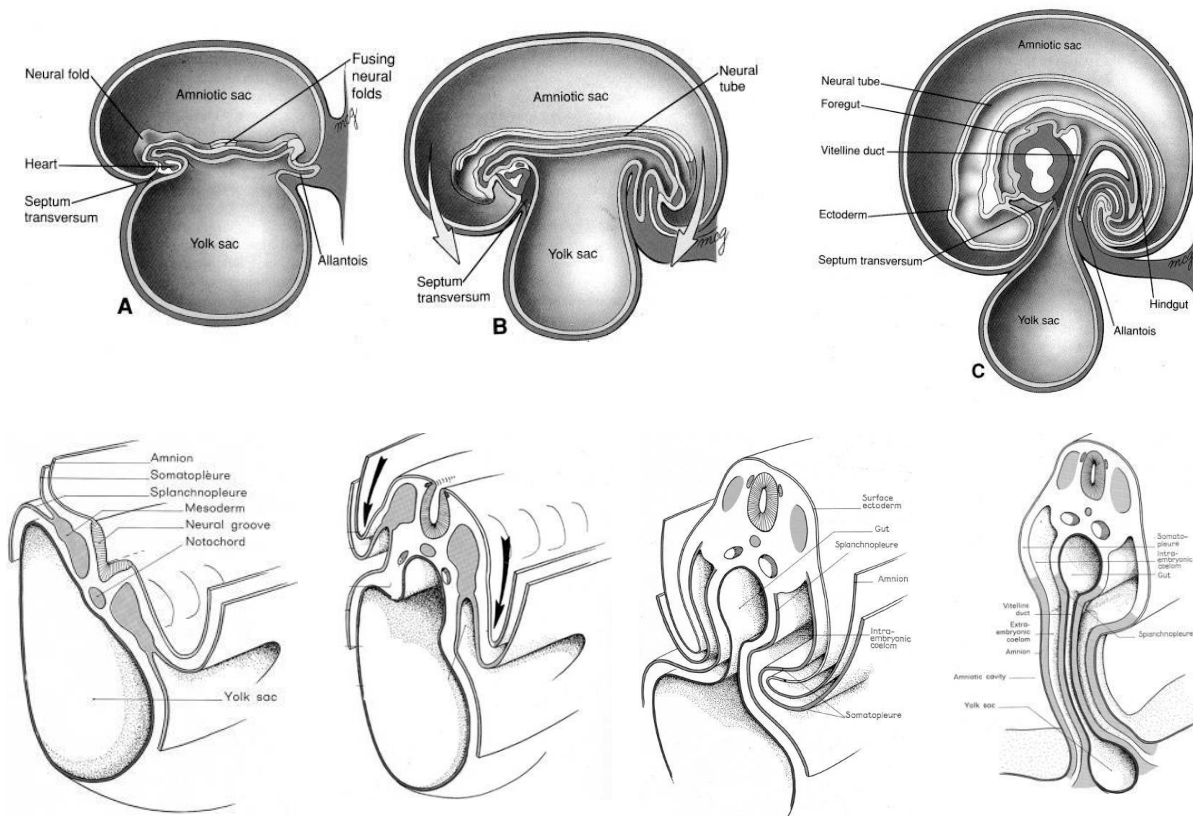
Risk: adhesions

Polyhydramnios: it is more than 2000 ml amniotic fluid.

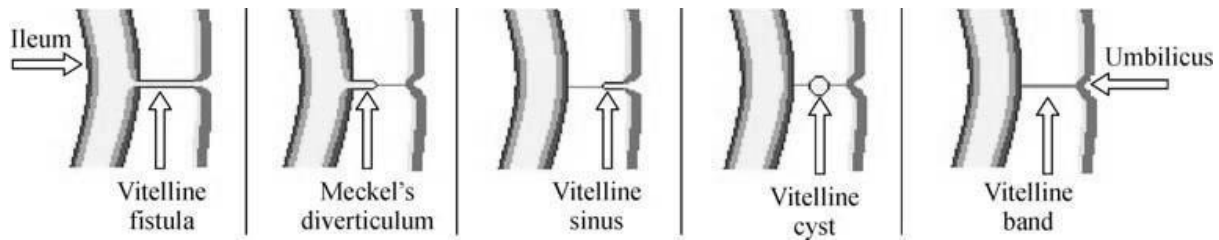
Causes:

- Idiopathic.
- Maternal diabetes.
- **Neural tube defect (e.g., anencephaly):** defective development of the brain with defective swallowing.
- GIT obstruction.

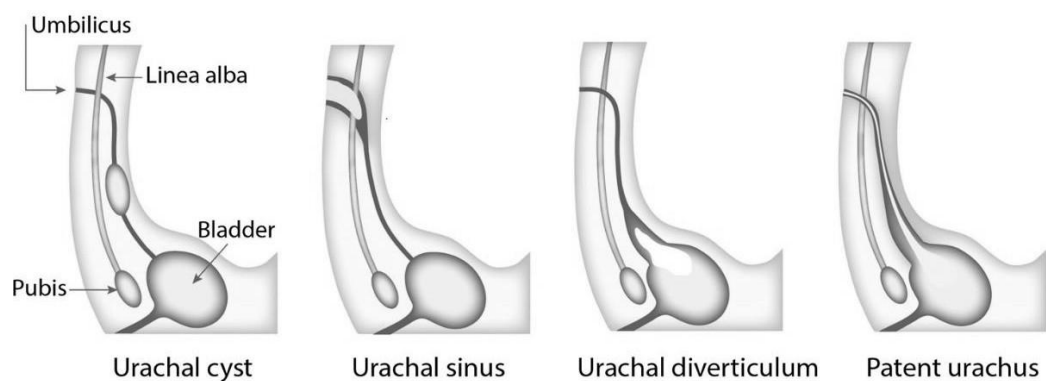
Risk: premature rupture of amniotic membrane and premature labor.



Yolk sac



Anomalies of vitelline canal



Anomalies of urachus

Yolk sac**Formation and progress:**

Primary Yolk sac: at the stage of blastocyst, the yolk sac is ventral to embryonic disc. Its roof is formed by endoderm and the rest of the wall is formed of Heuser's membrane (cells derived from endoderm).

Secondary yolk sac: at the stage of chorionic vesicle, the EEM surrounds the yolk sac. In this stage, a small pouch (called the allantois) projects from the yolk sac inside the connecting stalk.

Tertiary (definitive) yolk sac: after folding, the yolk sac divides into

The gut (sucked inside the embryo).

Definitive yolk sac: pushed to the connecting stalk.

Vitelline duct: connecting both, it disappears separating the gut from the yolk sac.

Functions of the yolk sac:

- 1) Nutritive function: of minimal importance in humans.
- 2) The endoderm of its roof forms the epithelial lining of the gut and respiratory system.
- 3) The allantois forms part of the urinary bladder.
- 4) Primary germ cells (spermatogonia and oogonia) develop from yolk sac and migrate to gonads.

Anomalies of vitelline duct:

- 1) **Vitelline ligament:** the duct is fibrosed but does not disappear.
- 2) **Vitelline cyst:** the duct is fibrosed but a middle part of it is patent.
- 3) **Meckel's diverticulum:** the part of the duct attached to the gut is patent, the rest disappears.
- 4) **Vitelline sinus:** the part of the duct attached to the umbilicus is patent, the rest disappears.
- 5) **Vitelline fistula:** the whole duct is patent.

ALLANTOIS**Formation and progress:**

- It is a diverticulum from the secondary yolk sac inside the connecting stalk. It is lined with endoderm.
- After folding it connects the hind gut (derived from endoderm) to the umbilical cord (derived from connecting stalk).
- The part connected to the hind gut will form part of the urinary bladder.
- The part extending to the umbilical cord is called the urachus which will obliterate forming median umbilical ligament connecting the urinary bladder to the umbilicus.
- It is surrounded by allantoic vessels.

Anomalies of allantois:

- 1) **Urachal cyst:** the urachus is fibrosed but a middle part of it is patent.
- 2) **Urachal diverticulum:** the part of the urachus attached to the urinary bladder is patent, the rest is fibrosed.
- 3) **Urachal sinus:** the part of the urachus attached to the umbilicus is patent, the rest is fibrosed.
- 4) **Urachal fistula:** the whole urachus is patent.

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