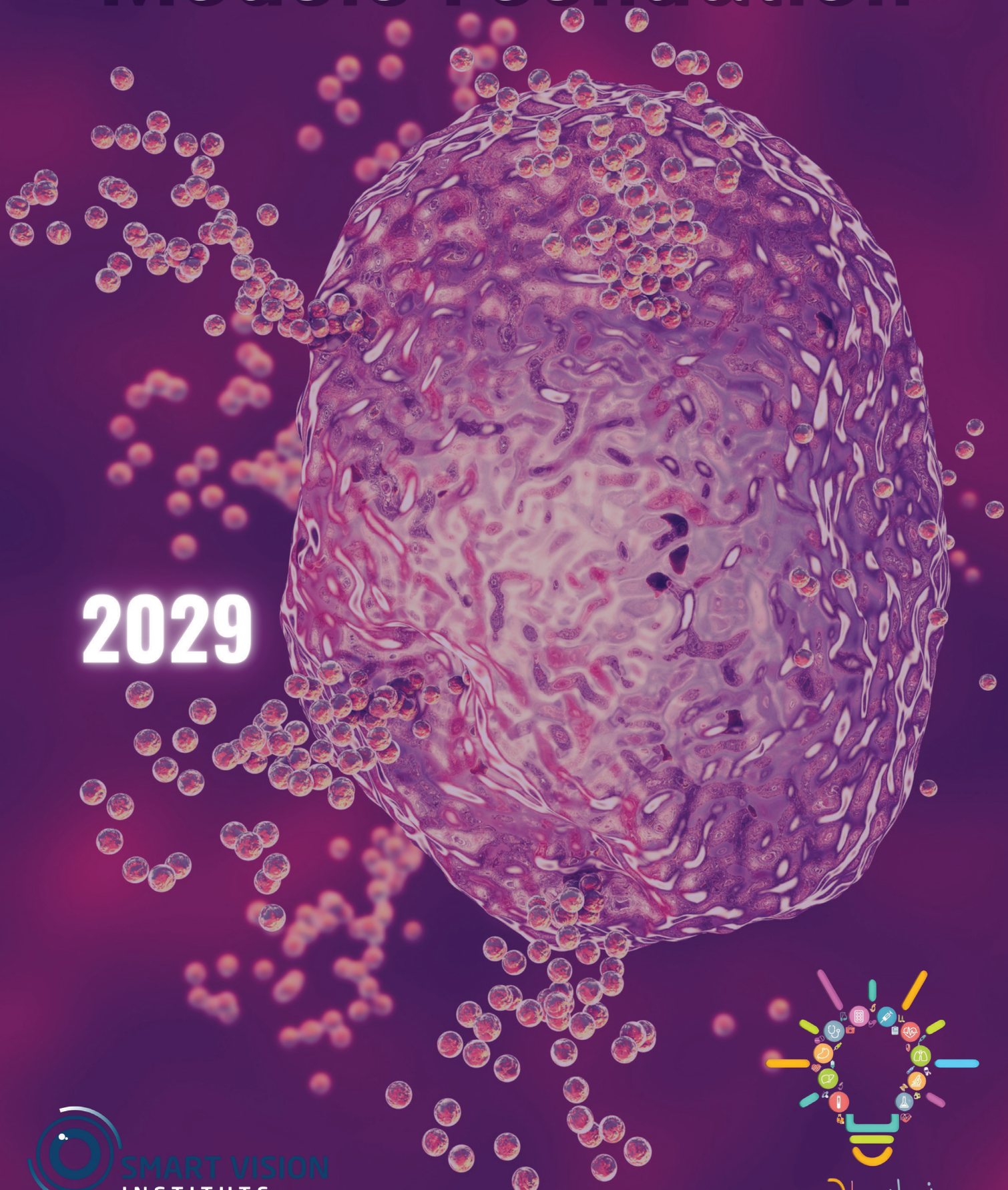
HISTOLOGY
Module Foundation



2029

SMART VISION INSTITUTE

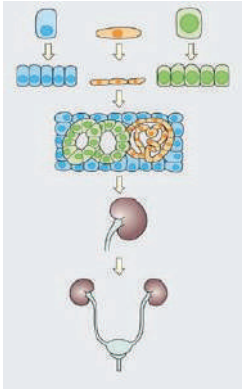
نبراس Nebras

في البداية نتمنى أن نكون قدمنا لكم ما يفيدكم و تتمنوه و نسألكم الدعاء لكل من كتب و أعاد صياغة هذا المحتوى و دققه ..

بشكل مباشر أو غير مباشر ...

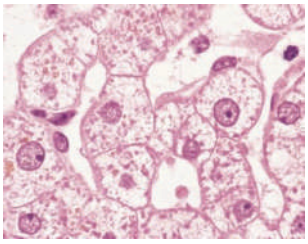
نبراس

Cell

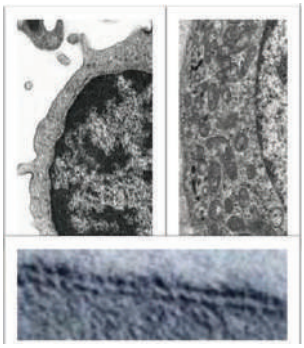


- The cell is the functional & structural unit of the body.
- A group of cells with similar structure & function will form tissues.
- These tissues are grouped to form organs.
- A group of organs collect to form the body systems.

Cell Membrane



- Plasma membrane = Plasmalemma
- **LM:** It cannot be seen by light microscope because it is too thin to be seen but the conden sation of the stain on the outer surface of the cell membrane marks its.
- **EM:**
  1. **At Low Magnification:** thin dense line 8-10 nm in thickness.
  2. **With Higher Magnification Magnification:** a trilaminar structure, with an outer (= extracellular leaflet) and an inner (= cytoplasmic leaflet) electron dense lines and a middle electron lucent zone in between.

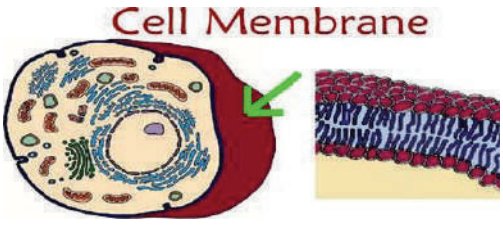


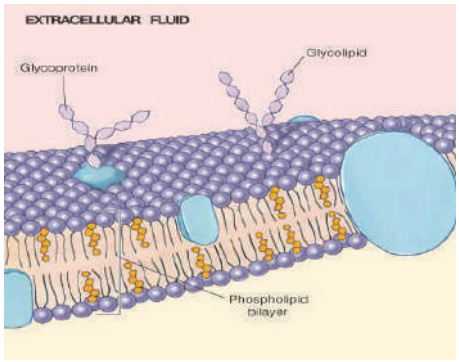
N.B: The entire structure is known as the unit membrane.

Molecular structure of the Cell membrane:

3 Components:

1. Lipid molecules:
   a. Phospholipids
   b. Cholesterol
2. Protein molecules.
3. Carbohydrate molecules





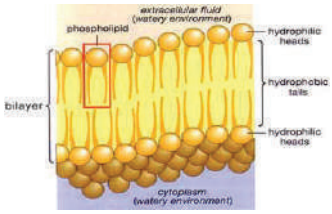
N.B:
The cell membrane & almost all the membranes surrounding the membranous organelles have the same structure except for minor differences.

N.B: Membrane phospholipids & the associated proteins are usually present in 1:1 proportion by weight

1. Lipid Molecules

A. Phospholipids:

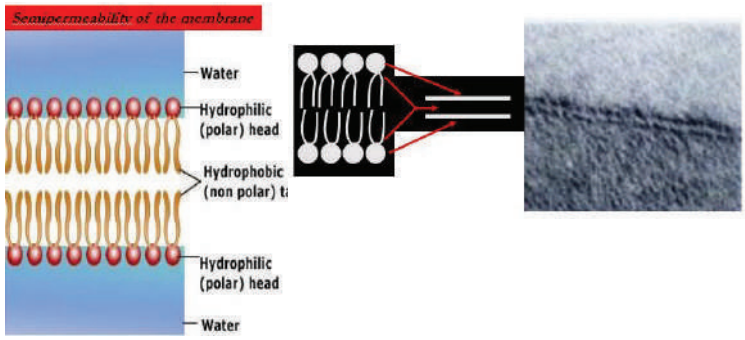
- **Each phospholipid molecule consists of:**
  1. **One polar hydrophilic head:** faces the aqueous media on either side of the membrane.
  2. **Two long non polar hydrophobic tails (fatty acids):** project towards the center of the membrane facing each other. They form weak non covalent bonds with each other, holding the bilayer together.



Why does the cell membrane appear as a trilaminar structure?

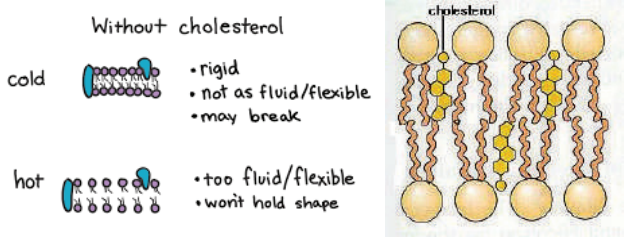
Deposition of osmium in the hydrophilic heads while the hydrophobic tails remain unstained.

- **Functions of Phospholipid molecules:**
  - **Prevent passage of:**
    1. Water soluble substances.
    2. Polar ions.
  - **Allow passages of:**
    1. Fat soluble substances.
    2. Nonpolar substances.



B. Cholesterol:

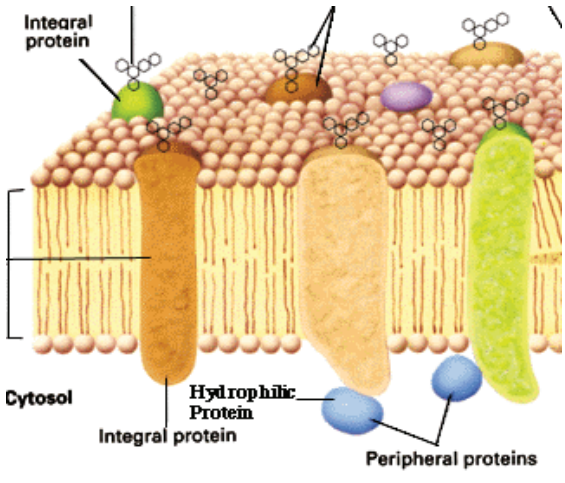
- **They are incorporated within the lipid bilayer.**
- **Functions of Cholesterol:**
  1. Stability of the membrane.
  2. Regulation of membrane fluidity in body temperature.



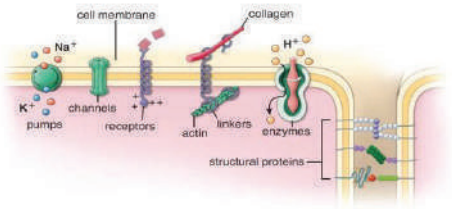
2. Protein Molecules

A. Integral Membrane Proteins:

- They are embedded within the lipid bilayer.
- Most of these proteins traverse the whole thickness of the membrane and are called transmembrane proteins while others are partially embedded within the membrane.



- **There are six functional forms of integral membrane proteins:**
  1. **Pumps:** transport ions (Na+, K+) actively across the membrane.
  2. **Channels:** transport substances passively.
  3. **Receptors:** allow binding of specific molecules e.g., hormone.
  4. **Enzymes:** ATP synthase of the inner mitochondrial membrane and some types of digestive enzymes in the small intestine.
  5. **Linkers:** anchor the intracellular cytoskeleton to the extracellular matrix.
  6. **Structural proteins:** form junctions between neighboring cells.

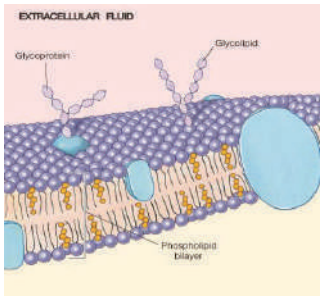


B. Peripheral Membrane Proteins:

- They are not embedded into lipid bilayer, but they are loosely associated with membrane.
- They are usually located on the cytoplasmic surface of the membrane.
- **Function:** form a link between the cell membrane and the cytoplasmic components.

3. Carbohydrate Molecules

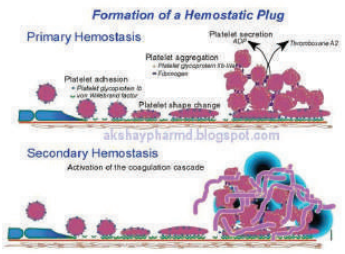
- They are present as glycoproteins and glycolipids of the cell membrane.
- They are oriented towards the outside of the membrane forming the cell coat or glycocalyx.
- The cell coat is represented by the "fuzzy" material on the outer surface of the membrane.



- **Functions of cell coat:**
  1. **Cellular recognition** e.g. the glycocalyx on the surface of red blood cells determines the four blood groups.
  2. **Cell cell adhesion.**
  3. **Receptor:** for ligands by the glycoproteins of the cell membrane.

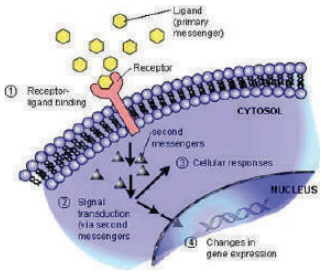
N.B:

- The glycocalyx vary from species to species/ from cell to cell.
- This diversity enable membrane carbohydrate to function as markers that distinguish one cell from another (e.g. The ABO blood system)



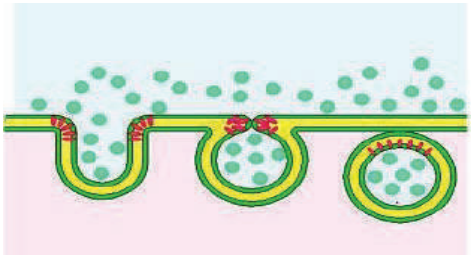
The ABO Blood System

Blood Type (genotype)	Type A (AA, AO)	Type B (BB, BO)	Type AB (AB)	Type O (OO)
Red Blood Cell Surface Proteins (phenotype)	A agglutinogens only	B agglutinogens only	A and B agglutinogens	No agglutinogens



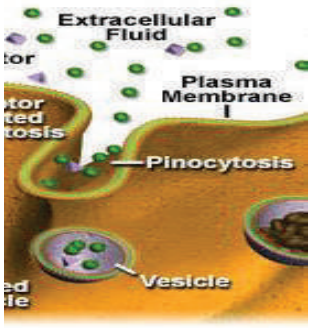
Vesicular transport across the cell membrane

- Mass transfer of materials through the cell membrane occurs by formation of vesicles.
- **It involves 2 processes:**
  1. Endocytosis.
  2. Exocytosis.



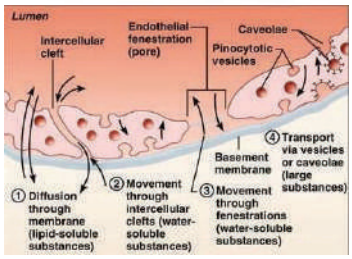
1. Endocytosis

- **Definition:** the uptake of material from the extracellular space.
- It is an active process that involves invagination of the membrane to form a vesicle.
- **3 mechanisms of endocytosis are present in the cell:**



A. Pinocytosis (cell drinking) :

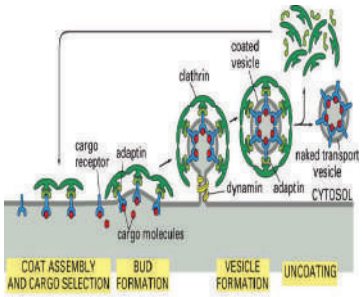
- **Definition:** a non selective process, occurs in nearly all cell types for uptake of fluid containing ions and small protein molecules.
- **Vesicle:** pinocytotic vesicles are small and have smooth surface.
- **Site:** most evident in the endothelium of blood vessels.



B. Receptor mediated endocytosis

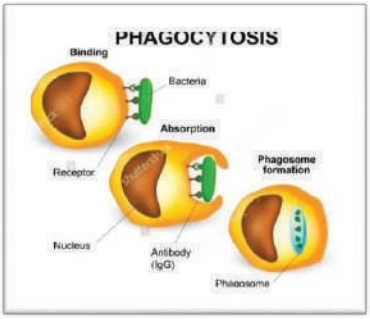
- **Definition:** a highly selective process resulting in uptake of specific substances by a specific cell that has receptors for these substances e.g. protein hormones.
- These receptors are concentrated in specialized regions of the plasma membrane called coated pits (coated by clathrin).

1. When a substance binds to its receptor, clathrin coated pits invaginate and give rise to clathrin coated vesicles containing this specific substance.
2. Clathrin is lost and recycled leaving uncoated vesicles.



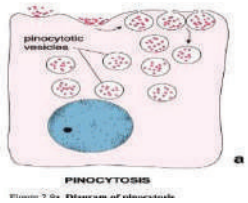
C. Phagocytosis (cell eating):

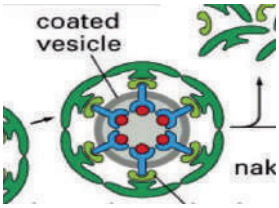
- **Definition:** ingestion of large solid particles, such as bacteria and cell debris, it is a receptor mediated endocytosis; however, it does not involve formation of coated pits or vesicles.
- **Sites:** phagocytes e.g. macrophages& neutrophils.

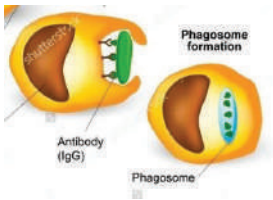


1. Binding of the receptor and foreign body results in extension of pseudopodia that engulf the particle.
2. Fusion of the membrane to internalize the particle into the cytoplasm forming a phagosome.
3. The contents of the phagosome are then digested through lysosome.

Types of endocytosis	Pinocytosis	Receptor mediated endocytosis	Phagocytosis
1. Endocytosed material	Fluid containing ions & small molecules.	Specific substances (ligand) e.g. hormone.	Large solid particles e.g. bacteria.
2. Receptors for endocytosed material	Nonselective.	Present.	Present.
3. Shape of the vesicle	Small& smooth.	Coated with clathrin.	No coated vesicle but the membrane fused to form phagosomes.
4. Type of cells	Nearly all cell types especially endothelium of blood vessels.	Specific cell that has receptor for specific substance.	Phagocytic cells.

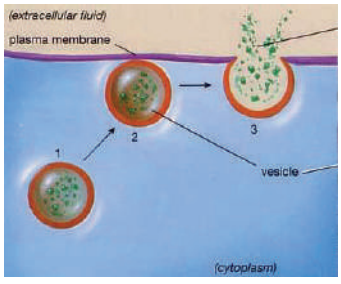






2. Exocytosis

- **Definition:** the release of cell products into the extracellular space.
- During this process, a vesicle moves from the cytoplasm to the cell membrane, fuses with it and discharges its content.
- **There are 2 types of exocytosis:**



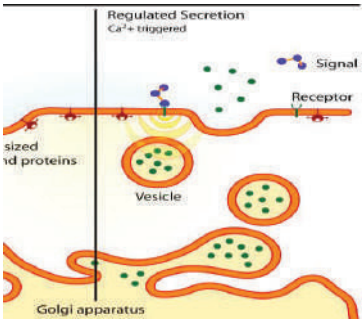
A. Regulated secretion (stimulus dependent)

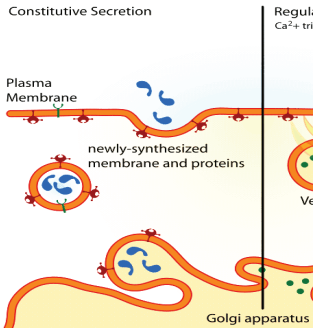
1. The secretory products become stored forming secretory granules.
2. As a result of a stimulus (hormonal or neural stimulus), these vesicles move to the surface and fuse with the cell membrane to pour their contents outside the cell. e.g., occurs during release of the digestive enzymes by the pancreas.

B. Constitutive secretion

- The secretory products leave the cell immediately after their synthesis. These cells lack secretory granules.
- The secretion is released continuously through secretory vesicles.
- E.g. occurs during release of antibodies by plasma cells.

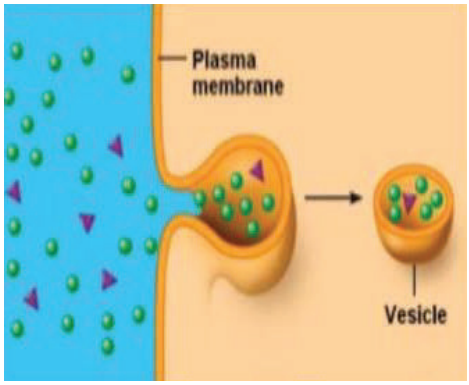
Types of exocytosis	Regulated secretion	Constitutive secretion
1. Stimulus	Stimulus dependent	No stimulus. They released continuously.
2. Secretory product	Concentrated & stored inside secretory granules.	Leave the cell membrane immediately after their synthesis. No secretory granules.
3. Example of the released secretion	Digestive enzymes from pancreatic cell.	Antibodies from plasma cell, fibers secreted from fibroblast.

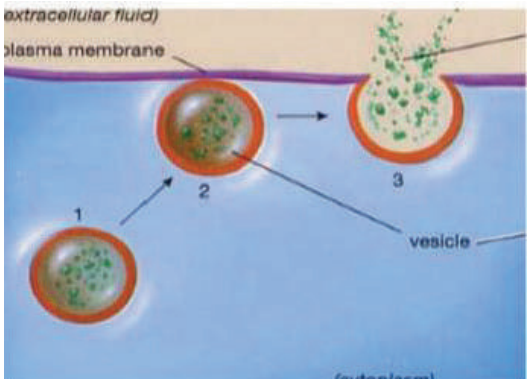




Membrane Recycling

- During the vesicular transport, the cell membrane is maintained; the excess membrane added to the cell membrane by exocytosis is constantly recycled again into the cytoplasmic compartments by endocytosis.





1) which the following substances aren't present in the cell membrane ? :

a. Triglycerides
b. Cholesterol
c. Glycoproteins
d. Phospholipids

2) The sugary coat of the outer surface of plasma membrane is called:

a. Glassy membrane
b. Cell wall
c. Glycocalyx
d. Cytoskeleton

3) In-receptor mediated endocytosis:

a. Receptors are dispersed over the cell outer surface
b. It is suitable for low density lipoproteins
c. Receptors are aggregated in coated pits
d. All the above

4) The process by which the cell membrane engulfs solid particles called:

a. Pinocytosis
b. Receptor-mediated endocytosis
c. Exocytosis
d. Phagocytosis

5) Uptake of extracellular fluid by the cell membrane is called:

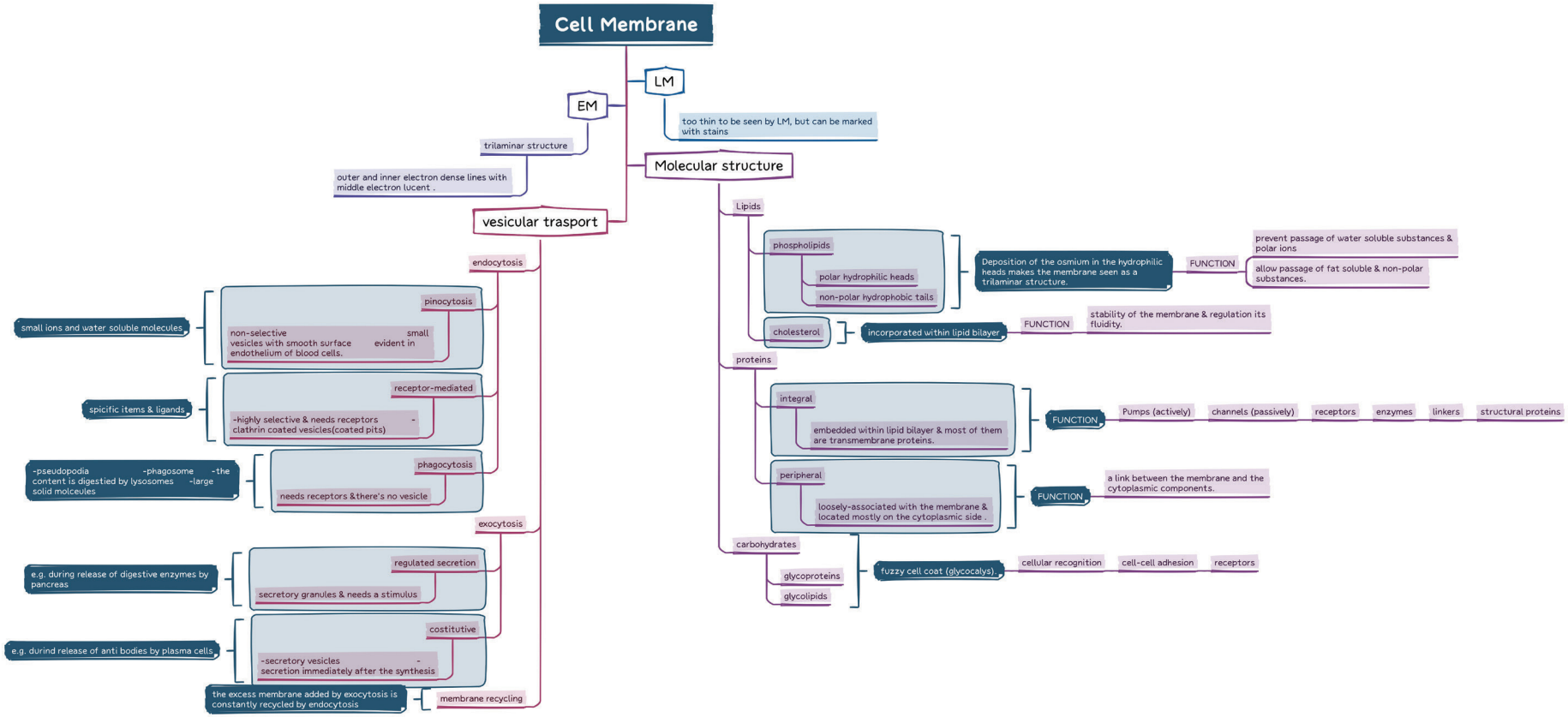
a. Phagocytosis
b. Exocytosis
c. Pinocytosis
d. Autophagy

6) Transport of molecules against concentration gradient by cell membrane is called:

a. Pinocytosis
b. Signal transduction
c. Passive diffusion
d. Active transport

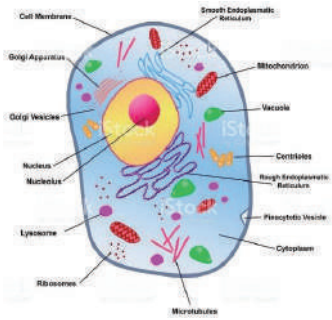
Answers

1. A
2. C
3. D
4. D
5. C
6. D



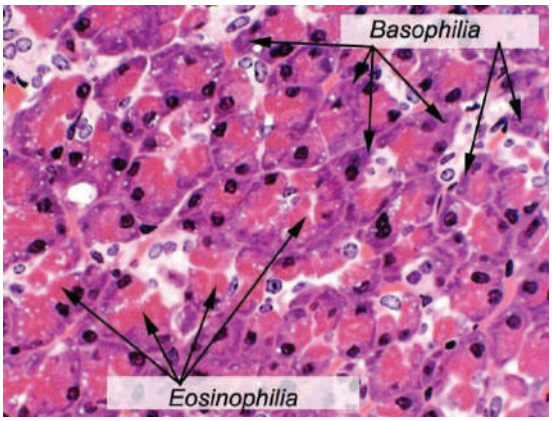
Cell organelles

- **Definition:** metabolically active structures carrying out specific essential functions.
- **Types:**
  1. **Membranous organelles:** nucleus, endoplasmic reticulum, Golgi apparatus, transport vesicles, endosomes, lysosomes, mitochondria, and peroxisomes.
  2. **Non membranous organelles:** ribosomes, centrosome, and the cytoskeleton.



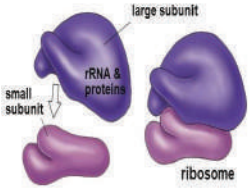
N.B: Haematoxylin and Eosin (H&E):

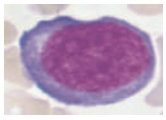
- **Haematoxylin** is a basic violet stain.
- **Eosin** is an acidic pink stain.
- **Basophilic structure**= A structure that has affinity to stain with basic dyes = acidic in nature So it stains violet with haematoxylin.
- **Acidophilic or eosinophilic structure**= A structure that has affinity to stain with acidic dyes = basic in nature So it stains pink with eosin.



1. Ribosomes

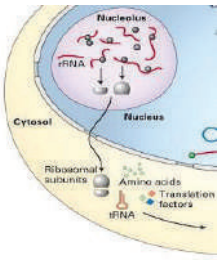
- **Definition:** granules of nucleoproteins (ribosomal RNA (rRNA) + proteins).
- **Site:** They are present in all cells especially in protein synthesizing cells.
- **Structure:** two subunits; small subunit & large subunit.



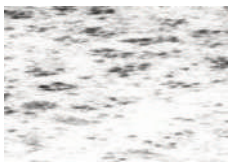


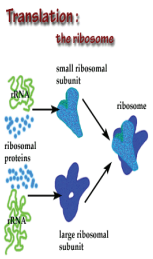
- **Synthesis:**

  1. The rRNAs are synthesized inside the nucleolus.
  2. Ribosomal associated proteins are synthesized in the cytoplasm.
  3. Ribosomal subunits then leave the nucleus, via the nuclear pores, to enter the cytoplasm.

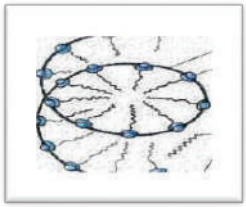


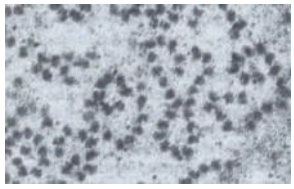
- The small and large subunits are present in the cytosol individually and do not form a ribosome until protein synthesis begins.
- **LM:** When present in large amounts they cause cytoplasmic basophilia.
- **EM:** Ribosomes are small electron dense granules.





- **Types:**



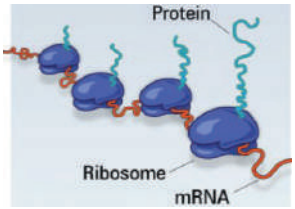


A. Free ribosomes:

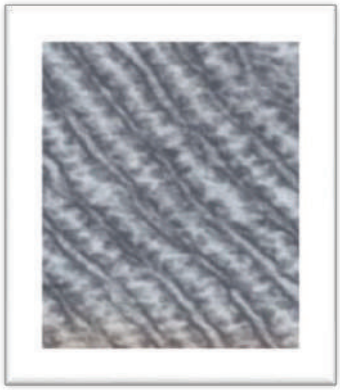
1. Solitary particles: scattered in the cytoplasm.

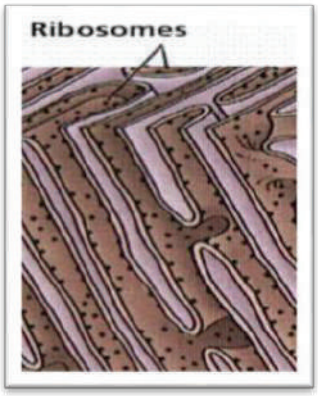
Function: act as a reserve.

2. Aggregated (polysomes): clusters of 10 or more connected by single strand of mRNA.

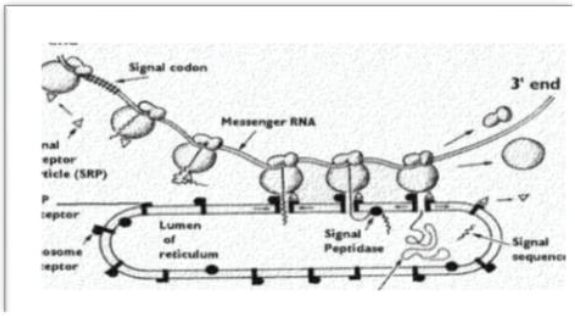


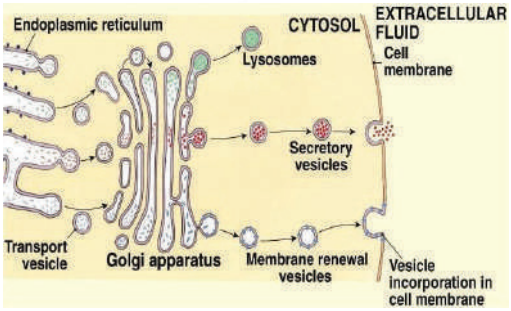
Function of polysomes: responsible for synthesis of cytosolic protein e.g. in dividing cells and growing cells, synthesis of hemoglobin in developing red blood cells and contractile protein in muscle cells.

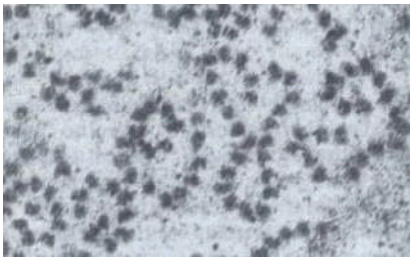




B. Attached ribosomes: these are polysomes that become attached to the outer membrane of the endoplasmic reticulum.





Types of ribosomes	Free solitary ribosomes	Free aggregated ribosomes (polysomes)	Attached ribosomes
1. LM		Not seen but in large amount give cytoplasmic basophilia.	Not seen but in large amount give cytoplasmic basophilia.
2. EM	Small electron dense particles.	10 or more ribosomes connected by a single strand of mRNA.	Small electron dense particles attached to rER.
3. Function	Reserve. 	Synthesis of cytosolic proteins (used within the cell) 	Synthesis of secretory proteins, lysosomal enzymes & membrane proteins. 

1) cytoplasmic basophilia is due to presence of high amount of :

a. Golgi apparatus
b. Ribosomes
c. Mitochondria
d. Peroxisomes

2) Concerning ribosomes, which of the following is false:

a. Free in the cytoplasm
b. Attached to the outer surface of rER
c. Attached to the outer surface of sER
d. Attached to the outer nuclear envelope

3) All the following are membranous organelles except:

a. Mitochondria
b. Golgi apparatus
c. Lysosomes
d. Ribosomes

4) Free ribosomes are responsible for the synthesis of:

a. Lipids
b. Proteins used in cell growth and division
c. Carbohydrates
d. Proteins secreted outside the cell

5) Ribosomes are constructed in:

a. Mitochondria
b. rER
c. Nucleolus
d. Golgi apparatus

Answers

1-B
2-C
3-D
4-B
5-B

Ribosome

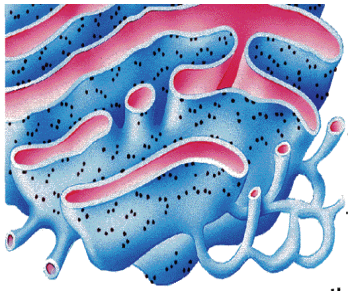
- 2 subunits synthesized from r-RNA and proteins
- LM : large amounts cause cytoplasmic basophilia
- EM : small electron dense granules

free Ribosome : solitary particles don't synthesize proteins but act as reserve

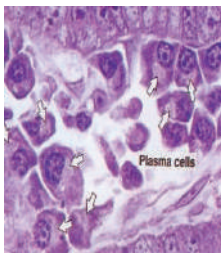
polysomes : clusters of 10 or more ribosomes responsible for synthesis of cytosolic proteins
EX : dividing & growing cells as synthesis of of hemoglobin in developing RBCs and concratile protein in muscle cells

attached ribosome : polysomes are attached to outer membrane of r-ER

2. Endoplasmic reticulum

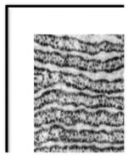


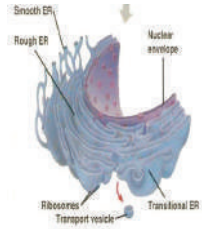
- The endoplasmic reticulum forms the most extensive membrane system in the cytoplasm.
- **The ER has two types:**
  - Rough endoplasmic reticulum (rER).
  - Smooth endoplasmic reticulum (sER).
  - Both types form a single membrane system.



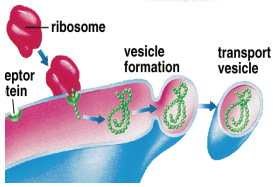
A. Rough Endoplasmic Reticulum (rER):

- **LM:** When present in large amounts they cause cytoplasmic basophilia due to their attached ribosomes.
- **EM:**

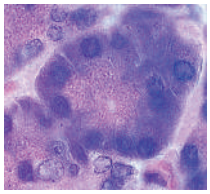




1. It consists of interconnected parallel flattened sacs called cisternae.
2. Its outer surface is studded with ribosomes, resting by their large subunit on the membrane.
3. It is continuous with the outer membrane of the nuclear envelope.
4. The lumen contains flocculent material that represents newly formed protein.

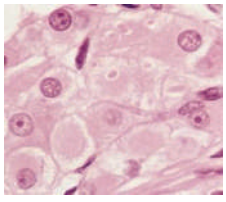


- **Functions:**



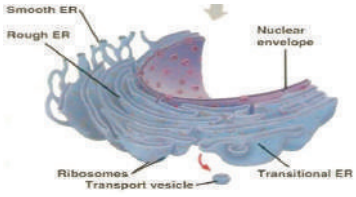
1. Synthesis of secretory proteins, lysosomal enzymes and proteins inserted into the cytoplasmic membranes.
2. Post translational modification of the newly formed protein e.g.folding, sulfation and initial glycosylation.
3. Transport the newly synthesized protein to the Golgi body by transport vesicles.

- **Sites:** Protein synthesizing & secreting cells e.g. liver cells, pancreatic acini, fibroblasts and plasma cells.



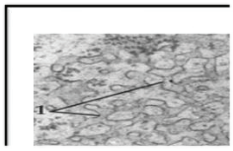
B. Smooth Endoplasmic Reticulum (sER)

- **LM:** Cells with large amounts of sER exhibit cytoplasmic eosinophilia.
- **EM:**

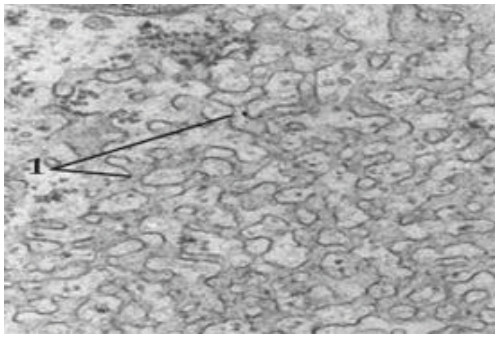


1. It consists of close network of interconnected branching tubules and vesicles.
2. The membranes have smooth surface.
3. The membranes of the sER are continuous with that of rER.

- **Functions:**
  1. Synthesis of membrane lipids; the phospholipids and cholesterol.
  2. Synthesis of steroid hormones.
  3. Synthesis of glycogen in liver.
  4. Detoxification of toxic substances e.g. alcohol and drugs.
  5. Regulation of calcium ions during muscle contraction.



- **Sites:** steroid secreting cells (in the adrenal cortex, testis and ovary), liver cells & muscles.

Types of endoplasmic reticulum	Rough endoplasmic reticulum	Smooth endoplasmic reticulum
1. LM	Not seen but in large amount give cytoplasmic basophilia.	Not seen but in large amount give cytoplasmic acidophilia.
2. EM	Parallel, flattened interconnected tubules. Studded with ribosomes.	Interconnected branching tubules and vesicles. No ribosomes.
3. Functions	1. Synthesis of secretory proteins, lysosomal enzymes& membrane proteins. 2. Post translational modification of protein. 3. Transport protein to Golgi.	1. Synthesis of lipid & cholesterol of the cell membrane. 2. Synthesis of steroid hormones. 3. Synthesis of glycogen. 4. Detoxification of toxic substances. 5. Storage of calcium in muscles.
4. Sites	Protein secreting cells e.g. liver , fibroblasts. 	Steroid secreting cells, liver & muscles. 

1) Protein is synthesized from:

a. Peroxisomes

b. Smooth endoplasmic reticulum

c. Ribosomes

d. Lysosomes

2) Rough endoplasmic reticulum is responsible for:

a. Lipid synthesis

b. Sorting & packaging of proteins

c. Synthesis of membrane lipid

d. For formation of lysosomal enzyme

3) Highly protein secreting cells are characterized by a supranuclear unstained area which represents the presence of:

a. Rough endoplasmic reticulum

b. ribosomes

c. Golgi apparatus

d. Secretory vesicles

4) Rough endoplasmic reticulum is formed of:

a. Interconnecting membranous cisterna

b. System of membranous vesicles

c. Interconnecting microtubules

d. Membranous tubules covered by lysosomes

5) Which of the following is a feature of smooth endoplasmic reticulum?

a. A basophilic structure

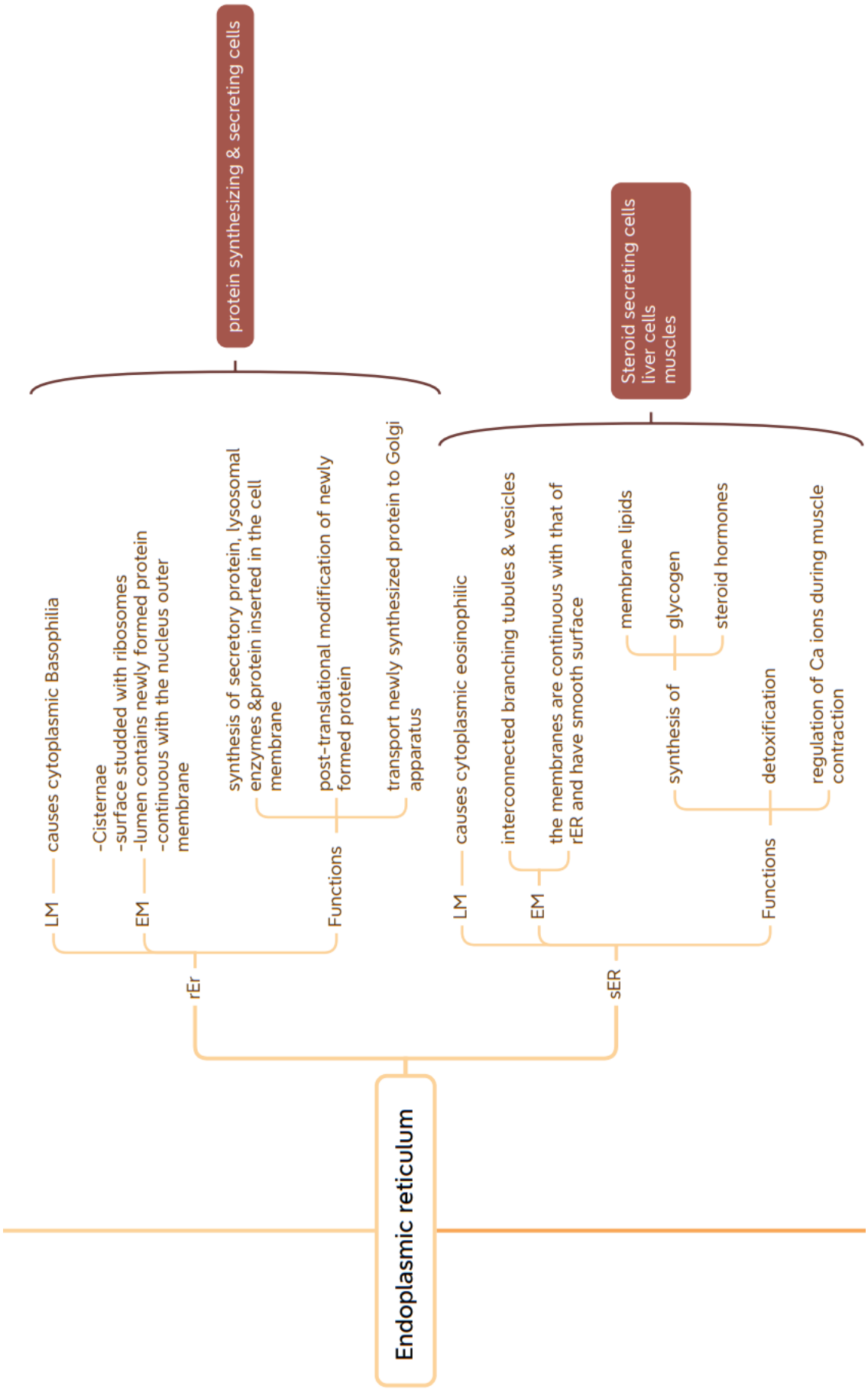
b. Covered by ribosomes

c. Continuous with nuclear membrane

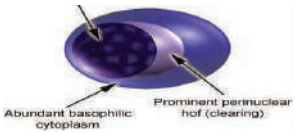
d. Interconnecting membranous tubules

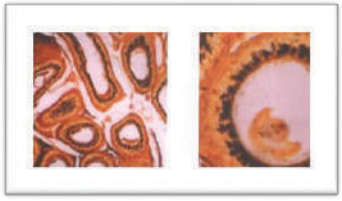
Answers:

1. C
2. D
3. C
4. A
5. D

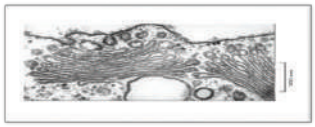

Endoplasmic reticulum
rEr
protein synthesizing & secreting cells
LM
causes cytoplasmic Basophilia
EM
-Cisternae
-surface studded with ribosomes
-lumen contains newly formed protein
-continuous with the nucleus outer membrane
Functions
synthesis of secretory protein, lysosomal enzymes &protein inserted in the cell membrane
post-translational modification of newly formed protein
transport newly synthesized protein to Golgi apparatus
sER
Steroid secreting cells
liver cells
muscles
LM
causes cytoplasmic eosinophilic
EM
interconnected branching tubules & vesicles
the membranes are continuous with that of rER and have smooth surface
Functions
membrane lipids
synthesis of
glycogen
steroid hormones
detoxification
regulation of Ca ions during muscle contraction

3. Golgi apparatus

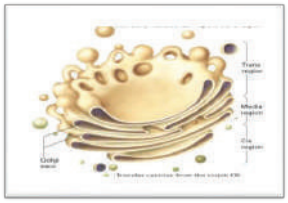




- **LM:**
  1. It is not stained with H&E in routine histological sections.
  2. H&E stained sections of the cells synthesizing protein, its site could be seen as negative Golgi image e.g. plasma cells.
  3. It can be seen in histological sections stained with silver stain.



- **EM:**
  1. It consists of saccules or cisternae called the Golgi stacks.
  2. Each stack consists of 4 6 cisternae (flattened, curved, membrane bounded, slightly expanded at the ends).
  3. The Golgi stack is cup shaped with a convex surface and a concave surface:

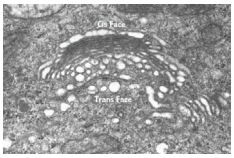


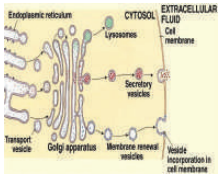
a) The cis face (forming face; immature face):
- Convex in shape.
- Lies near to the rER.
- It is the site where the transport vesicles containing the newly formed proteins from rER enter the Golgi for further processing.

b) The trans face (secretory face; mature face):
- Concave in shape.
- It is the site where the modified protein is packaged and released from the Golgi in large secretory vesicles.

c) The medial compartment: Between the cis & trans compartments.

- **Functions:**
  1. Post translational modifications of proteins e.g.removal, addition or modification of sugars
  2. Packaging of different proteins in membrane bounded vesicles.
  3. Sorting and targeting of vesicles to the right destination:
     - Formation of lysosomes.
     - Formation of secretory granules for exocytosis.
     - Membrane recycling.





- **Sites:** Protein synthesizing and secretory cells.

N.B:

Cytoplasmic Organelles that participate in the process of Protein synthesis:

1. Ribosomes (factories)
2. Rough endoplasmic reticulum (modification& transport)
3. Golgi apparatus (chemical modification,package,sorting& targeting)

1)Golgi apparatus can be stained by:

a. Silver

b. PAS

c. Sudan |||

d. Haematoxylin & eosin

2)One of the following statements is not a feature of Golgi apparatus ?

a. Formed of saccules arranged in stacks

b. Demonstrated by silver stain

c. Responsible for detoxification of drugs & hormones

d. Produce secretory vesicles and lysosomes

3) which of the following isn't related to the functions of Golgi apparatus:

a. Modification of protein

b. Concentration of protein

c. Synthesis of protein

d. Sorting & package of protein

4)Transport vesicles arises from:

a. Rough endoplasmic reticulum

b. Smooth endoplasmic reticulum

c. Golgi apparatus (GA)

d. Cell membrane

5) Golgi apparatus is very prominent in:

a. Embryonic cells

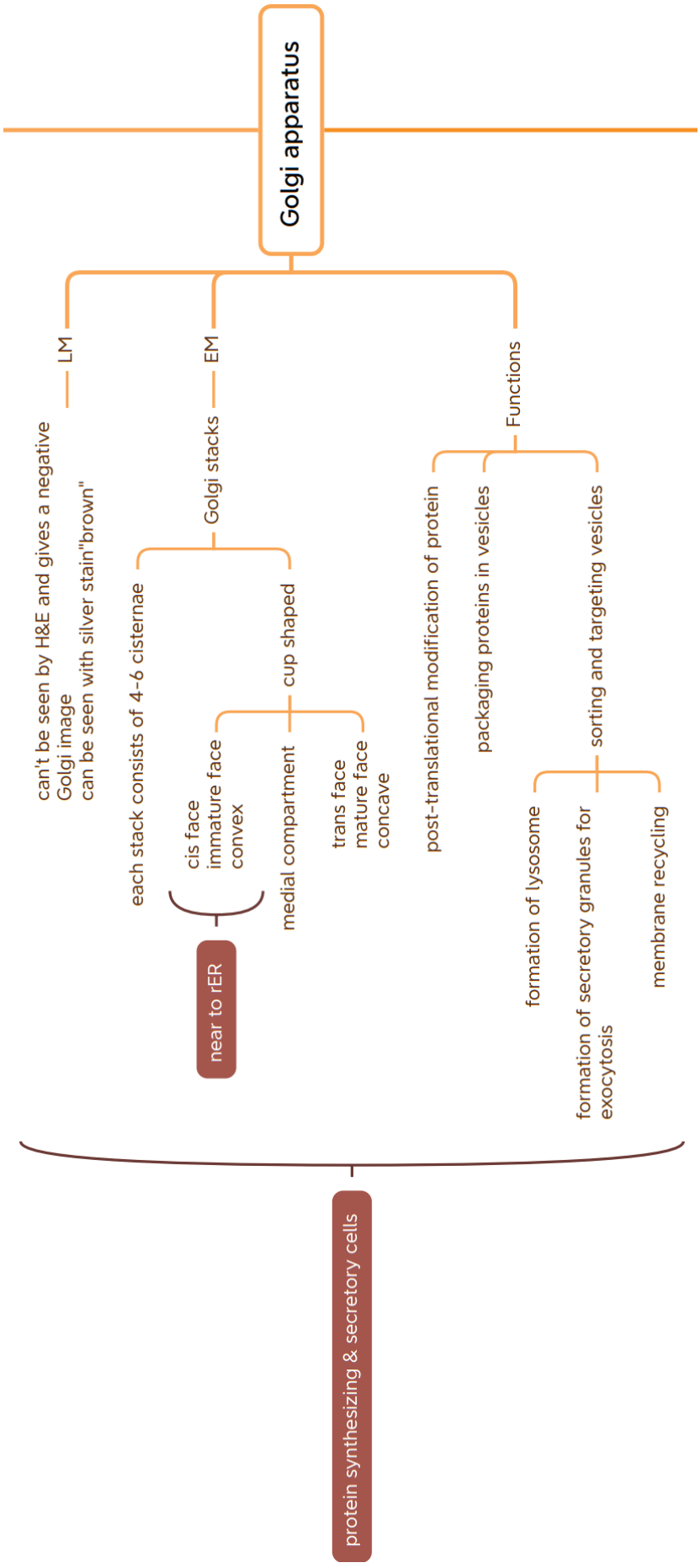
b. Erythroblasts

c. Malignant cells

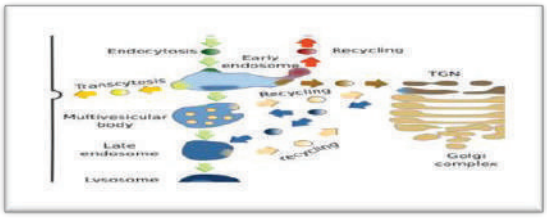
d. Plasma cells

Answers

1. A
2. C
3. C
4. C
5. D

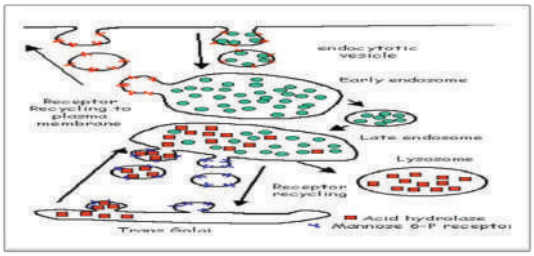

Golgi apparatus
LM
can't be seen by H&E and gives a negative Golgi image
can be seen with silver stain"brown"
EM
Golgi stacks
each stack consists of 4-6 cisternae
cup shaped
cis face
immature face
convex
near to rER
medial compartment
trans face
mature face
concave
Functions
post-translational modification of protein
packaging proteins in vesicles
sorting and targeting vesicles
formation of lysosome
formation of secretory granules for exocytosis
membrane recycling
protein synthesizing & secretory cells

4. Endosomes



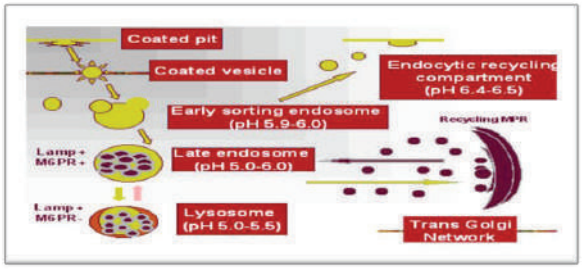
- **Definition:** are system of vesicles and tubules involved in the endocytotic pathway.
- **Types:**

A. Early endosomes:



- **Site:** at the periphery of the cell as a part in the pathway of the receptor mediated endocytosis.
- **Content:** the receptors ligands complex.
- The membrane of the endosomes pumps H+ ions into its interior → lowers the pH of endosomes to less than 6 → uncoupling of the receptors and the ligands.
- The receptors recycle to the cell membrane and the ligands move to the late endosomes.

B. Late endosomes:



- **Site:** deep within the cytoplasm near the Golgi complex.
- **They receive:**
  1. The ligands from early endosomes.
  2. Clathrin coated vesicles containing lysosomal enzymes from Golgi complex.
- **PH:** 5.5. (The enzymes become active at the acidic pH of the late endosome).
- The lysosomal enzymes in the late endosome begin to degrade the ligands accompanied by further decrease in the internal pH which then "mature" to form lysosomes.

Types of endosomes	Early endosome	Late endosome
1. Site	Periphery of cytoplasm.	Deep in cytoplasm , near Golgi.
2. Content	Receptor ligand complex.	1. Ligands from early endosome. 2. Lysosomal enzymes from Golgi.
3. Function	Uncoupling of the receptor from ligand.	Lysosomal enzymes begin to degrade ligands, then the late endosome matures to lysosome.
4. pH	Less than 6.	5.5.

1. Which of the following is a characteristic feature of early endosomes?

A) They are located near the Golgi complex.

B) They receive clathrin-coated vesicles containing lysosomal enzymes.

C) They have an internal pH of less than 6.

D) They degrade ligands into smaller molecules.

2. What triggers the uncoupling of receptor-ligand complexes in early endosomes?

A) Movement of the endosome to the Golgi complex.

B) Acidification due to H+ ions being pumped into the endosome.

C) The addition of clathrin-coated vesicles.

D) Binding of lysosomal enzymes to the ligands.

3. What is the fate of receptors after they are uncoupled from ligands in early endosomes?

A) They are sent to the Golgi complex.

B) They are degraded by lysosomal enzymes.

C) They are recycled back to the cell membrane.

D) They mature into lysosomes.

4. What do late endosomes primarily receive from the Golgi complex?

A) Receptor-ligand complexes.

B) Clathrin-coated vesicles containing lysosomal enzymes.

C) Proton pumps that decrease internal pH.

D) Vesicles containing receptors for recycling.

5. At what stage in the endocytic pathway does degradation of ligands begin, and what promotes this process?

A) Early endosome; pH drops below 6.

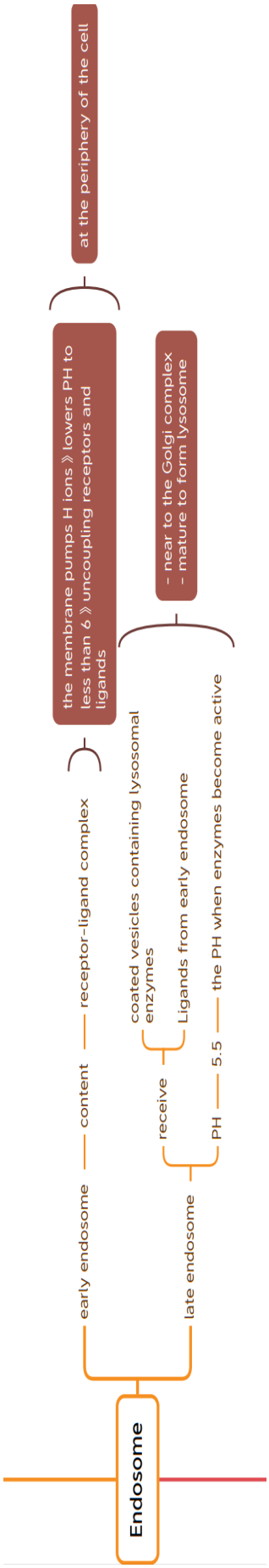
B) Early endosome; lysosomal enzymes become active.

C) Late endosome; pH decreases to 5.5, activating lysosomal enzymes.

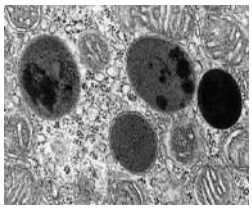
D) Late endosome; ligands are recycled to the cell membrane.

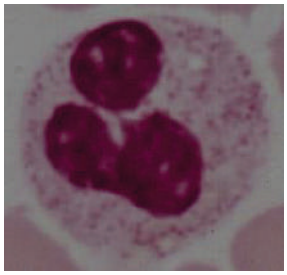
Answers

1. C
2. B
3. C
4. B
5. C

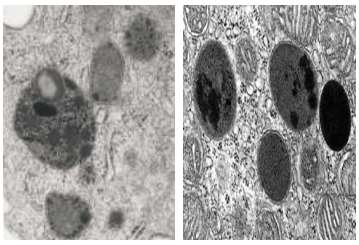

Endosome
early endosome
content
receptor-ligand complex
the membrane pumps H ions ⟫ lowers PH to less than 6 ⟫ uncoupling receptors and ligands
at the periphery of the cell
late endosome
receive
coated vesicles containing lysosomal enzymes
Ligands from early endosome
PH
5.5
the PH when enzymes become active
- near to the Golgi complex
- mature to form lysosome

5. Lysosomes

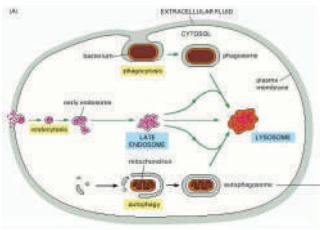




- **Definition:** membrane bounded organelle containing about 40 types of acid hydrolytic digestive enzymes (proteases, nucleases, phosphatases, and lipases).
- **Function:** They are responsible for intracellular digestion of different materials.
- **Synthesis:** by a gradual maturation process as by fusion of the clathrin coated vesicles coming from Golgi complex with late endosomes.
- Lysosome has a surrounding membrane with unique phospholipids & specialized glycoproteins line the lysosomal membrane from inside that prevents:
  1. The leak out of the enzymes to the cytoplasm.
  2. Protects the membrane from hydrolysis by its own enzymes.
     - If a lysosome leaks its contents, the released enzymes would be inactive because of neutral pH of the cytoplasm.

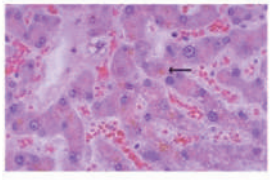


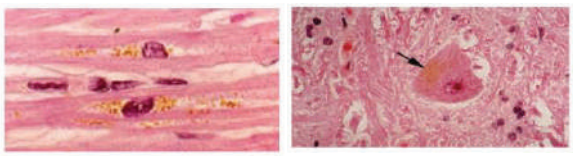
- **LM:** They can be recognized by several histochemical methods used to demonstrate the lysosomal enzymes.
- **EM:** Lysosomes are heterogeneous in shape and the appearance of their interior. Some are electron dense, others show electron lucent areas.
- **Site:** are abundant in phagocytic cells.



Pathways for intracellular digestion by lysosomes:

1. **Extracellular small particles:** internalized by pinocytosis and receptor mediated endocytosis → early endosome → late endosome where the endocytosed materials are degraded by the lysosomal hydrolases.
2. **Extracellular large particles:** are engulfed in the process of phagocytosis → forms a phagosome → fuses with a late endosome.
3. **Intracellular particles:** are removed by a process called autophagy → the enclosure of this organelle by membranes from sER → forms an autophagosome → fuses with a late endosome.
   - The hydrolytic enzymes digest most of the content of the lysosomes.
   - Any indigestible substances remain in lysosomes forming residual bodies.
   - In long lived cells, accumulated residual bodies indicate cellular aging and are called lipofuscin pigments.





1) which of the following statement isn't related to the lysosomes :

a. Could be identified by histochemical reactions

b. Abundant in plasma cells

c. It is heterogeneous

d. PH 5 is optimum for activity of their enzymes

2) Lysosome is present in:

a. Macrophage

b. Neutrophil

c. Phagocytic cell

d. All the above

3) Cells that are actively involved in phagocytosis of extra cellular material would contain highly levels of:

a. rER

b. sER

c. Lysosomes

d. Ribosomes

4) Vesicle enclosed by single membrane, for intracytoplasmic digestion:

a. Peroxisome

b. Lysosome

c. Golgi

d. Ribosome

5) All hydrolytic enzymes in lysosome except:

a. Phospholipase

b. Acid phosphatase

c. Nuclease

d. Oxidase

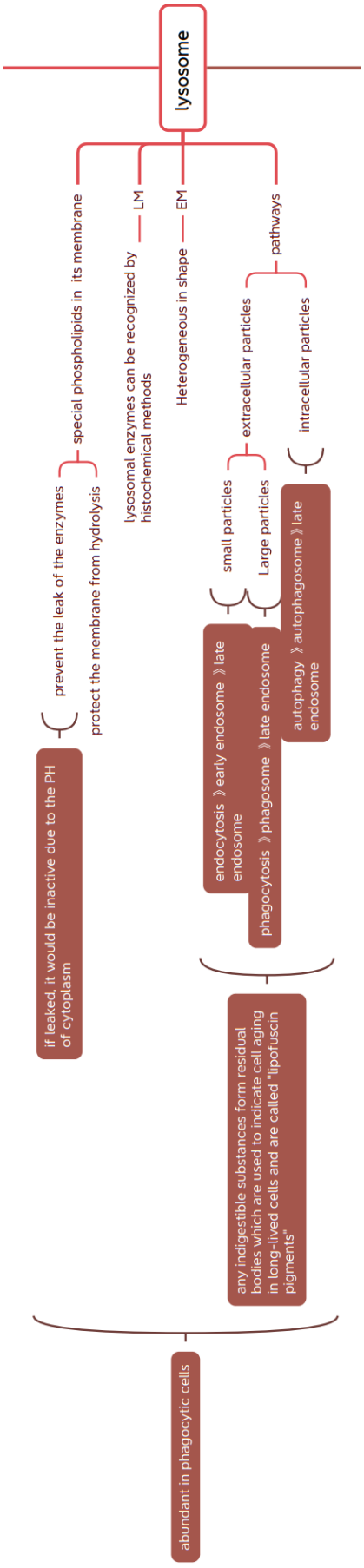
1-B

2-D

3-C

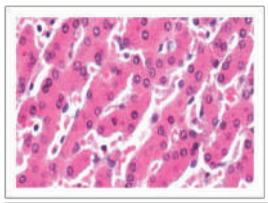
4-B

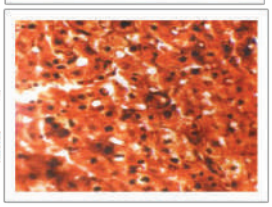
5-D


lysosome
abundant in phagocytic cells
any indigestible substances form residual bodies which are used to indicate cell aging in long-lived cells and are called "lipofuscin pigments"
if leaked, it would be inactive due to the PH of cytoplasm
prevent the leak of the enzymes
protect the membrane from hydrolysis
special phospholipids in its membrane
lysosomal enzymes can be recognized by histochemical methods
LM
Heterogeneous in shape
EM
endocytosis 》early endosome 》late endosome
phagocytosis 》phagosome 》late endosome
autophagy 》autophagosome 》late endosome
small particles
Large particles
extracellular particles
intracellular particles
pathways

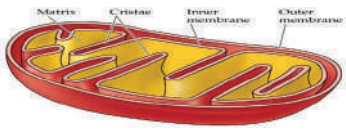
6. Mitochondria

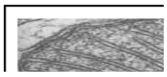
- **Function:** Powerhouses of the cell as they are the sites of adenosine triphosphate (ATP) production.
- **Sites:** All cells EXCEPT terminal keratocytes & RBCs.
- **Structure:**
- **LM:** When present in large numbers contribute to the cytoplasmic eosinophilia (due to large amount of membrane they contain).





- **EM:**

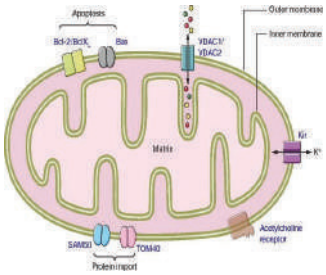




a. Membrane bounded organelles.

b. Surrounded by two membranes: outer and inner, which define two mitochondrial compartments:
   - The intermembranous space: between the two membranes.
   - The matrix space: enclosed by the inner membrane.

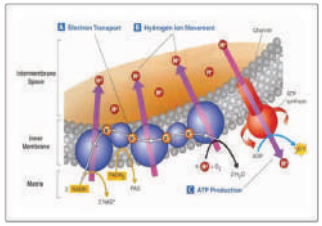
1. The outer mitochondrial membrane



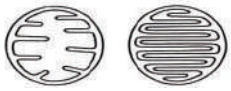
- It is smooth and porous.
- **Function:** allows passage of small molecules due to the presence of specific transmembrane proteins called porins.

2. The inner mitochondrial membrane

a. Folded into cristae which increase its surface area; the number of cristae is greater in cells of greater demand for ATP.



- **Types of cristae:**
  - **Lamellar cristae:** most of cells.
  - **Tubular cristae:** steroid secreting cells.

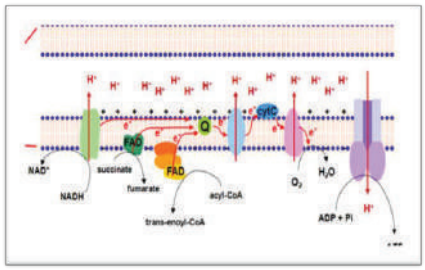


b. Impermeable to ions and small molecules due to presence of phospholipid called cardiolipin.

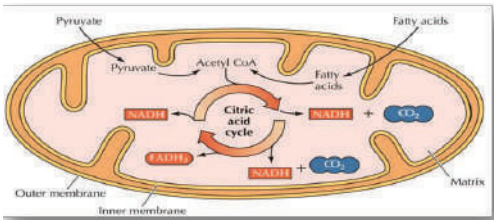
- **Function:** contains the enzymes of the electron transport system (respiratory chain enzymes) and the ATP synthase (known as elementary particles attached to the cristae and their heads are projecting toward the matrix like a lollypop).

3. Intermembranous space

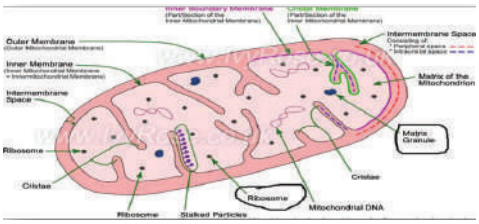
- Contains substances diffusing from the cytoplasm through the outer membrane and ions pumped out of the matrix space through the inner membrane.



4. Matrix space

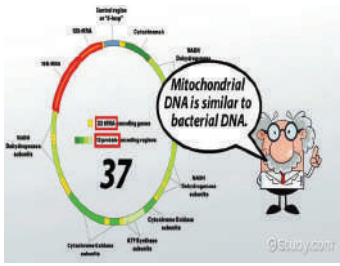


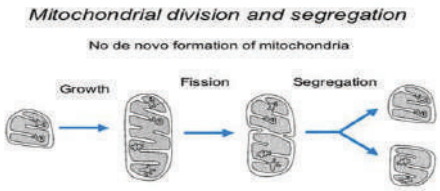
- Surrounded by the inner mitochondrial membrane.
- **Functions:**
  a. Enzymes involved in mitochondrial functions as citric acid cycle.
  b. Mitochondrial DNA and few ribosomes.
  c. Matrix granules: store calcium ions, play a role in mitochondrial regulation of Ca 2+ intracellular concentration.



The genetic system of mitochondria:

- **The mitochondrial DNA:**
  a. A circular molecule.
  b. Limited coding capacity.
  c. Represents 1% of the total DNA of the cell.
- **Function:** Mitochondria can synthesize some of their structural proteins by their own RNAs.
  - Most of the mitochondrial proteins are encoded by the nuclear DNA and are synthesized in the cytoplasm and imported into mitochondria.
  - Mitochondria are self replicating organelles.

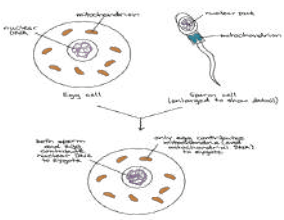




How do mitochondria adapt to its function? (E/M)

a. **Outer membrane:** smooth &porous contains mitochondrial porins allow easy passage of small molecules.
b. **Inner membrane** is folded into numerous cristae → increase surface area for energy production.
c. **Inner membrane** contains cardiolipin → make it highly impermeable to ions & small molecules.
d. **Matrix space:** contains enzymes for citric acid cycle, mito DNA & ribosomes→ synthesize some of their structural proteins, also contains matrix granules→ store Ca thus play an important role in regulation of intracellular Ca concentration.

What is your source of mitochondria?



1)Which of the following organelles are the powerhouse of the cell ?

a. Ribosomes
b. Mitochondria
c. Golgi apparatus
d. Endoplasmic reticulum

2)Mitochondrial DNA isn't characterized by which of the following:

a. It is a single standard
b. It is similar to that of bacterial chromosome
c. It has a circular structure
d. It is synthesized within the mitochondrion

3)Which one of the following statements is not related to mitochondria?

a. They are membranous organelles
b. They can be stained by Janus green B-stain
c. They are the powerhouse of the cell
d. Their outer membrane is provided with cristae

4)Enzymes of oxidative phosphorylation for ATP production present in the:

a. Mitochondria
b. Secondary lysosomes
c. Primary lysosomes
d. Rough ER

5) Mitochondria ATpase enzyme is mainly located in :

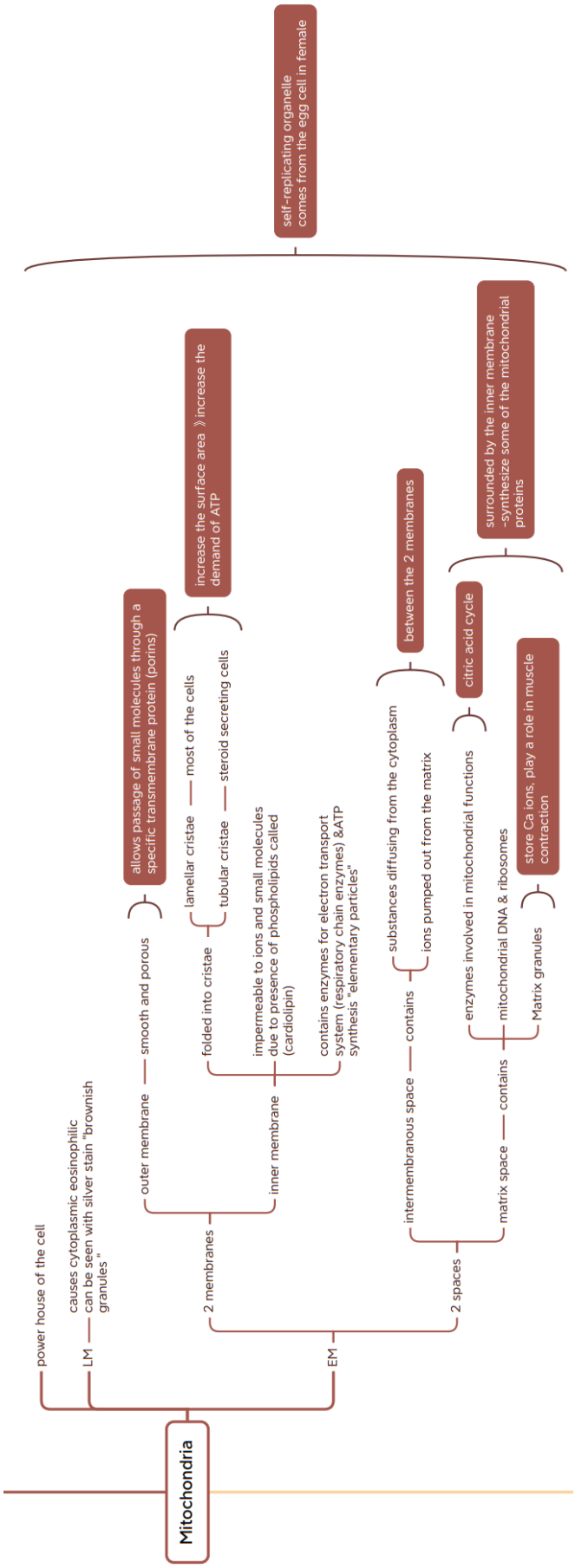
a. Intercristae space
b. External membrane
c. Matrix space
d. Cristae

6) In which Type of Cells Mitochondria has Tubular Cristae ?

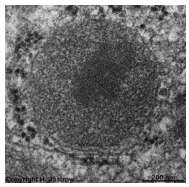
a. Protein Synthesis cells
b. Steroid Secreting Cells
c. Glycogen Synthesis Cells
d. Cardiac muscle Cells

Answer

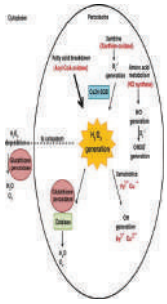
1. B
2. A
3. D
4. A
5. D
6. B

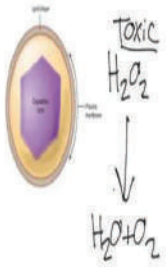

Mitochondria
power house of the cell
LM
causes cytoplasmic eosinophilic
can be seen with silver stain "brownish granules"
EM
2 membranes
outer membrane
smooth and porous
allows passage of small molecules through a specific transmembrane protein (porins)
inner membrane
folded into cristae
lamellar cristae
most of the cells
tubular cristae
steroid secreting cells
increase the surface area ⟫ increase the demand of ATP
impermeable to ions and small molecules due to presence of phospholipids called (cardiolipin)
contains enzymes for electron transport system (respiratory chain enzymes) &ATP synthesis "elementary particles"
2 spaces
intermembranous space
contains
substances diffusing from the cytoplasm
ions pumped out from the matrix
between the 2 membranes
matrix space
contains
enzymes involved in mitochondrial functions
citric acid cycle
mitochondrial DNA & ribosomes
Matrix granules
store Ca ions, play a role in muscle contraction
surrounded by the inner membrane
-synthesize some of the mitochondrial proteins
self-replicating organelle
comes from the egg cell in female

7. Peroxisome

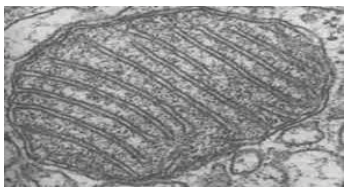
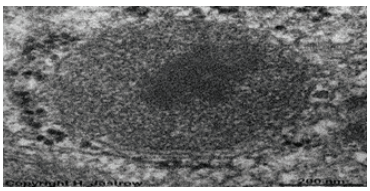


- **Definition:** membrane bounded organelles that contain oxidative enzymes.
  - Peroxisomes possess no genetic material of their own.
- **Structure of Peroxisome**
- **LM:** They are not seen by H&E stain.
- **EM:**
  a. Small, spherical bodies with fine granular electron dense content.
  b. Surrounded by a single membrane.





- **Functions of peroxisomes**
  a. **β oxidation of long chain fatty acids to release energy.** However, they differ from mitochondria in that they are unable to store this energy in the form of ATP. This energy is released as heat to maintain body temperature.
  b. **Generation of hydrogen peroxide,** which detoxifies toxic agents.
  c. **Contain catalase enzyme** that converts the excess hydrogen peroxide into water, thus protecting the cell.
  d. **Detoxification of alcohol** in cooperation with the smooth endoplasmic reticulum in the liver.

	Mitochondria	Peroxisome
1. LM	▪ Not seen by H&E except in large amount cause cytoplasmic acidophilia. ▪ By special stain (silver stain) appear as brownish granules.	Not seen.
2. EM	**Double membrane:** outer is smooth, and inner is folded into cristae enclosed matrix space.	Single membrane enclosed fine granular contents.
3. Function	Production of energy & store it in the form of ATP.	1. Produce energy & released it in the form of heat (unable to store it). 2. Produce hydrogen peroxide. 3. Convert excess hydrogen peroxide into water. 4. Detoxification of toxic substances.
4. Sites	All body cells except red blood cells & keratinocytes.	Many cells especially liver
5. Genetic material	Present 	Absent 

1)which of the following isn't true regarding to Peroxisomes:

a. Dispersed in the cytoplasm association with SER

b. Produced hydrogen peroxide

c. Contain catalase enzyme

d. Originate from lysosomes

2) which of the following isn't related to the functions of peroxisome:

a. Beta oxidation of long chain fatty acids

b. Energy that comes out as heat and not stored as ATP

c. 2H2Oz(toxic)+catalase□H2O+O2 □H2O+O2

d. Digest nutrients, fertilization

e. Oxidases are important in liver cells for detoxification

3. Which of the following correctly describes the energy release during β-oxidation of long-chain fatty acids in peroxisomes?

A) Energy is stored in the form of ATP.

B) Energy is released as heat to maintain body temperature.

C) Energy is transferred to the mitochondria for ATP production.

D) Energy is stored within the peroxisome for later use.

4. What role does catalase play in the function of peroxisomes?

A) It facilitates the generation of hydrogen peroxide for detoxification.

B) It breaks down long-chain fatty acids into ATP.

C) It converts excess hydrogen peroxide into water to protect the cell.

D) It detoxifies alcohol in cooperation with the rough endoplasmic reticulum.

5. Which of the following is TRUE regarding the structure and visibility of peroxisomes?

A) Peroxisomes can be visualized using H&E staining under a light microscope.

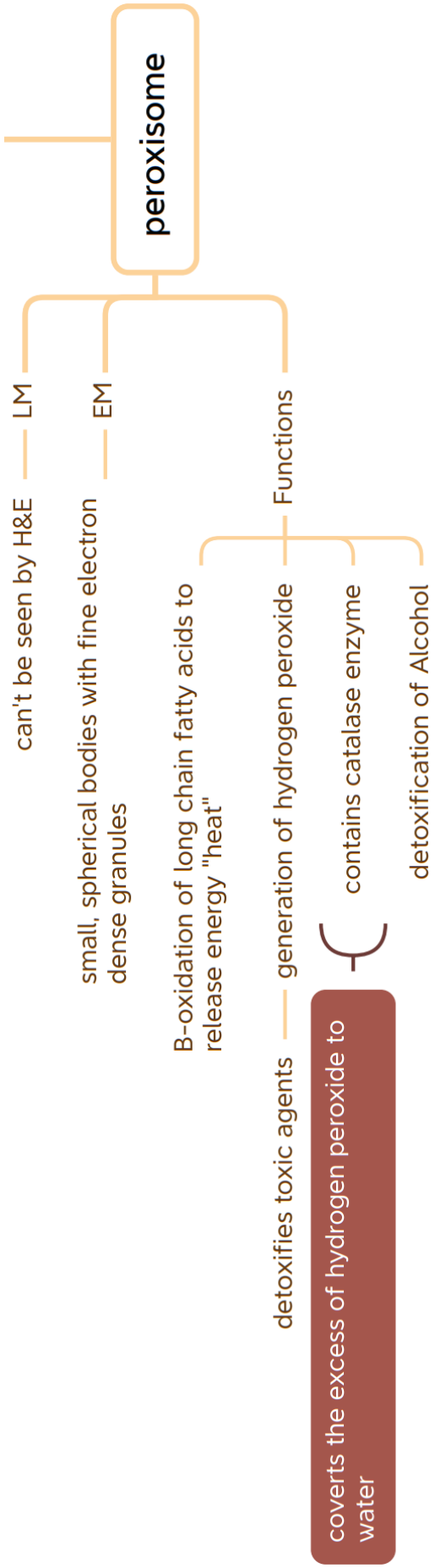
B) They have a single membrane and are filled with electron-lucent content.

C) They appear as small spherical bodies with fine granular electron-dense content under an electron microscope.

D) Peroxisomes contain their own genetic material for enzyme production.

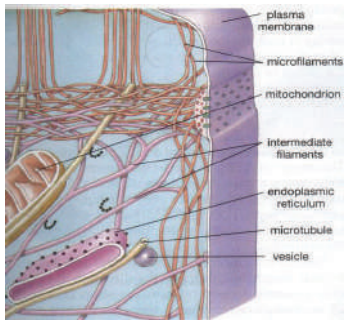
Answer

1-D
2-C
3-B
4-C
5-C


peroxisome
LM
can't be seen by H&E
EM
small, spherical bodies with fine electron dense granules
Functions
B-oxidation of long chain fatty acids to release energy "heat"
detoxifies toxic agents
generation of hydrogen peroxide
contains catalase enzyme
detoxification of Alcohol
coverts the excess of hydrogen peroxide to water

8. Cytoskeleton

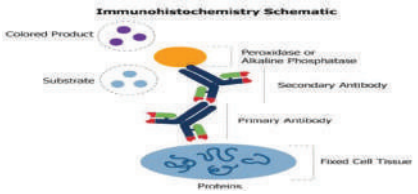
- The cytoskeleton is a network of structural proteins (non-membranous cell organelles).
- **Types of cytoskeletons:**



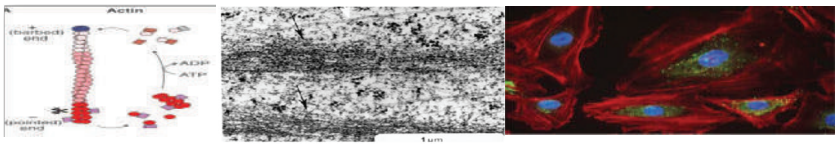
3 types, depending on their thickness& their structural proteins:

1. Microfilaments (actin filaments)

- **Diameter:** 7 nm.
- **LM:** can be visualized by using immunohistochemical staining.
- **EM:** thin electron dense filaments.
- **Structural proteins:** monomers of G actin (globular actin) polymerize to form F actin (filamentous actin) arranged as a double helix.



- They are dynamic structures that can elongate & shorten.
- **Functions of microfilaments:**

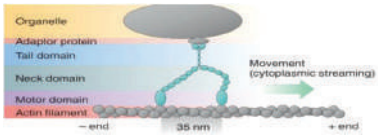


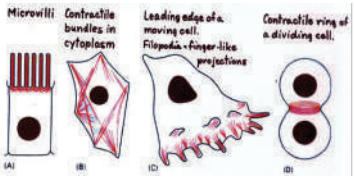
A. Cell motility for:

- Cell migration.
- Cytoplasmic streaming: during movement of organelles and transport of vesicles.
- Cytokinesis: formation of contractile ring during cell division.
- Muscle contraction associated with myosin.

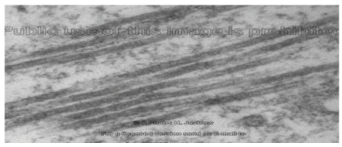
B. Structural role:

- Maintenance of the cell shape.
- Formation the core of microvilli.

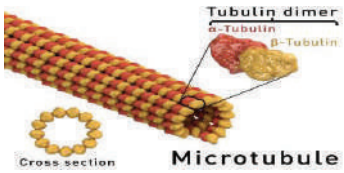


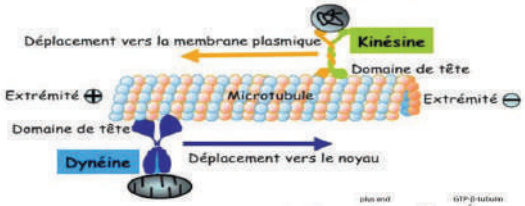


2. Microtubules

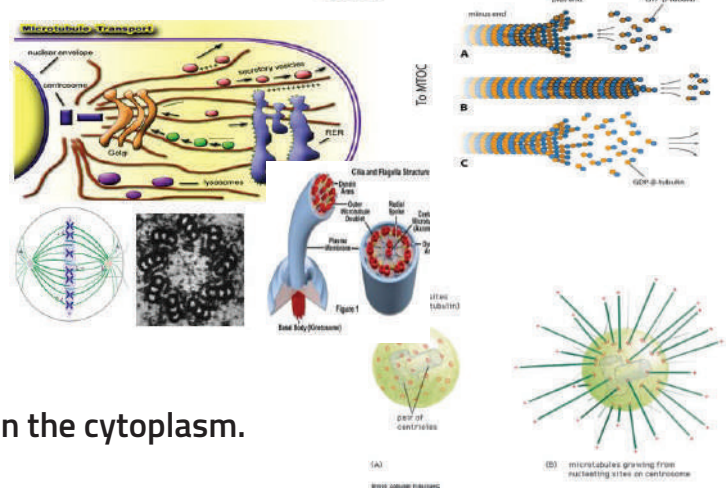


- **Diameter:** 25 nm.
- **LM picture:** by using immunohistochemical staining.
- **EM picture:** fine tubules.
- **Structural proteins:**
  A. A globular protein dimer called tubulin (each is composed of alpha and beta subunits).
  B. Chains of tubulin dimers form a protofilament.
  C. The wall of a microtubule is made up of 13 protofilaments that run longitudinally.

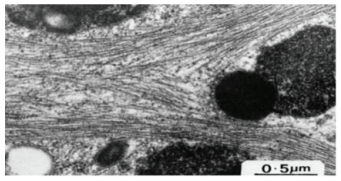




- **Motor proteins associated with microtubules:** Kinesin & dynein; they use ATP to provide energy for movement of vesicles and organelles along the microtubules.

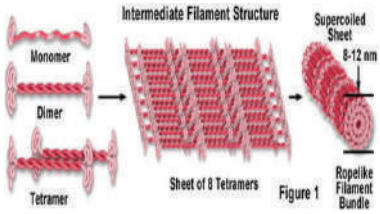


- **Microtubules are dynamic structures;** can elongate & shorten
- **Functions of microtubules:**
  a. **Transport:** of organelles & vesicles in the cytoplasm.
  b. **Structural role:**
     - Formation of the mitotic spindle.
     - Formation of centrioles, cilia & flagella.

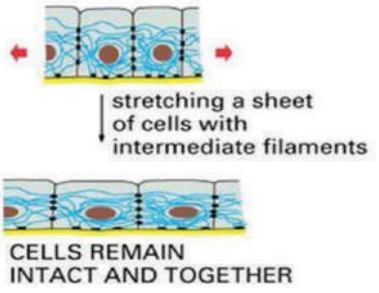


- **The microtubule organizing centers:**
  a. Centriole which forms the mitotic spindle.
  b. The basal bodies of cilia and flagella.

3. Intermediate filaments :



- **Diameter:**10 nm
- **LM:** by using immunohistochemical staining.
- **EM:** electron dense filaments thicker than actin filaments.
- **Structural proteins:** like woven ropes.
- **Function of intermediate filaments:** They are the most stable (not dynamic) types of the cytoskeletons thus they play a structural role .



1)which of the following isn't considered one of the intermediate filaments:

a. Desmin

b. Myosin

c. Vimentin

d. Cytokeratin

2)which of the followings isn't considered a membranous organelle:

a. Mitochondria

b. Filaments

c. Lysosomes

d. Golgi apparatus

3) Complex network of microtubule, intermediate filaments, microfilaments:

a. Ribosome

b. Proteasome

c. Lysosome

d. Cytoskeleton

4) Fixed diameter with 13 protofilaments, their length varies according to tubulin:

a. Microtubule

b. Intermediate filaments

c. Microfilaments

5) Which type of Cytoskeleton form mitotic Spindle:

a. Intermediate filament keratin

b. Microfilaments

c. Microtubule

d. Intermediate filament lamin

Answer

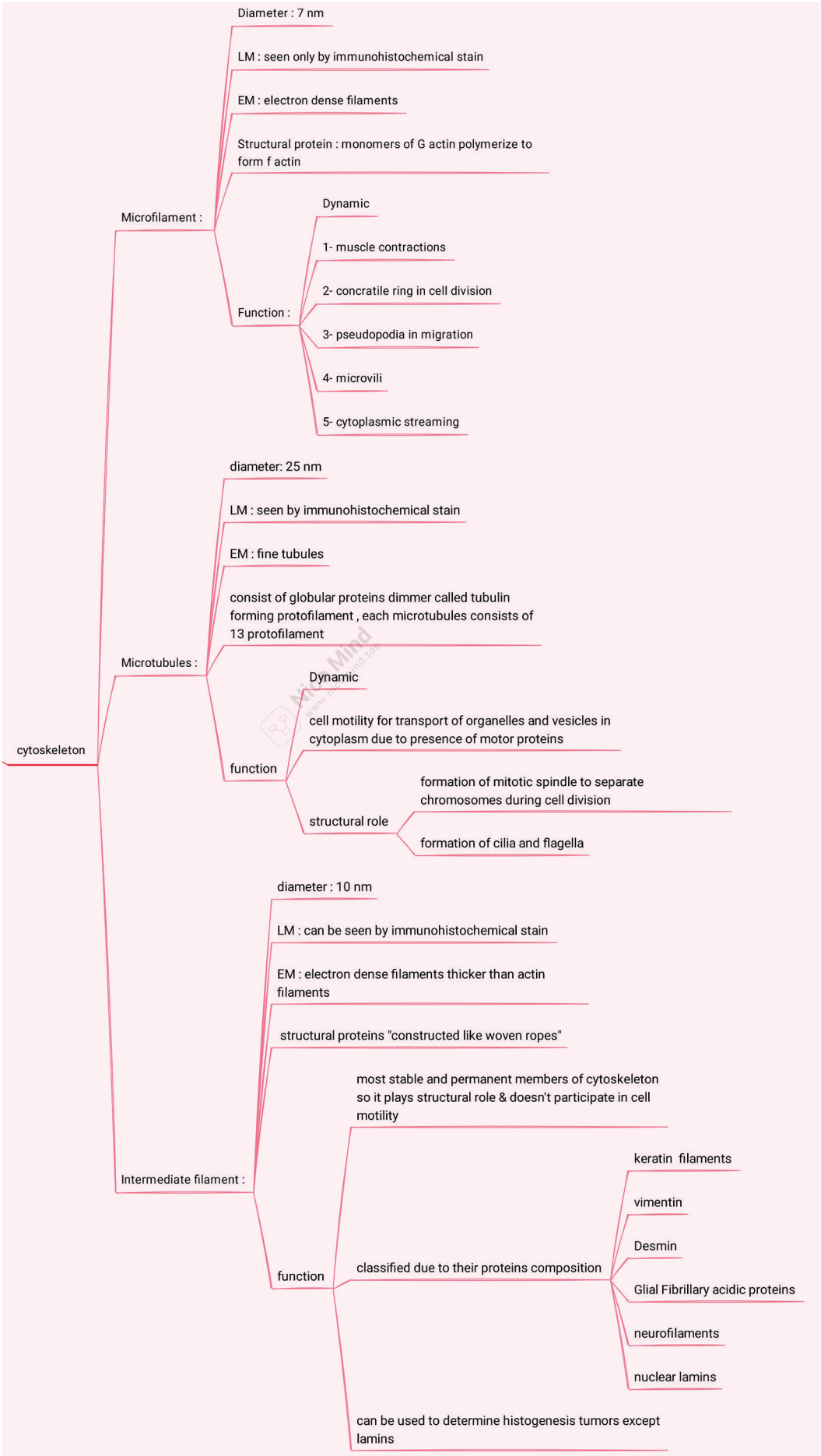
1-B

2-B

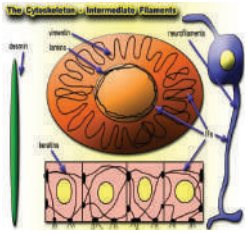
3-D

4-A

5-C


cytoskeleton
Microfilament :
Diameter : 7 nm
LM : seen only by immunohistochemical stain
EM : electron dense filaments
Structural protein : monomers of G actin polymerize to form f actin
Function :
Dynamic
1- muscle contractions
2- concratile ring in cell division
3- pseudopodia in migration
4- microvili
5- cytoplasmic streaming
Microtubules :
diameter: 25 nm
LM : seen by immunohistochemical stain
EM : fine tubules
consist of globular proteins dimmer called tubulin forming protofilament , each microtubules consists of 13 protofilament
function
Dynamic
cell motility for transport of organelles and vesicles in cytoplasm due to presence of motor proteins
structural role
formation of mitotic spindle to separate chromosomes during cell division
formation of cilia and flagella
Intermediate filament :
diameter : 10 nm
LM : can be seen by immunohistochemical stain
EM : electron dense filaments thicker than actin filaments
structural proteins "constructed like woven ropes"
function
most stable and permanent members of cytoskeleton so it plays structural role & doesn't participate in cell motility
classified due to their proteins composition
keratin filaments
vimentin
Desmin
Glial Fibrillary acidic proteins
neurofilaments
nuclear lamins
can be used to determine histogenesis tumors except lamins

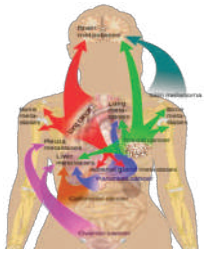
Classification Of Intermediate Filaments:



- **According to their protein composition and their cellular distribution into:**

A. Cytoplasmic:

1. **Keratin:** epithelial cells.
2. **Vimentin:** in the cells of mesenchymal origin e.g., fibroblasts.
3. **Desmin:** muscle cells.
4. **Glial fibrillary acidic protein:** neuroglia.
5. **Neurofilaments:** nerve cells.

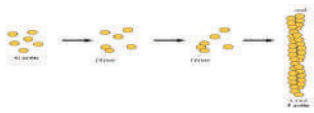
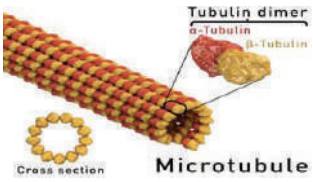
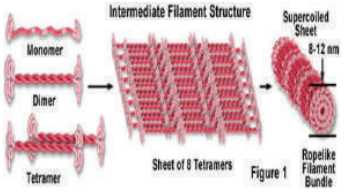


B. Nuclear:

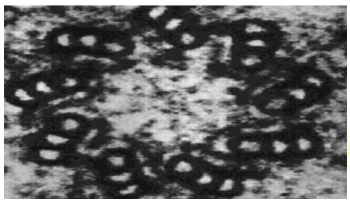
- **Lamins:** lining the inner nuclear envelope.

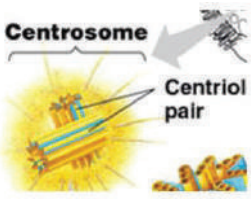
N.B:

The intermediate filaments (except for the lamins) are located in specific tissue types; they can be used to determine the origin of cancer by immunohistochemical staining.

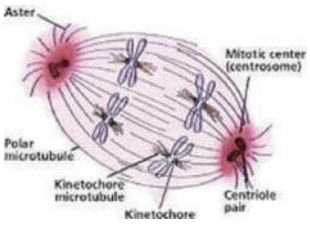
Cytoskeleton	Microfilaments	Microtubules	Intermediate filaments
1. Diameter	7 nm.	25 nm.	10 nm.
2. LM	Seen only by immunohistochemistry.	Seen only by immunohistochemistry.	Seen only by immunohistochemistry.
3. EM	Thin electron dense filaments.	Fine tubules.	Thicker electron dense filaments.
4. Structural proteins	Monomers of G actin polymerize to form F actin.	Tubulin dimer polymerize to protofilaments. 13 protofilaments form a microtubule,	Woven ropes.
5. Functions	**Dynamic** 1. Muscle contraction. 2. Contractile ring in cell division. 3. Pseudopodia in migration. 4. Microvilli. 5. Cytoplasmic streaming. 	**Dynamic.** 1. Transport of organelles & vesicles. 2. Formation of centrioles, cilia & flagella. 	**Not dynamic.** Structural support. 

Centrosome

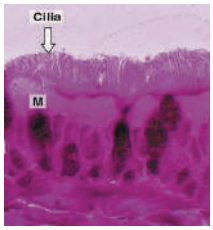




- **Definition:** a non membranous organelle.
- **EM:**
  1. It is formed of 2 centrioles, perpendicular to each other.
  2. Each centriole is composed of 9 triplets of microtubules (a sum of 27 microtubules).
  3. Each triplet is composed of three microtubules (one complete; formed of 13 protofilaments and 2 incomplete; each is formed of 10 protofilaments).

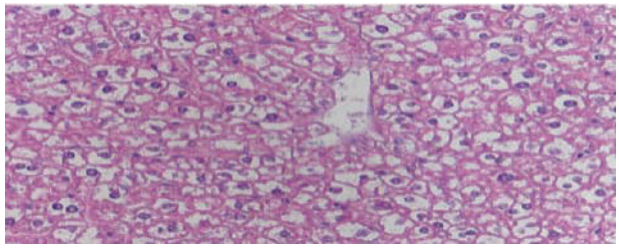


- **Functions of centrosome:**
  1. It is the microtubule organizing center.
  2. Formation of mitotic spindles.
  3. Formation of cilia & flagella.

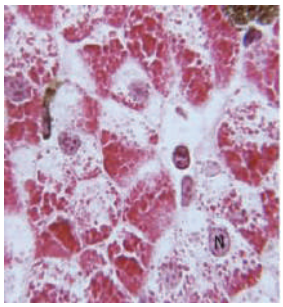


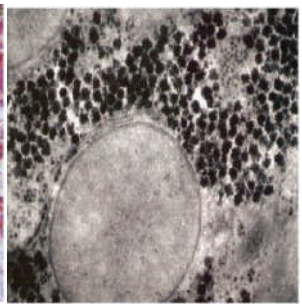
Cytoplasmic Inclusions

1. **Stored Food:**

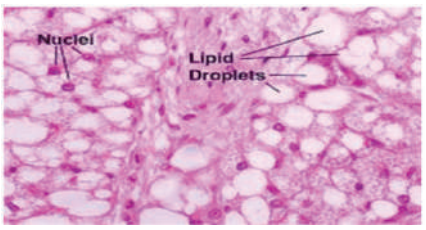


   A. Glycogen
   - Storage form of carbohydrates.
   - **Function:** source of energy.
   - **Sites:** mainly in liver & muscle cells.
   - **LM:**
     - **H&E:** not visualized as they dissolve during preparation of the specimen leaving a pale vacuolated cytoplasm.
     - **Periodic acid Schiff:** appears magenta red.
     - **Best's carmine:** appears bright red.
   - **EM:** dense granules, larger than ribosomes.
     In cytoplasm of hepatocytes, glycogen appears as rosette shaped aggregates

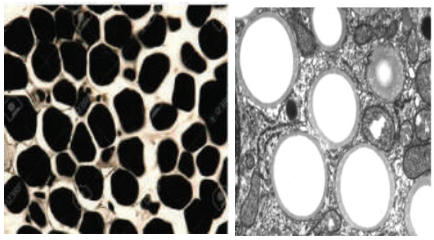




B. Lipids

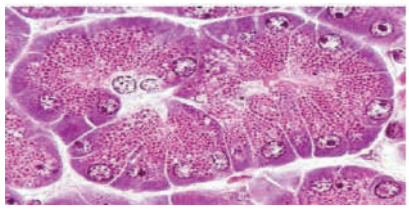


- **Function:**
  1. Source of energy.
  2. Synthesis of membranes & steroid hormones.
- **Sites:** stored in the adipocytes; many other cell types contain few small lipid droplets.
- **LM:**
  - H&E: not visualized because they dissolve during preparation of the specimen leaving a pale vacuolated cytoplasm.
  - Osmium tetroxide: appear black.

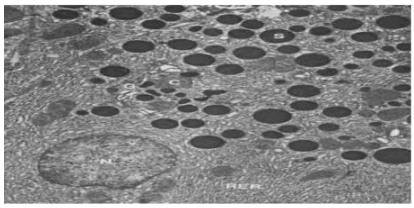


- **EM:** grey non membrane bounded small droplets or large globules.

C. Proteins

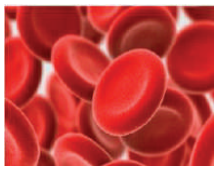


- **Site:** in protein synthesizing cells e.g. salivary gland and pancreas.
- **LM:** eosinophilic zymogen granules.
- **EM:** homogenous electron dense membrane bounded secretory granules.

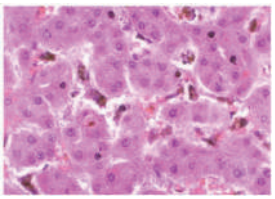


2. Pigments:

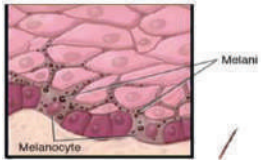
A. Endogenous pigments



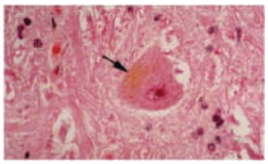
1. **Hemoglobin:** in red blood cells.
2. **Hemosiderin:** brownish granules in phagocytic cells of liver and spleen following phagocytosis of old RBCs.

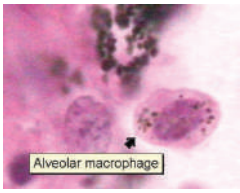


3. **Melanin pigment:** brown to black granules.



4. **Lipofuscin pigment:** yellow brown pigment present in cells with long life span.





B. Exogenous pigments

1. **Tattooing:** colored pigments are injected into the deep layers of the skin.
2. **Dust & smokes:** in lung of smokers and people living in polluted areas.

1. Which of the following accurately describes the structure of a single centriole in the centrosome?

A) 9 pairs of microtubules, each made up of 13 protofilaments.

B) 9 triplets of microtubules, with one complete microtubule and two incomplete microtubules.

C) 27 microtubules, each formed from 13 protofilaments.

D) 9 doublets of microtubules, each with 10 protofilaments.

2. Which function of the centrosome is related to its role as the microtubule-organizing center?

A) Formation of cilia and flagella.

B) Generation of cellular energy.

C) Packaging of proteins into vesicles.

D) Detoxification of alcohol.

3. What is the arrangement of the two centrioles in the centrosome?

A) They are parallel to each other and surrounded by a membrane.

B) They are perpendicular to each other and surrounded by a membrane.

C) They are parallel to each other and composed of 9 pairs of microtubules.

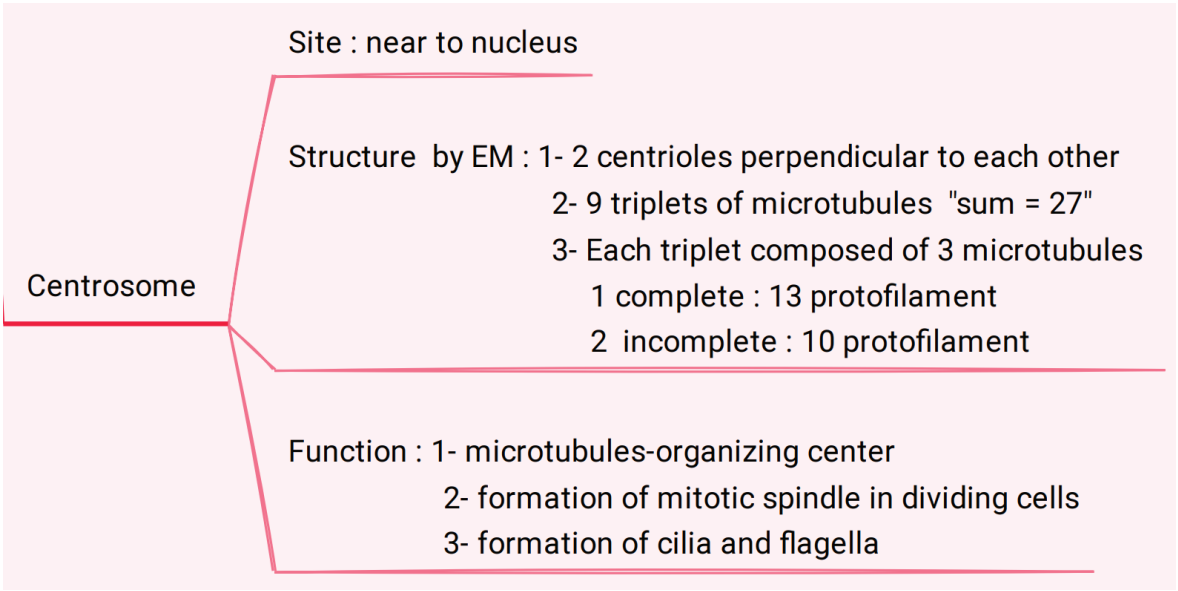
D) They are perpendicular to each other and are non-membranous.

Answer

1-B

2-A

3-D



1)Which of the following is an exogenous pigment?

a. Lipochrome pigment

b. Melanin pigment

c. Haemoglobin

d. Dust pigment

2)Which one of the following structures increases with age?

a. Ribosomes

b. Mitochondria

c. Lysosomes

d. Lipofuscin pigment

3)The only endogenous pigment of the following:

a. Carotene

b. Dust particles

c. Carbon particles

d. Melanin

4)which of the following isn't considered one of the inclusions:

a. Glycogen

b. Melanin

c. Ribosomes

d. Fat

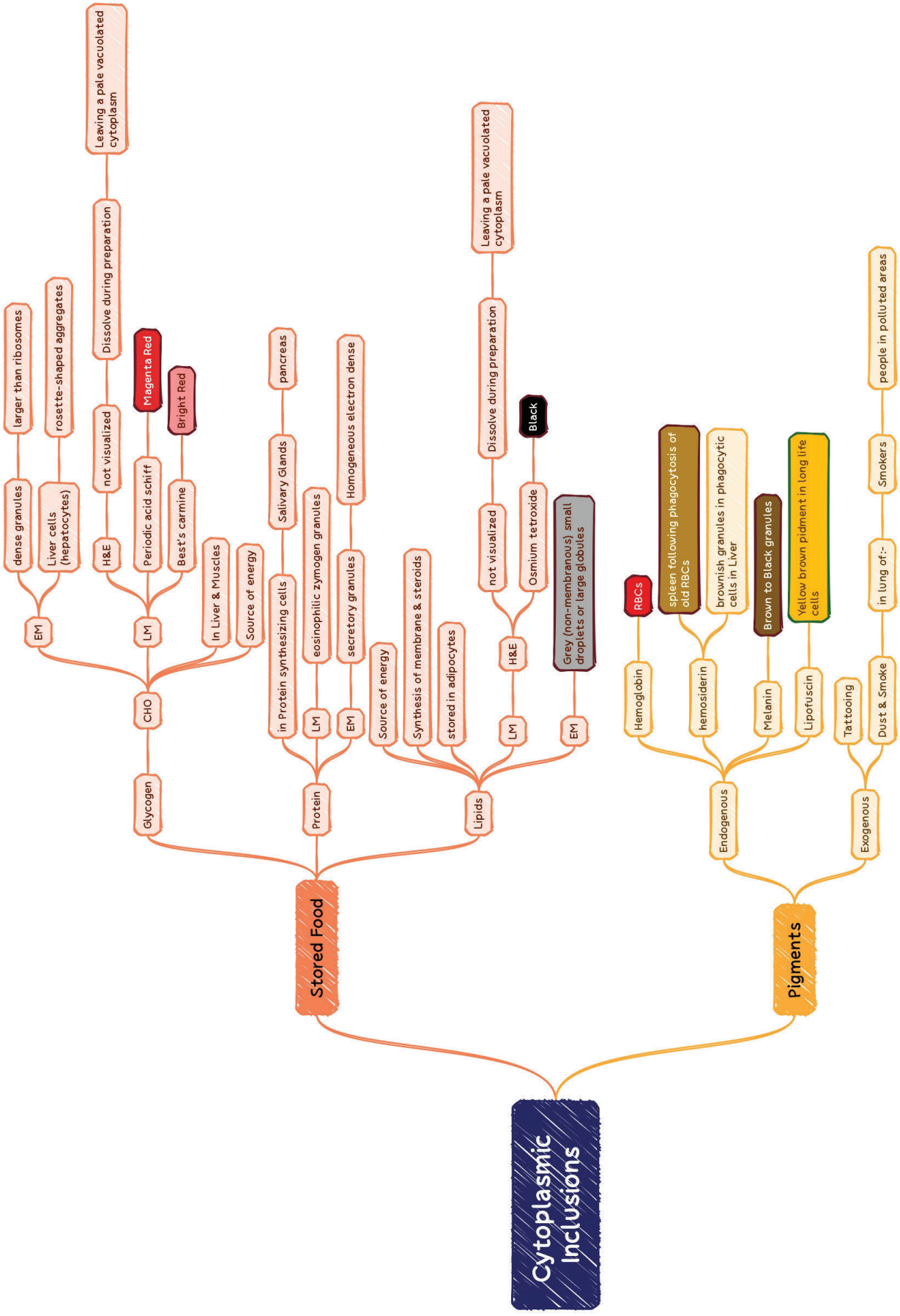
Answer

1-D

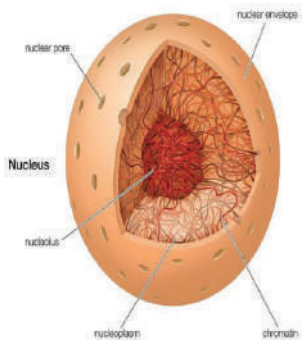
2-D

3-D

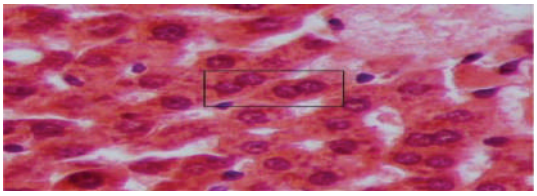
4-C



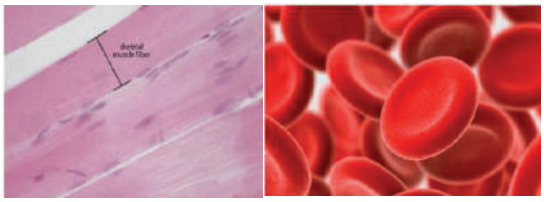
Nucleus



- It is the largest membranous organelle of the cell.
- **Functions:**
  1. It contains the chromosomes.
  2. Contains the machinery for DNA replication& RNA transcription.
- **Number:**
  1. **Single:** most of the cells.
  2. **Binucleated:** liver cells.
  3. **Multinucleated:** skeletal muscle fibers.
  4. **Absent:** RBCs.

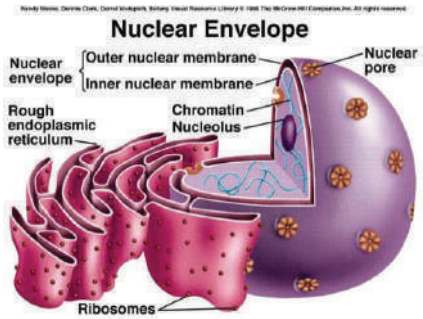


Cytoplasmic Inclusions



A. The Nuclear Envelope:

- It consists of two parallel membranes; outer & inner separated by the perinuclear cisterna.
- It is perforated by the nuclear pores which provide a channel between the nucleus and cytoplasm.

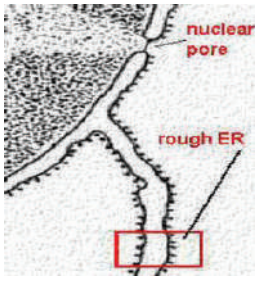


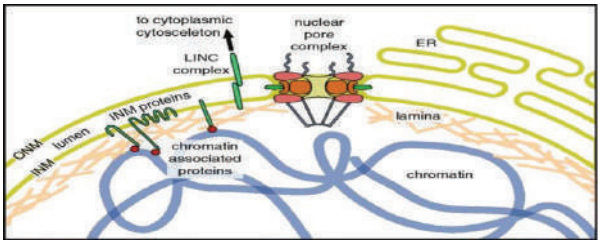
1. The outer membrane:

- It is continuous with the rough endoplasmic reticulum. It is covered with ribosomes on its outer surface.
- **Function:** The ribosomes synthesize the transmembrane proteins of the nuclear membranes.

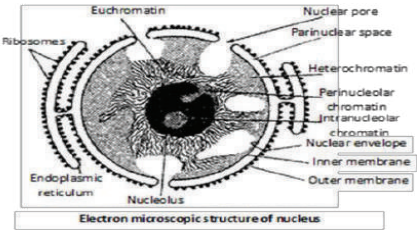
2. The inner membrane:

- It is supported at its inner surface by the lamins.
- **Functions of the lamin:**
  1. Supports the nuclear envelope.
  2. Influences chromosome distribution and function.



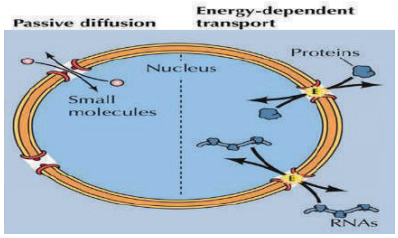


3. The nuclear pores:

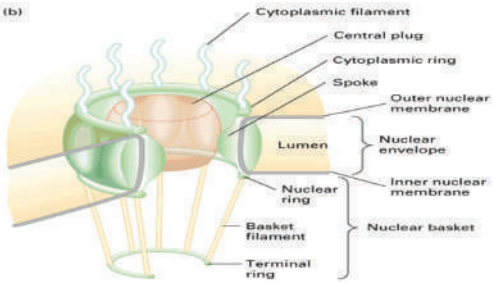


Electron microscopic structure of nucleus

- **Definition:** They are perforations in the nuclear envelope where the outer and inner nuclear membranes fuse.
- **Distribution:** not uniformly distributed.
- **Number:** vary according to the cell activity.
- **Function:** provide a bidirectional channel through which the nucleus and cytoplasm communicate.

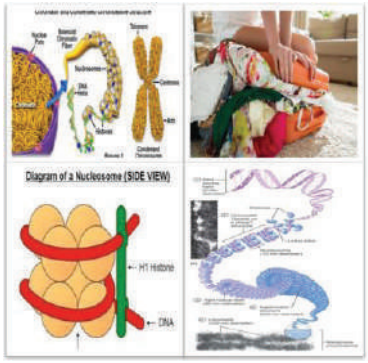


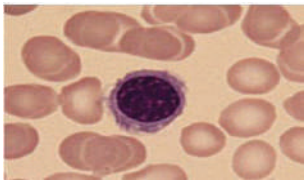
Nuclear Pore Complex →



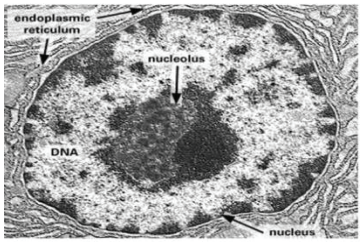
B. The Chromatin

- It is formed of DNA + histone proteins.
- **DNA is extensively packaged in chromatin as:**
  1. A segment of the DNA is wrapped two times around eight histone proteins to form a nucleosome. Each nucleosome is separated from the next by a region of linker DNA.
  2. Repeating nucleosomes with intervening DNA (linker DNA) form a 10 nm fiber (beads on a string).
  3. This chain of nucleosomes is packed to form a 30nm fiber.
  4. Higher orders of packaging gives the compact structure 700nm seen in the metaphase of the dividing cell known as the chromatid of a chromosome.

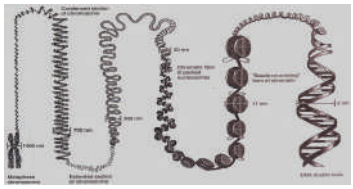




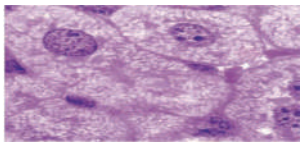
- **Types of chromatins:**
  1. **Heterochromatin (condensed chromatin; the inactive chromatin):**
     - **LM:** appears as dense basophilic clumps.
     - **EM:** appears as condensed filaments or granules distributed in the following
     - **Sites:**
       - **Nucleolar associated heterochromatin:** around the nucleolus.
       - **Peripheral heterochromatin:** at the inner nuclear membrane(associated with the nuclear lamin).
       - **Heterochromatin islands:** swimming in the nuclear sap.
     - **Function:** transform into euchromatin when needed.



2. Euchromatin (extended chromatin; the active chromatin)

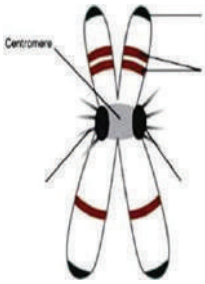


- **LM:** appears as lightly stained basophilic areas.
- **EM:** appears as dispersed filaments or granules.
- **Function:** It is stretched so, the genetic information in the DNA can be transcribed.
- The proportion between euchromatin and heterochromatin differs from one cell to another according to its activity.

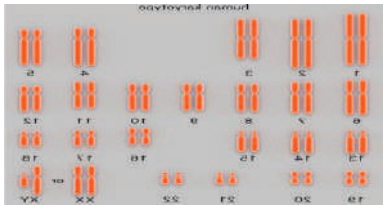


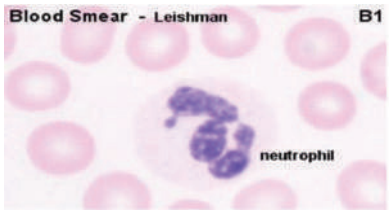
Types of chromatin	Heterochromatin	Euchromatin
1. LM	Dense basophilic clumps.	Lightly stained basophilic areas.
2. EM	**Electron dense filaments or granules distributed in:** 1. Around nucleolus. 2. Associated with inner nuclear membrane. 3. Swimming in nuclear sap.	Dispersed fine filaments or granules.
3. Function	Inactive part acts as a reserve (transformed into euchromatin when needed).	Active part (transcribed into RNA).
4. Sites	Inactive cells.	Active cells e.g., dividing cells.

- **Chromosome**
  - **During cell division:** chromatin is condensed into the chromosomes; formed from two chromatids held together at the centromere. Each chromatid is formed of a single DNA molecule.

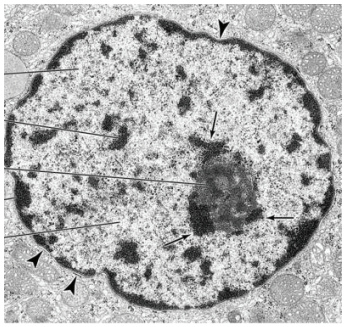


- **Karyotyping**
  - The somatic cell contains 46 chromosomes.
  - **Karyotyping:** is the arrangement of the chromosomes during metaphase into groups of homologous pairs (22 homologous pairs of autosomes and one pair of sex chromosomes).
  - **In females (44 autosomes +XX):** one X chromosome is heterochromatic
  - (Barr body), it can be identified in neutrophils, attached to the nucleus in the form of a drumstick mass.





C. The Nucleolus

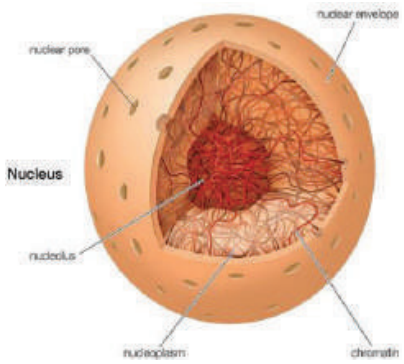


- **Definition:** It is a spherical body with no surrounding membrane.
- **Number:** single or multiple.
- **Function:** it is the site of formation of ribosomal RNA.

These rRNA's are packaged with their associated protiens to form ribosomal subunits that are exported to the cytoplasm via nuclear pores to start protein synthesis

D. The Nucleoplasm (nuclear matrix; sap)

- **Definition:** It is a colloidal protein solution
- **Function:** provides a medium for the rapid diffusion of metabolites.



1) Largest component of the cell, not present in RBCs:

a. Nucleolus
b. Nucleus
c. Cytoplasm
d. Chromatin

2) Nucleus may be :

a. Mononucleated
b. Binucleated
c. Multinucleated
d. All the above

3) Nuclear membrane :

a. Basophilic
b. Double walled membrane
c. Interrupted by pores
d. All the above

4) which of the following isn't related to the properties of Heterochromatin:

a. Coiled, inactive chromatin
b. Inactive gene, electron dense
c. In small lymphocyte
d. Active in protein forming cell

5) Site of heterochromatin:

a. Attached to inner envelope
b. Scattered in nuclear sap
c. Around nucleolus
d. All the above

6) which of the following isn't related to the properties of Euchromatin :

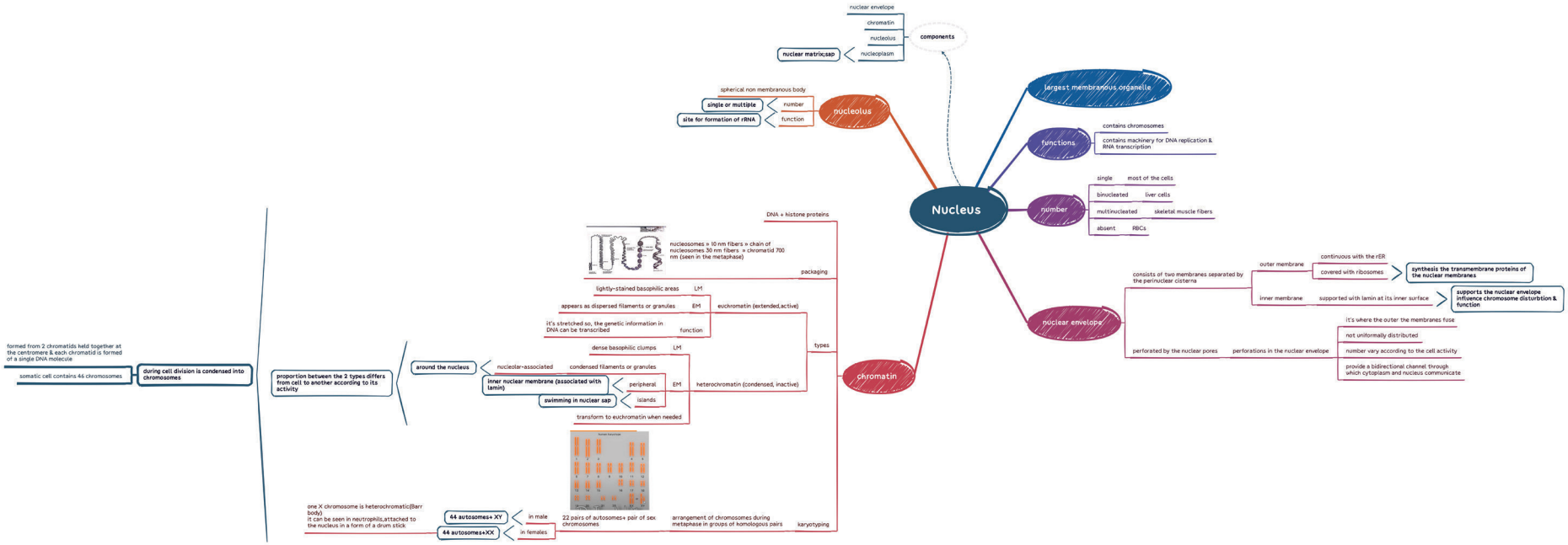
a. Extended, uncoiled
b. Active gene
c. Coarse clumps, dark basophilic
d. Electron lucent, clear nucleolus

7) Which of the follow best describes the nuclear envelope

a. It has few nuclear pores in active cell
b. It has uniformly distributed nuclear pores
c. It is supported from the inside by nuclear lamina

Answer

1-B
2-D
3-D
4-D
5-D
6-C
7-C



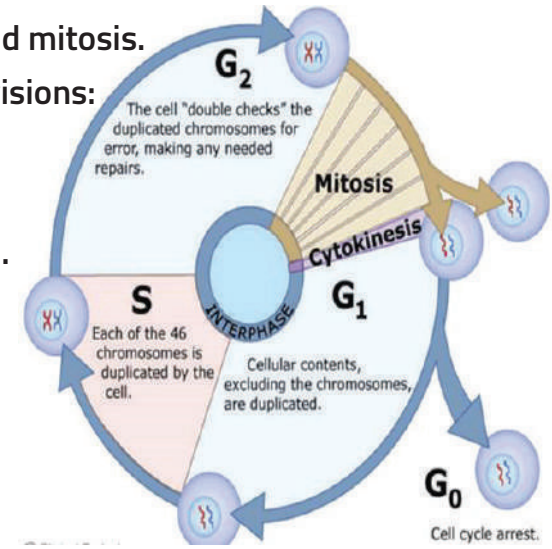
Cell Cycle & Cell Division

The Cell Cycle:

- **Definition:** it is the alternation between interphase and mitosis.

I. Interphase: a longer period between two mitotic divisions:

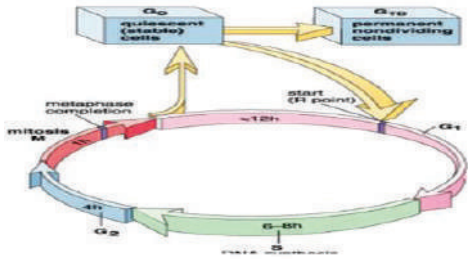
1. The cell increases in size.
2. Performs its normal functions.
3. Replicates its DNA for preparing itself for division.



II. Mitosis: a shorter period during which parent cell gives 2 daughter cells each containing the same number of chromosomes (identical to the parent cell = 46 chromosomes).

I-Interphase (الطور البينى):

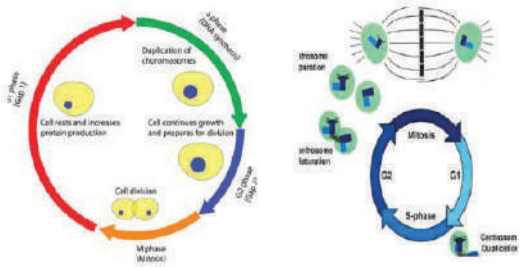
First gap phase (G 1 phase)



- **It is the longest period of the cell cycle between the end of mitosis and the beginning of DNA replication:**

1. The RNA and protein synthesis occurs.
2. The cell attains its full size.
3. The cell performs its function.
4. Duplication of centrosomes occurs near the transition between G1 and S phase.

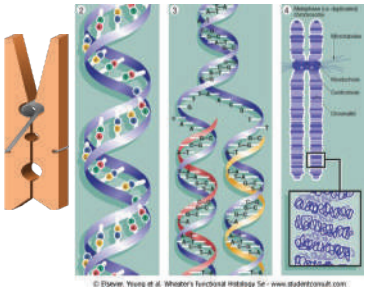
The GO phase:



- **Definition:** Differentiation of the cell to carry out specialized function and no longer divide (outside the cycle).
- GO may be permanent or temporary.

DNA synthesis phase (S phase):

- Replication of DNA, thus the amount of DNA is doubled but not the total chromosomal number.

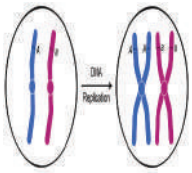


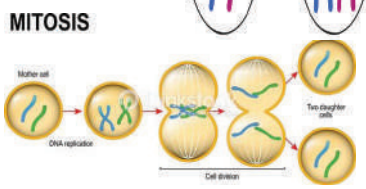
Types of chromosomes:

- **S - Chromosomes** made of one DNA molecule (interphase chromosomes = chromatin or chromatids).
- **D - C hromosomes** (mitotic chromosomes):are formed during the S phase.

  Each d chromosome is formed of two chromatids, linked at the centromere.

  Each chromatid is made of a DNA molecule.

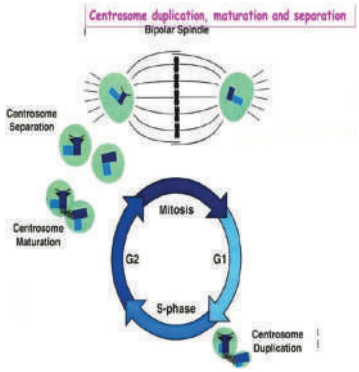




Second gap phase (G2 phase):

- It starts by the end of the DNA replication and lasts until the beginning of mitosis.

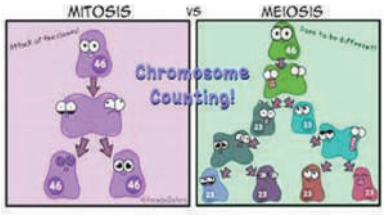
  1. Proteins and energy essential to mitosis are stored.
  2. Duplication of the centrosome is completed.



Cell Division:

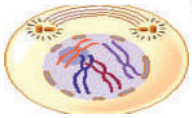
Mitosis

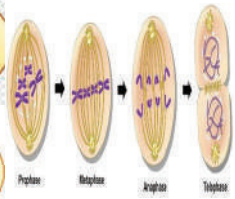
- **Definition:** division of the somatic cell into two daughter cells identical to the mother cell.
- **Function:**
  1. Growth & development of the organism.
  2. Renewal & repair of cells.

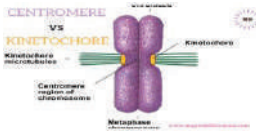


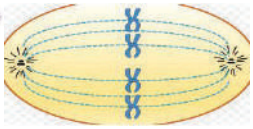
A. Prophase الطور التمهيدي :

1. The nucleolus disappears.
2. Condensation of chromatin gives rise to 46 rod shaped short d chromosomes.
3. Each pair of centrioles migrates to opposite pole of the cell forming the mitotic spindles.
4. The nuclear envelope breaks up into small vesicles







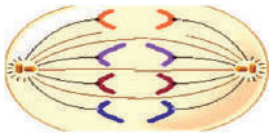


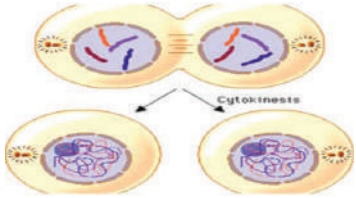
B. Metaphase الطور الاستوائي:

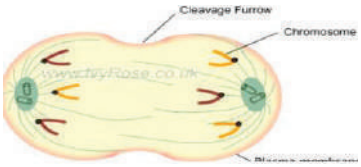
1. The 46 d chromosomes become maximally condensed.
2. The chromosomes aligned at the equatorial plate of the cell.
   - Each pair of sister chromatid is attached to the mitotic spindles at the kinetochore.

C. Anaphase الطور الانفصالي :

1. Division of the centromere results in the separation of the sister chromatids.
2. Each 46 chromatids migrate toward the opposite poles of the cell.
3. In late anaphase, a constriction (cleavage furrow) develops at the equatorial plate of the cell.

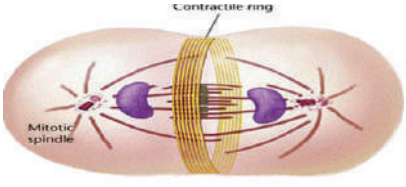


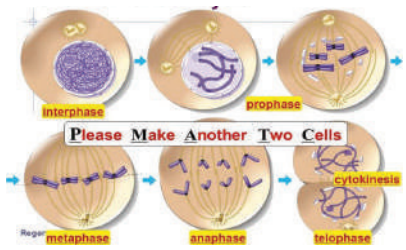




D. Telophase الطور النهائى:

1. The mitotic spindle disappears.
2. The nucleolus reappears.
3. The chromosomes start uncoiling (46 s chromosomes).
4. The nuclear envelope is reformed around the new sets of chromosomes.
5. Division of the cytoplasm (cytokinesis): the cleavage furrow becomes deeper due to the formation of a contractile ring of microfilaments until it divides the cytoplasm and its organelles in half resulting into two daughter cells.



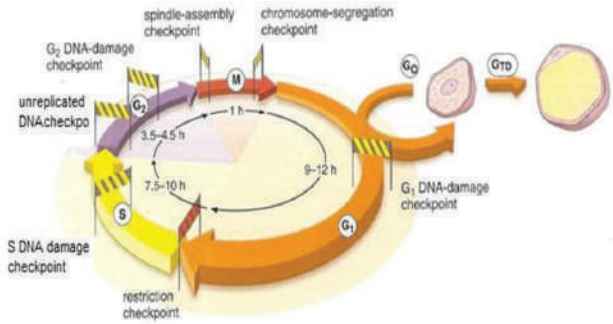


Regulation of the cell cycle:

- The cell cycle is regulated by growth factors that control cell proliferation to keep its coordination with the needs of the living organism.
- Several checkpoints control the transition between the cycle stages.
- Checkpoints detect external or internal problems and stop the cycle until the problem solved.

Checkpoints of the cell cycle:

1. The restriction checkpoint:



- It occurs in the G1 phase.
- It detects the cell size & its interactions with the surrounding environment.
- Cells that do not receive appropriate growth stimuli do not progress past this point (G1 phase) and will be die by apoptosis.
- It is the most important checkpoint in the cell cycle.

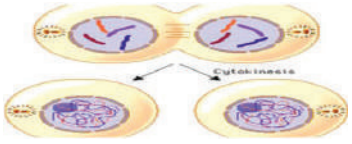
2. DNA damage checkpoints:

- It occurs in G1, S, and G2 phases.
- It blocks cell cycle progression until repair of the damaged DNA or cell apoptosis occurs.

3. The unreplicated DNA checkpoint:

- It occurs in the G2 phase.
- It prevents progression of the cycle into the mitosis before complete synthesis of DNA.

4. The spindle assembly checkpoint (the metaphase checkpoint):

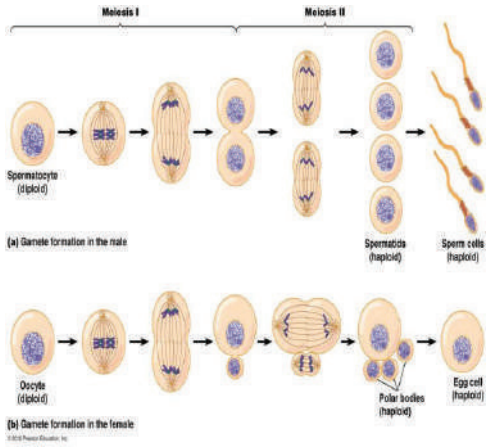


- It occurs in mitosis.
- It prevents entry into anaphase until all chromosomes have attached properly to the mitotic spindle.

5. The chromosome segregation checkpoint:

- It occurs in telophase.
- It prevents the cytokinesis until all of the chromosomes have been correctly separated.

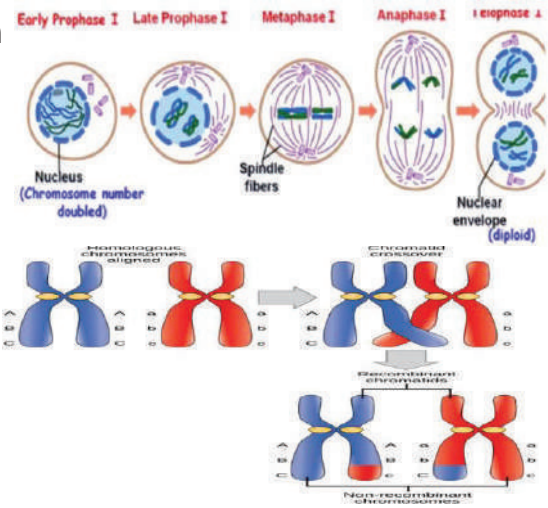
Meiosis



- It occurs in germ cells and results in the formation of gametes.
- It results in formation of 4 daughter cells (each contains 23 s chromosomes=haploid number).
- **It consists of two successive divisions:** without an intervening S phase.

I. First meiotic division (reductional division):

- It is preceded by interphase with an S phase, in which the chromosomes are replicated (46 s chromosomes → 46 d chromosomes).



1. Prophase I:

A. Pairing of the homologous chromosomes occurs forming tetrads(bivalent).

B. Crossing over occurs between the chromatids of the homologous chromosomes so that each homologous chromosome is no longer solely paternal or maternal but a mixture of both.

C. The nucleolus and the nuclear envelope disappear, and the mitotic spindle is formed.

2. Metaphase I:

- The paired chromosomes arrange themselves at the equatorial plate of the cell.

3. Anaphase I:

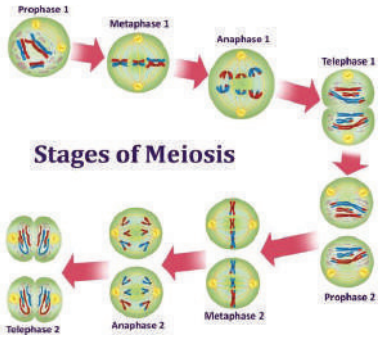
- The centromeres do not divide, instead, each chromosome of homologous pairs moves separately towards the opposite poles of the cell.

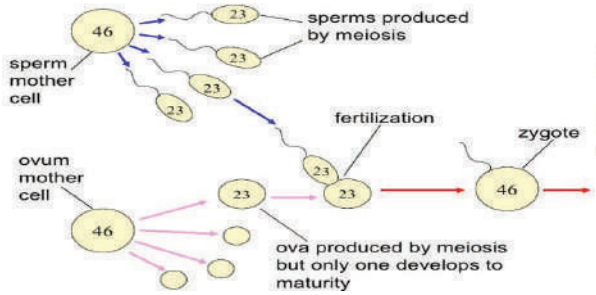
4. Telophase I:

- Cytokinesis occurs results in two daughter cells each containing the haploid number (23d chromosomes).

II-Second meiotic division (equatorial division):

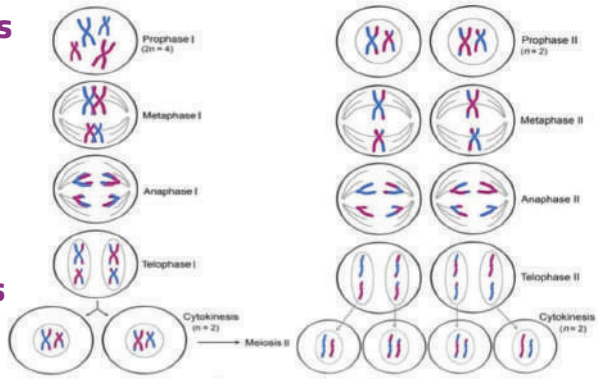
- It is similar to mitosis but, it is not preceded by S phase.
- It results in formation of 4 daughter cells, each contains 23 s chromosomes (haploid number).





46 d chromosomes

23 d chromosomes



23 S chromosomes

	Mitosis	Meiosis
1. Types of cells	Somatic cells	Germ cells of testis & ovaries
2. No of division	Single division	2 successive divisions: Meiosis I & Meiosis II.
3. Interphase	Preceded by interphase with S phase	Meiosis I preceded by interphase with S phase, Meiosis II not preceded by S phase.
4. Prophase	No crossing over	Meiosis I: Crossing over occurs
5. Metaphase	46 d chromosomes arranged individually at the equatorial plane of the cells.	In Meiosis I :23 bivalent arranged at the equatorial plane of the cells.
6. Anaphase	Each chromosome divides at centromere into 2 chromatids	In Meiosis I: each chromosome of a bivalent moves apart.
7. Cells produced	Two daughter cells with diploid number of chromosomes (46 S) Daughter cells are genetically identical	Four daughter cells with haploid number of chromosomes (23 S) Daughter cells are genetically variable.

Meiosis	Meiosis I	Meiosis II
1. Preceded S phase	Present (the cell enter the prophase with 46 d chromosomes).	Absent (the cell enter the prophase with 23 d chromosomes).
2. Prophase	Pairing of homologous chromosomes result in 23 tetrad. Crossing over occurs between each tetrad .	No pairing No crossing over.
3. Metaphase	23 tetrad arranged at the equatorial plane of the cells.	23 d chromosomes arranged individually at the equatorial plane of the cells.
4. Anaphase	No division of the centromere. Each chromosome moves independently to the opposite pole of the cell.	Centromere splits so each chromatid moves independently to the opposite pole of the cell.
5. Telophase	Cytokinesis results in 2 daughter cells each with 23 d chromosomes.	Cytokinesis results in 4 daughter cells each with 23 S chromosomes.

1) In which phase of mitosis occur "disappearing of nucleolus" ?

a. Prophase

b. Anaphase

c. Metaphase

d. Telophase

2)In which phase of Cell Cycle Protein Synthesis occurs:

a. Interphase

b. Meiosis

c. S phase

d. Telophase

3) Which statement describes the interphase?

a. Storage of energy occurs during G1 phase

b. S phase occurs in the static cell population

c. The centrosome starts its duplication in G2 phase

d. It is the period between two successive cell divisions

4)In which phase of Cell Cycle occur The Restriction Checkpoint:

a. G1 Phase

b. G2 Phase

c. S phase

d. G1,G2,S

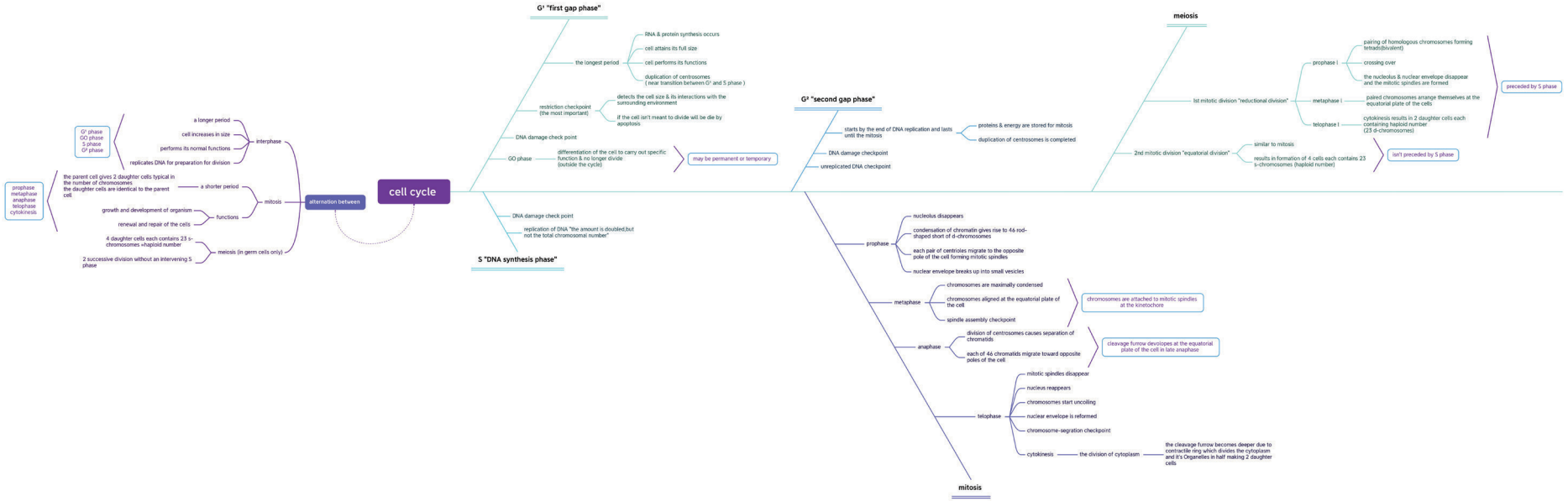
Answer

1-A

2-A

3-D

4-A

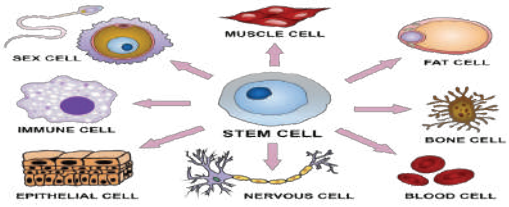


Cell Proliferation & Cell Death

Difference between cell proliferation and cell differentiation:

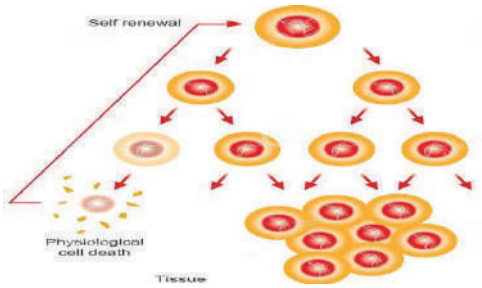
Cell differentiation

It is the process by which unspecialized cells acquire specialized structural and/or functional features that characterize the specialized cells.



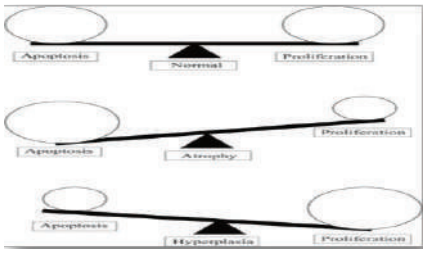
Cell proliferation

Increase in the number of cells by division.



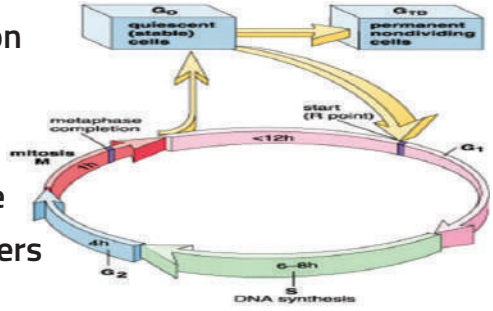
Cell proliferation & differentiation:

- Early development: Rapid proliferation of embryonic cells, which then differentiate to produce the many specialized types of cells that makeup the organs.
- As cells differentiate: The rate of proliferation decreases, and many cells are arrested in the GO stage.
- Cell proliferation is balanced with cell death to maintain a constant number of cells.

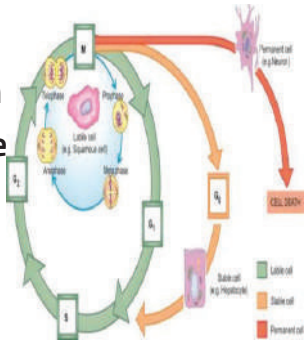


Classification of the body cells according to their ability of proliferation:

1. **Static cell population (non-dividing, permanent):**
   - They leave the cell cycle to perform specialized function (GO stage), e.g. cardiac muscle fibers & neurons.
2. **Stable cell population(quiescent):**
   - They are considered to be in Go stage, but they may be stimulated to divide by signals e.g. smooth muscle fibers and the epithelial cells of the liver and kidney.



3. Labile cell population:



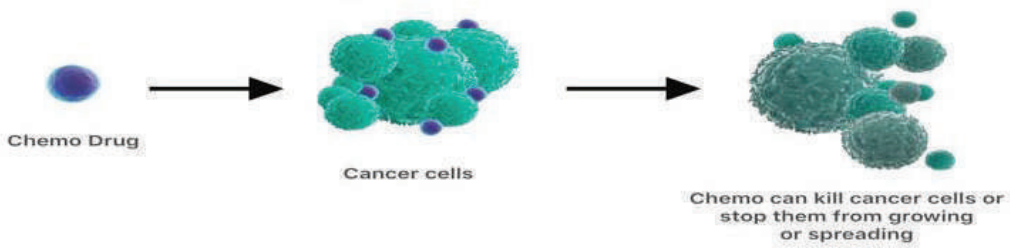
- They are continuously renewing cells e.g. cells have short life span as blood cells, epithelial cells of the skin &epithelial cells lining the digestive tract
- They are replaced by proliferation of the stem cells.

Cancer and labile cells

Cancer

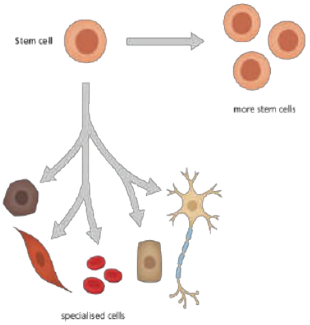
Affects more the labile cells

Chemotherapy destroys the labile cells



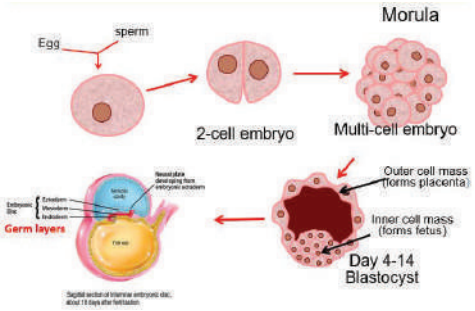
Stem Cells

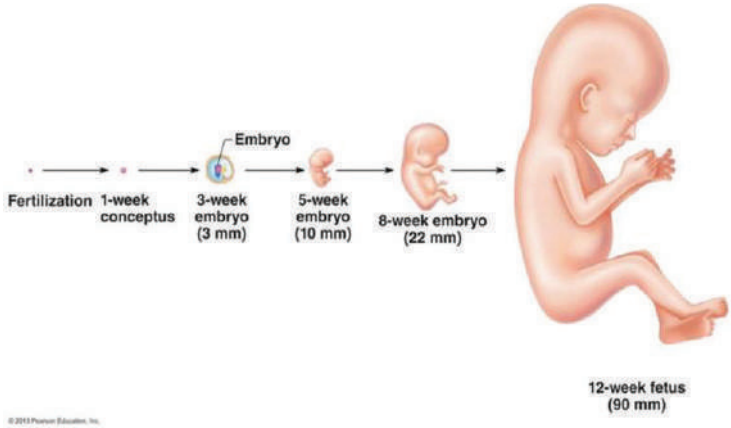
- **Definition:** undifferentiated (unspecialized) cells that can proliferate & differentiate to give specialized cells.



- **Stem cell properties:**
  1. **Self renewal:** the ability of the cell to go through numerous cycles of cell division while maintaining the undifferentiated state.
  2. **Potency:** the capacity to differentiate into different cell types.
- **Types of stem cells:**

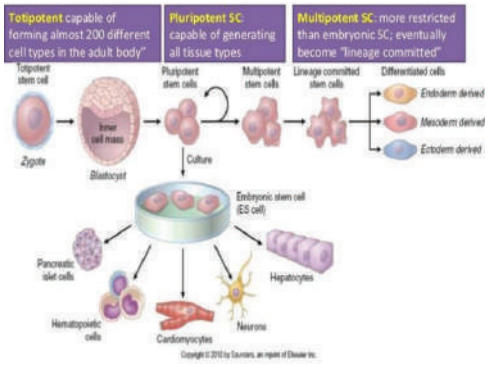
Stage of Embryogenesis





1. Totipotent stem cells

- They have the potential to generate all types of cells and construct a complete organism.
- They are derived from the cells produced by the first few divisions of the fertilized ovum (morula cells).



2. Pluripotent stem cells

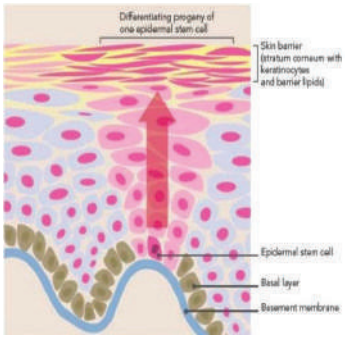
- They can differentiate into the derivatives of the three germ layers =ectoderm, endoderm, and mesoderm.
- They are derived from the inner cell mass of the blastocyst.

3. Multipotent stem cells:

- They can produce cells of a closely related family e.g. hematopoietic stem cells that can differentiate into red blood cells, white blood cells and platelets.

4. Unipotent cells

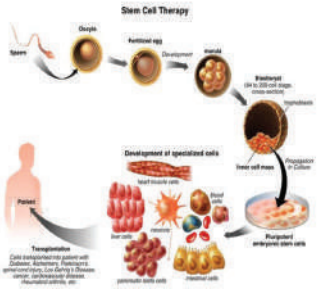
- They can produce a single type of mature cell but still have the property of self renewal which distinguishes them from nonstem cells e.g. stem cells in the skin epidermis.



Potential sources of stem cells for clinical application:

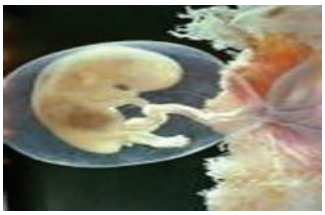
1. Embryonic stem cells

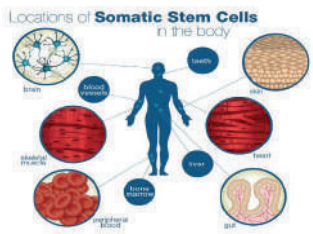
- They are pluripotent stem cells derived from inner cell mass of blastocyst.
- **Advantage:** They can specialize and become any type of body cells
- **Disadvantage:** ethical restriction.



2. Adult stem cells:

- Most of them are multipotent.



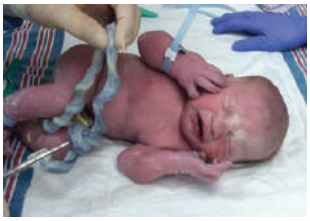


3. Amniotic fluid stem cells:

- They are multipotent.

4. Umbilical cord blood stem cells:

- They are pluripotent.



Cell Death

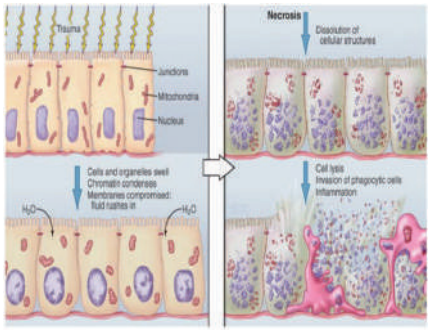
Types of cell death

Apoptosis

Necrosis

1. Necrosis = accidental cell death:

- **Causes:** It is a pathological process due to e.g. hypoxia, radiation or pathogens such as viruses.
- **Morphological features:**
  A. Damage of the cell membrane with cell swelling& rupture.
  B. Breakdown of cell organelles.
  C. Denaturation or coagulation of cytoplasmic proteins.
  D. Inflammation with extensive damage of the surrounding tissue.



2. Apoptosis = programmed cell death:

- It is a physiological process controlled by several genes (loss of mitochondrial function initiates several reactions that lead to cell death).

1. Which of the following statements best defines cell differentiation?

A) The process by which cells undergo mitosis.

B) The increase in the number of unspecialized cells.

C) The process by which unspecialized cells acquire specialized structural and functional features.

D) The balance between cell death and cell proliferation.

2. What happens to cell proliferation as cells undergo differentiation during early development?

A) The rate of proliferation increases.

B) Cells are arrested in the G1 phase.

C) Cells are arrested in the G0 stage.

D) Cell proliferation continues at the same rate as in early development.

3. Which type of cells are classified as non-dividing, permanent cells that leave the cell cycle to perform specialized functions?

A) Labile cells.

B) Stem cells.

C) Stable cells.

D) Static cells.

4. Which of the following is an example of a stable cell population?

A) Cardiac muscle fibers.

B) Neurons.

C) Smooth muscle fibers.

D) Epithelial cells of the skin.

5. Cancer treatments such as chemotherapy primarily affect which type of cells?

A) Static cells.

B) Labile cells.

C) Stable cells.

D) Totipotent stem cells.

6. Which property of stem cells allows them to go through numerous cycles of cell division while maintaining their undifferentiated state?

A) Potency.
B) Totipotency.
C) Self-renewal.
D) Differentiation.

7. Which type of stem cell has the ability to generate all types of cells and form a complete organism?

A) Pluripotent stem cells.
B) Multipotent stem cells.
C) Totipotent stem cells.
D) Unipotent stem cells.

8. From which source are pluripotent stem cells derived during embryogenesis?

A) The morula.
B) The inner cell mass of the blastocyst.
C) Hematopoietic stem cells.
D) The zygote.

9. Which of the following stem cells has the capacity to differentiate into cells of a closely related family, such as hematopoietic stem cells?

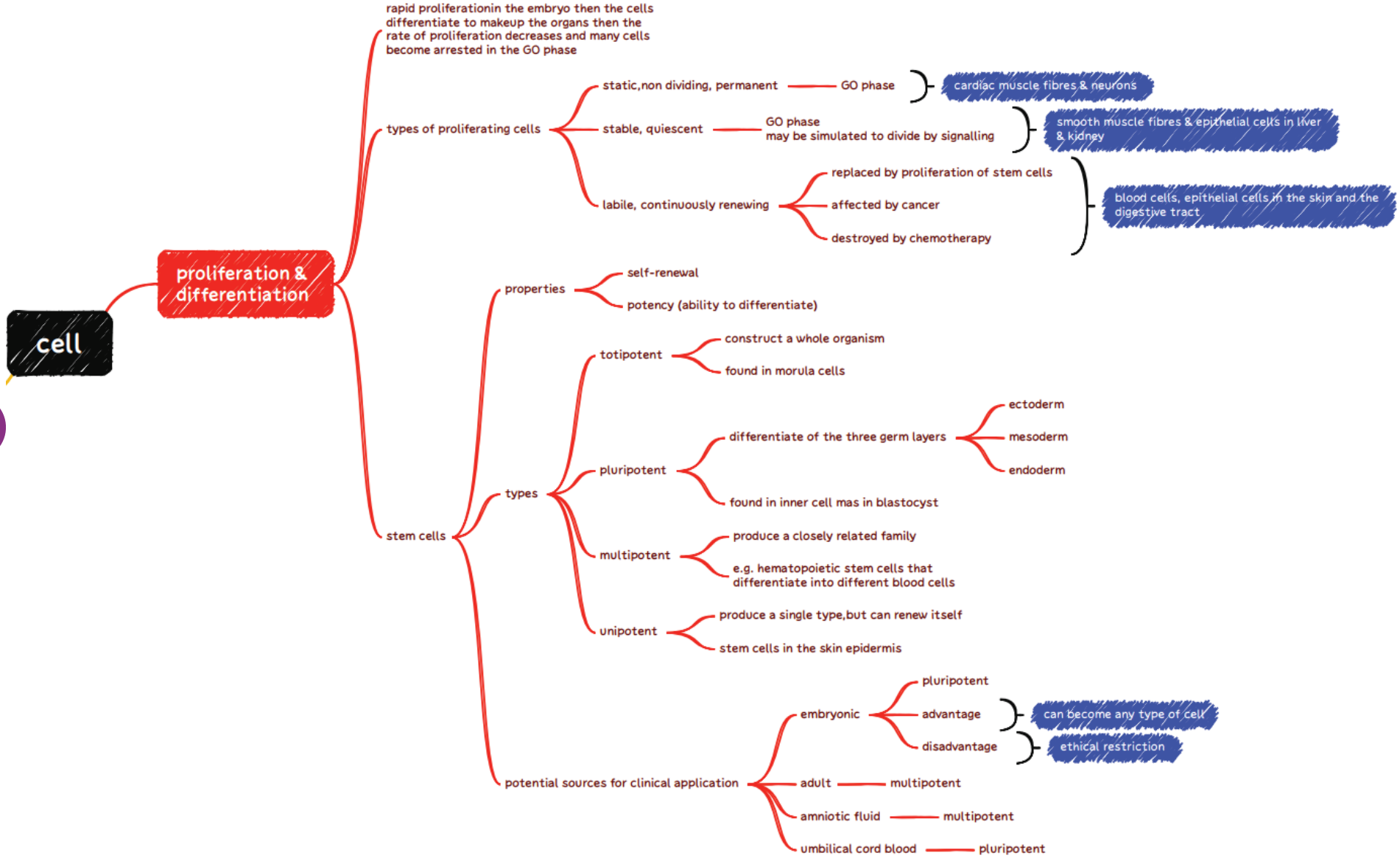
A) Pluripotent stem cells.
B) Totipotent stem cells.
C) Multipotent stem cells.
D) Unipotent stem cells.

10. What is a key advantage of using embryonic stem cells for clinical application?

A) They can differentiate only into hematopoietic cells.
B) They can specialize into any type of body cell.
C) They are not affected by ethical restrictions.
D) They are multipotent.

Answer

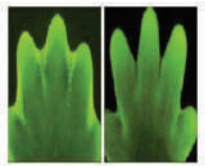
1-C
2-C
3-D
4-C
5-B
6-C
7-C
8-B
9-C
10-B


cell
proliferation & differentiation
rapid proliferationin the embryo then the cells differentiate to makeup the organs then the rate of proliferation decreases and many cells become arrested in the GO phase
types of proliferating cells
static,non dividing, permanent
GO phase
cardiac muscle fibres & neurons
stable, quiescent
GO phase may be simulated to divide by signalling
smooth muscle fibres & epithelial cells in liver & kidney
labile, continuously renewing
replaced by proliferation of stem cells
affected by cancer
destroyed by chemotherapy
blood cells, epithelial cells in the skin and the digestive tract
stem cells
properties
self-renewal
potency (ability to differentiate)
types
totipotent
construct a whole organism
found in morula cells
pluripotent
differentiate of the three germ layers
ectoderm
mesoderm
endoderm
found in inner cell mas in blastocyst
multipotent
produce a closely related family
e.g. hematopoietic stem cells that differentiate into different blood cells
unipotent
produce a single type,but can renew itself
stem cells in the skin epidermis
potential sources for clinical application
embryonic
pluripotent
advantage
can become any type of cell
disadvantage
ethical restriction
adult
multipotent
amniotic fluid
multipotent
umbilical cord blood
pluripotent

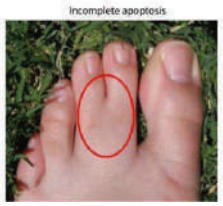
What makes a cell decide to commit suicide?

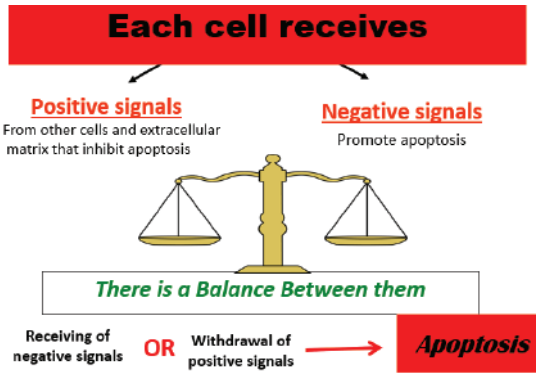
I-During embryonic development:

Removal of excess cells that have no function e.g. during morphogenesis and for determination of organ size.



Development of toes

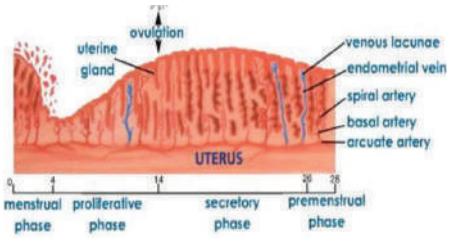




II-In adult:

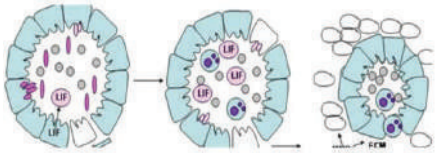
1. Hormone dependent:

- Involution of the endometrium during the menstrual cycle
- Regression of lactating mammary gland after weaning.
- Regression of prostate in old males



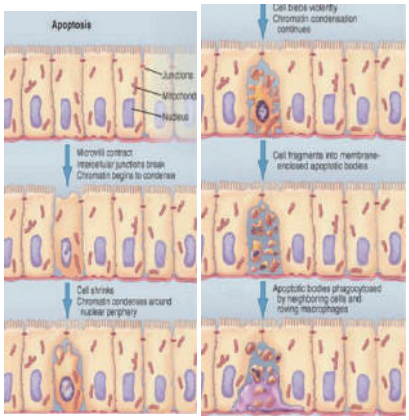
2. Elimination of cells during cell cycle when their DNA damage is not repaired.

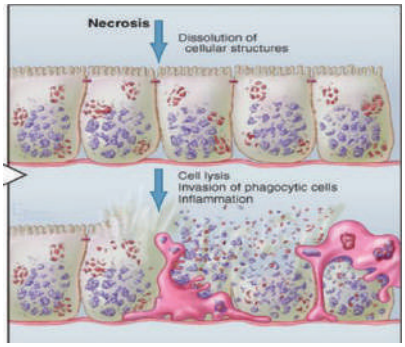
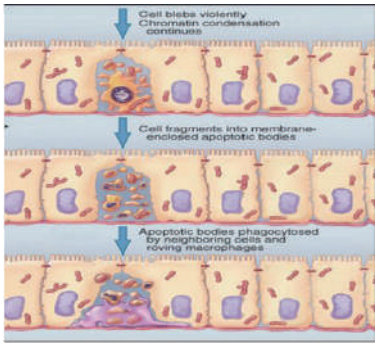
3. Maintaining a constant number of cells in proliferating cell populations, e.g. intestinal epithelium.



Morphological features of apoptosis:

1. Loss of microvilli and intercellular junctions.
2. Shrinkage of the cell with membrane blebing.
3. Breakdown of DNA with hypercondensation of chromatin and its collapse against the nuclear periphery.
4. Change of cell membrane characters without loss of its integrity.
5. Cell organelles remain apparently normal but become clumped inside the cytoplasm.
6. Fragmentation of the cell into apoptotic bodies that contain fragments of the nucleus, mitochondria, and other organelles.
7. The apoptotic bodies are removed by the phagocytic cells.



	Necrosis	Apoptosis
1. Type	Pathological.	Physiological.
2. Cell membrane	Damage with loss of its integrity.	Change of some characters without loss of its integrity.
3. Organelles	Broken down.	Intact.
4. Proteins	Denatured or coagulated.	Broken down of DNA with hypercondensation of chromatin.
5. Apoptotic bodies	Absent	Present
6. inflammation	Present	Absent
		

1. Which of the following is NOT a morphological feature of necrosis?

A) Damage of the cell membrane with swelling and rupture.

B) Denaturation or coagulation of cytoplasmic proteins.

C) Formation of apoptotic bodies containing nuclear fragments.

D) Breakdown of cell organelles.

2. What is a key feature that differentiates apoptosis from necrosis at the cellular level?

A) Loss of mitochondrial function.

B) Involvement of inflammation with extensive tissue damage.

C) Cell swelling and rupture leading to tissue damage.

D) Release of viral particles causing cell damage.

3. Which of the following examples illustrates hormone-dependent apoptosis in an adult?

A) Elimination of damaged intestinal epithelial cells.

B) Involution of the endometrium during the menstrual cycle.

C) Cell swelling and denaturation of proteins in the prostate.

D) Removal of excess cells during embryonic morphogenesis.

4. During apoptosis, what happens to the chromatin inside the nucleus?

A) It undergoes random fragmentation with loss of membrane integrity.

B) It remains unchanged while the cytoplasmic organelles break down.

C) It hypercondenses and collapses against the nuclear periphery.

D) It is released into the cytoplasm, triggering immune responses.

5. What is the fate of apoptotic bodies formed during apoptosis?

A) They cause inflammation and extensive tissue damage.

B) They swell and rupture, releasing cellular contents into surrounding tissue.

C) They are engulfed and removed by phagocytic cells.

D) They fuse together, forming large necrotic areas in tissues.

Answer

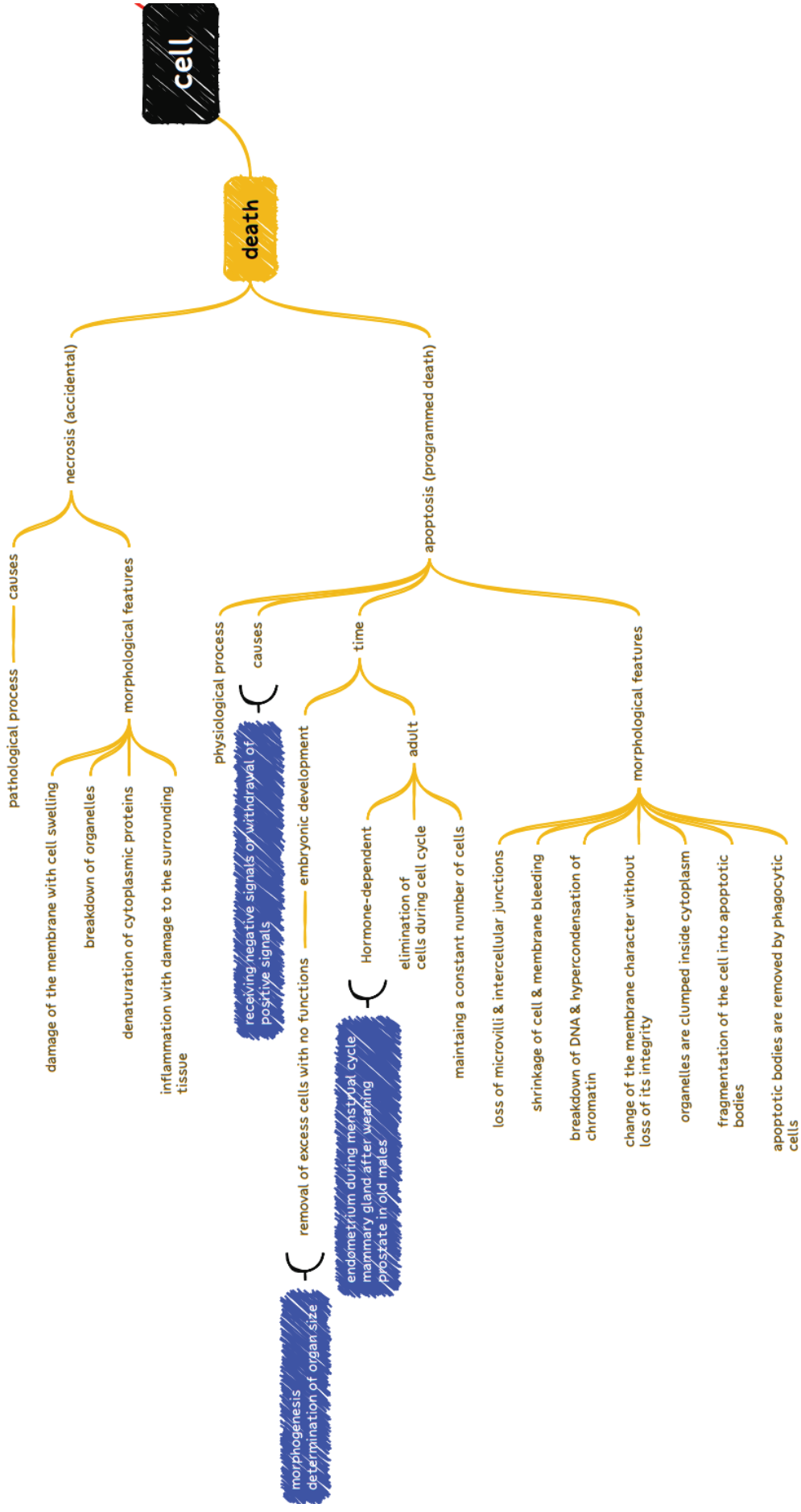
1-C

2-A

3-B

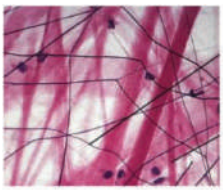
4-C

5-C


cell
death
necrosis (accidental)
pathological process
causes
damage of the membrane with cell swelling
morphological features
breakdown of organelles
denaturation of cytoplasmic proteins
inflammation with damage to the surrounding tissue
apoptosis (programmed death)
physiological process
causes
receiving negative signals or withdrawal of positive signals
embryonic development
removal of excess cells with no functions
morphogenesis
determination of organ size
time
Hormone-dependent
endometrium during menstrual cycle
mammary gland after weaning
prostate in old males
adult
elimination of cells during cell cycle
maintaing a constant number of cells
morphological features
loss of microvilli & intercellular junctions
shrinkage of cell & membrane bleeding
breakdown of DNA & hypercondensation of chromatin
change of the membrane character without loss of its integrity
organelles are clumped inside cytoplasm
fragmentation of the cell into apoptotic bodies
apoptotic bodies are removed by phagocytic cells

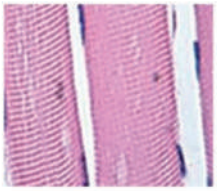
Epithelium

- **Basic tissues:** A group of similar cells specialized to perform a commonfunction. These tissues exist in associations forming body organs.**They are 4:**



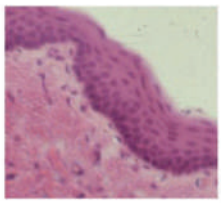
Connective tissue

Arises from mesoderm



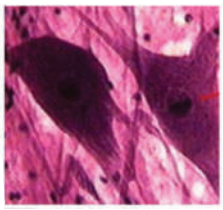
Muscular tissue

Arises from mesoderm



Epithelial tissue

Arises from mesoderm, ectoderm,mesoderm

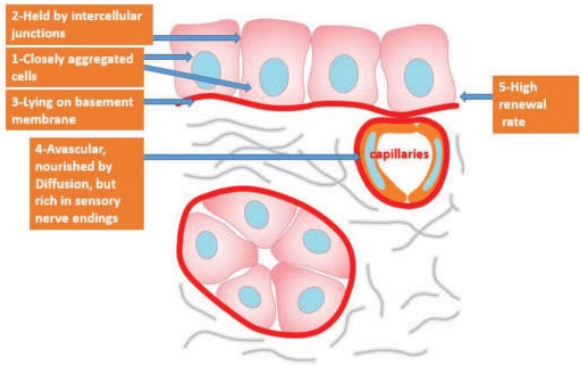


Nervous tissue

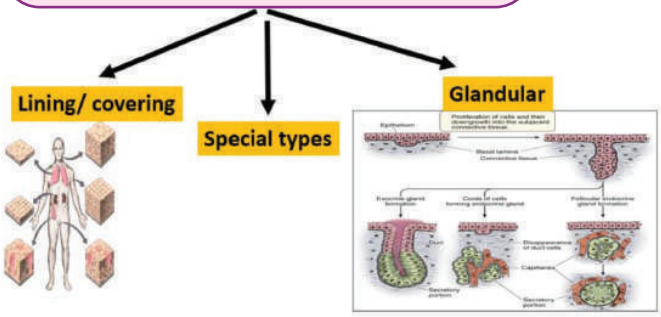
Arises from ectoderm

Epithelium

Characteristics of Epithelium:

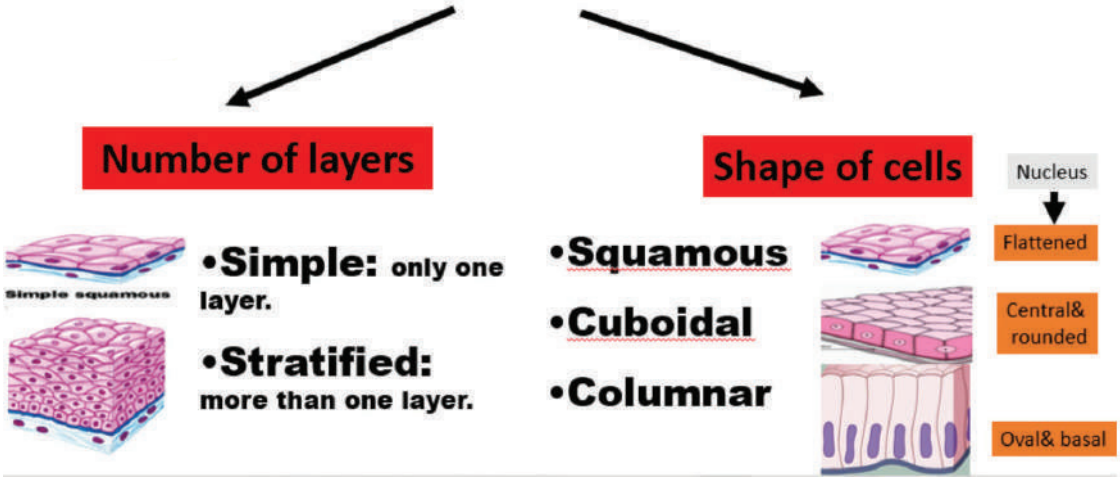


Classification of Epithelium:



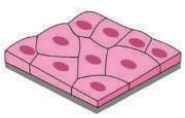
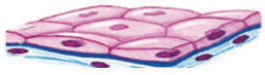
I-Lining Epithelium

EpitheliumClassification of covering epithelia

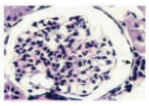
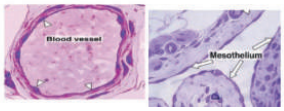


Simple Epithelium

1. Simple Squamous:

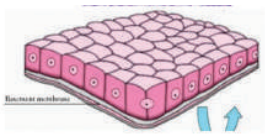



- **Side view:** Flat cells & Flattened nucleus.
- **Surface view:** polygonal.
- **Sites:**
  a. **Filtration:** Bowman, s capsule of kidney.
  b. **Diffusion:** alveoli of lung.
  c. **Smooth passage:** endothelium of blood vessels and lymph vessels.
  d. **Allows free mobility:** mesothelium of leura, pericardium and peritoneum..

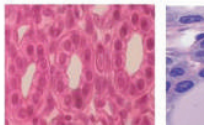
2. Simple cuboidal:

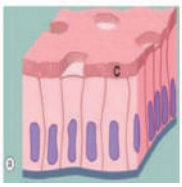
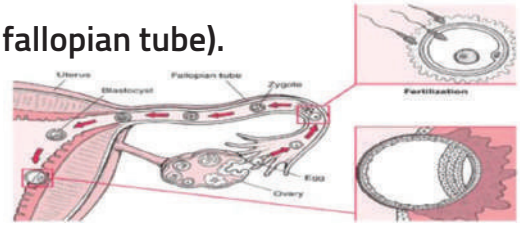
- **Shape:** cubical cells with central rounded nuclei.
- **Sites:** Kidney tubules & Thyroid follicles (ion exchange).



3. Simple columnar:

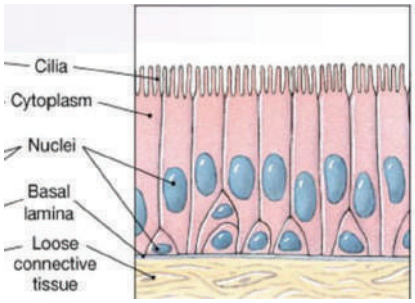
- **Shape:** columnar cells, the nuclei are oval & basal
- **Types & Sites:**
  a. **Non ciliated:** Secretion & absorption (stomach, small intestine, gall bladder). (may have microvilli)
  b. **Ciliated:** Secretion (uterus, fallopian tube).



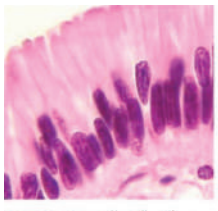
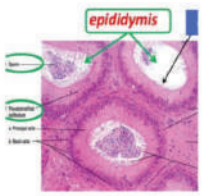



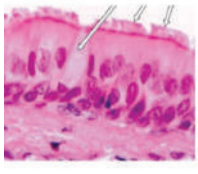
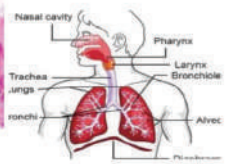
4. Pseudostratified columnar epithelium:

a. Crowded cells, all cells lie in contact with the basement membrane, but they do not all reach the surface.
b. The cells that reach the surface are tall columnar cell, while the other cells which do not reach the surface are short and triangular.
c. Several layers of nuclei, each lies at the widest portion of the cell, giving false appearance of stratification.



- **Types & Sites:**
  a. **Non ciliated with microvilli:** male genital tract.
  b. **Ciliated:** most of respiratory system (pseudostratified ciliated columnar epithelium with goblet cells).

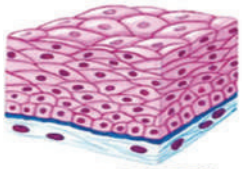



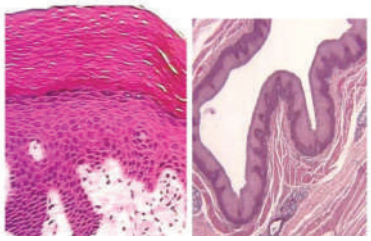
Stratified Epithelium

It is classified according to the shape of the most superficial layer of cells.

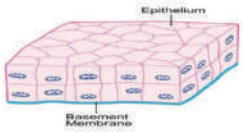
1. Stratified squamous:

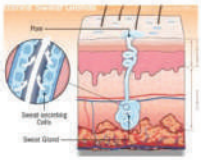


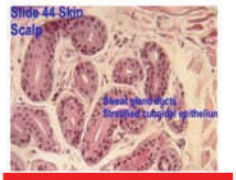
- **Function: protection.**
- **Structure:**
  - a. **Basal layer:** low columnar; cuboidal cells.
  - b. **Intermediate layers:** Polygonal cells.
  - c. **Superficial layer:** Squamous cells.
- **Types:**
  - a. **Keratinized:** The superficial cells are filled with keratin (skin).
  - b. **Non keratinized:** In wet surfaces subjected to wear & tear (cornea, esophagus, mouth cavity & vagina).



2. Stratified cuboidal:



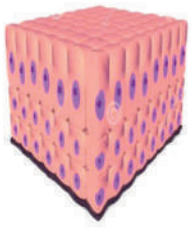




Ducts of sweat glands

- Uncommon type.
- Two layers of cuboidal cells.

3. Stratified columnar:

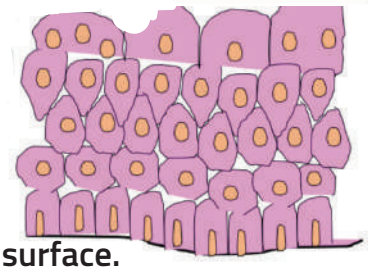


Conjuctival fornix

- Uncommon type.
- The superficial cells are columnar in shape.

Transitional Epithelium:

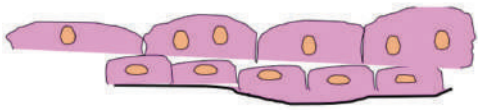
- Change its shape and number of layers, according to the functional state of the organ, e.g. urinary bladder& ureter.



Empty bladder

1. **A basal layer:** low columnar cells.
2. **Intermediate layers:** polygonal cells,tend to be pear shaped near surface.
3. **The surface layer:** large cuboidal (dome shaped cells; umbrella cells).

Full bladder



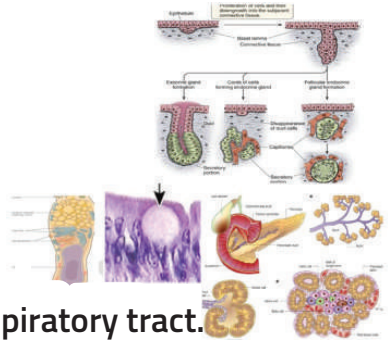
1. **Superficial:** large, flattened cells.
2. **Basal:** cuboidal cells.

How does the transitional epithelium adapt to its function?

1. Decrease of number of layers due to gliding of the cells.
2. Flattened cells

→ **Increase surface area**

II-Glandular Epithelium



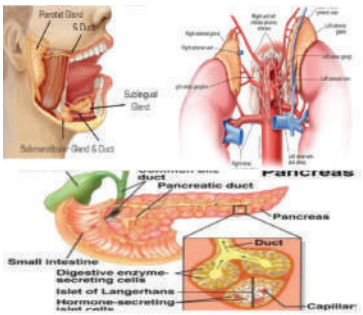
- **Function:** fluid secretion.
- **Origin:** from the covering epithelium
- **Types Of Glandular Epithelium:**

1. According to number of cells

a. **Unicellular glands:** consist of one cell e.g., goblet cells present in the small and large intestine and the respiratory tract.

b. **Multicellular glands:** consist of groups of cells e.g., most glands of the body.

2. According to the presence or absence of a duct system:

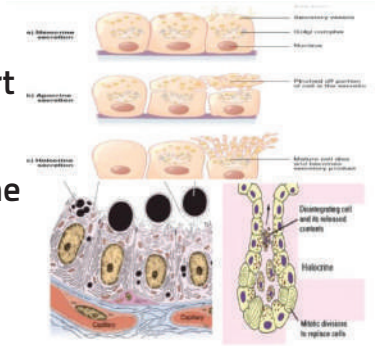


a. **Exocrine glands:** in which the secretion is carried by ducts e.g., salivary glands.

b. **Endocrine glands or ductless glands:** in which the secretion is released into the blood vessels e.g., thyroid gland and suprarenal gland.

c. **Mixocrine (mixed exocrine and endocrine) glands:** contain the two types e.g., pancreas.

3. secretory (the secretion of mode the to Accordingmechanism):



a. **Merocrine glands:** the secretory granules are discharged by exocytosis through the cell membrane without losing any part of the cell e.g., pancreas& salivary glands.

b. **Apocrine glands:** the secretion is discharged together with the apical parts of the cytoplasm e.g., mammary gland.

c. **Holocrine glands:** the secretion is discharged with the whole cell leading to its complete destruction e.g., sebaceous gland.

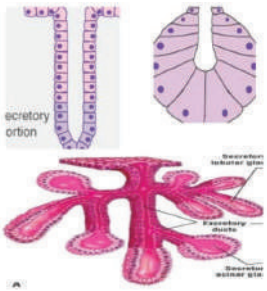
4. According to the nature of secretion:

a. **Serous glands:** secrete a watery secretion e.g., parotid salivary gland.

b. **Mucous glands:** secrete mucous e.g., goblet cells and sublingual salivary gland.

c. **Mixed glands:** secrete both mucous and serous secretions e.g., submandibular salivary gland.

d. **Glands with special secretions:** ceruminous glands which secrete ear wax and sebaceous glands which secrete a fatty secretion (sebum).



5. According to the shape of the secretory portion:

a. **Tubular:** the secretory units are tubular in shape.

b. **Alveolar (acinar):** the secretory units are rounded.

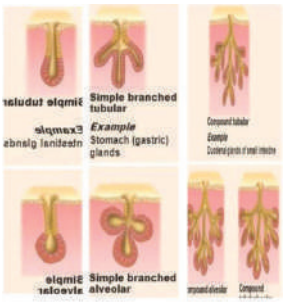
c. **Tubuloalveolar (tubuloacinar):** the secretory units have both tubular and alveolar parts.

6. According to the branching of the ducts and branching of the secretory portion:

a. **Simple glands:** have only one unbranched duct and one secretory unit.

b. **Simple branched glands:** have one unbranched duct and branched secretory units.

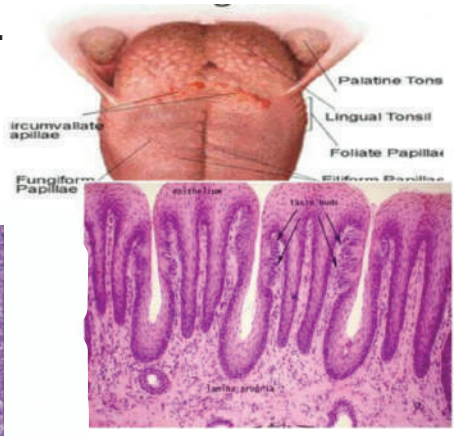
c. **Compound glands:** have branched duct system& branched secretory units.



III-Special Types of Epithelium

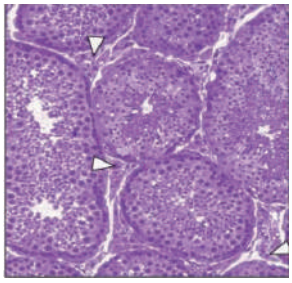
1. Neuroepithelium: The epithelial cells act as nerve receptors.

- **Sites:**
  a. The taste buds of the tongue.
  b. The organ of Corti in the ear.
  c. The retina of the eye.



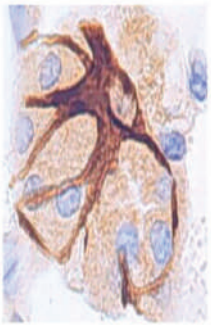
2. Germinal epithelium:

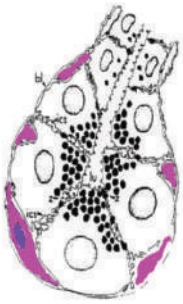
- The epithelium carrying the function of reproduction.
- **Sites:** in the testis and ovary.



3. Myoepithelial cells:

- **Definition:** modified stellate epithelial cells which surround the secretory units (the acini) and the ducts of the glands.
- **Structure:** contain myosin and actin myofilaments.
- **Function:** they are able to contract and squeeze the secretion from the glands.
- **Sites:**
  a. Salivary gland.
  b. Mammary gland.
  c. Sweat glands





Functions of Epithelium:

1- Protection (stratified)
2- Absorption (simple)
3- Filtration (simple)
4- Gas diffusion (simple)
5- Secretion (glandular)
6- Contraction (special)
7- Reproduction (special)
8- Perception (special)

1)Called uro-epithelium:

a. Transitional
b. Stratified squamous
c. Stratified cubical
d. Stratifies columnar

2)Its function is distensibility:

a. Transitional
b. Stratified squamous
c. Stratified cubical
d. Stratified columnar

3)The epithelium lining of the blood vessels is called :

a. Transitional epithelium
b. Simple columnar epithelium
c. Mesothelium
d. Endothelium

4)The epithelial lining of the serous (need mobility) membrane is called :

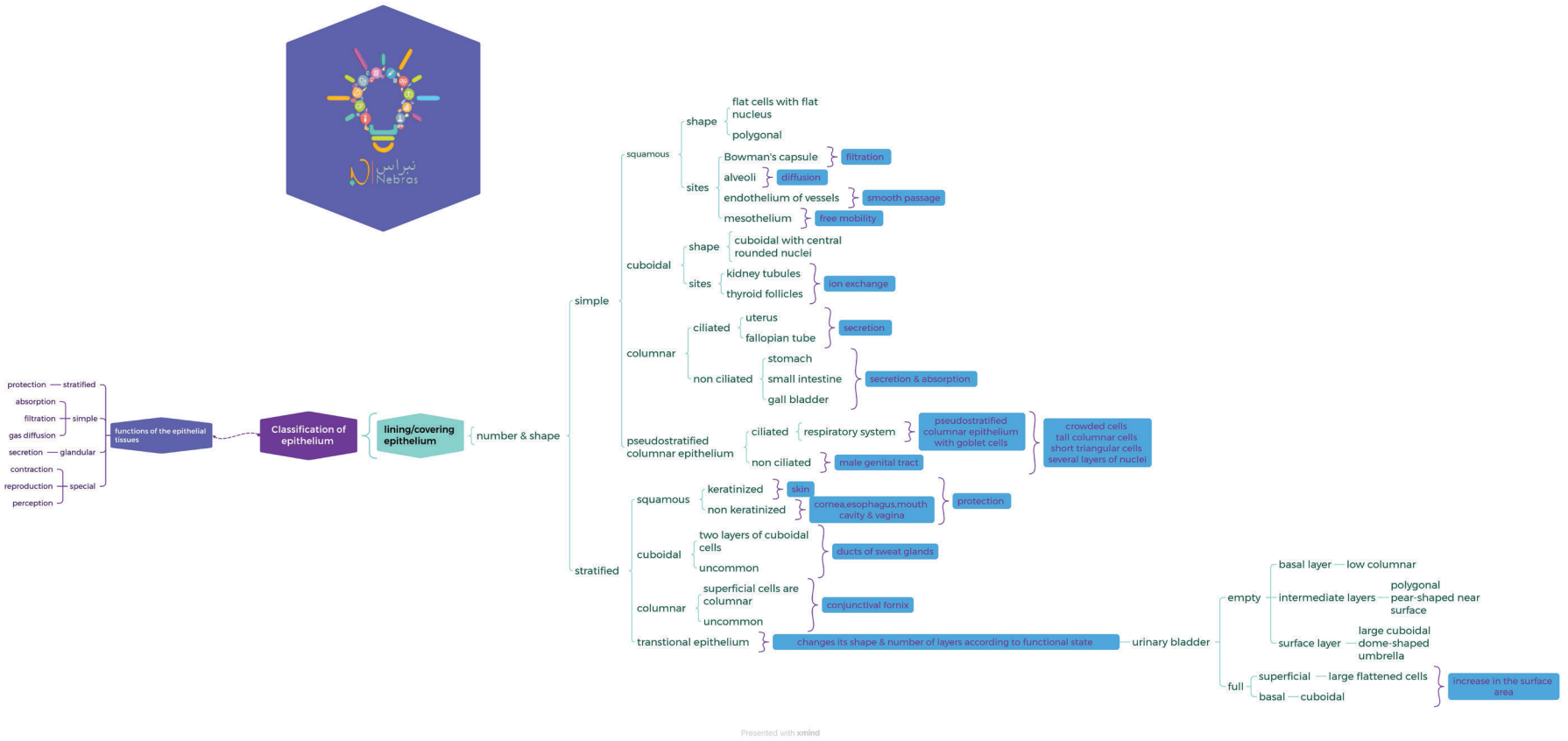
a. Transitional epithelium
b. Simple columnar
c. Mesothelium
d. Endothelium

5) Neuro epithelium is present in:

a. Bone marrow
b. Thymus
c. Trachea
d. Tongue

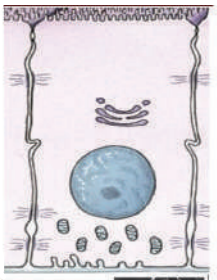
Answer

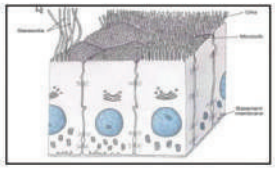
1-A
2-A
3-D
4-C
5-B



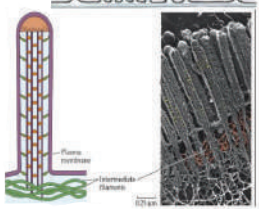
Epithelial Cell Polarity

- **Definition :** The epithelial cell has an apical,basal, and lateral surfaces, each surface exhibits special structural modifications to carry out specific functions.



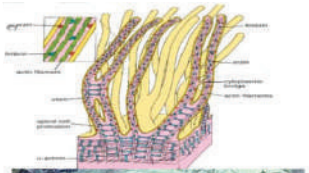


I- Apical Modifications



1. Microvilli:

- **Definition:** non motile, finger like cytoplasmic projections arise from the apical surface of epithelial cells.
- **Structure:** a core of actin filaments.
- **Function:** increase the surface area for absorption.
- **Sites:** The cells of the intestine and kidney tubules.



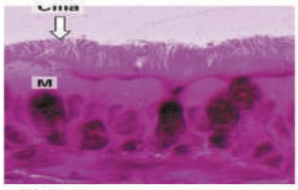
2. Stereocilia:

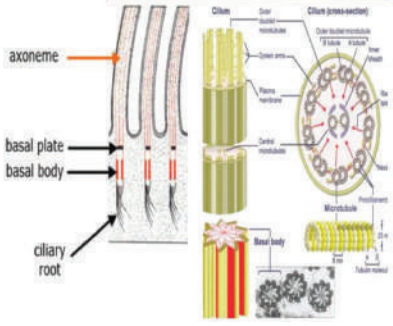
- **Definition:** long, branching microvilli.
- **Function:** increase the surface area for absorption.
- **Site:** the non ciliated pseudostratified columnar epithelium of the male genital ducts e.g. the epididymis.

3. Cilia and flagella:

- **Definition:** motile cytoplasmic projections that extend from the cell surface.
- **Cilia:** are hair like processes that are longer than microvilli.

- **Flagella:** resemble cilia in structure but they are much longer and are single for each cell e.g., flagellum of the sperm.
- **Structure: each cilium is formed of:**



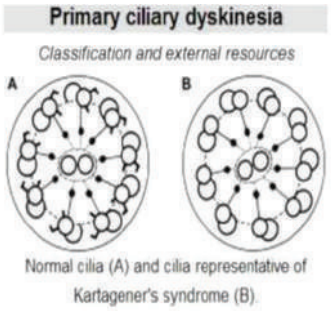


  a. **The basal body:** replicate of the centrioles (9 triplets of microtubules) from which the shaft arises. The basal body is present in the apical cytoplasm.
  b. **The shaft (axoneme):** extends from the cell surface. It contains 9 peripheral doublets of microtubules + a central pair of singlet microtubules (9x2+2=20 microtubules).
  c. **Rootlets:** extend from underneath the basal body, in the form of radiating microtubules anchoring the cilium into the cytoplasm.

N.B:

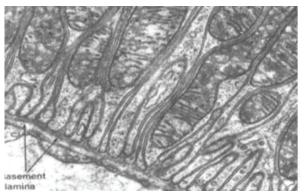
Abnormal proteins of cilia or flagella resulting from mutation.

- **Male infertility:** due to immotile sperm.
- **Chronic respiratory infection :** caused by lack of cleaning action of cilia in the epithelium of respiratory tract.



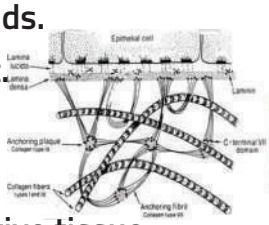
Apical modifications	Microvilli	Stereocilia	Cilia
1. Motility	Non motile	Non motile	Motile
2. Length	Shorter.	Longer.	Longer.
3. Shape	Finger like cytoplasmic projections.	Branching microvilli.	Hair like cytoplasmic projections.
4. Structure	Core of actin filaments.	Core of actin filaments.	Consists of basal body, shaft & rootlets, all formed of microtubules.
5. Function	Increase surface area for absorption.	Increase surface area for absorption.	Move a layer of fluid.
6. Most common sites	In & testinal cellskidney tubules.	Male genital tracts e.g. epididymis.	Respiratory tract.

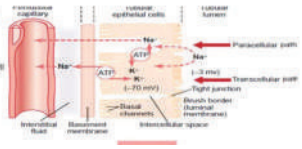
II- Basal Modification:



1. Basal infoldings:

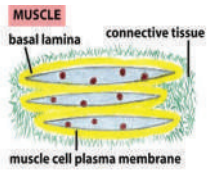
- **Definition:** the basal cell membrane is thrown into folds.
- **Function:** increase the surface area for ions transport.
- **Site:** kidney tubules





2. Basement membrane:

- **Site:** in the interface between epithelium and connective tissue.
- **Structure:**
  - A. **The basal lamina:** formed of adhesive glycoprotein.
  - B. **The reticular lamina:** formed of fine network of collagen fibrils.



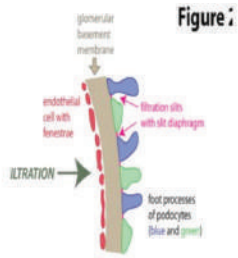
- Some non epithelial cells are invested مغلفة by a basal lamina like material called external lamina e.g., muscle fibers, Schwann cell خلية موجودة فى الجهاز العصبى الطرفى مسئولة عن تكوين غلاف الميالين حول الليفة العصبية and adipocytes (the external lamina protects the fat cells from mechanical stress الضغط الحركي).
- It is not called basal lamina because these cells have no basal surface.

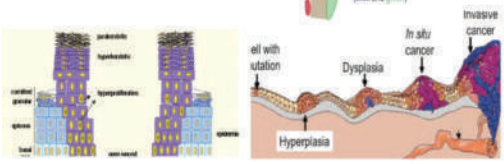
Functions of Basement Membrane:

A. **Structural attachment:** attachment of the epithelial cells to the underlying connective tissue.

B. **Filtration:** regulates exchanges of macromolecules between the epithelium and the surrounding tissues.

C. **Tissue scaffold:** it directs the migration of epithelial cells (re epithelization) during wound repair.
It acts as barrier against passage of malignant cells.





3. Basal cell to matrix adhesions: Hemidesmosomes

1)Fix epithelium to basement membrane and C.T:

a. Hemidesmosome
b. Basement membrane
c. Basal infoldings
d. Desmosome

2) These are motile has like structures on surface some epithelial cells:

a. Flagella
b. Cilia
c. Stereocilia
d. Micro villi

3) Long motile structure on the surface of some epithelial cells are known as :

a. Microvilli
b. Cilia
c. Flagella
d. Stereocilia

4) It is brush border shaped:

a. Stereocilia
b. Cilia
c. Microvilli
d. Flagella

5)Has core of actin filament inserted in terminal web:

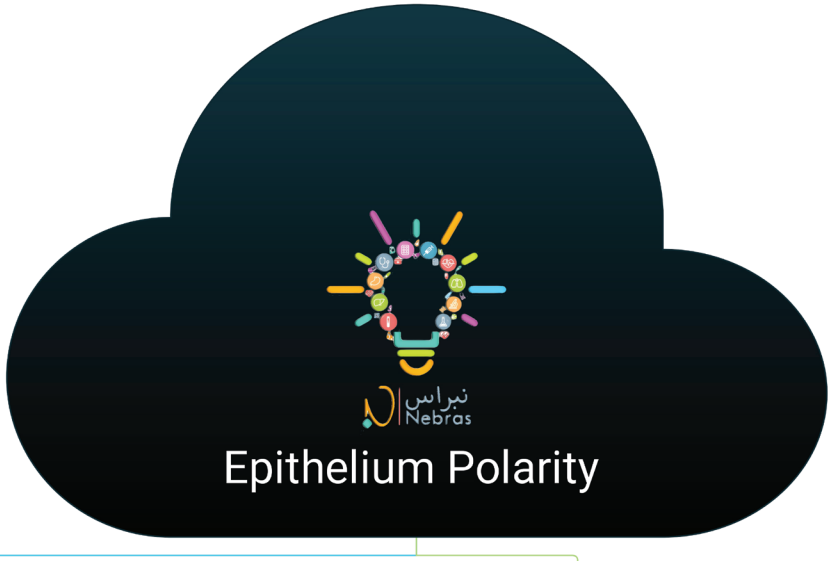
a. Stereocilia
b. Cilia
c. Microvilli
d. Flagella

6) With EM, finger like projections on the apical surface of epithelial cells are called :

a. Inter digitations
b. Infoldings
c. Filaments
d. Microvilli

Answer

1-A
2-A
3-C
4-B
5-B
6-D



Apical Specialization

MICROVILLI

- Composed of Actin filaments
- Finger like projections
- Inc Surface Area for absorption
- Present in Intestinal Cells & Kidney tubules

SteroCilia

- Long branching MICROVILLI
- Present in Epididymis in pseudostratified columnar epithelium of male genital tract

CILIA&FLAGELLA

1.Basal Body

- 9 triplets of microtubules (27)

2. Shaft (Axoneme)

- 9 doublets of microtubules + A pair of central singlet microtubules (20)

3. Rootlets

- Lie under the basal body
- Has radiating Microtubule
- Anchor the cilium with the cytoplasm

Basal Specialization

Components

1.Basal Foldings

- Inc Surface Area for Ions Exchange like Kidney tubules

2. Basement Membrane

I. Basal Lamina

- formed of glycoproteins (Laminin)

2. Reticular Lamina

- formed of a framework of Collagen fibrils

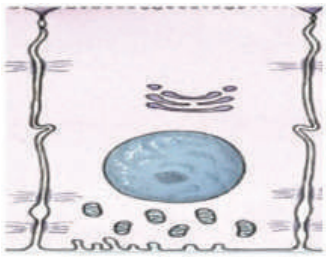
3.Basal cell to matrix adhesion (Hemidesmosomes)

Function

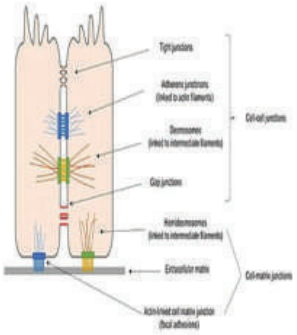
1. Structural Attachment of epithelium to underlying CT
2. Filteration and regulation of exchange of macromolecules between epithelium & other tissues
3. Tissue Scaffold (Re-epithelization during wound repair)

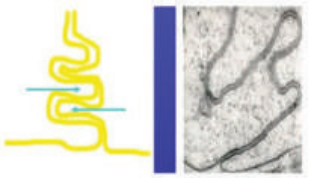
Lateral Specialization & Intercellular Junctions

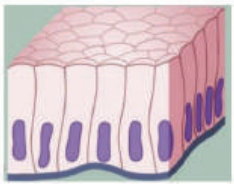
Lateral Specialization:



1. **Cellular interdigitations:** increase the surface area for transport.
   - **Sites:** cells of the intestine and kidney tubules.
2. **Intercellular junctions:** link the neighboring cells together.





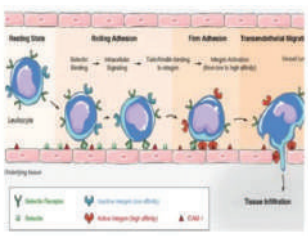


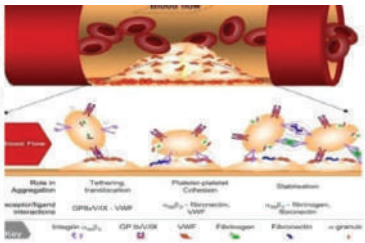
Types Of Cell Junctions

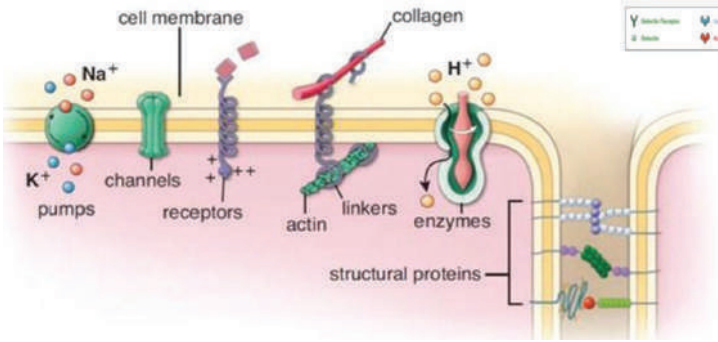
1. Cell to cell adhesion.
2. Cell to matrix adhesion.

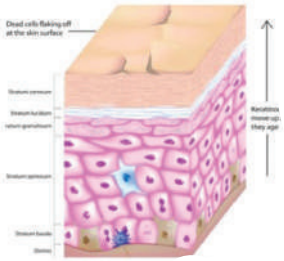
Cell adhesion is a dynamic process:

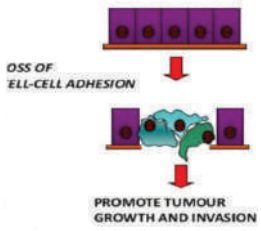
1. Non adhesive cells become adhesive.
2. Adhesive cells become non adhesive.



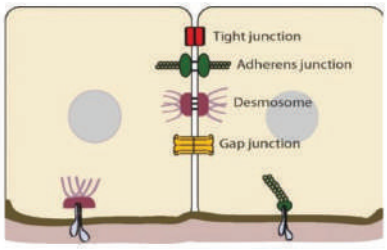






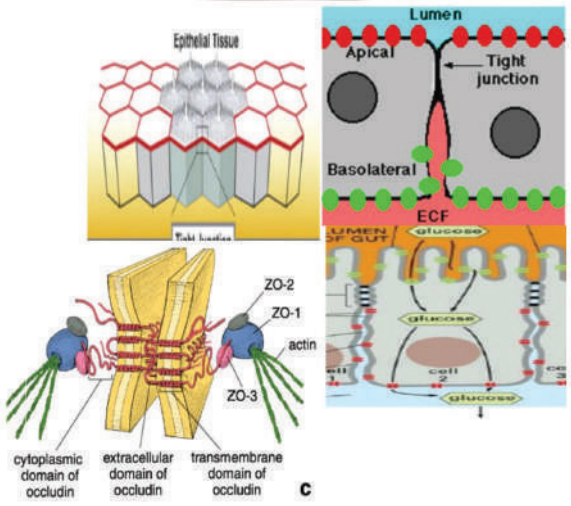


Cell To Cell Junctions



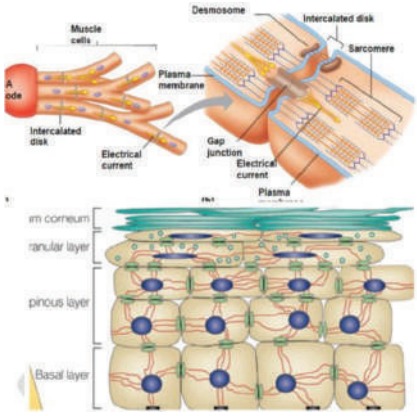
I. Tight junction (occluding Junction, zonula

- **Site:** at the apical parts of the cells.
- **Function:** restrict the passage of molecules between the epithelium (barrier) e.g. epithelial cells of intestine.
- **Structure:**
  A. The outer leaflets of adjacent cell membranes are fused together, forming a belt like junction.
  B. 2 transmembrane proteins (occludin & claudin) join together to seal (occlude) the intercellular space → no intercellular space between the adjacent cells.

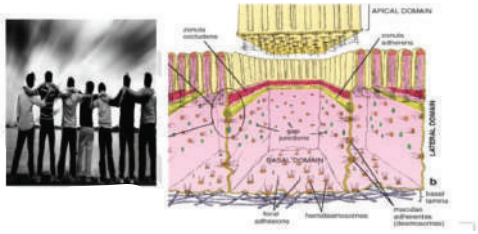


II. Anchoring junctions

- **Site:** in cells that are subjected to severe mechanical stress e.g. cardiac muscles and epidermis of skin.
- **Function:** provide strong attachment and act as a link between the cytoskeleton of adjacent cells.
- **Histological structure:** 2 types:

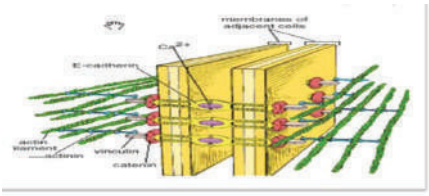


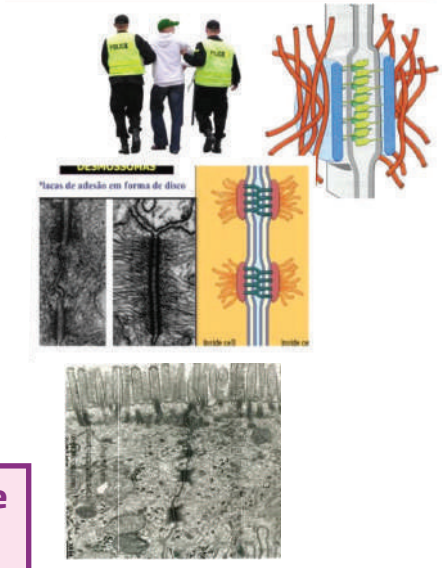
- **Zonula adherens:**
  1. Belt like specialization that encircles the apical part of the 2adjoining cells.
  2. The intercellular space between the adjacent cell membranes is 20 nm (the usual intercellular space).
  3. Cadherins adhere the two cells together (ca dependant).
  4. The cytoplasmic part of cadherins is attached to actin filaments inside the cells.



Removal of Ca^{2+} leads to disruption of the junction.

- **Macula adherens (desmosomes):**





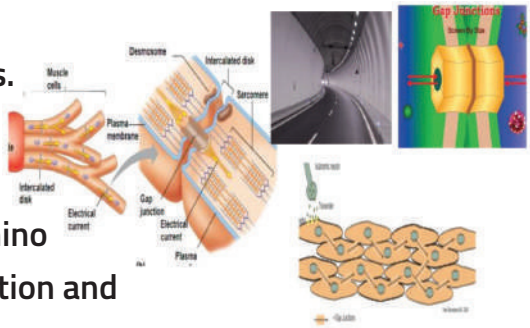
1. A spot like specialization of the cell membrane
2. Two plaques located opposite each other on the cytoplasmic aspects of the adjacent cell membranes , to which cytokeratin filaments are inserted.
3. Cadherins connect the two cells together (Ca dependent).
4. The intercellular space between the opposing cell membranes is 30 nm.
5. Dense vertical filamentous material is present in the intercellular space that represents the extracellular domains of cadherins.

In the presence of a calcium chelating agent, the desmosome breaks into 2 halves and the cells separate.

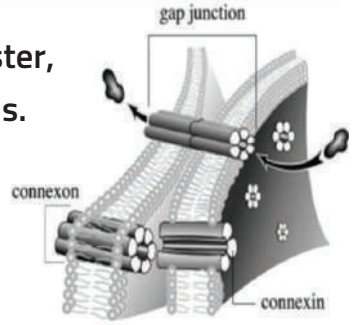
N.B: Intercellular junctional complexes:

- In several epithelia the zonula occludens, the zonula adherens and macula adherens are present in a definite order from the apex toward the base of the cell.

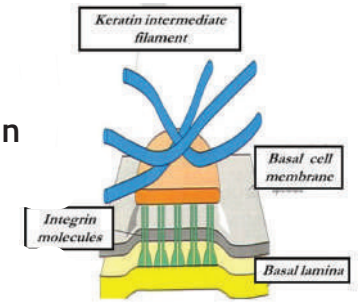
III-Communicating junction (gap junction, nexus):



- **Sites:** in epithelial cells, cardiac and smooth muscle cells.
- **Function:**
  - They permit communication rather than adhesion.
  - They permit the exchange of molecules e.g., ions, amino acids allowing passage of signals involved in contraction and communication from one cell to another.
- **Histological structure:**
  1. A spot like junction, formed of protein channels.
  2. The channel is called connexons which are formed of 6 transmembrane proteins called connexins.
  3. When two connexons of opposing cell membranes are in register, they form a channel connecting the cytoplasm of adjacent cells.
  4. The intercellular space is 3nm.

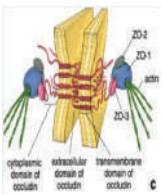
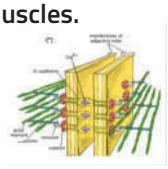
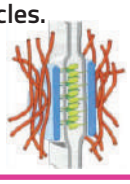
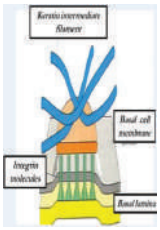


Cell To Matrix Junctions



Hemidesmosomes (basal cell polarity):

- **Definition:** half of desmosome but are different functionally and in their content.
- **Site:** at the base of the epithelial cells to connect them with the basement membrane.
- **Structure:** The CAMs are integrins, their extracellular parts bind to proteins of the basal lamina while the intracellular parts bind to keratin filaments.

Types of Junctions	Tight junction	Zonula adherence	Desmosomes	Hemi-desmosome	Gap junction
1- Transmembrane protein (structural)	Claudin & occluding.	Cadherin.	Cadherin.	Integrin.	Connexin.
2- Type of attached filaments.	Actin.	Actin.	Keratin.	Keratin.	--------
3- Shape of junction.	Belt like.	Belt like.	Spot like.	Spot like.	Spot like.
4- structural features	Fusion of transmembrane proteins.	Binding of actin filaments on both sides of the adjacent cell membranes by transmembrane proteins.	Intracellular plaques on both sides of adjacent cell membranes, attached from one side to keratin & other sides to transmembrane proteins.	Half a desmosome on the side of the basal cell membrane.	Connexons are in register to each others.
5- Intercellular space	No space	20 nm.	30 nm.	--------	3 nm.
6- Function	Barrier (prevents passage of molecules in the intercellular space)	Strong attachment between cells.	Strong attachment between cells.	Binds the basal cell membrane to basal lamina.	Allows exchange of molecules between cells.
7- Most common sites	Cells of intestine. 	Cells subjected to sever mechanical stress such as epidermal cells of skin and cardiac muscles. 	Cells subjected to sever mechanical stress such as epidermal cells of skin and cardiac muscles. 	Epithelial cells. 	Cardiac & smooth muscles. 

1)Encircle apex of cell:

a. Tight junction
b. Adherens junction
c. Desmosome
d. Gap junction

2)Encircle cell like belt:

a. Tight junction
b. Hemidesmosomes
c. Desmosome
d. Gap junction

3)In zonula adherens, transmembrane is attached to. ..... filament:

a. Actin
b. Myosin
c. Intermediate
d. Collagen

4)Wide inter cell space show dark midline:

a. Tight junction
b. Adherens junction
c. Desmosome
d. Gap junction

5)Strongest type of junction:

a. Tight junction
b. Adherens junction
c. Desmosome
d. Gap junction

6)In gap junction: each channel is formed of.....connexon

a. 3
b. 2
c. 5
d. 8

7)Permit exchange of ions, passage of impulses :

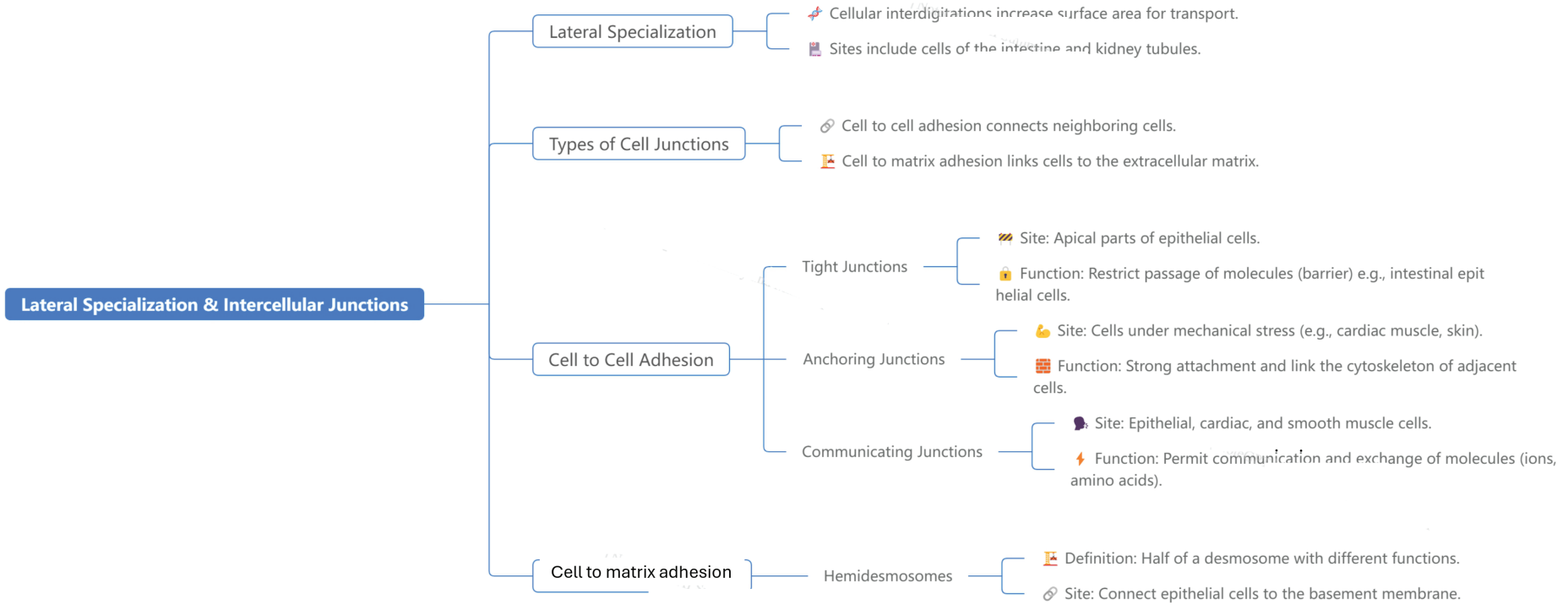
a. Tight junction
b. Adherens junction
c. Desmosome
d. Gap junction

8) Keratin filaments (Tono filaments) are present in this junction:

a. Desmosome
b. Zonula adherens
c. Occluding junction
d. Gap junction

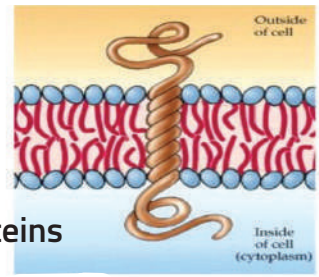
1-A
2-A
3-A
4-C
5-C
6-B
7-D
8-C

Lateral Specialization & Intercellular Junctions

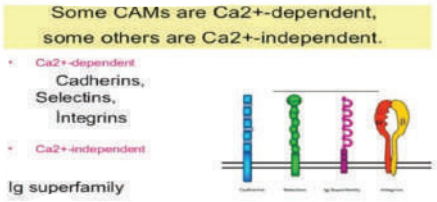


Cell Adhesion Molecules (CAMs)

- **Definition:** Transmembrane proteins play important role in cell to cell & cell to matrix adhesion.
- **Structure:** they consist of:
  - Extracellular domain.
  - Intramembranous domain.
  - **Cytoplasmic domain:** binds to cytoskeleton through linkers proteins



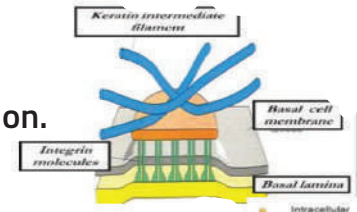
- **Types:**
  1. Calcium dependent: affected by the calcium concentration in the tissue.
  2. Calcium independent.

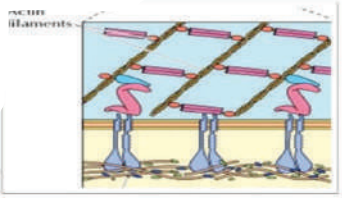


I- Calcium dependent CAMs:

1- Integrins:

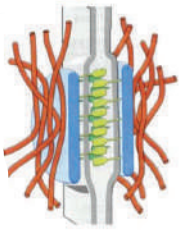
- **Function:** involved in cell to matrix adhesion.
- They are linked indirectly to cytoskeleton through anchoring proteins.

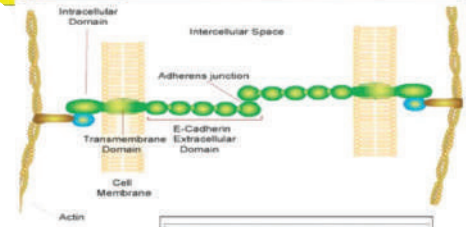




2- Cadherins:

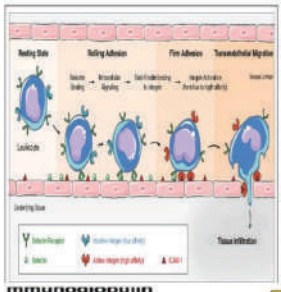
- **Function:** involved in cell to cell adhesion.
- They are present in the adhering junction.
- They are linked indirectly to cytoskeleton.

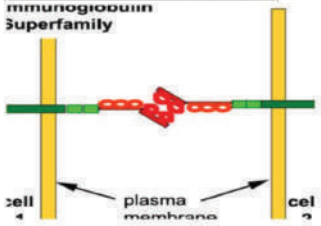




3- Selectins:

- **Function:** involved in cell to cell adhesion specifically the transient cell to cell adhesion between neutrophils and endothelial cells of the blood vessels (promote migration of neutrophils from the blood to the connective tissue).
- They bind to specific oligosaccharides on the selectin receptor of another cell.

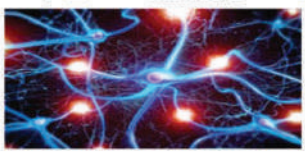




II-Calcium independent CAMs:

Immunoglobulin superfamily:

- **Function:** It has many important functions e.g., Neural cell to cell adhesion molecule, plays an important role in nervous system development.



1. Which of the following CAMs is specifically involved in cell-to-matrix adhesion and is linked to the cytoskeleton through anchoring proteins?

A) Cadherins
B) Integrins
C) Selectins
D) Immunoglobulin superfamily

2. What is the key difference between cadherins and selectins in terms of their role in cell adhesion?

A) Cadherins are involved in cell-to-cell adhesion, while selectins mediate cell-to-matrix adhesion.
B) Cadherins require calcium for function, while selectins do not.
C) Cadherins facilitate stable cell-to-cell adhesion, whereas selectins mediate transient cell-to-cell adhesion between neutrophils and endothelial cells.
D) Both cadherins and selectins are calcium-independent adhesion molecules.

3. Which of the following cell adhesion molecules is primarily involved in transient adhesion during neutrophil migration from the blood into connective tissue?

A) Cadherins
B) Integrins
C) Selectins
D) Immunoglobulin superfamily

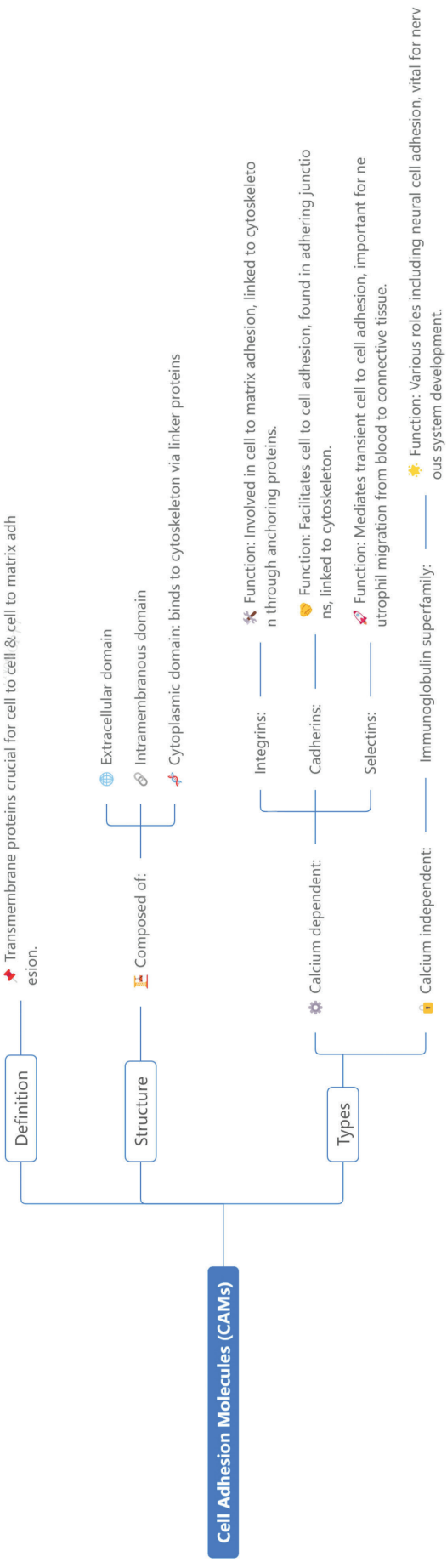
4. What is a distinctive feature of the cytoplasmic domain of CAMs, regardless of type?

A) It binds directly to the extracellular matrix.
B) It forms a calcium-binding site.
C) It binds to the cytoskeleton via linker proteins.
D) It binds to oligosaccharides on the receptor of another cell.

5. Which of the following is TRUE regarding the immunoglobulin superfamily of CAMs?

A) It requires calcium for cell adhesion.
B) It is primarily involved in cell-to-matrix adhesion.
C) It has important functions in neural cell-to-cell adhesion, particularly during nervous system development
D) It is a subtype of cadherins involved in the formation of adhering junctions.

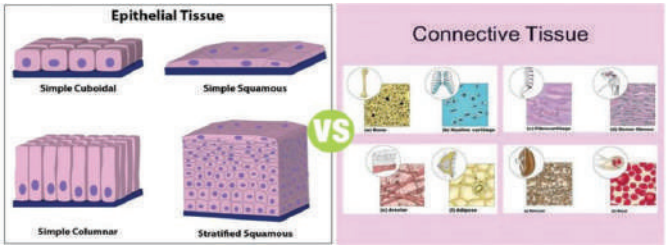
1-B
2-C
3-C
4-C
5-C


Cell Adhesion Molecules (CAMs)
Definition
Transmembrane proteins crucial for cell to cell & cell to matrix adhesion.
Structure
Composed of:
Extracellular domain
Intramembranous domain
Cytoplasmic domain: binds to cytoskeleton via linker proteins
Types
Calcium dependent:
Integrins:
Function: Involved in cell to matrix adhesion, linked to cytoskeleton through anchoring proteins.
Cadherins:
Function: Facilitates cell to cell adhesion, found in adhering junctions, linked to cytoskeleton.
Selectins:
Function: Mediates transient cell to cell adhesion, important for neutrophil migration from blood to connective tissue.
Calcium independent:
Immunoglobulin superfamily:
Function: Various roles including neural cell adhesion, vital for nervous system development.

Connective Tissue

Characteristics of CT:

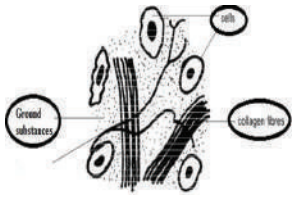
1. All types of connective tissues arise from the mesoderm.
2. Variable degrees of vascularity.
3. Several types of cells.
4. Extracellular matrix.



Structure of CT:

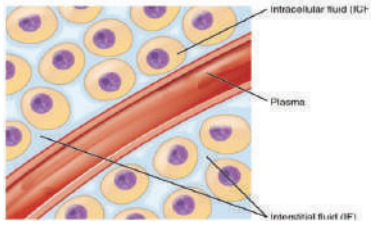
1. Cells.
2. Ground substance
3. Fibers.

Matrix



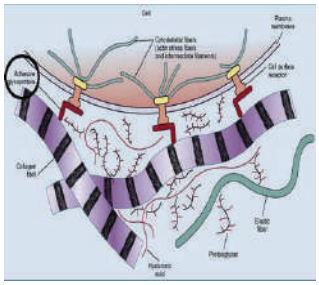
I- Ground Substance:

It is composed of:

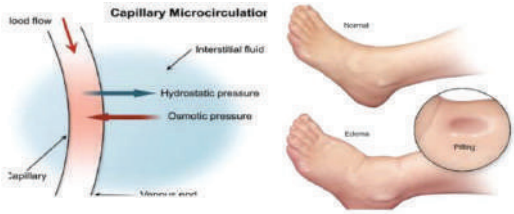


1. Interstitial fluid: that escape through the capillary wall as a result of the hydrostatic pressure.

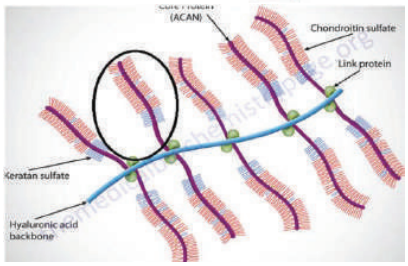
- **Edema:** an increase in the tissue fluid due to loss of the equilibrium between the tissue fluids entering and leaving the matrix of CT.



2. Adhesive glycoproteins: They serve as a glue that binds cells to matrix e.g., fibronectin & laminin.

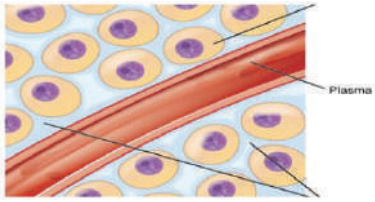


3. Proteoglycans: consist of a protein core + glycosaminoglycans (GAGs, e.g., chondroitin sulfate and keratan sulfate).



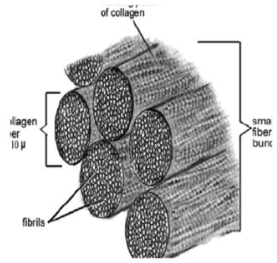
- The proteoglycans attached to hyaluronic acid form proteoglycan aggregates (negatively charged) that traps water --> forming a substance that varies from fluid to viscous gel

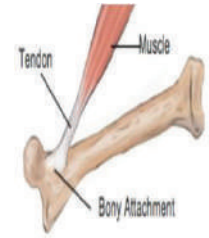
- **Functions:**

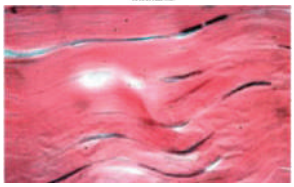


A. A medium through which nutrients can diffuse between the blood capillaries and the cells.
B. Resist compression (lubricant / shock absorber).
C. A barrier to bacterial penetration: although some bacteria secrete the enzyme hyaluronidase that hydrolyzes the ground substance and facilitates bacterial invasion.

II- CT fibers:

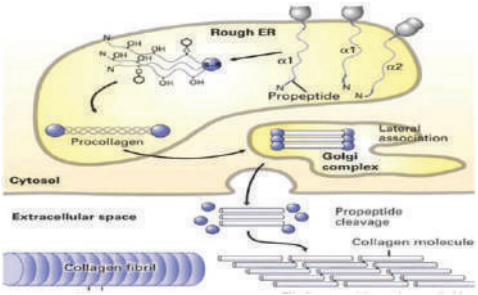


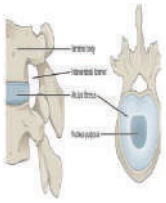


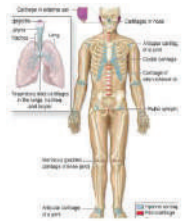


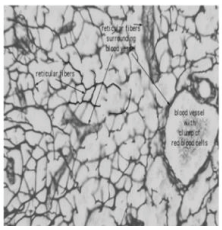
1- Collagen fibers:

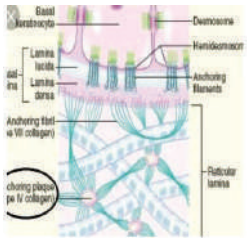
- **Characters:**
  - A. They are the most abundant CT fibers.
  - B. They are the strongest type (high tensile strength i.e.the ability to resist longitudinal stress).
  - C. In fresh state: they have a white appearance (white fibers).
- **Structure:**
  - A. Cylindrical structures.
  - B. Run in wavy bundles.
  - C. The individual fibers do not branch while the bundles of fibers do.
  - D. They stain pink with H&E (eosinophilic), blue with Mallory's stain & green with Masson's trichrome stain.



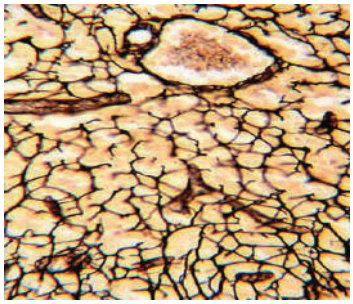








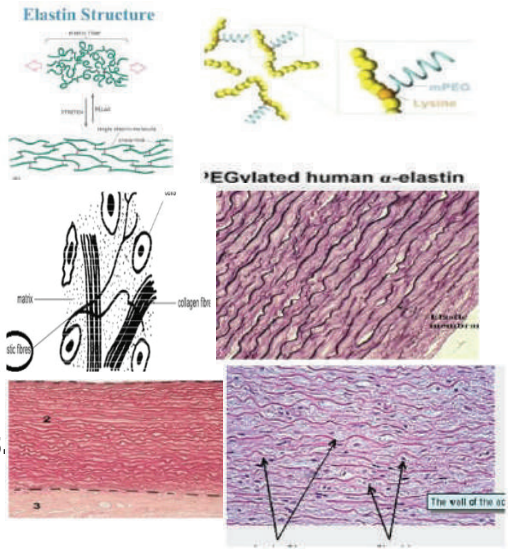
- **Synthesis of collagen:**
  - A. Procollagen is formed inside the fibroblasts then it is released by exocytosis into the extracellular space.
  - B. Procollagen is cleaved to form collagen molecules which assemble spontaneously into collagen fibrils.
  - C. Collagen fibrils are assembled into collagen fibers.
  - D. Collagen fibers bundled together into collagen bundles.
- **Types of collagen:**
  - About 20 different types of collagen fibers, differ by their composition, morphology, distribution in tissues and functions.
  - **Type I:** in connective tissue proper, fibrocartilage and bone.
  - **Type II:** in cartilage (hyaline and elastic).
  - **Type III:** reticular fibers.
  - **Type IV:** in basement membrane.



2- Reticular fibers:

- They consist of type III collgen.
- They are short, thin and branching fibers forming a network.
- They are not stained by H&E, they are stained by silver stain(brown to black).
- They have supportive function (support the cells and blood vessels of the organs).

3-Elastic fibers:



- **Characters:**
  - They contain protein called elastin that allows them to stretch and recoil.
  - In fresh state: they appear yellow (the yellow fibers).
- **Structure:**
  - **A. They may exist in two forms:**
    1- Long and thin branching fibers.
    2- Parallel sheets , present in the walls of blood vessels.
  - **B. They stain weakly with H&E, brick red with orcein & dark violet with VVG.**

	Collage fibers	Reticular fibers	Elastic fibers
1. Fresh state	White.	---------	Yellow.
2. Stain	H&E : pink. Mallory: blue. Masson: green.	Silver: brown.	H&E: faint. VVG: dark violet. Orcein: brick red.
3. Types	20 types, most common is type I.	Collagen type III.	---------
4. Description	▪ Cylindrical. ▪ Run in bundles. ▪ Fibers are not branched but bundles do.	Short branching fibers that form a network.	Either long & thin branching fibers or parallel sheets.
5. Function	Tensile strength.	Support.	Flexibility & elastic recoil (due to elastin protein).

III- CT Cells:

Types of CT cells:

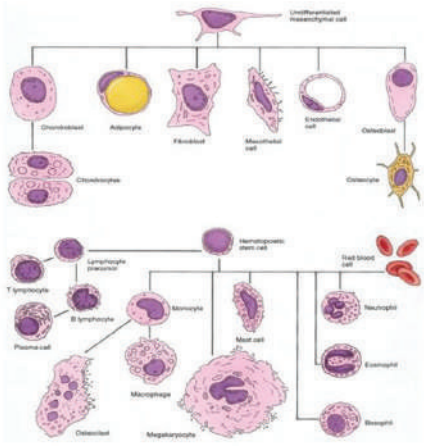
1- Resident (fixed) cells:

- **Development:** within the connective tissue.
- **Characters:** stable & long-lived.

2- Transient(wandering) cells:

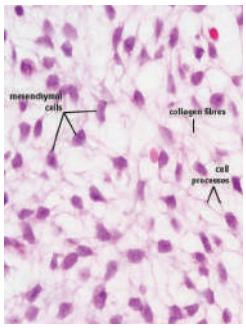
- **Origin:** in the bone marrow, circulate in the blood and when they receive a stimulus, they leave the blood and migrate into the connective tissue to perform specific functions.
- **Characters:** motile, short-lived and replaced by stem cells.

Resident (Fixed) CT cells	Transient (Wandering) CT cells
1. Undifferentiated mesenchymal stem cells. 2. Fibroblasts. 3. Fibrocytes. 4. Adipocytes. **Mast cells&**	1. Plasma cells. 2. Leukocytes. **Macrophages???**



1- Undifferentiated Mesenchymal Cells:

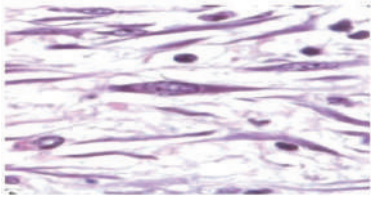
- **Origin:** mother cell of CT.
- **Function:** Stem cells that divide and differentiate into many types of CT cells.
- **Structure:**
  - **Shape:** stellate with few processes.
  - **Nucleus:** pale.
  - **Cytoplasm:** pale basophilic (polysomes).



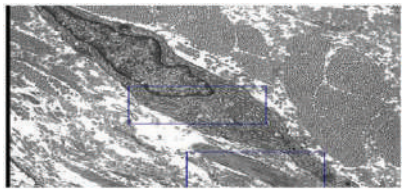
2- Fibroblasts:

- They are the most common cells in CT.
- **Origin:** UMC.
- **Function:** Secrete the ground substance &the fibers of the matrix.
- **Structure:**

  LM:
  - Shape: spindle with processes.
  - Nucleus: large& pale.
  - Cytoplasm: deeply basophilic.

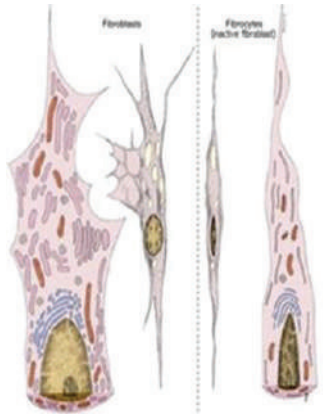


  EM: protein synthesizing cells
  - Numerous rough endoplasmic reticulum & well developed Golgi but no secretory granules.



After they synthesize the matrix, they become quiescent and are called fibrocytes.

3- Fibrocytes:



- **Origin:** Less active fibroblast.
- **Function:** maintenance of the matrix.
- **Structure:**

LM:

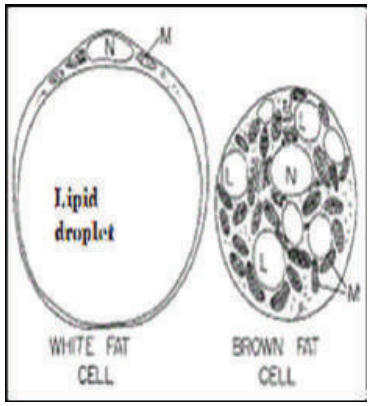
- Shape: smaller with fewer processes.
- Nucleus: small & dark.
- Cytoplasm: eosinophilic.

EM: fewer organelles (fewer rER and small Golgi).

If the matrix is injured, they can return to their more active state (fibroblast) to repair the matrix

	Fibroblast	Fibrocyte
1. Origin	Undifferentiated mesenchymal cells.	Fibroblast after being less active.
2. Function	Secretes ground substances& fibers.	Maintains matrix.
3. LM **A. Shape** **B. Nucleus** **C. cytoplasm**	 Spindle with processes. Large & pale. Deep basophilic.	 Smaller with fewer processes. Small & dark. Acidophilic.
4. EM	**Protein synthesizing cells:** Many rER, well developed Golgi but no secretory granules.	**Less active cell:** Few rER, small Golgi

4- Fat cells (adipocytes):



- **Origin:** UMC.
- **Function:** storage of fat.
- **Structure:**

1 Unilocular adipocytes:

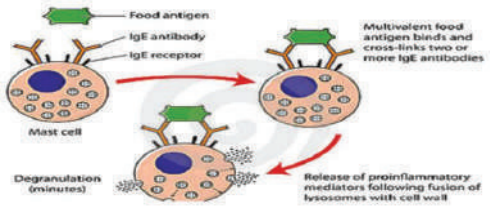
- **Shape:**
  - large spherical cells when singe
  - polyhedral when grouped
- Cytoplasm: occupied by a single large lipid droplet that pushes the cytoplasm to a thin peripheral rim with peripheral flattened nucleus giving them a signet ring appearance.

2. Multilocular adipocyte:

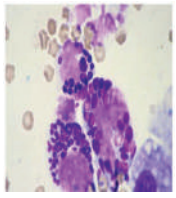
- Shape: polygonal and smaller.
- Nucleus: central rounded.
- Cytoplasm: numerous small lipid droplets and numerous mitochondria.

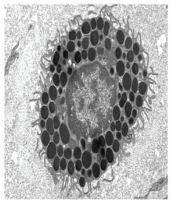
	Unilocular fat cell	Multilocular fat cell
1. Shape	Large rounded or polygonal.	The same but smaller.
2. Cytoplasm	Contains single, large lipid droplet.	Contains numerous lipid droplets & numerous mitochondria.
3. Nucleus	Flattened & peripheral (signet ring appearance).	Rounded & central.
4. Function	Storage of energy.	Production of heat.

5- Mast cells:



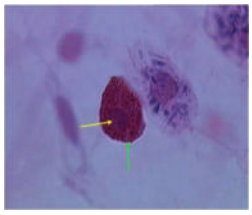
- **Origin:** Haemopoietic stem cells.
- **Function:** Secrete histamine and heparin that initiate allergic and local inflammatory response.
- **Structure:**





LM:

- Shape: a large cell.
- Nucleus: rounded and central.
- Cytoplasm: contains basophilic granules that may obscure the nucleus.

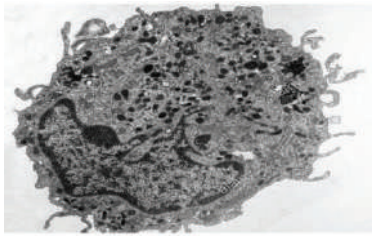


EM: numerous secretory granules (release their contents by degranulation in response to allergen).

- **Metachromasia:** A certain stain give to their granules a color differs than that of the dye e.g., toluidine blue stain gives a purple color instead of blue, due to the chemical composition of the secretory granules(heparin).

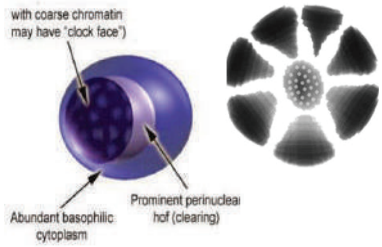
6- Macrophages:

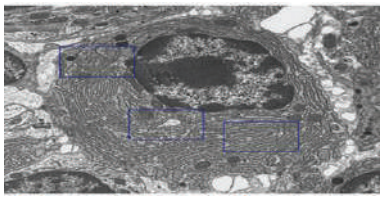
- **Origin:** Blood monocytes.
- **Function:** phagocytosis of foreign materials including bacteria& dead cells.
- **Structure:**



- Shape: large& irregular.
- Nucleus: eccentric kidney shaped.
- Cytoplasm: numerous lysosomes.

7- Plasma cells:





- **Origin:** B lymphocytes.
- **Function:** synthesis of antibodies against foreign bodies entering the CT.
- **Structure:**

LM:

- Shape: large oval.
- Nucleus: spherical and eccentric with a cartwheel appearance (due to arrangement of chromatin).
- Cytoplasm: basophilic with negative Golgi image (prominent juxtanuclear Golgi apparatus appears unstained against the deeply basophilic cytoplasm).

EM: Protein synthesizing cells: numerous rER, large well developed Golgi but no secretory granules.

	Mast cell	Macrophage	Plasma cell
1. Origin	Hemopoietic stem cell.	Monocyte	B- lymphocyte.
2. Function	Secretes histamine & heparin	Phagocytosis.	Secretes antibodies.
3. LM A. Shape B. Nucleus C. cytoplasm	Large. Rounded & central. Basophilic with large granules, showing metachromasia.	Large & irregular. Kidney shaped & eccentric.	Large & oval Spherical,cartwheel & eccentric. Basophilic with negative Golgi image.
4. EM	Secretory granules.	Lysosomes.	Protein synthesizing cells: many rER & well- developed Golgi but no secretory granules.

1) Which statement is not a feature of elastic fibers?

a. They may appear as long, thin, and branched fibers

b. They are arranged in parallel sheets in the wall of the blood vessels

c. They are strongly stained with H&E

d. They have a great flexibility

2) Which statement describes the adipocyte?

a. Its nucleus is peripheral in the multilocular cell

b. The unilocular cell is polyhedral in shape when present in group

c. The multilocular cell is larger than the unilocular one

d. Abundant mitochondria are present in the unilocular cell

3)Which of the following stains can demonstrate the reticular fibers?

A. Best's carmine stain.

B. Hematoxylin and eosin stain.

C. Silver stain.

D. Orcein stain

4) A mast cell does not have one of the following features:

A. Shows metachromasia.

B. Has many lysosomes.

C. Its granules contain heparin and histamine.

D. Originates from hemopoietic stem cell.

5)Which of the following isn't considered one of the characteristics of plasma cell:

A. Cart wheel like nucleus.

B. Well developed golgi apparatus.

C. Secretion of antibodies.

D. Abundant smooth endoplasmic reticulum

6)Which of the following cells are responsible for the synthesis of the ground substance?

A. Undifferentiated mesenchymal cells.

B. Fibroblasts.

C. Plasma cells.

D. Macrophages.

7)Multilocular adipocytes:

A. Show a lesser amount of mitochondria if compared to unilocular adipocytes.

B. Are the main energy depot for adult humans.

C. Are large polyhedral cells with a flattened eccentric nucleus.

D. None of the above

8) Cells that are generally fixed to connective tissue include each of following, except:

A. Fibroblasts.

B. Plasma cells.

C. Mast cells.

D. Fibrocytes.

9) The connective tissue cell that secretes histamine is:

A. Fibroblast.

B. Macrophage.

C. Plasma cell.

D. Mast cell.

Answer

1-C

2-B

3-C

4-B

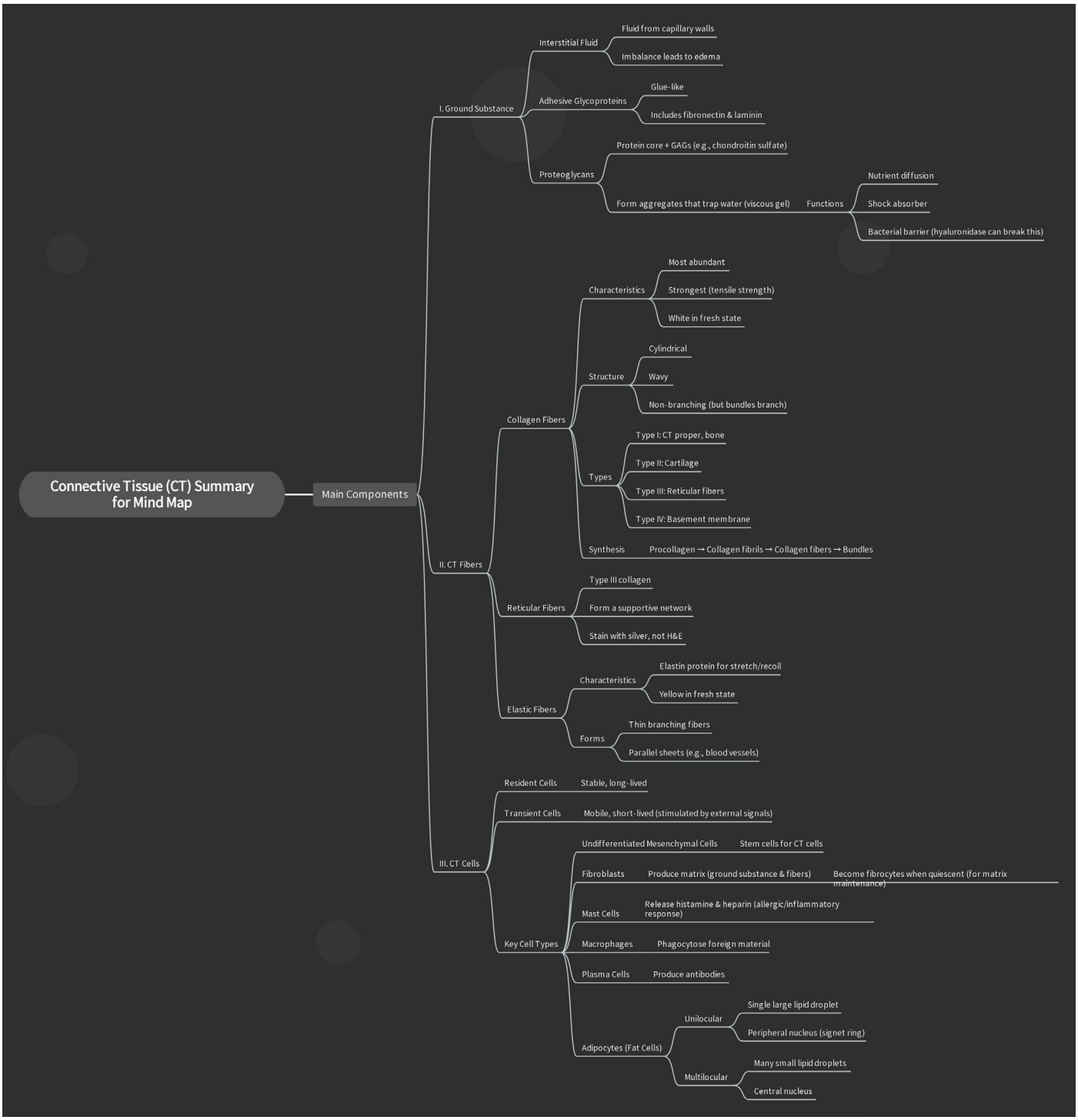
5-D

6-B

7-D

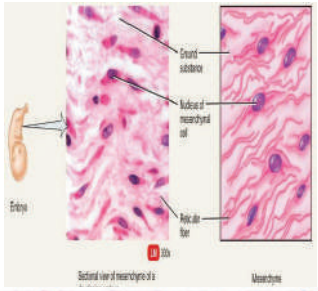
8-B

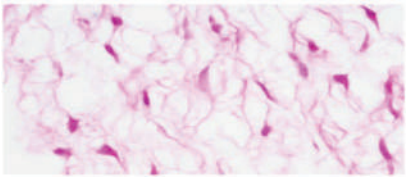
9-D


Connective Tissue (CT) Summary for Mind Map
Main Components
I. Ground Substance
Interstitial Fluid
Fluid from capillary walls
Imbalance leads to edema
Adhesive Glycoproteins
Glue-like
Includes fibronectin & laminin
Proteoglycans
Protein core + GAGs (e.g., chondroitin sulfate)
Form aggregates that trap water (viscous gel)
Functions
Nutrient diffusion
Shock absorber
Bacterial barrier (hyaluronidase can break this)
II. CT Fibers
Collagen Fibers
Characteristics
Most abundant
Strongest (tensile strength)
White in fresh state
Structure
Cylindrical
Wavy
Non-branching (but bundles branch)
Types
Type I: CT proper, bone
Type II: Cartilage
Type III: Reticular fibers
Type IV: Basement membrane
Synthesis
Procollagen → Collagen fibrils → Collagen fibers → Bundles
Reticular Fibers
Type III collagen
Form a supportive network
Stain with silver, not H&E
Elastic Fibers
Characteristics
Elastin protein for stretch/recoil
Yellow in fresh state
Forms
Thin branching fibers
Parallel sheets (e.g., blood vessels)
III. CT Cells
Resident Cells
Stable, long-lived
Transient Cells
Mobile, short-lived (stimulated by external signals)
Key Cell Types
Undifferentiated Mesenchymal Cells
Stem cells for CT cells
Fibroblasts
Produce matrix (ground substance & fibers)
Become fibrocytes when quiescent (for matrix maintenance)
Mast Cells
Release histamine & heparin (allergic/inflammatory response)
Macrophages
Phagocytose foreign material
Plasma Cells
Produce antibodies
Adipocytes (Fat Cells)
Unilocular
Single large lipid droplet
Peripheral nucleus (signet ring)
Multilocular
Many small lipid droplets
Central nucleus

Connective Tissue Types

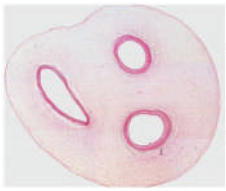
I- Embryonic CT:

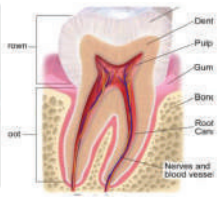




1- Mesenchymal CT:

- **Structure:**
  - **Cells:** UMSCs with their processes come in contact with each other forming a network.
  - **Fibers:** reticular fibers.
  - **Ground substance:** gel like.
- **Site:** embryo.



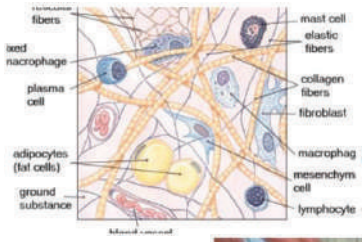


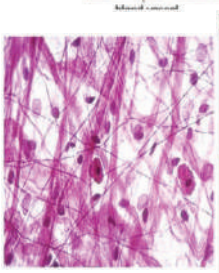
2- Mucoid CT:

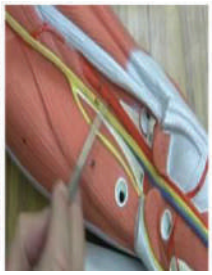
- **Structure:**
  - **Cells:** UMSCs (spindle) appear like fibroblasts.
  - **Fibers:** unapparent collagen (have the same refractive index as the matrix).
  - **Ground substance (Wharton jelly):** abundant, basophilic & homogenous composed of hyaluronic acid.
- **Site:** umbilical cord, pulp of growing teeth.

Embryonic CT	Mesenchymal CT	Mucoid CT
1. Cells	Undifferentiated mesenchymal cells (stellate with processes).	Undifferentiated mesenchymal cells (spindle resembles fibroblast).
2. Fibers	Reticular.	Unapparent collagen.
3. Ground substance	Gel like.	Abundant, homogenous & basophilic (called Wharton jelly).
4. Sites	Embryo.	1- umbilical cord. 2- Dental pulp.

II- CT Proper:

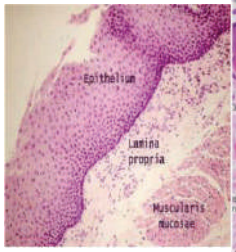


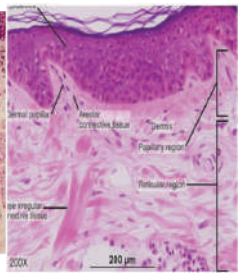


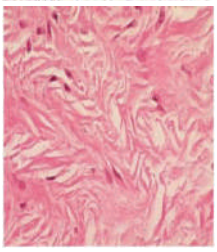


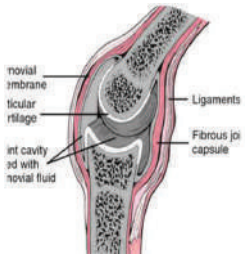
1- Loose areolar CT:

- **Structure:**
  - **Cells:** All types cells especially fibroblasts & macrophage.
  - **Fibers:** All fibers (collagen, elastic& reticular).
  - **Ground substance:** Abundant
- **Function:**
  - A. **Fibers:** supports and binds tissues.
  - B. **Ground substance:** nutrition.
  - C. **Cells:** defends against infection (by its white blood cells, plasma cells, mast cells and macrophages).
- **Sites:** it is the most widely distributed connective tissue in the body.
  - A. Under the epithelium in all mucous membranes
    It is present under the epithelium in all mucous membranes forming the lamina propria.
  - B. The papillary layer of dermis.
  - C. It surrounds glands, blood vessels and nerves.



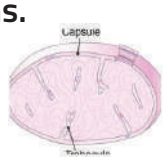


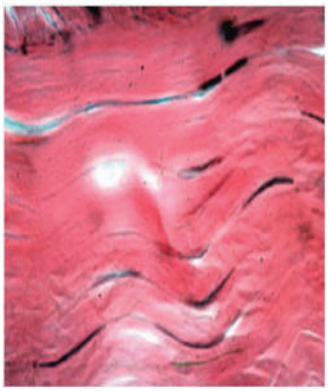




2- Dense Irregular CT:

- **Structure:**
  - **Fibers:** collagen run in all directions (irregular).
  - **Cells:** few fibroblasts.
  - **Ground substance:** little.
- **Function:** resist tension in different directions.
- **Sites:**
  - A. The reticular layer of dermis of the skin.
  - B. The capsules of the organs.
  - C. The fibrous capsules of the joints.





3- Dense regular CT (White fibrous CT):

- **Structure:**
  - **Fibers:** collagen bundles, wavy, parallel in one direction.
  - **Cells:** rows of flattened fibroblasts (tendon cells).
  - **Ground substance:** little.
- **Function:** resist pulling force in one direction.
- **Sites:**
  - A. Tendons. B. Ligaments.

CASE:

A 12-year-old boy admitted to the hospital, suffering from severe pain in his knee joint and inability to move it after playing a football match. After examination and investigations, he was diagnosed as a tear in the posterior cruciate ligament.

1- What is the type of tissue affected in this case?

2- What is your expectation for the healing of this tear? Explain your answer.

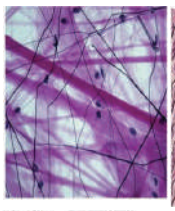
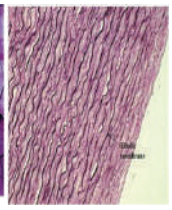
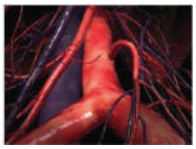
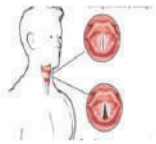
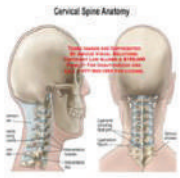
Answer:

1. White fibrous CT.
2. If the tear is mild: healing can occur spontaneously with conservative treatment, but if the tear is severe, it needs surgical interference because this type of tissue is poorly vascularized.

	Loose areolar CT	Dense regular CT	Dense irregular CT
1. Cells	All types especially fibroblast & macrophage.	Flattened fibroblast (tendon cells).	Fibroblasts.
2. Fibers	All types.	Collagen in wavy parallel bundles.	Collagen run irregularly.
3. Ground substance	Good amount	Little	Little
4. Vascularity	Highly vascular.	Poor.	Poor.
5. Function	1. Support & bind tissues. 2. Nutrition (high vascularity). 3. Defense against infection.	Resists pulling force in a single direction.	Resists tension in all directions.
6. Sites	1. Papillary dermis. 2. Beneath epithelium. 3. Around blood vessels & nerves.	Tendon & ligaments.	1. Reticular dermis. 2. Capsules of organs & joints.

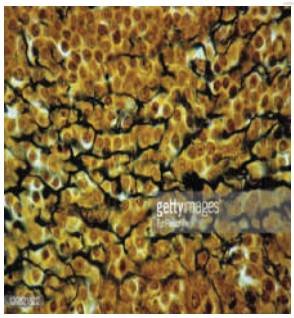
4- Elastic CT:

- **Structure:**
  - Elastic fibers that run in all directions or they may form fenestrated membranes.
- **Function:** flexibility and elastic recoil.
- **Sites:**
  1. Arteries.
  2. Vocal cords.
  3. Ligamenta flava & ligamenta nuchae.

5- Reticular CT:

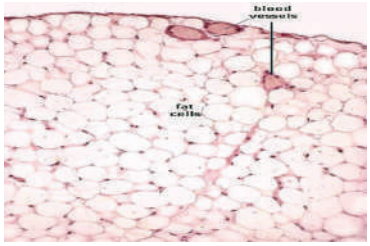
- **Structure:**
  - **Fibers:** Reticular fibers forming a network.
  - **Cells:** Reticular cells (fibroblasts).
- **Function:** Form framework to support cells of an organ.
- **Sites:**
  1. Liver.
  2. Spleen, lymph nodes & bone marrow.



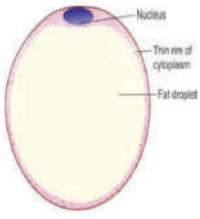
	Elastic CT	Reticular CT
1. Cells	---------	Reticular cells.
2. Fibers	Elastic fibers.	Reticular fibers.
3. Function	Flexibility & elastic recoil.	Support.
4. Sites	1. Arteries. 2. Vocal cords. 3. Elastic ligaments of the vertebral column.	Bone marrow, liver, spleen & lymph nodes.

6- Adipose CT:

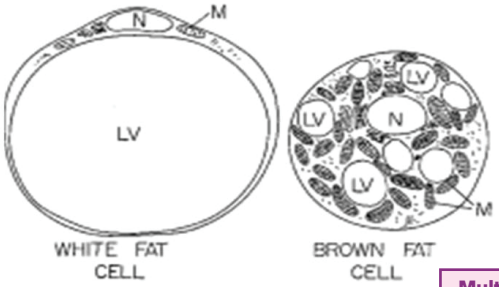
- **Structure:**
  - **Cells:** Adipose cells.
  - **Fibers:** Reticular fibers.
  - **Ground substance:** Sparse.

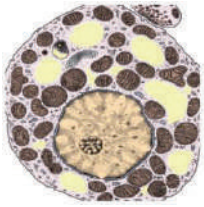


It is highly vascular



Unilocular adipocytes

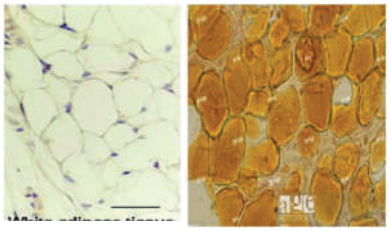




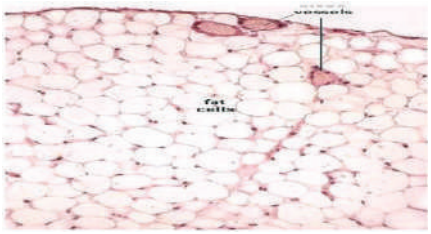
Multilocular adipocytes

Types Of Adipose CT:

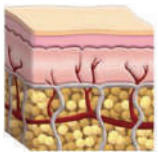
A- Unilocular (White adipose CT):

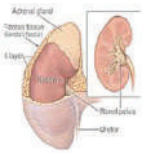


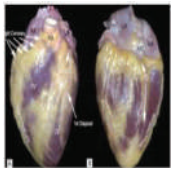
- **Color:** varies from white to yellow due to the presence of carotenoids dissolved in fat droplets of the cells.
- **Structure:** It is formed of unilocular adipocytes.
- **Sites:** All the subcutaneous tissue of the body& around vital organs.
- **Functions:**

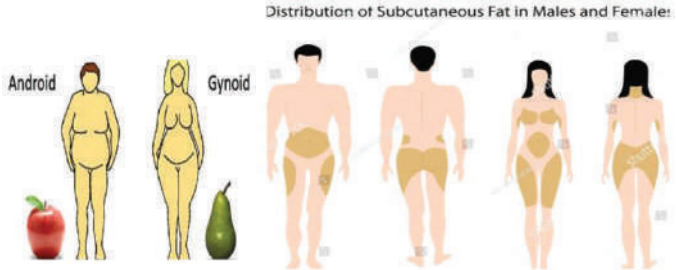


1. Storage of energy.
2. Shaping body.
3. Shock absorber (especially in palm& sole).
4. Support vital organs e.g., heart & kidney.
5. Thermal insulation (due to the poor heat conduction of adipose tissue).



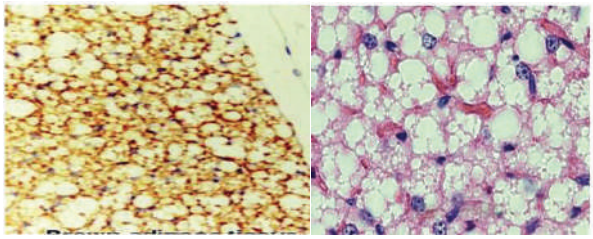






B- Multilocular (Brown adipose CT):

- **Color:** brown due to the large number of blood capillaries and the colored cytochromes inside the numerous mitochondria.
- **Structure:** multilocular adipocytes.
- **Sites:** in certain areas in the abdomen and neck of the human embryo and the newborn.



- **Function:** Thermogenesis: Production of heat to protect the newborn against cold.

As children grow, the lipid droplets coalesce together and the brown fat changes into white fat.

	Unilocular adipose CT	Multilocular adipose CT
1. Cells	Unilocular fat cells.	Multilocular fat cells.
2. Fibers	Reticular.	Reticular.
3. Ground substance	Little in amount, highly vascular.	Highly vascular.
4. Color	Yellow due to carotenoids inside fat droplets.	Brown due to the color of blood inside blood vessels & cytochrome inside numerous mitochondria.
5. Site	1- all subcutaneous tissues. 2- around vital organs.	Abdomen & neck of the human embryo and newborn.
6. Functions	1- storage of energy. 2- shock absorber. 3- shaping of the body. 4- support vital organs. 5-thermal insulation.	Thermogenesis (heat production).

1) The loose areolar connective tissue isn't found in which of the following site:

A. Around blood vessels.

B. Around glands.

C. Papillary layer of epidermis.

D. Umbilical cord.

2) One of the following is not a component of the mucoid connective tissue:

A. Reticular fibers.

B. Fibroblasts like cells.

C. Abundant intercellular substance.

D. Hyaluronic acid.

3) The type of connective tissue that is characterized by loosely arranged fibersand relatively abundance of cells is the..... Connective tissue.

A. Areolar.

B. Dense regular.

C. Dense irregular.

D. Mucoid.

4)What type of tissue makes up the reticular dermis (underlying tissue) of the skin?

A. Elastic connective tissue.

B. Loose connective tissue.

C. Dense irregular connective tissue.

D. Dense regular connective tissue.

5) What type of connective tissue can resist tensile stress from many directions?

A. Dense irregular ct.

B. Reticular ct.

C. Dense regular ct.

D. Loose ct.

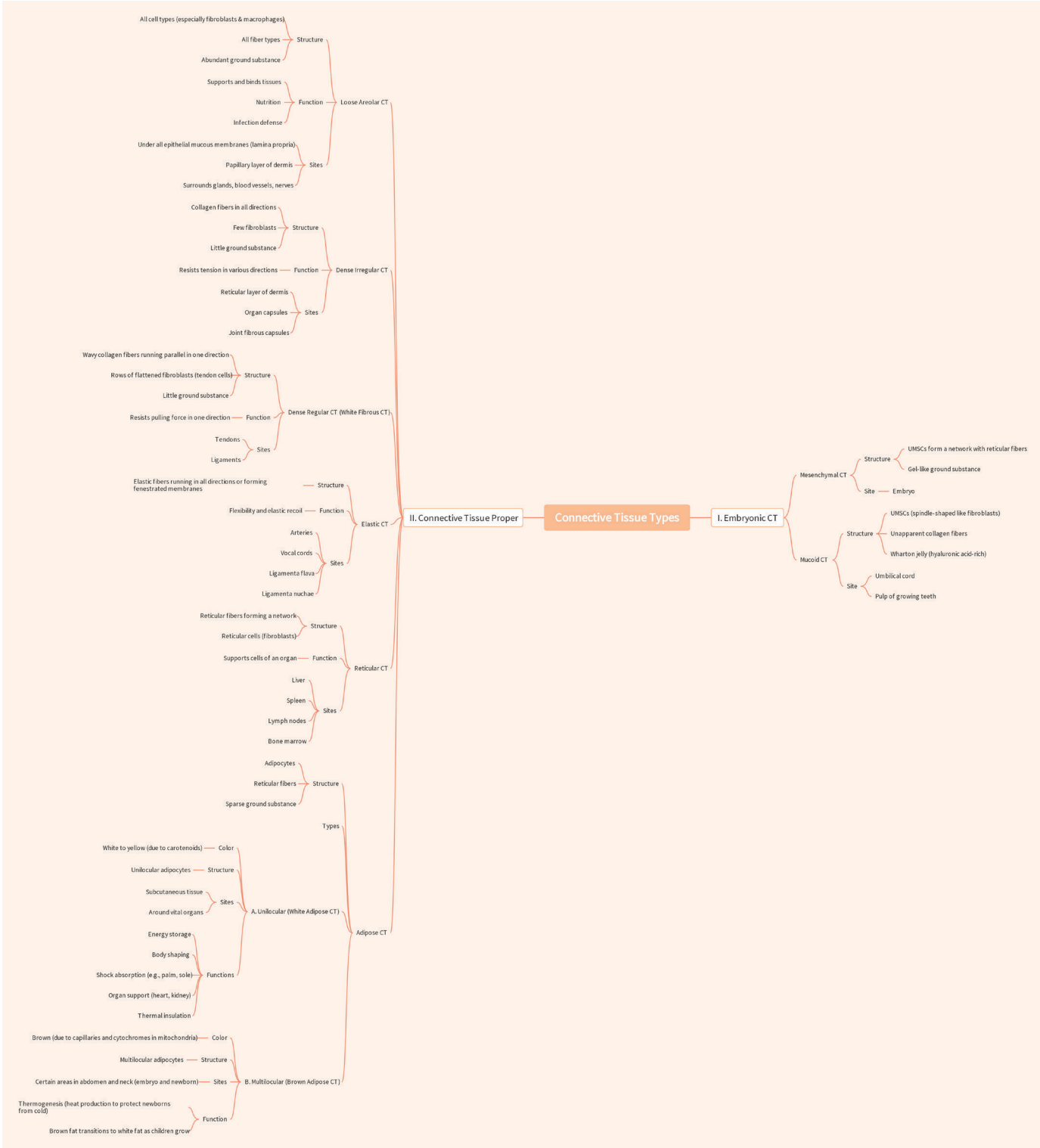
1-D

2-A

3-A

4-C

5-A


Connective Tissue Types
I. Embryonic CT
Mesenchymal CT
Structure
UMSCs form a network with reticular fibers
Gel-like ground substance
Site
Embryo
Mucoid CT
Structure
UMSCs (spindle-shaped like fibroblasts)
Unapparent collagen fibers
Wharton jelly (hyaluronic acid-rich)
Site
Umbiical cord
Pulp of growing teeth
II. Connective Tissue Proper
Loose Areolar CT
Structure
All cell types (especially fibroblasts & macrophages)
All fiber types
Abundant ground substance
Function
Supports and binds tissues
Nutrition
Infection defense
Sites
Under all epithelial mucous membranes (lamina propria)
Papillary layer of dermis
Surrounds glands, blood vessels, nerves
Dense Irregular CT
Structure
Collagen fibers in all directions
Few fibroblasts
Little ground substance
Function
Resists tension in various directions
Sites
Reticular layer of dermis
Organ capsules
Joint fibrous capsules
Dense Regular CT (White Fibrous CT)
Structure
Wavy collagen fibers running parallel in one direction
Rows of flattened fibroblasts (tendon cells)
Little ground substance
Function
Resists pulling force in one direction
Sites
Tendons
Ligaments
Elastic CT
Structure
Elastic fibers running in all directions or forming fenestrated membranes
Function
Flexibility and elastic recoil
Sites
Arteries
Vocal cords
Ligamenta flava
Ligamenta nuchae
Reticular CT
Structure
Reticular fibers forming a network
Reticular cells (fibroblasts)
Function
Supports cells of an organ
Sites
Liver
Spleen
Lymph nodes
Bone marrow
Adipose CT
Structure
Adipocytes
Reticular fibers
Sparse ground substance
Types
A. Unilocular (White Adipose CT)
Color
White to yellow (due to carotenoids)
Structure
Unilocular adipocytes
Sites
Subcutaneous tissue
Around vital organs
Functions
Energy storage
Body shaping
Shock absorption (e.g., palm, sole)
Organ support (heart, kidney)
Thermal insulation
B. Multilocular (Brown Adipose CT)
Color
Brown (due to capillaries and cytochromes in mitochondria)
Structure
Multilocular adipocytes
Sites
Certain areas in abdomen and neck (embryo and newborn)
Function
Thermogenesis (heat production to protect newborns from cold)
Brown fat transitions to white fat as children grow

Skin

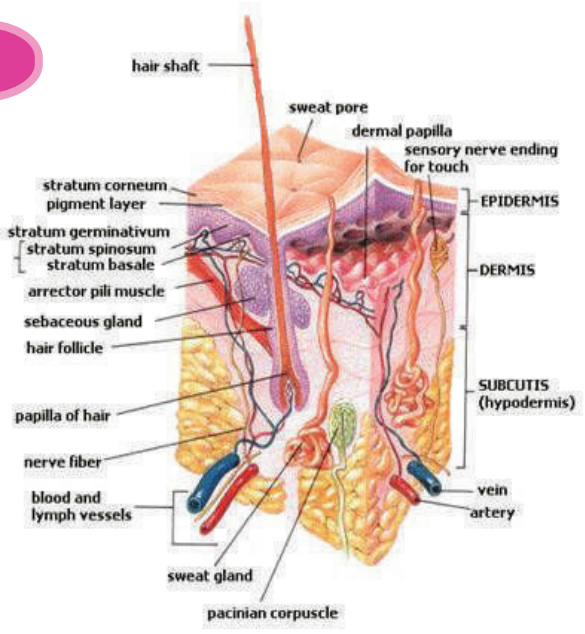
The integumentary system:الجهاز الغلافى

It consists of:

1.The skin skin.

2.The skin appendages:

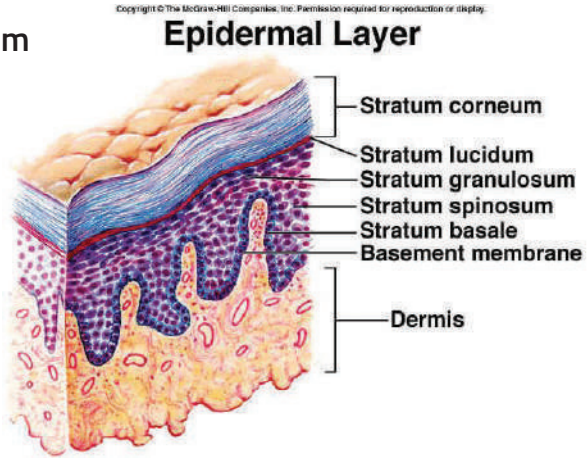
- Hair.
- Nail.
- Sweat, sebaceous & mammary glands.



Skin:

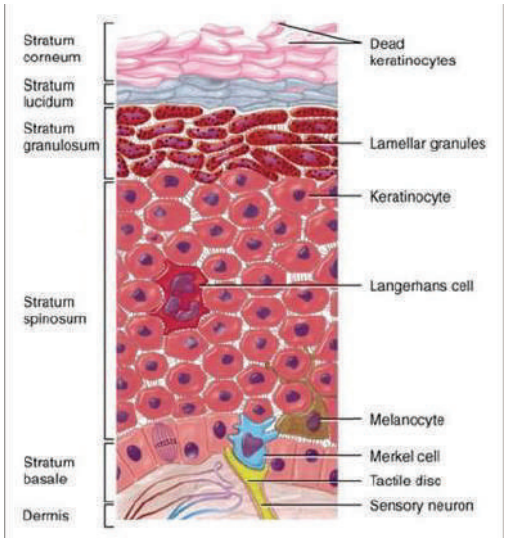
- **It consists of two layers:**

1. **The epidermis:** the superficial epithelium derived from ectoderm. It is avascular but rich in sensory nerve endings especially for pain.
2. **The dermis:** the deeper vascular connective tissue layer derived from mesoderm.

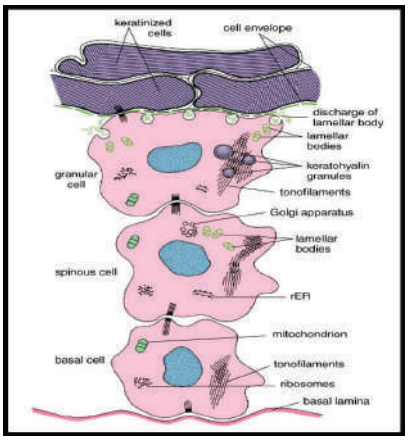


The epidermis

- It is a keratinized stratified squamous epithelium.
- **It consists of four types of cells:**
  1. Keratinocytes.
  2. Melanocytes.
  3. Langerhans cells.
  4. Merkel's cells.

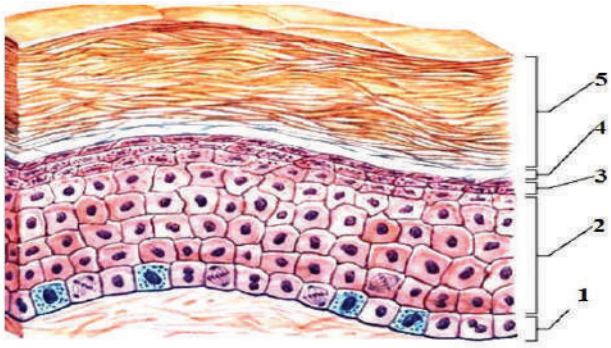


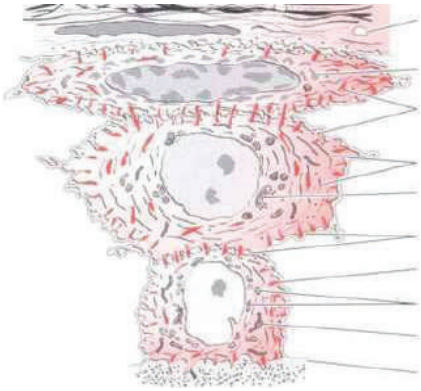
A. Keratinocytes:



- They are the most abundant cells in the epidermis.
- **Keratinization (15 - 30 days):**
  - The superficial epithelial cells are shed off at the surface and are replaced by cells arise from stem cells in the basal layer.
  - **As the cells move upwards:**
    1. The keratin filaments (cytokeratin filaments) accumulate inside the cells.
    2. The nucleus and organelles are disappearing.
    3. The cells die.
  - **If the process of keratinization occurs more rapidly (one week):** The superficial keratinized cells will accumulate and desquamate forming thick scales (dandruff).

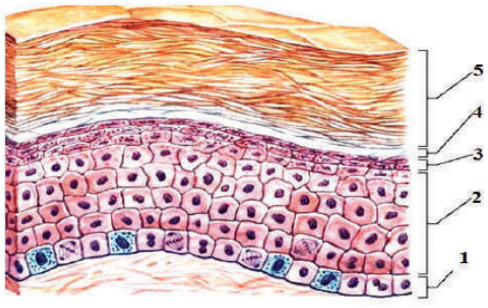
The keratinocytes are arranged in 5 layers:



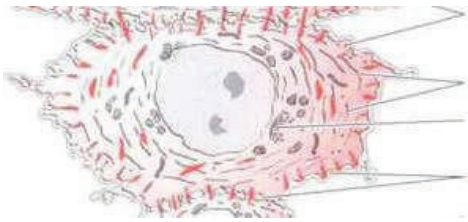


1. Stratum germinativum = Stratum basale:

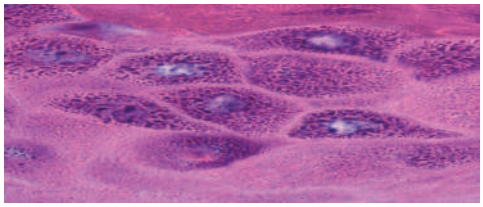
- **Number of layers:** one layer.
- **Structure:**
  1. **Shape of cells:** low columnar.
  2. **Nucleus:** large oval.
  3. **Cytoplasm:** deep basophilic (numerous polysomes).
  4. The cells are attached together by **desmosomes** and to the basement membrane by hemidesmosomes.
  5. **Frequent mitotic figures.**
- **Function:** renewal of keratinocytes.



2. Stratum spinosum = Prickle cell layer:

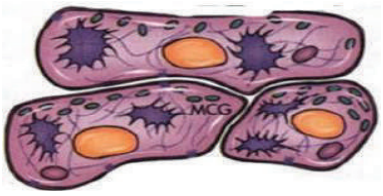


- **Number of layers:** 5 -10.
- **Structure:**
  1. Shape of cells: polyhedral.
  2. Multiple spinous processes which interdigitate the similar processes of adjacent cells by numerous desmosomes.
- **Function:** resisting the effects of friction and pressure.



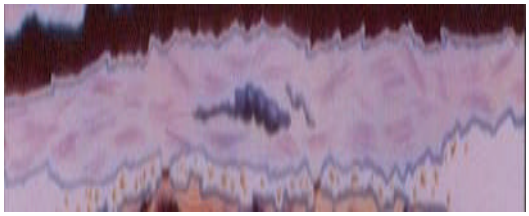
3. Stratum granulosum = granular layer:

- **Number of layers:** 3 - 5.
- **Structure:**
  1. **Shape of cells:** diamond shaped, the long axis of these cells is parallel to the skin surface.
  2. **Nucleus:** flattened.
  3. **Cytoplasm:** deeply basophilic& granular, contains:
  - a. **Keratohyaline granules:** non membrane bounded granules (packing keratin filaments together).



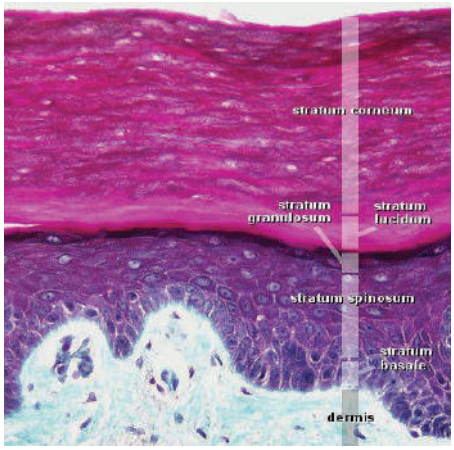
  - b. **Membrane bounded lamellated granules:** Its synthesis starts in stratum spinosum and they increase in number in stratum granulosum, collect near the cell membrane then discharge their contents in the intercellular spaces.
- **Function:** waterproof barrier of the skin.

4. Stratum lucidum = clear zone:



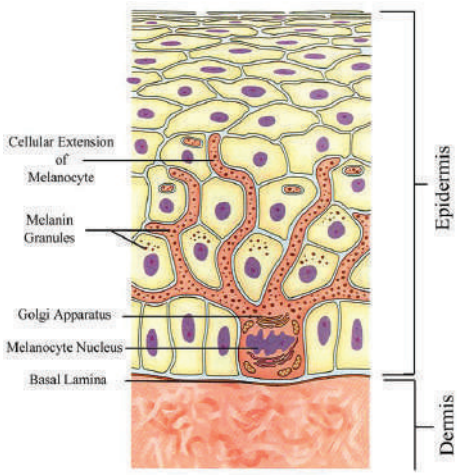
- **Number of layers:** 2 - 3 layers.
- **Structure:**
  - a. **Shape of cells:** flattened & pale.
  - b. **The nuclei and the organelles:** are degenerating.
  - c. **The cytoplasm:** contains densely packed keratin filaments oriented parallel to the skin surface.

5. Stratum corneum = horny layer:



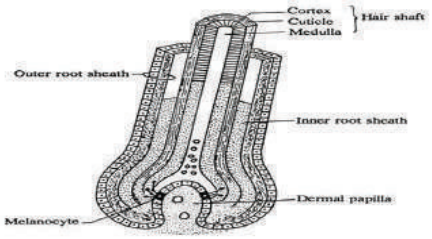
- **Number of layers:** 20 30.
- **Structure:**
  1. **Shape of cells:** flat cells in the form of eosinophilic horny scales.
  2. **The nuclei and organelles:** degenerated.
  3. **Cytoplasm:** contains densely packed keratin filaments.
  4. The cells adhere to each another by **remnants of desmosomes.**

B. Non keratinocytes:

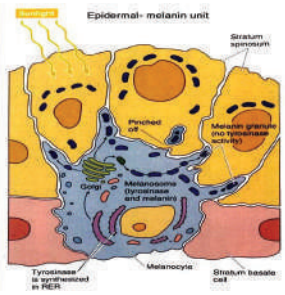


Melanocytes:

- **The color of the skin depends on the interaction of three factors:**
  1. The content of carotene (yellow).
  2. The oxygenated hemoglobin in the capillaries (red).
  3. The melanin pigments (brown to black).
- **Features:**
  1. **Site:** in the epidermis, between the cells of the stratum basale (also found in the hair follicle).
  2. **Structure:** branching cell, its cytoplasm contain melanosomes.



- **Function:** Melanin formation which protect against the harmful effect of ultraviolet rays, thus exposure to sun light accelerates the rate of melanin production.



- **Cytocrine secretion:**

unusual mode of secretion, in which the cytoplasmic processes of melanocytes transfer the melanosomes into the neighboring epidermal cells.

- **The number of melanocytes:**

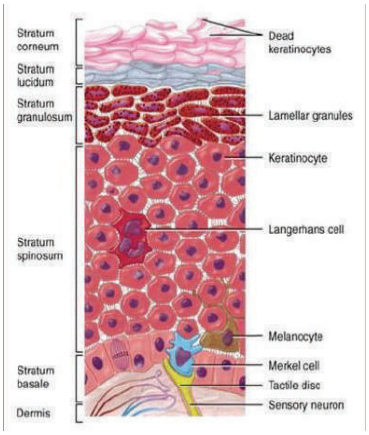
Nearly the same in all races. Although, hereditary and racial factors control the amount and size of melanosomes and the rate of transfer by melanocytes.

Disorders of Melanocytes:

1. Albinism: Lack of pigmentation, in which the melanocytes fail to form melanin.

2. Vitiligo: a depigmentation disorder occurs due to degeneration of melanocytes.

Langerhans cells:



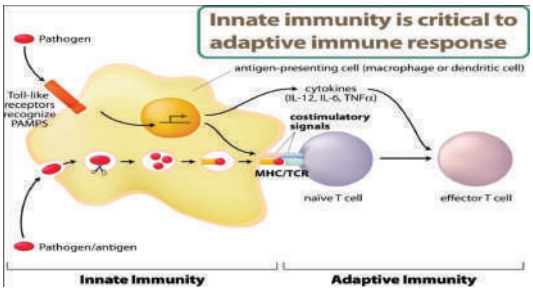
- **Origin:** blood monocytes (mononuclear phagocytic system) derived from the bone marrow
- **Features:**

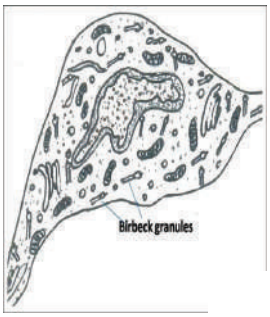
LM:

- **Shape:** branching cells with multiple cytoplasmic processes.
- **Nucleus** folded & irregular.
- **Cytoplasm:** pale.
- **Site:** between the cells of stratum spinosum.

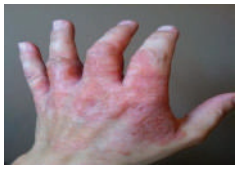
EM:

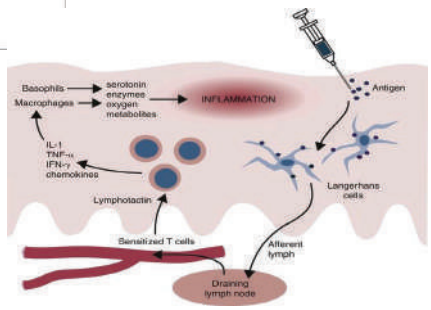
- **Numerous lysosomes.**
- **2 Nos:** No keratin & No desmosomes between the Langerhans cells and keratinocytes.





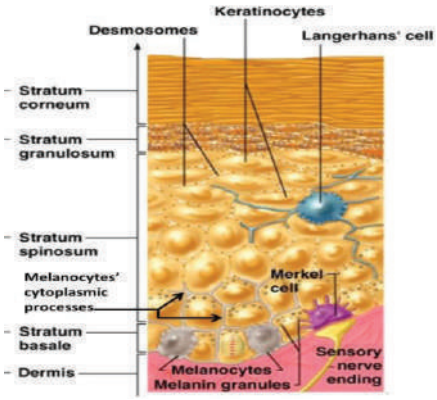
- **Function:** Immune function Antigen presenting cells (binding, processing and presenting the antigen to T lymphocytes). They are involved in the cutaneous contact hypersensitivity reaction.





Merkel's cells:

- **Features:**
  - **Shape:** large cells with short processes Large cells with short processes, with their long axis parallel to the basement membrane.
  - **Site:** the basal layer of the epidermis.
  - They are attached to the keratinocytes by desmosomes.
  - The sensory nerve fibers pierce the basement membrane, end as expanded discs near the Merkel's cells



- **Function:** Receptors for fine touch sensation (the sensory nerve fibers travers the basement membrane of the epidermis to end as expanded tactile discs near theMerkel's cells)..

1) Which statement doesn't describe the cells of the stratum granulosum?

a. Their long axis is parallel to the skin surface

b. Their nuclei are flattened

c. They have eosinophilic cytoplasm

d. They contain membranous and non-membranous granules

2) What is the histological feature of Merkel's cells?

a. They are attached to the basement membrane by hemidesmosomes

b. They are large cell with long processes

c. They are not attached to the adjacent keratinocytes

d. Their long axis are parallel to the basement membrane

3) Which statement doesn't characterize Langerhans cells?

a. They are members of mononuclear cells derived from the bone marrow

b. They have a dark cytoplasm

c. They are not attached to the adjacent keratinocytes by desmosomes

d. They don't have keratin filaments in their cytoplasm

4) In Which layer of Skin prickle cell exist

a. Stratum corneum

b. Stratum lucidum

c. Stratum Spinousum

d. Stratum basale

5) A Boy His Hand was penetrated by a foreign body, He had tenderness rough on the affected area and redness, Which Cell is Responsible for this?

a. Langerhans cells

b. Melanocyte

c. Stem cells

d. Merckle's cell

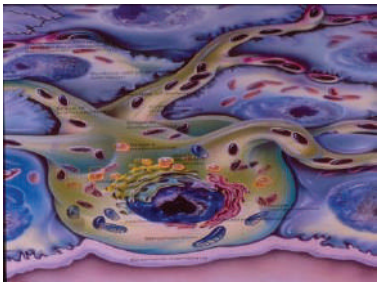
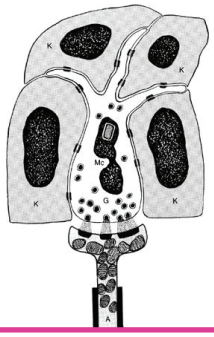
1-C

2-D

3-D

4-C

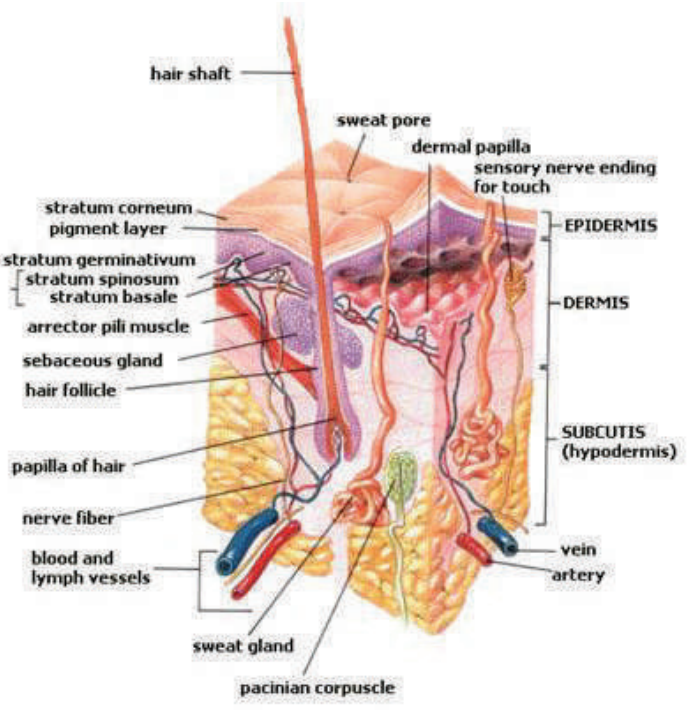
5-A

	Melanocyte	Langerhan's cell	Merkel's cell
1. Site	Basal layer.	Stratum spinosum.	Basal layer.
2. Function	Melanin secretion which acts as a screen against UV radiation.	Antigen presenting cell responsible for cutaneous hypersensitivity.	Receptors for light touch.
3. Structure	Branching cells. Cytoplasm contains melanosomes. 	Branching cells with irregular nucleus. Cytoplasm contains lysosomes.	Large cell with short processes. Connected to keratinocytes by numerous desmosomes. 

II. The Dermis

- It is a connective tissue layer.
- **It contains:**

1. Epidermal downgrowths: the hair follicles, the sweat glands & the sebaceous glands.
2. Sensory nerve endings (receptors).
3. Numerous capillaries capillaries: for thermoregulation and nutrition.



1. Which of the following best describes the structure of the papillary layer of the dermis?

a) Dense irregular connective tissue rich in capillaries

b) Loose connective tissue with sensory nerve endings for pressure sensation

c) Loose connective tissue with blood capillaries and receptors for fine touch

d) Dense regular connective tissue with elastic fibers

2. What distinguishes the reticular layer from the papillary layer in terms of its structure and function?

a) It contains hair follicles and is rich in blood vessels.

b) It has dense irregular connective tissue and is less vascular.

c) It consists of loose connective tissue and capillaries.

d) It interdigitates with the basement membrane of the epidermis.

3. Which of the following is NOT true about the components found in the dermis?

a) Sensory nerve endings are present only in the papillary layer.

b) Sebaceous glands are found as epidermal downgrowths in the dermis.

c) The dermis contains numerous capillaries for thermoregulation and nutrition.

d) Collagen fibers are present in the reticular layer of the dermis.

4. Which sensory function is associated with the papillary layer of the dermis?

a) Pressure sensation

b) Fine touch and temperature sensation

c) Vibration sensation

d) Proprioception

5. The dermis contains which of the following elements that support its role in thermoregulation?

a) Sensory nerve endings for fine touch

b) Dense irregular connective tissue

c) Numerous capillaries in both papillary and reticular layers

d) Collagen and elastic fibers for pressure sensation

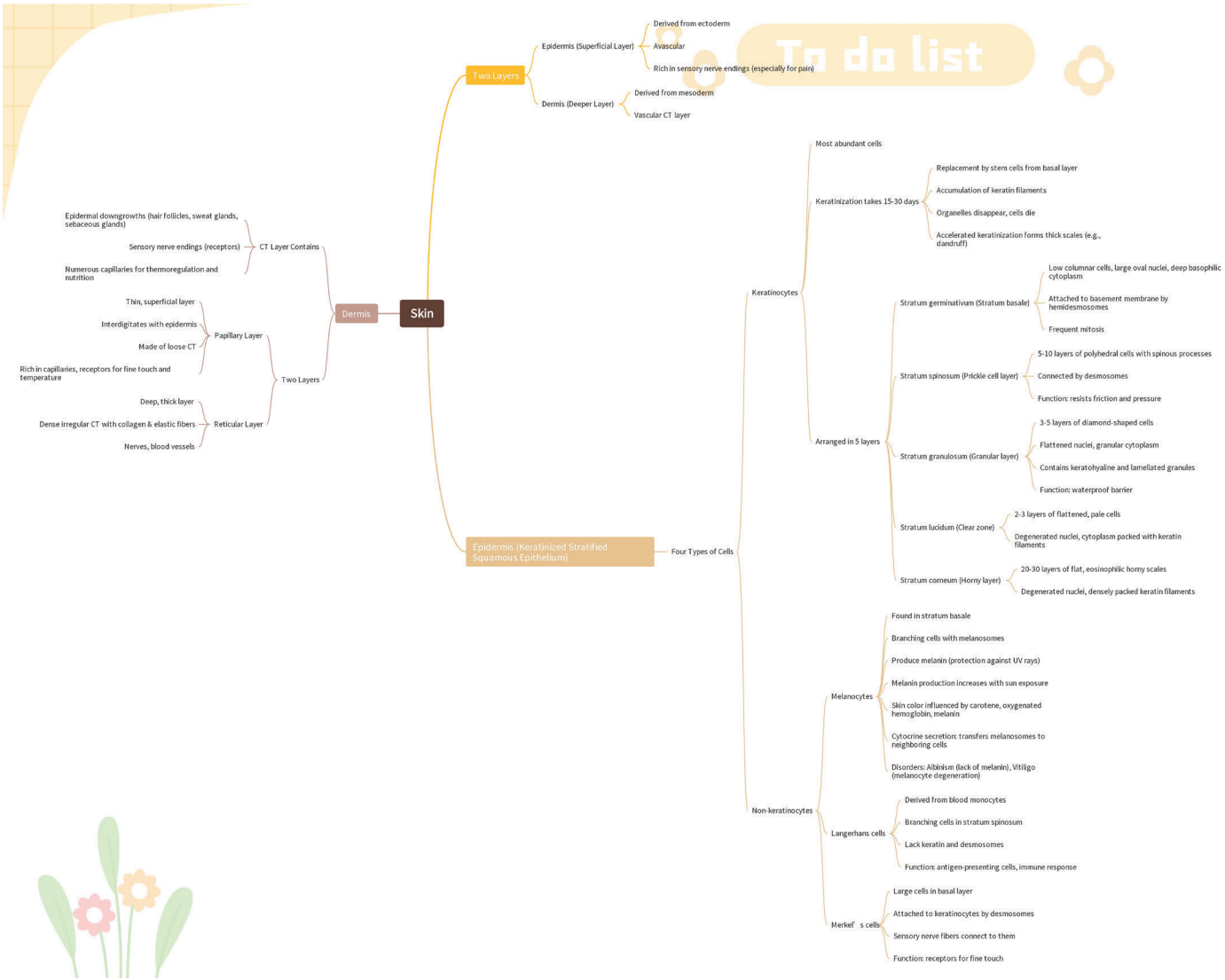
1-c

2-b

3-a

4-b

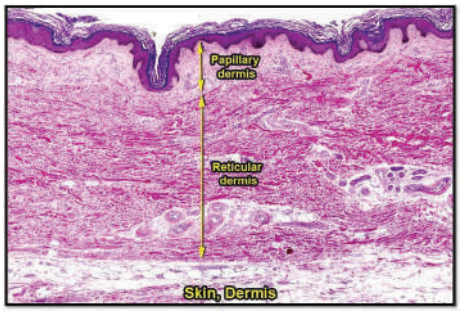
5-c


To do list
Skin
Two Layers
Epidermis (Superficial Layer)
Derived from ectoderm
Avascular
Rich in sensory nerve endings (especially for pain)
Dermis (Deeper Layer)
Derived from mesoderm
Vascular CT layer
Dermis
CT Layer Contains
Epidermal downgrowths (hair follicles, sweat glands, sebaceous glands)
Sensory nerve endings (receptors)
Numerous capillaries for thermoregulation and nutrition
Two Layers
Papillary Layer
Thin, superficial layer
Interdigitates with epidermis
Made of loose CT
Rich in capillaries, receptors for fine touch and temperature
Reticular Layer
Deep, thick layer
Dense irregular CT with collagen & elastic fibers
Nerves, blood vessels
Epidermis (Keratinized Stratified Squamous Epithelium)
Four Types of Cells
Keratinocytes
Most abundant cells
Keratinization takes 15-30 days
Replacement by stem cells from basal layer
Accumulation of keratin filaments
Organelles disappear, cells die
Accelerated keratinization forms thick scales (e.g., dandruff)
Arranged in 5 layers
Stratum germinativum (Stratum basale)
Low columnar cells, large oval nuclei, deep basophilic cytoplasm
Attached to basement membrane by hemidesmosomes
Frequent mitosis
Stratum spinosum (Prickle cell layer)
5-10 layers of polyhedral cells with spinous processes
Connected by desmosomes
Function: resists friction and pressure
Stratum granulosum (Granular layer)
3-5 layers of diamond-shaped cells
Flattened nuclei, granular cytoplasm
Contains keratohyaline and lamellated granules
Function: waterproof barrier
Stratum lucidum (Clear zone)
2-3 layers of flattened, pale cells
Degenerated nuclei, cytoplasm packed with keratin filaments
Stratum corneum (Horny layer)
20-30 layers of flat, eosinophilic horny scales
Degenerated nuclei, densely packed keratin filaments
Non-keratinocytes
Melanocytes
Found in stratum basale
Branching cells with melanosomes
Produce melanin (protection against UV rays)
Melanin production increases with sun exposure
Skin color influenced by carotene, oxygenated hemoglobin, melanin
Cytocrine secretion: transfers melanosomes to neighboring cells
Disorders: Albinism (lack of melanin), Vitiligo (melanocyte degeneration)
Langerhans cells
Derived from blood monocytes
Branching cells in stratum spinosum
Lack keratin and desmosomes
Function: antigen-presenting cells, immune response
Merkel s cells
Large cells in basal layer
Attached to keratinocytes by desmosomes
Sensory nerve fibers connect to them
Function: receptors for fine touch

The dermis is formed of two layers:

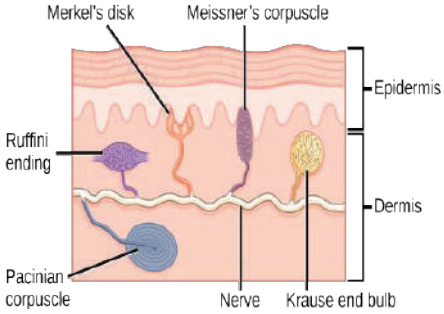
I. Papillary layer:

- It is the thin superficial layer, interdigitating with the basement membrane of the epidermis.
- **Structure:** loose connective tissue rich in blood capillaries & receptors for fine touch and temperature sensation.



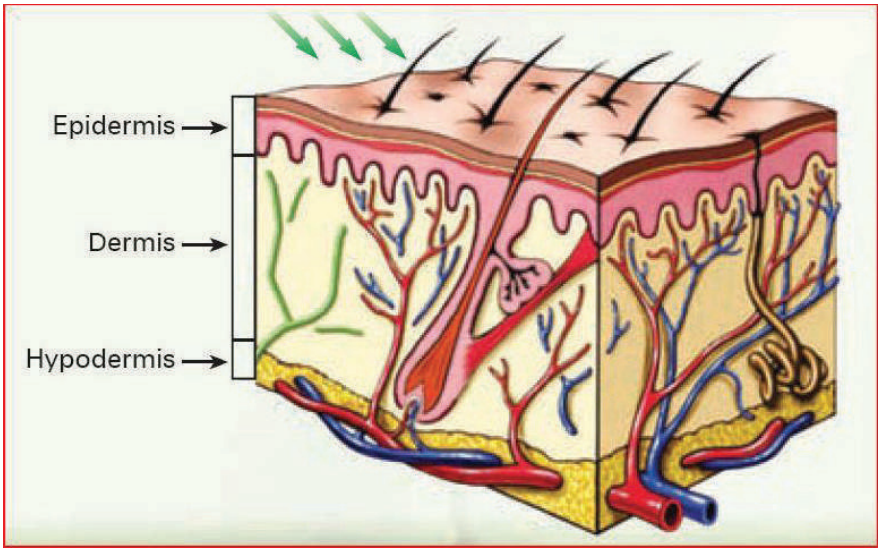
II. Reticular layer:

- It is the deep thick layer.
- **Structure:** dense irregular connective tissue (more fibrous and less vascular than the papillary layer)**contains:**
  1. Collagen& elastic fibers.
  2. Sensory nerve endings for pressure sensation.



III. The hypodermis

- It is a subcutaneous layer lies under the dermis (it is not a part of the skin).
- **Structure:** loose connective tissue rich in fat cells.
- **Functions:**
  1. Attaches the skin to the underlying tissue.
  2. Storage of fat.
  3. Contains the large blood vessels that supply the skin.
  4. Allows a great mobility of the skin (except palm & sole the mobility is limited by interlocking fibers).



1. Which of the following is NOT a function of the hypodermis?

a) Provides mobility to the skin, except in certain areas like the palm and sole

b) Serves as the main site for sensory nerve endings in the skin

c) Acts as a storage area for fat

d) Attaches the skin to underlying tissues

2. What structural characteristic of the hypodermis differentiates it from the dermis?

a) It contains dense irregular connective tissue.

b) It has a high concentration of capillaries for thermoregulation.

c) It consists of loose connective tissue rich in fat cells.

d) It includes epidermal downgrowths like sebaceous glands.

3. Which of the following statements is true about the hypodermis and its relationship with the skin?

a) It is part of the skin and provides the main blood supply for the epidermis.

b) It is not part of the skin and contains large blood vessels that supply the skin.

c) It is mainly responsible for the limited mobility of the skin on the palm and sole.

d) It is formed of dense connective tissue and provides structural rigidity to the skin.

4. Which statement characterizes the hypodermis?

a. It is a part of the skin layer

b. It consists of dense irregular connective tissue

c. In the palm and sole, it limits the mobility of the skin by interlocking fibers

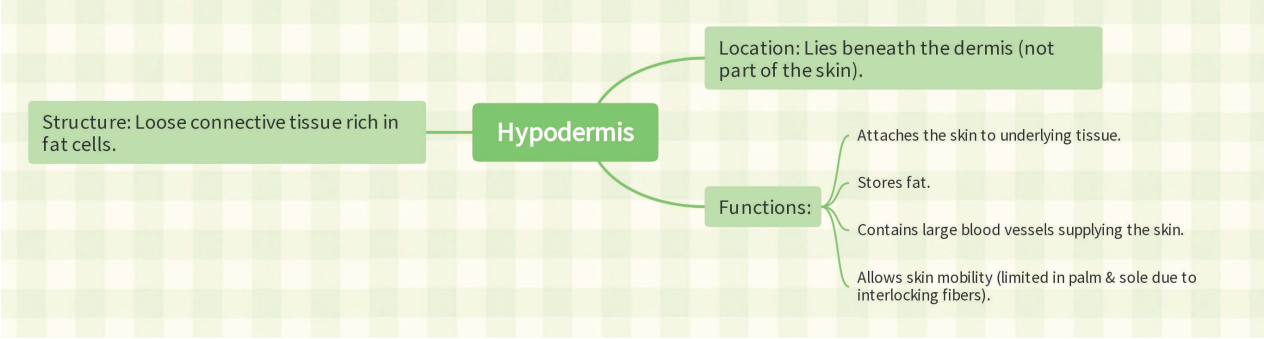
d. It is avascular

1-b

2-c

3-b

4-b

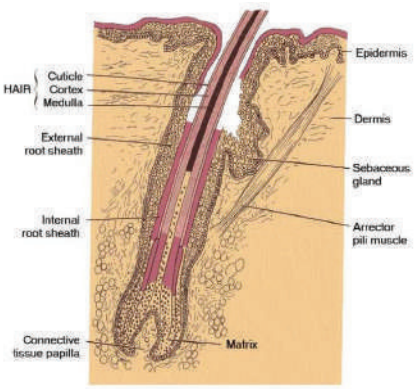


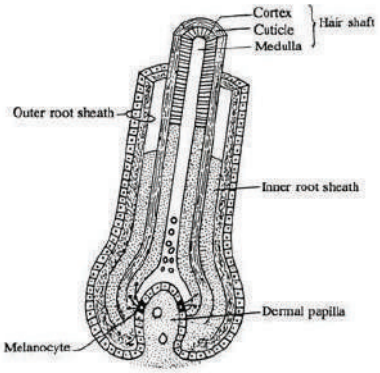
IV. Skin appendages , Hair &Nail

1. Hair

A. Hair follicle:

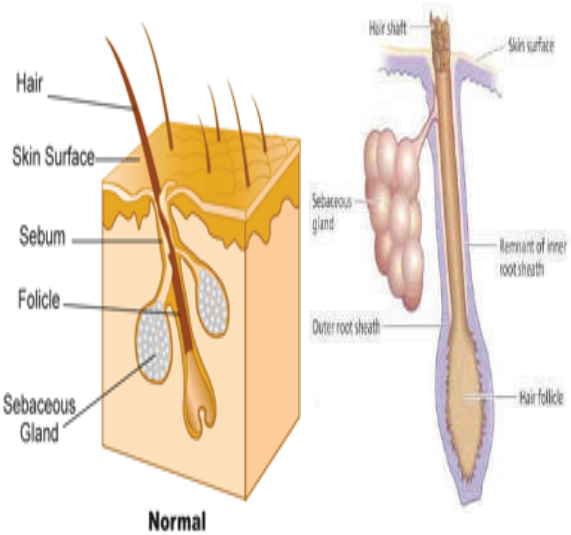
- **Definition:** an epidermal down growth into the dermis, containing the hair.
- **Function:** it is responsible for production & growth of hair.
- **Structure:**
  1. It is an epidermal down growth into the dermis, ends by the hair bulb (terminal dilatation).
  2. The hair bulb is invaginated by a vascular connective tissue called dermal papilla (if the dermal papillae are destroyed, the hair follicle dies and the hair will not grow again).



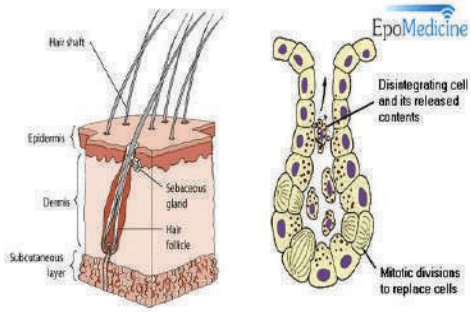


2. Sebaceous Glands:

- **Origin:** from the upper third of the hair follicle.
- **Sites:** They are most numerous over the head and ano genital area.
- **Type:** simple or simple branched alveolar, holocrine glands.
- **Activity:** they are relatively inactive until puberty when they are stimulated by elevated sex hormones.

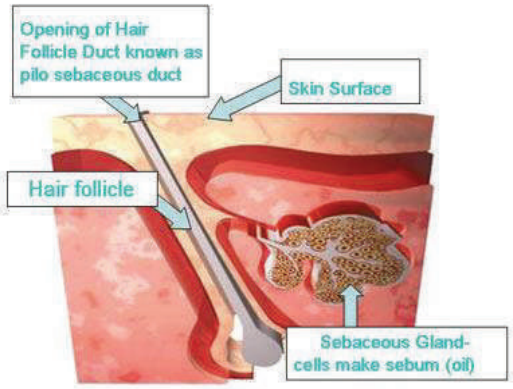


- **Structure:**



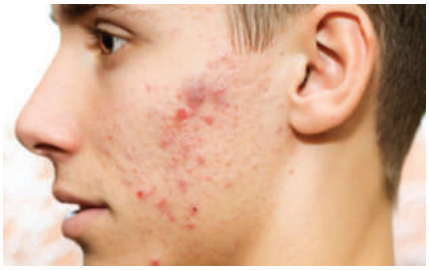
A. The secretory portion:

- It is pale & alveolar in shape.
- It is lined by a layer of flattened germinal cells resting on a basement membrane.
- This layer proliferates & differentiates, becomes polyhedral and accumulate sebum.
- Then they are pushed to the center, where they degenerate while discharging their secretion.
- **Sebum:**
  - **Definition:** fatty substance+ cell debris + keratin.
  - **Functions:**
    1. Lubrication of the skin surface and hair.
    2. Has a bactericidal effect.



B. The excretory duct:

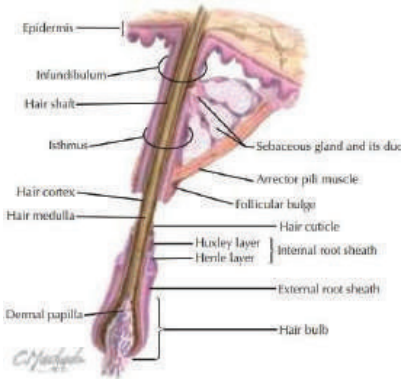
- It is short and wide, opens obliquely into the upper third of the hair follicle; directly into the skin surface.
- It is lined by stratified squamous epithelium.



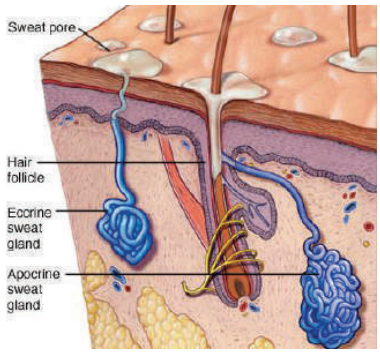
Chronic inflammation of the obstructed sebaceous glands due to disturbance of the normal flow of sebum which occurs at adolescence.

Pilosebaceous unit:

- It consist of the hair follicle, the sebaceous gland, and the arrector pili muscle
- The arrector pili smooth muscle (piloerector muscle) extends in an oblique direction from the hair follicle to the papillary layer of the dermis, beneath the sebaceous gland.
- It's contraction helps squeezing the alveoli of the sebaceous gland release its secretion into the excretory duct

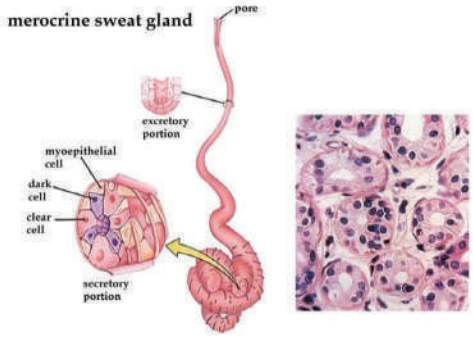


3. Sweat Glands:



- **Type:** simple coiled tubular glands.
- **Site:** deep in the dermis or the hypodermis.
- **Classification:** the eccrine & the apocrine glands.

A. The eccrine sweat glands:



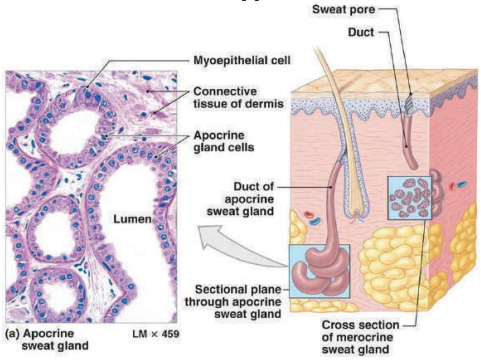
- **Site:** all over the body.
- **Secretion:** watery rich in sodium chloride.
- **Activity:** since birth.
- **Structure:**

1. **The secretory portion:** small rounded acini with narrow lumen and and lined by stratified cuboidal epithelium composed of three cell types:
   - **Dark pyramidal cells:** secreting glycoprotein (mucoid).
   - **Clear cuboidal cells:** secreting a watery secretion.
   - **Myoepithelial cells:** move the secretion into the ducts.
2. **The excretory duct:** lined by stratified cuboidal cells. It ascends in a helical course to the epidermis where it opens on the skin surface.

B. The apocrine sweat glands:

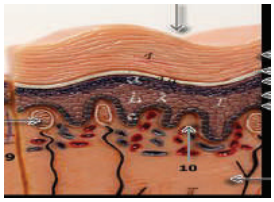
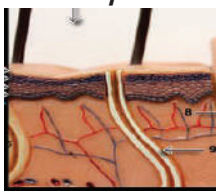
- **Site:** in the skin of axilla, areola of the breast, and perianal region.
- **Secretion:** viscous, has a characteristic odor.
- **Activity:** at puberty.
- **Structure:**

1. **The secretory portion:** appears in the form of small rounded acini with narrow lumen and lined by stratified cuboidal epithelium composed of three cell types:
   - Cuboidal cells with apical secretory granules.
   - Myoepithelial cells.
2. **The excretory duct:** lined by stratified cuboidal cells, opens into the hair follicle.



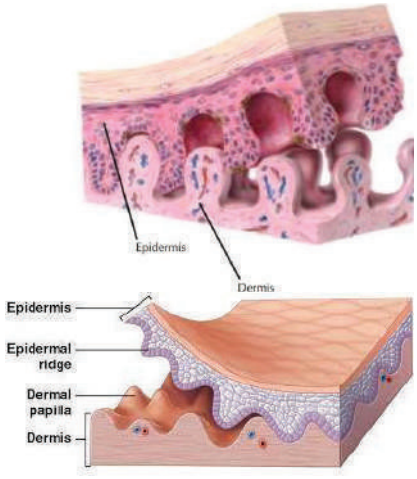
N.B:
The secretory cells undergo merocrine secretion, not apocrine therefore the glands are misnamed.

	Eccrine sweat gland (ec= outside)	Apocrine sweat gland
1. Site	All over the body.	Axilla , perianal region & breast.
2. Activity	Since birth.	At puberty.
3. Secretion	Watery.	Viscous with odour.
4. Secretory portion	▪ Smaller with narrow lumen. ▪ **Consists of 3 types of cells:** 1. Dark pyramidal: gives mucous secretion. 2. Clear cuboidal: gives watery secretion. 3. Myoepithelial cell: squeeze secretion into the duct.	▪ Large with wider lumen. ▪ **Consists of 2 types of cells:** 1. Cuboidal cell: gives mucous secretion. 2. Myoepithelial cell.
5. Duct	Opens into skin surface.	Opens into hair follicles.

	Thick skin	Thin skin
1. Thickness	Thicker (5 layers).	Thinner (4 layers, stratum lucidum is absent).
2. Stratum corneum	Thicker	Thinner
3. Hair follicles	Absent.	Present.
4. Sebaceous glands	Absent.	Present.
5. Sweat glands	More.	Less.
6. Sites	Palm & sole. 	The rest of the body. 

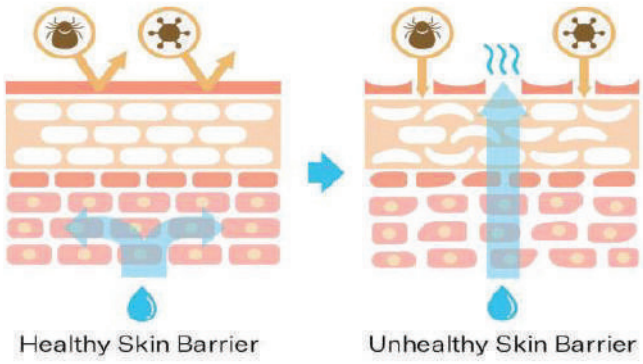
Dermo - epidermal junction

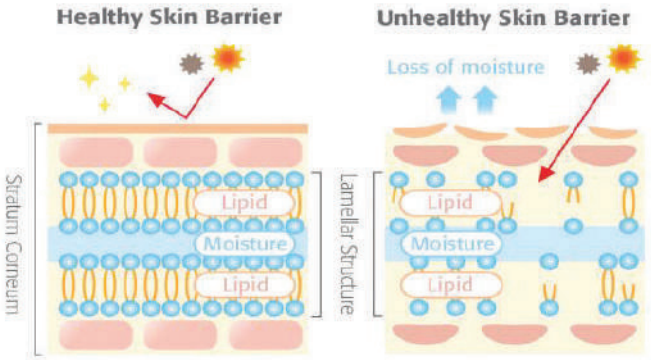
- **Definition:** The boundary between epidermis & dermis.
- **It shows:**
  1. Dermal papillae: finger like connective tissue protrusions projecting into the under surface of the epidermis.
  2. Epidermal ridges: Similar epidermal protrusions projecting into the dermis.
- **In thick skin:** the epidermal ridges are deeper, the dermal papillae are longer and more closely spaced.



Functions of the integumentary system:

1. Protection of the body against any injurious agents (Keratin in stratum corneum).
2. Water proof barrier: lipid rich extracellular material in stratum granulosum&corneum.
3. Screening against ultraviolet rays: melanin pigments.
4. Perception of stimuli: sensory nerve endings.
5. Excretion of nitrogenous products and sodium chloride: in sweat.
6. Formation of vitamin D: mainly in stratum basale and spinosum.





1. Which of the following is true about the function of the hair follicle?

a) It is responsible for secreting sebum directly into the skin surface.

b) It contains sebaceous glands that produce hair keratin.

c) It is an epidermal down growth that produces and promotes hair growth.

d) It originates from the dermis and invaginates into the hypodermis.

2. What is the consequence if the dermal papilla in the hair bulb is destroyed?

a) The sebaceous glands will become hyperactive.

b) The hair follicle will die and hair will not grow again.

c) The sweat glands will cease functioning.

d) The hair will become thicker and darker.

3. Which of the following statements best describes the origin of sebaceous glands?

a) They originate from the lower third of the hair follicle.

b) They are found in the hypodermis and directly open to the skin surface.

c) They develop from the upper third of the hair follicle.

d) They are stimulated by low levels of sex hormones throughout life.

4. What type of secretion is produced by sebaceous glands?

a) A watery secretion rich in sodium chloride

b) A fatty substance mixed with cell debris and keratin

c) A viscous secretion with a strong odor

d) A glycoprotein-rich mucoid secretion

5. Which component is NOT part of the pilosebaceous unit?

a) Hair follicle

b) Sebaceous gland

c) Apocrine sweat gland

d) Arrector pili muscle

6. How do eccrine sweat glands differ from apocrine sweat glands?

a) Eccrine glands are found only in the axillary and perianal regions, while apocrine glands are found all over the body.

b) Eccrine glands are inactive until puberty, while apocrine glands are active from birth.

c) Eccrine glands secrete a watery secretion, while apocrine glands secrete a viscous secretion.

d) Eccrine glands open into hair follicles, while apocrine glands open directly onto the skin surface.

7. Which of the following is a unique feature of the secretory portion of eccrine sweat glands?

a) They are lined by a single layer of cuboidal cells.

b) They are lined by stratified cuboidal epithelium and contain three distinct cell types.

c) They contain dark pyramidal cells that secrete sebum.

d) They have a wide lumen for the passage of thick secretion.

8. Apocrine sweat glands become active at puberty and secrete:

a) A watery secretion high in sodium chloride

b) A mucoid glycoprotein secretion

c) A viscous secretion with a characteristic odor

d) A fatty substance mixed with keratin and cell debris

9. What is the role of myoepithelial cells in both eccrine and apocrine sweat glands?

a) They secrete sebum.

b) They contract to move the secretion into the excretory ducts.

c) They regulate the production of sweat.

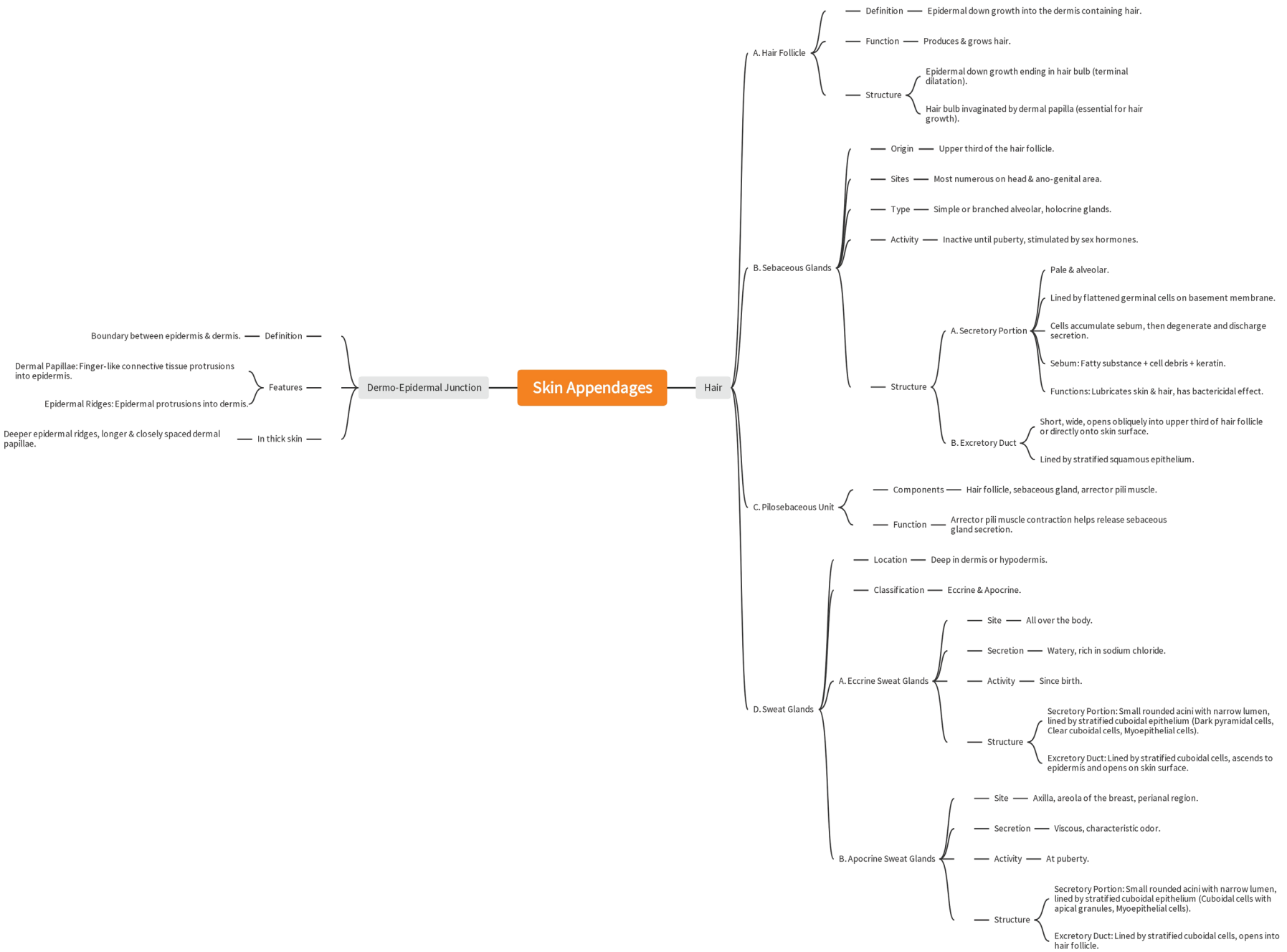
d) They protect the epithelium from external toxins.

10) Which type of protein is found in hair

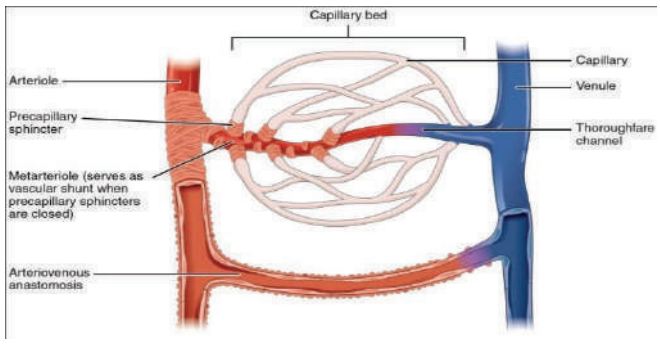
a. Myosin

b. Keratin

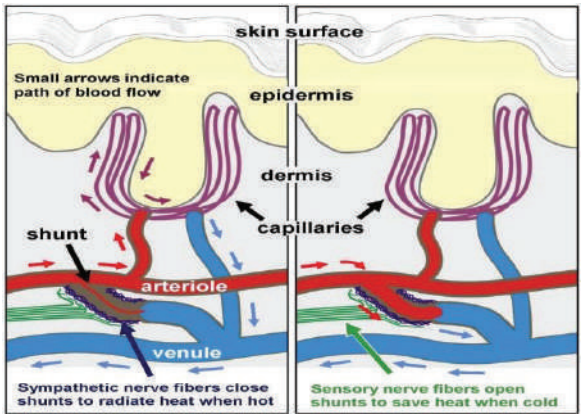
1-c, 2-b, 3-c, 4-b, 5-c, 6-c, 7-b, 8-c, 9-b, 10-B


Skin Appendages
Dermo-Epidermal Junction
Definition
Boundary between epidermis & dermis.
Features
Dermal Papillae: Finger-like connective tissue protrusions into epidermis.
Epidermal Ridges: Epidermal protrusions into dermis.
In thick skin
Deeper epidermal ridges, longer & closely spaced dermal papillae.
Hair
A. Hair Follicle
Definition
Epidermal down growth into the dermis containing hair.
Function
Produces & grows hair.
Structure
Epidermal down growth ending in hair bulb (terminal dilatation).
Hair bulb invaginated by dermal papilla (essential for hair growth).
B. Sebaceous Glands
Origin
Upper third of the hair follicle.
Sites
Most numerous on head & ano-genital area.
Type
Simple or branched alveolar, holocrine glands.
Activity
Inactive until puberty, stimulated by sex hormones.
Structure
A. Secretory Portion
Pale & alveolar.
Lined by flattened germinal cells on basement membrane.
Cells accumulate sebum, then degenerate and discharge secretion.
Sebum: Fatty substance + cell debris + keratin.
Functions: Lubricates skin & hair, has bactericidal effect.
B. Excretory Duct
Short, wide, opens obliquely into upper third of hair follicle or directly onto skin surface.
Lined by stratified squamous epithelium.
C. Pilosebaceous Unit
Components
Hair follicle, sebaceous gland, arrector pili muscle.
Function
Arrector pili muscle contraction helps release sebaceous gland secretion.
D. Sweat Glands
Location
Deep in dermis or hypodermis.
Classification
Eccrine & Apocrine.
A. Eccrine Sweat Glands
Site
All over the body.
Secretion
Watery, rich in sodium chloride.
Activity
Since birth.
Structure
Secretory Portion: Small rounded acini with narrow lumen, lined by stratified cuboidal epithelium (Dark pyramidal cells, Clear cuboidal cells, Myoepithelial cells).
Excretory Duct: Lined by stratified cuboidal cells, ascends to epidermis and opens on skin surface.
B. Apocrine Sweat Glands
Site
Axilla, areola of the breast, perianal region.
Secretion
Viscous, characteristic odor.
Activity
At puberty.
Structure
Secretory Portion: Small rounded acini with narrow lumen, lined by stratified cuboidal epithelium (Cuboidal cells with apical granules, Myoepithelial cells).
Excretory Duct: Lined by stratified cuboidal cells, opens into hair follicle.

7. Regulation of the body temperature:



- **In hot weather:**
  1. Increase sweating.
  2. Vasodilatation of the dermal capillaries & closure of the arteriovenous shunt increase cutaneous blood flow& increase heat loss.
- **In cold weather:** constriction of dermal blood vessels and opening of the arteriovenous shunts decrease cutaneous blood flow and decrease heat loss.



Which structure is responsible for water proof barrier of the skin?

1. Cytokeratin in the stratum corneum.
2. Keratohyaline granules in the stratum granulosum.
3. Desmosomes in the stratum spiosum.
4. Lamellated granules in the stratum granulosum.