Molecular Biology and Histology (111501105)
Second Semester 2023 /2024

Body Tissues
Epithelial Tissue

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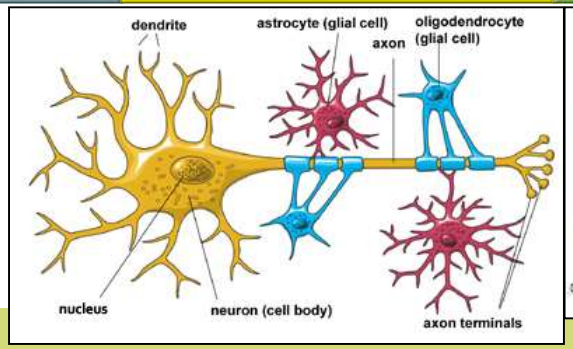
A tissue is a collection of cells with a usually common embryologic origin that function together to perform a specialized activity. In addition to the cells, a tissue contains a substance that's present between the cells called the extracellular matrix (ECM).

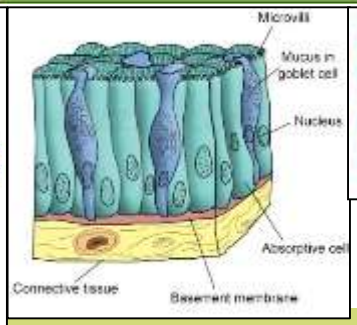
- Body tissues can be generally divided into 4 main types according to the *type of cells* and the *amount and content of the ECM* they possess.

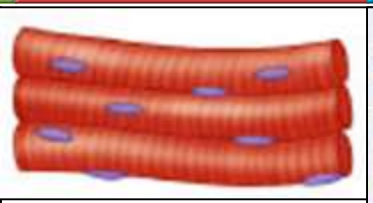
- The main types of body tissues are:
  1. Epithelial tissue
  2. Connective tissue
  3. Muscular tissue
  4. Nervous tissue

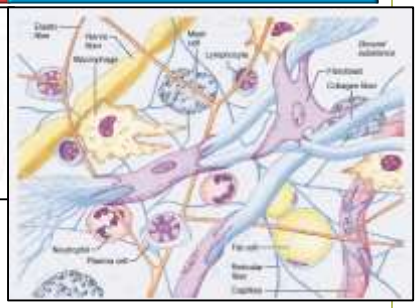
Table 1: Types of tissues and their characteristics

Tissue	Nervous	Epithelial	Muscular	Connective
Cells	Have intertwining elongated processes	Aggregated polyhedral cells	Elongated contractile cells	Several types of fixed and wandering cells
Amount of ECM	Very small	Small	Moderate	Abundant
Main Function	Transmission of nerve impulse	Lining, Secretion	Movement	Support, protection









Epithelial Tissue

- The epithelial tissue has the following characteristics:

1. It covers surfaces or lines cavities. As a result, it's in contact with another medium (air or fluid), which means that it's exposed to foreign bodies and chemicals. To endure these adverse conditions, the epithelium has a rapid turn-over (time from birth till the death of the cell).

2. It's formed of sheets of closely packed cells. As a result, the cells assume a polyhedral shape (columnar, cuboidal, etc…).

Polyhedral = A 3D geometric shape with several faces. From Greek *poly-* = many and *-hedron* = surface

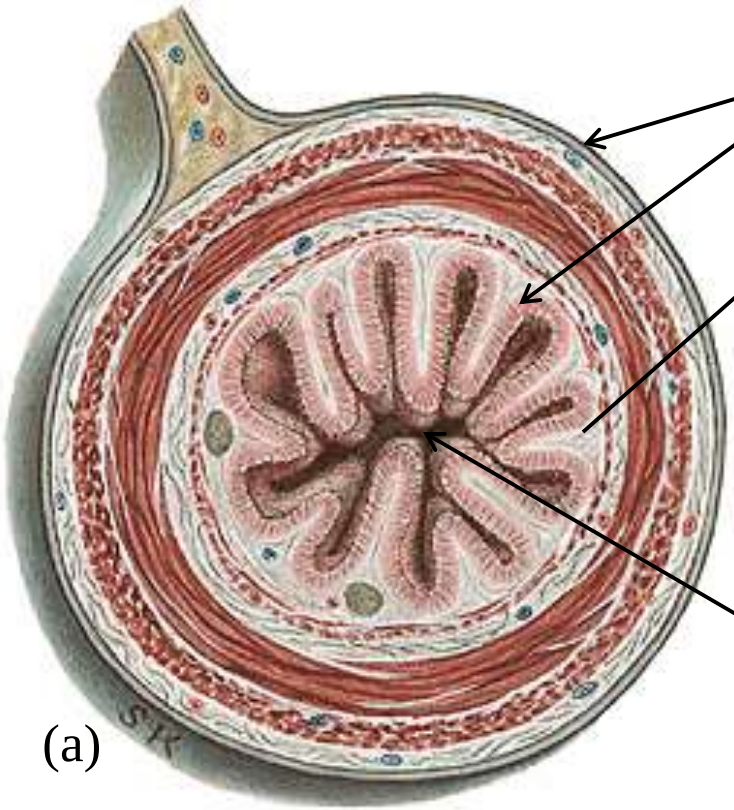
3. The cells are polar and are connected with each other and with the underlying tissue by various types of complexes.

4. The epithelium rests upon a sheet of extracellular matrix called the *Basal Lamina.*

5. Epithelia have a layer of connective tissue under them, for example: lamina propria of the gastrointestinal tract and the dermis of the skin.

6. Epithelial tissues are avascular (lack blood vessels). It takes its nourishments by diffusion from underlying vascular tissues.

a- = Not, lack.



(a)

Epithelium

Lamina propria (connective tissue)

Abdominal cavity (fluid)

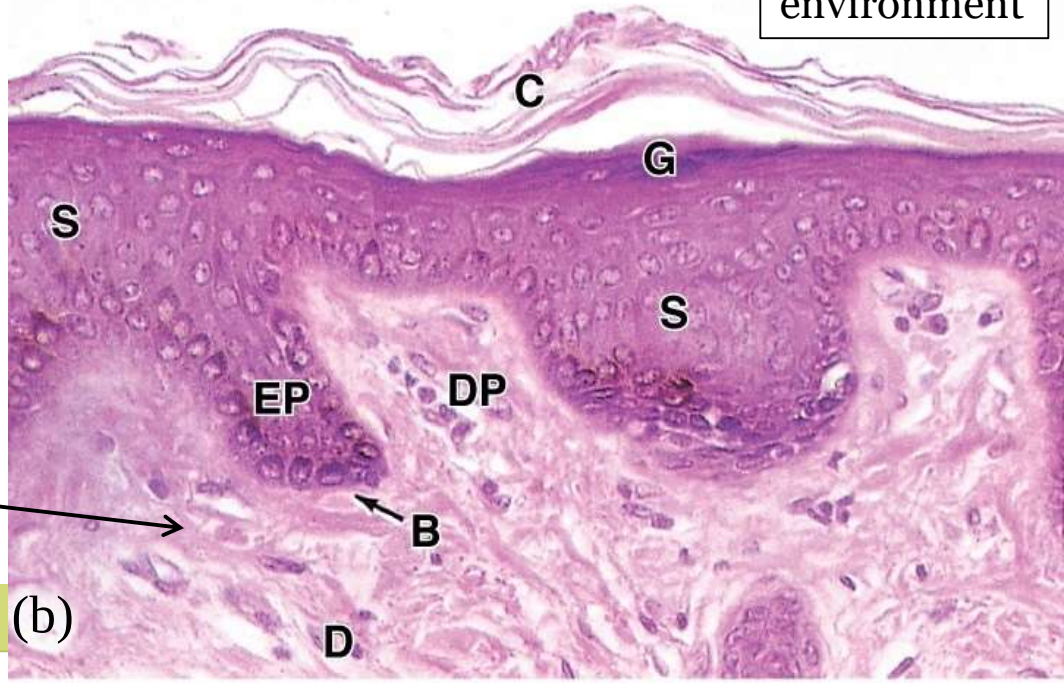
Lumen (air+fluid)

Fig.1: Characteristics of Epithelial tissues. (a) Cross section of small intestine. (b) Section through the skin.

External environment

Epithelium (Epidermis)

Connective tissue (Dermis)

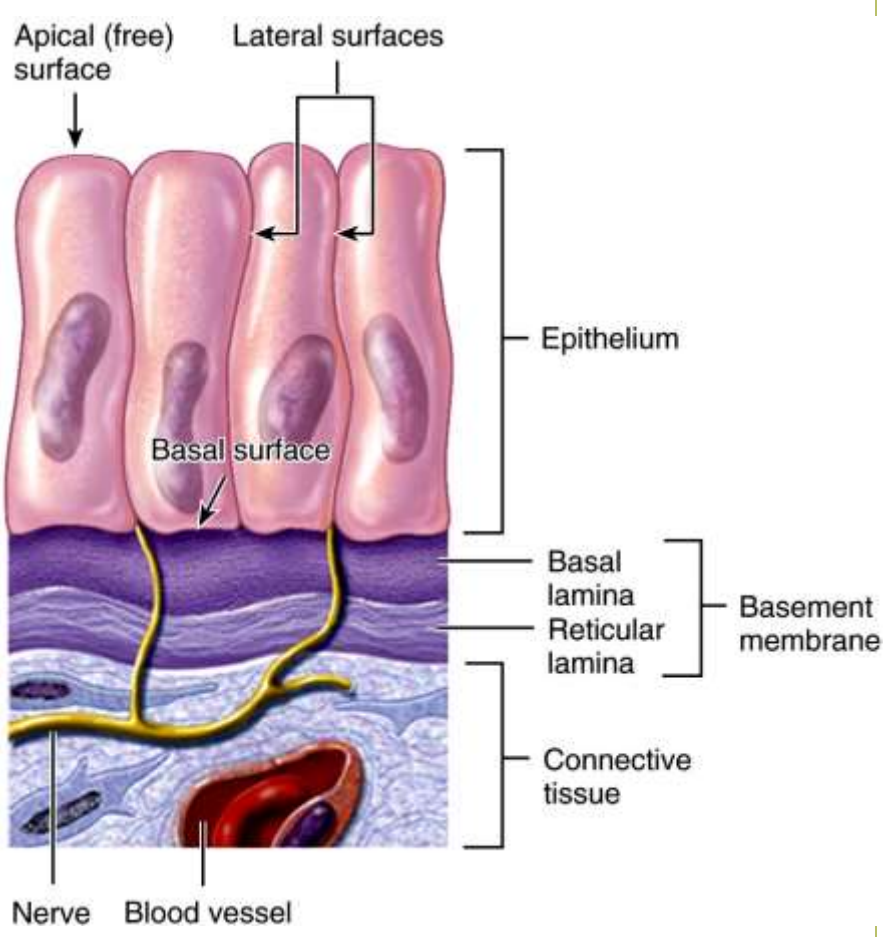


Functions of Epithelial Tissue:

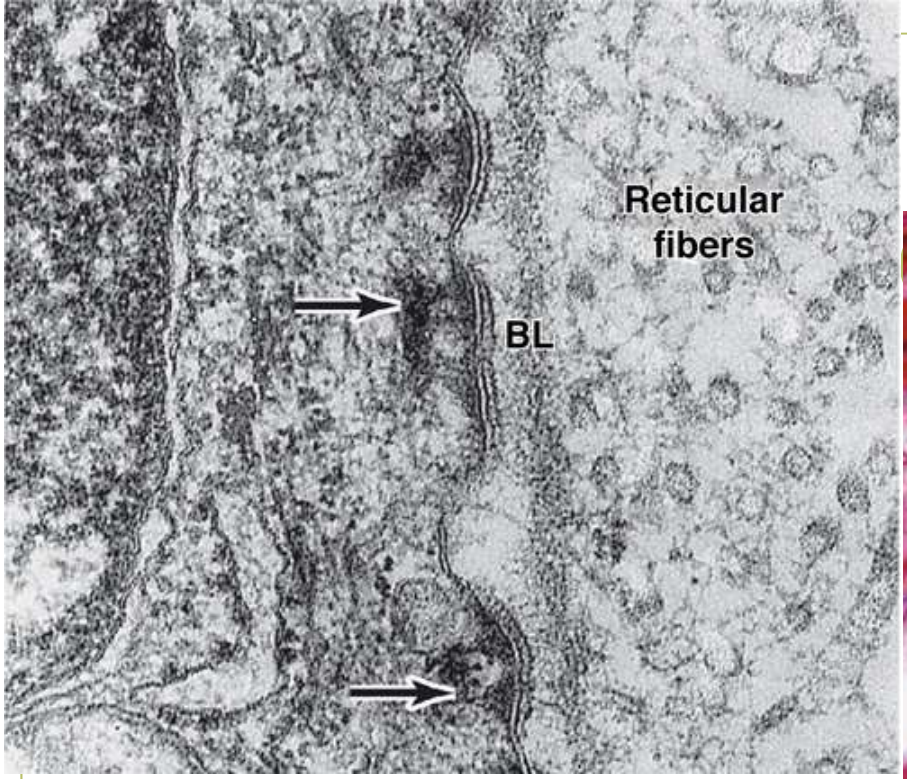
1. Lining, covering and protection.
2. Secretion (epithelium of stomach and glands).
3. Absorption (epithelium of the intestines).
4. Contraction (myoepithelial cells).

Basal Lamina and Basement Membrane

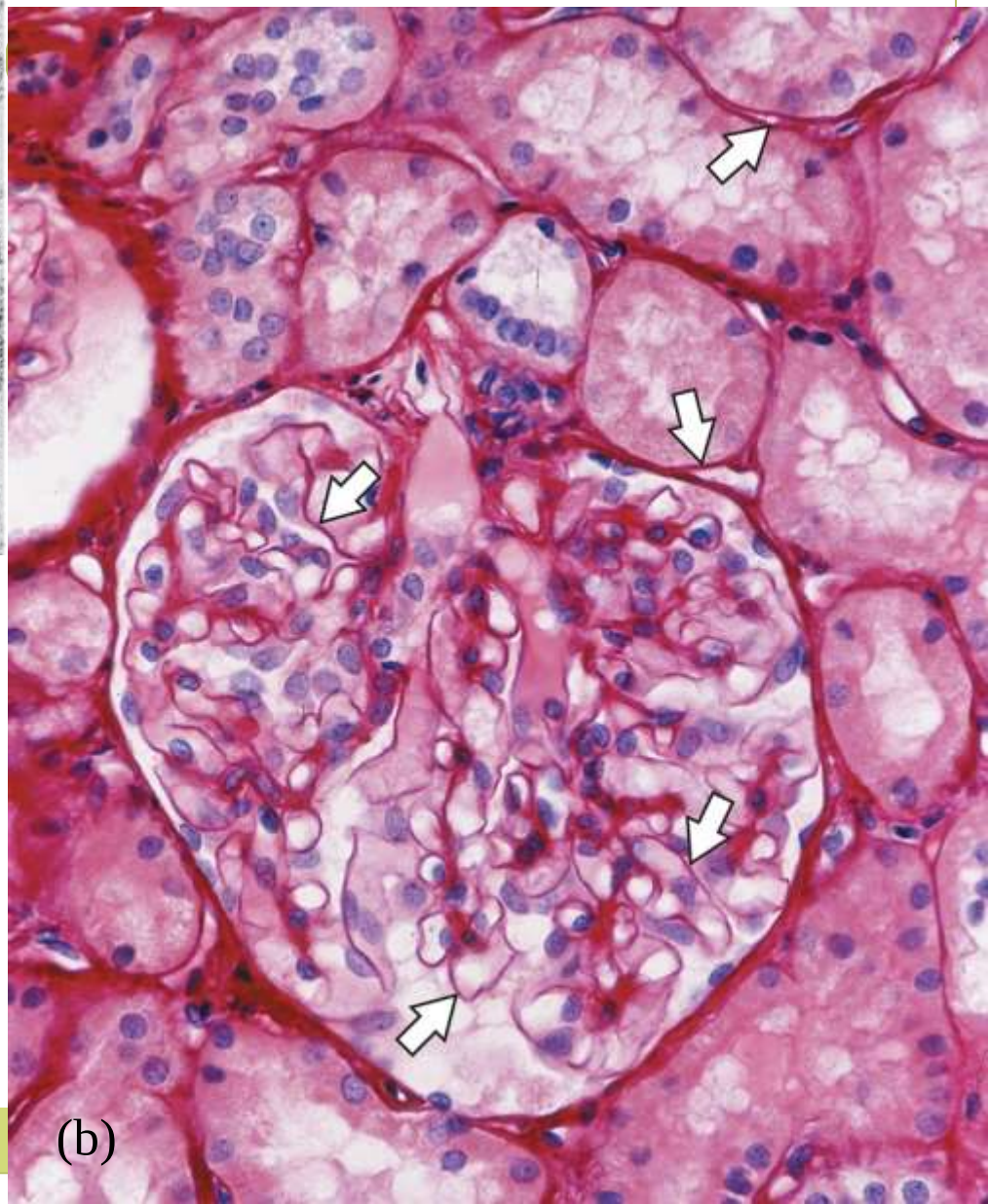
- ***Basal lamina*** is a sheet of *ECM* located under the epithelium. It's very thin and can only be seen by the electron microscope.



- ***Basement membrane*** is a much thicker structure seen by the light microscope. It's formed of the *basal lamina and the reticular lamina*. The reticular lamina is the upper reticular-fiber-rich part of the connective tissue that's usually located under the epithelium.



(a)



(b)

Fig.2: (a) EM image showing the basal lamina (BL); note underlying reticular lamina. (b) LM image showing the basement membrane (white arrows).

Functions of Basal Lamina:

1. Provide structural support for the epithelium.

2. Help in filtering of substances that pass through (depending on the number and size of holes in it).

3. Affect cell proliferation, differentiation and migration.

4. Important for cell repair (as in repair of nerve fiber and neuromuscular junctions).

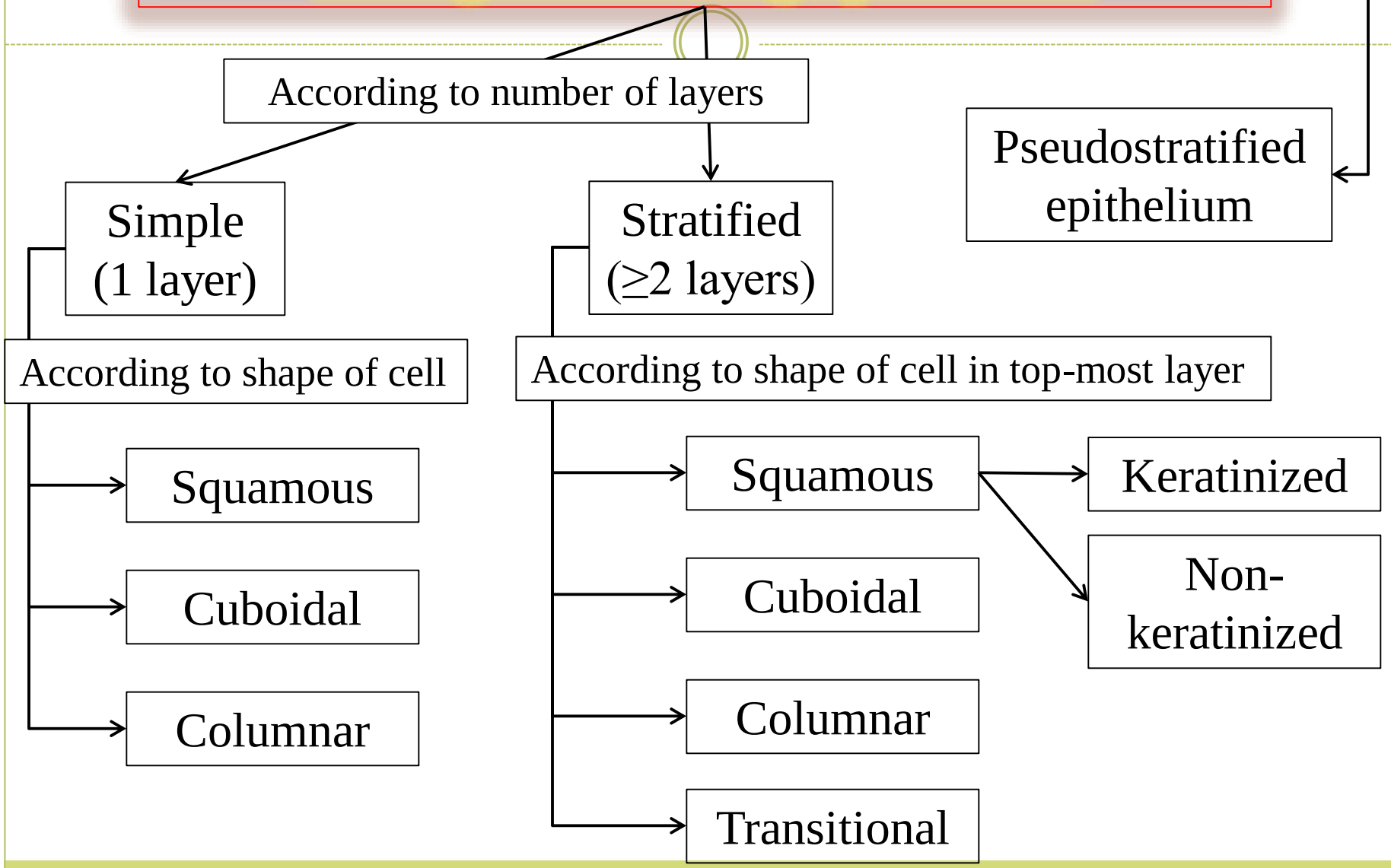
Types of Epithelium

- Epithelium can be divided into two general groups:

1) Lining or covering epithelium
2) Glandular epithelium → Main function is secretion

- However, some lining epithelial cells secrete (like those in the stomach) and some glandular cells are present between cells of lining epithelium (like goblet cells of small intestine)

Lining or covering epithelium



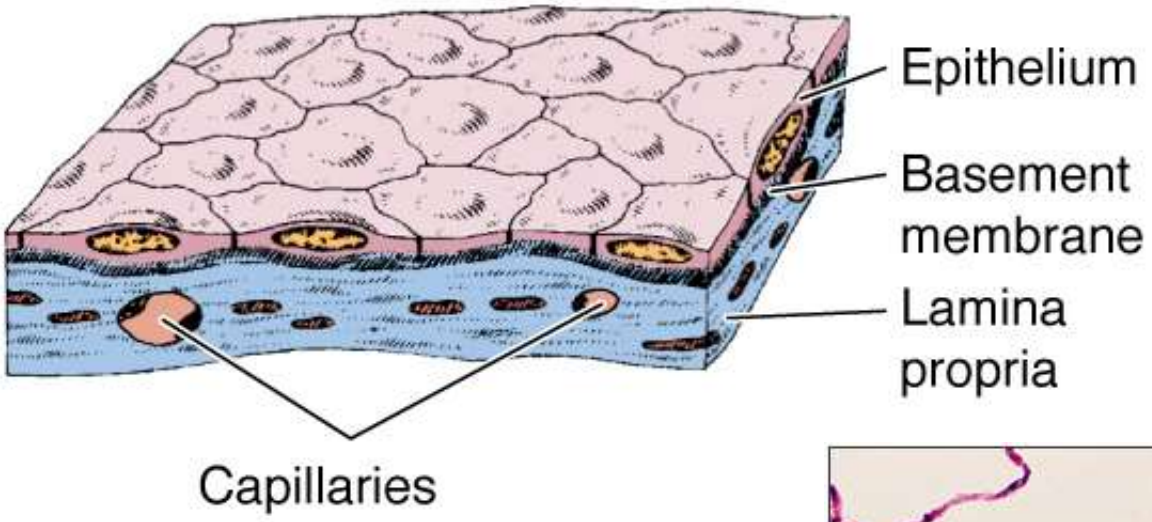
Simple Squamous epithelium

- Formed of a single layer of flattened squamous cells.

- It's found in:
  - Capillaries → Endothelium
  - Lining of body cavities → Mesothelium
  - Lining alveoli → Pneumocytes

- Function: Their thin cytoplasm allows various substances to pass easily across them (endothelium and pneumocytes). Mesothelial cells, also, produce a lubricating fluid.

Squamous = from squama = scale . Endo- = Inner. Meso- = middle



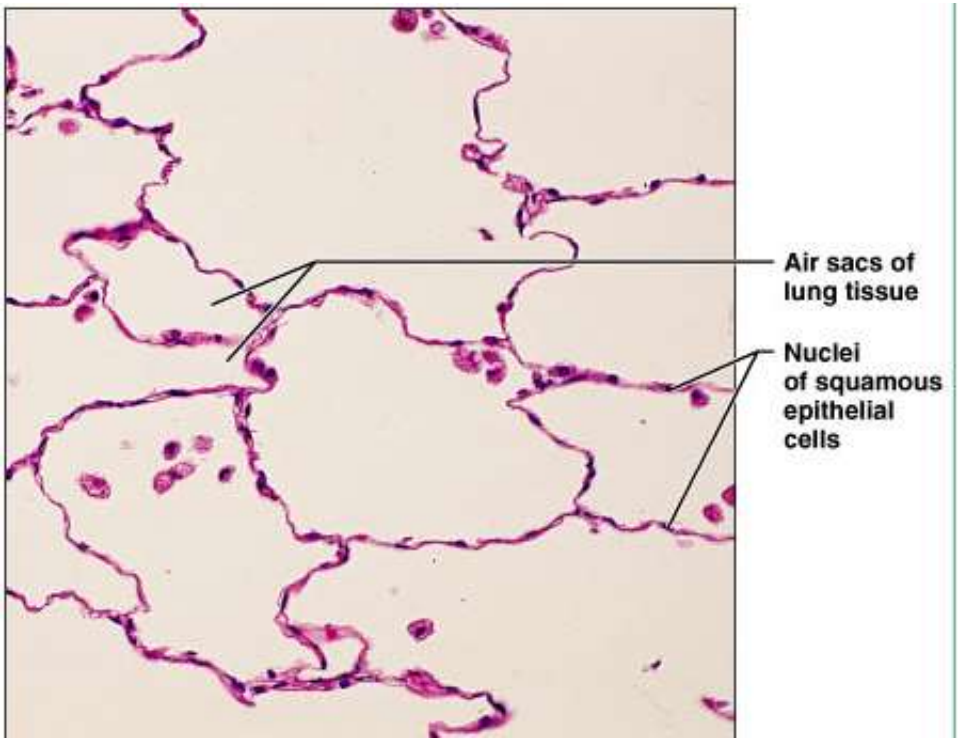
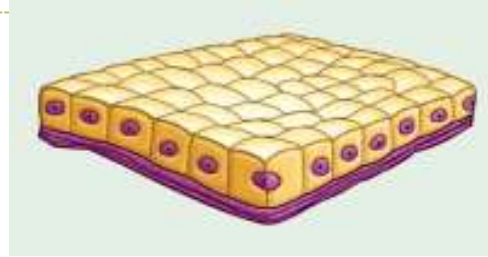


Fig.3: Simple squamous epithelium. To the right, we can see the thin pneumocytes lining the lung alveoli. Notice their bulging dark nuclei.

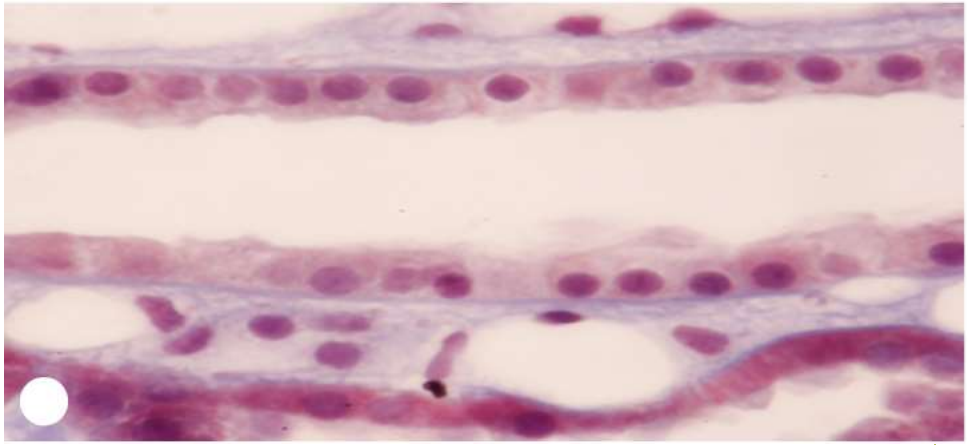
Pneumo- = related to lung, from pneuma = breath. Alveoli (single = alveolus) = little cavity.

Simple Cuboidal epithelium

- Formed of a single layer of cubical cells.



- It's found in:
  - Renal tubules
  - Covering the ovary



- Function: Covering of organs. Involved in active transport.

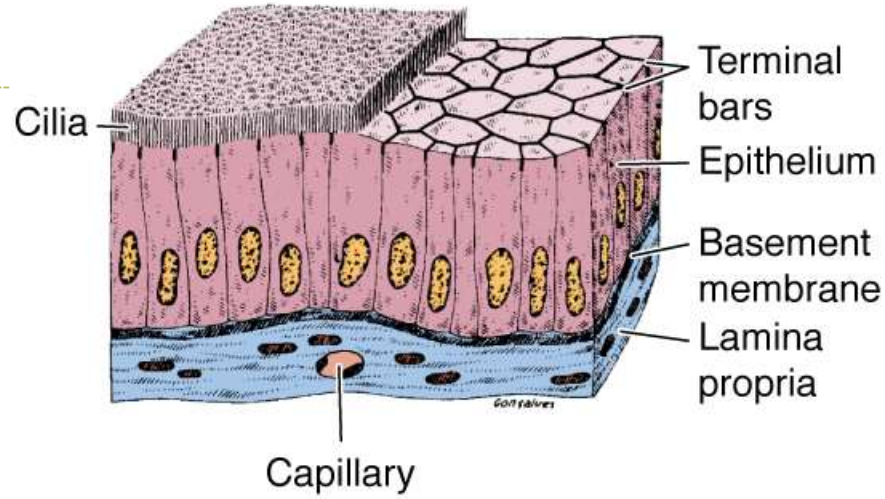
Fig.4: Simple cuboidal epithelium of the renal tubules. Note the round nuclei.

Simple Columnar epithelium

- Formed of a single layer of tall cells that could be ciliated or not.

- It's found in:
  - Ciliated: Uterine tubes.
  - Non-ciliated: most of the gastrointestinal tract.

- Function: Secretion as in the stomach. Absorption as in the small intestine.



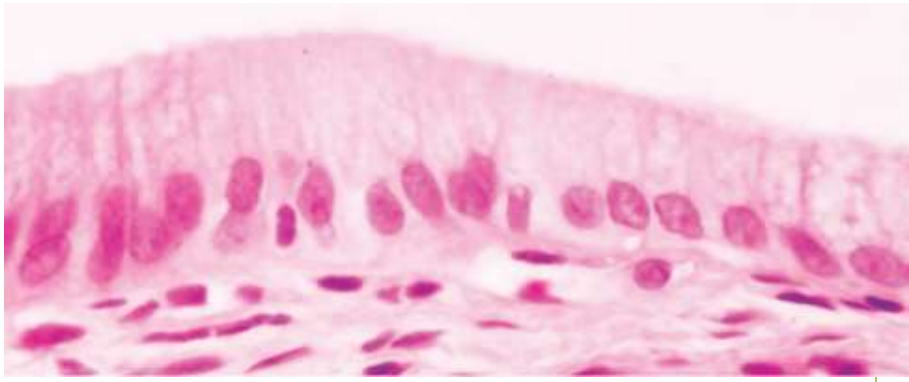


Fig.5: Simple columnar epithelium of the gallbladder. Note the oval nuclei.

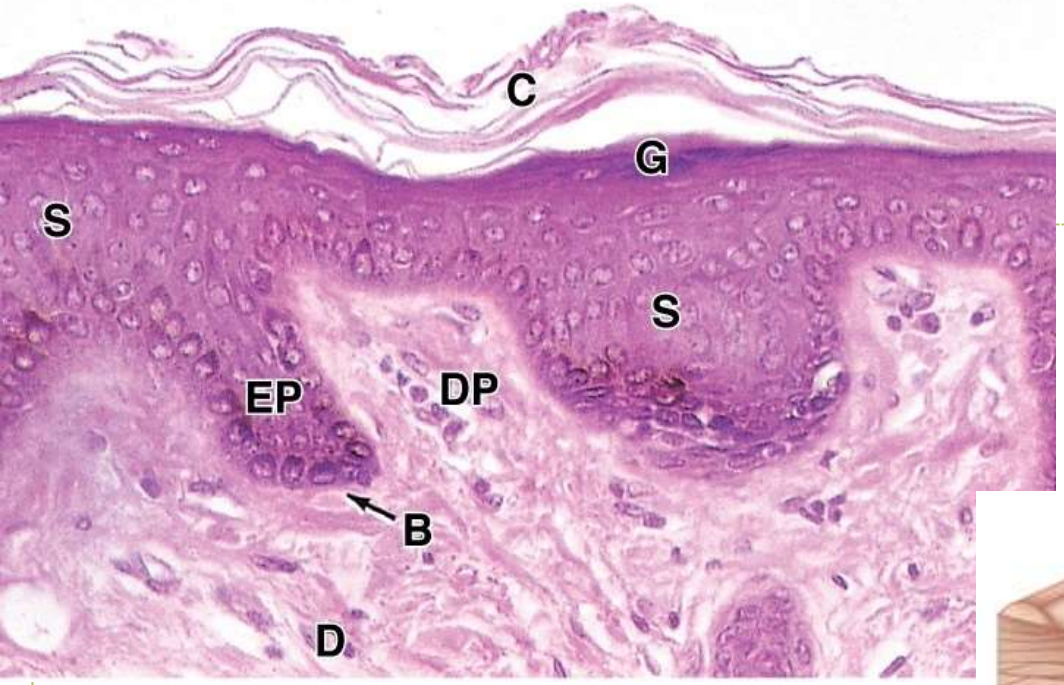
Stratified Squamous epithelium - keratinized

- Formed of multiple layers of cells. The topmost layer is formed of squamous cells. The epithelium is covered by keratin (a non-living material).

- It's found in areas that require great protection:
  - Skin → Epidermis

- Function:
  1) Protection
  2) Prevent water loss

Keratin = horn.



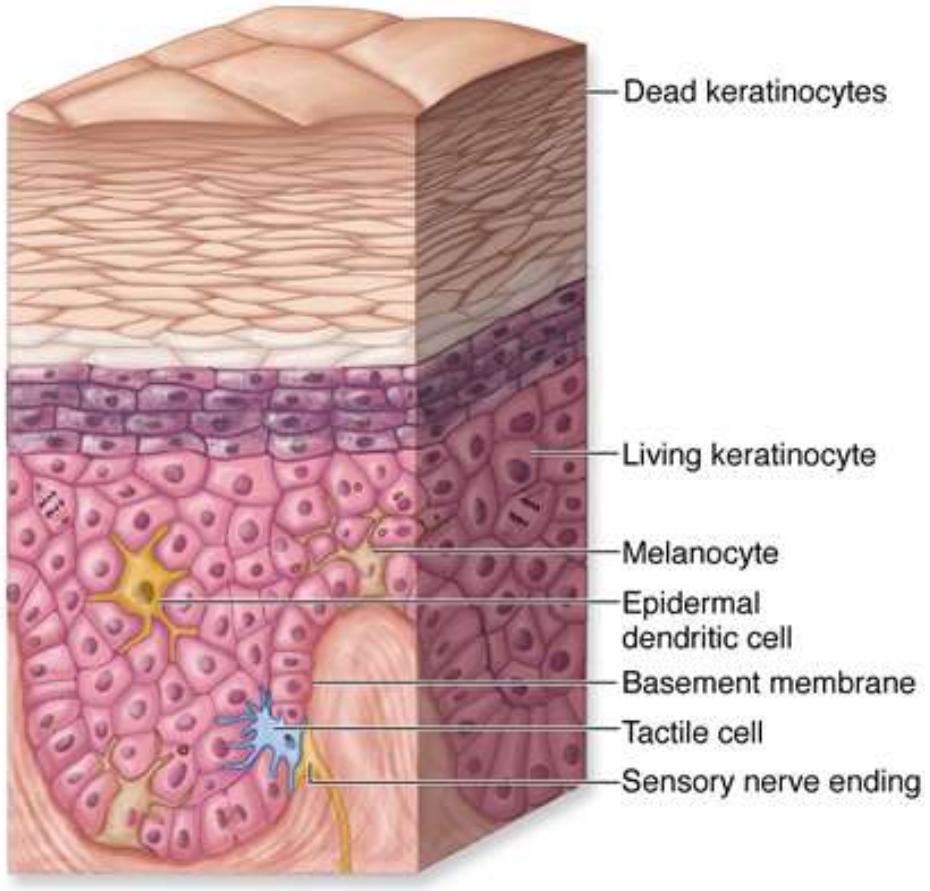


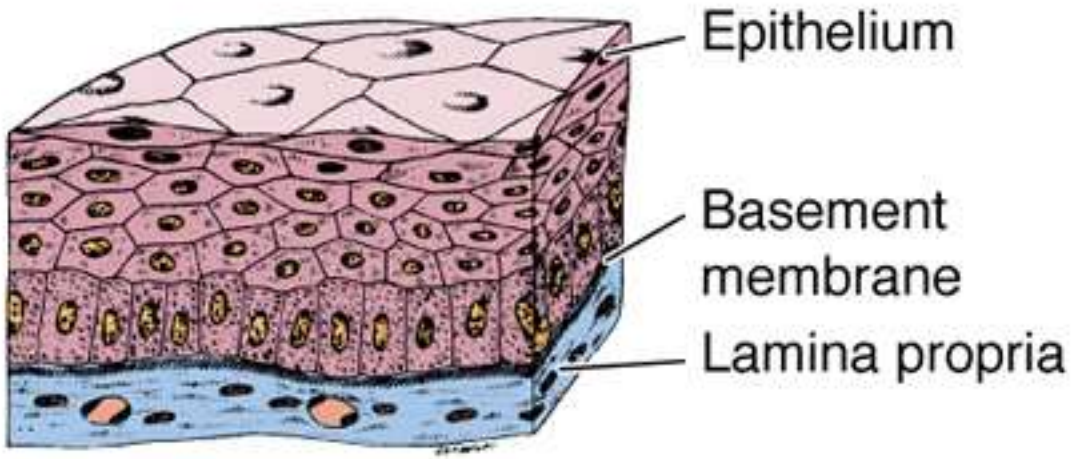
Fig.6: Epidermis of skin. Notice the keratin layer.

Stratified Squamous epithelium – Non-keratinized

- Formed of multiple layers of cells. The topmost layer is formed of squamous cells. The epithelium is not covered by keratin.

- It's found in areas that require protection and water loss is not a big problem:
  - Mouth, esophagus, anal canal
  - Vagina

- Function: protection, secretion.



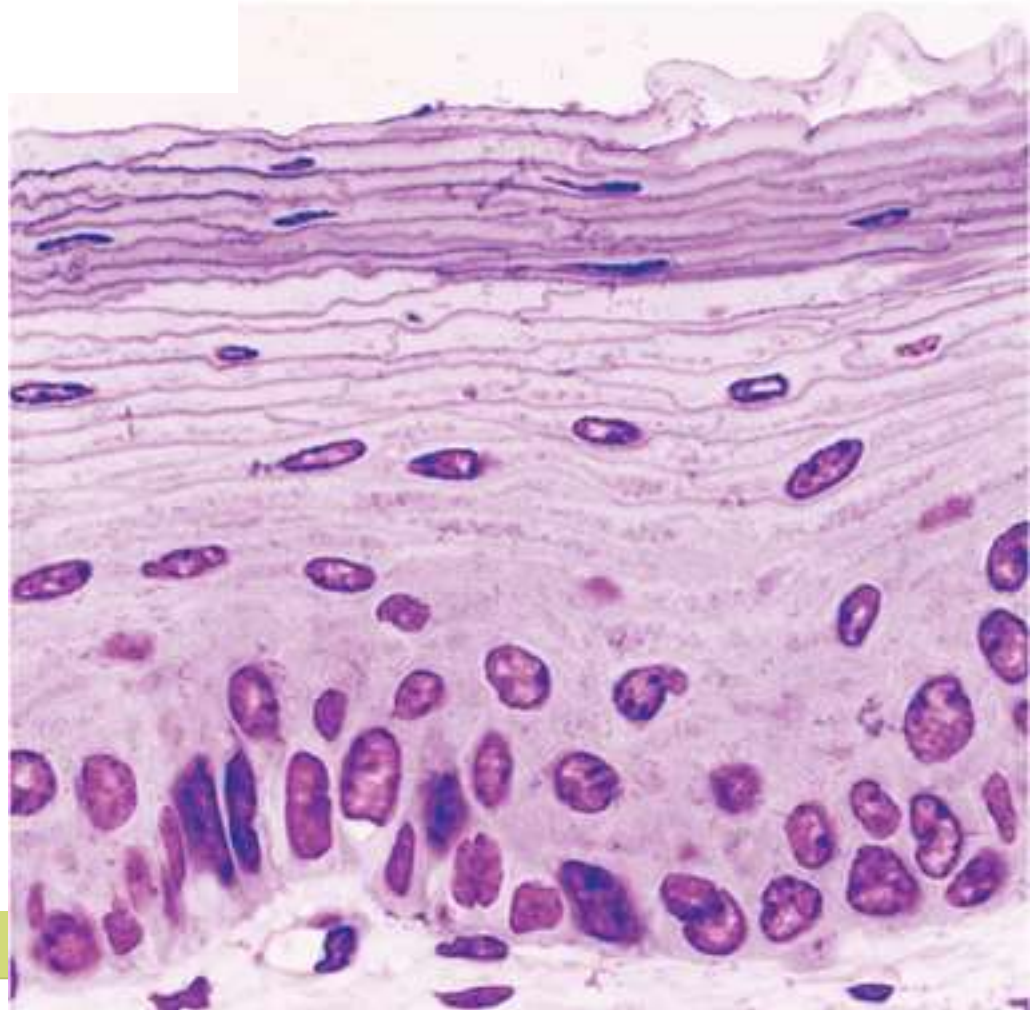
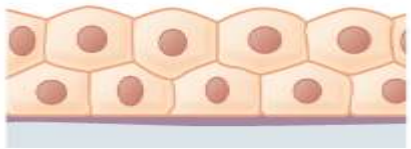
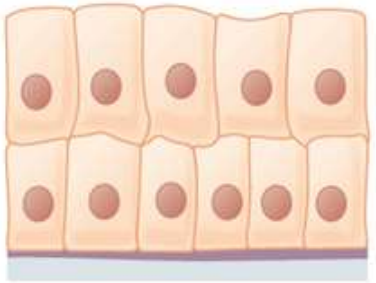


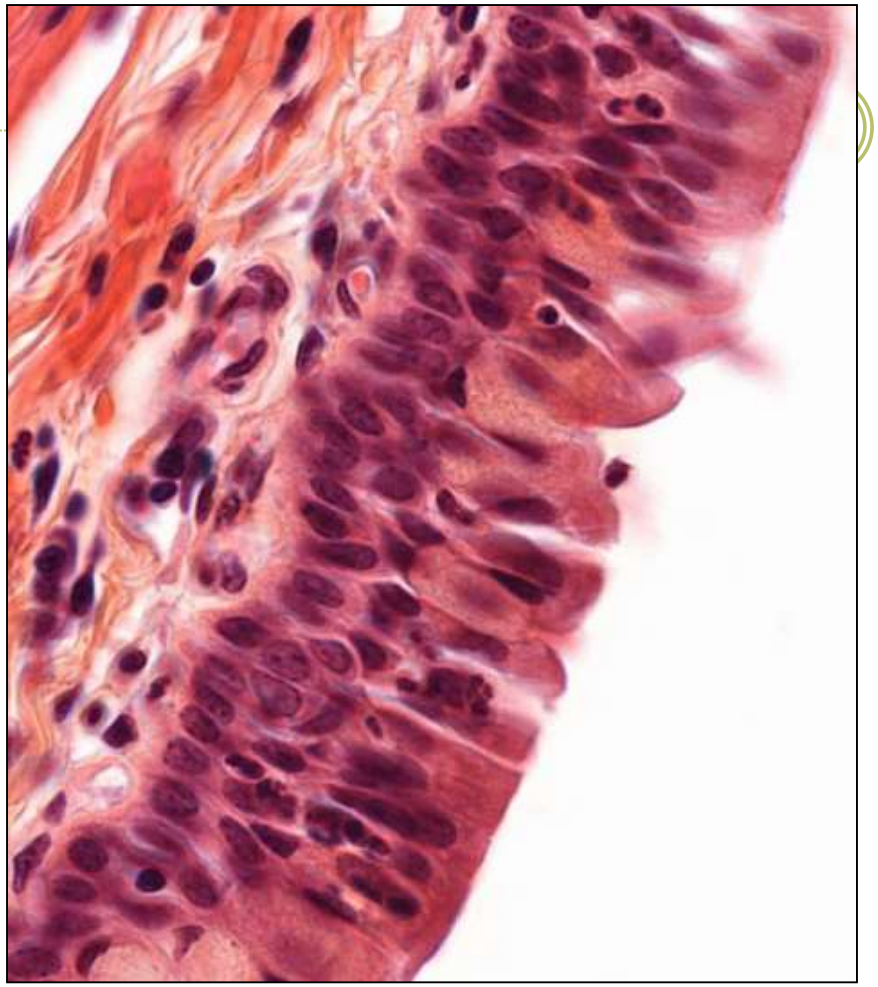
Fig.7: Stratified squamous epithelium. To the right, we can see that this epithelium in the esophagus is non-keratinized (the topmost layer has nuclei).

Stratified Cuboidal and Columnar epithelium

	Stratified Cuboidal	Stratified Columnar
Number of layers	Multiple	Multiple
Top-most layer	Cuboidal	Columnar
Location	Large excretory ducts of salivary and sweat glands	Conjunctiva
Function	Protection and secretion	Protection and secretion







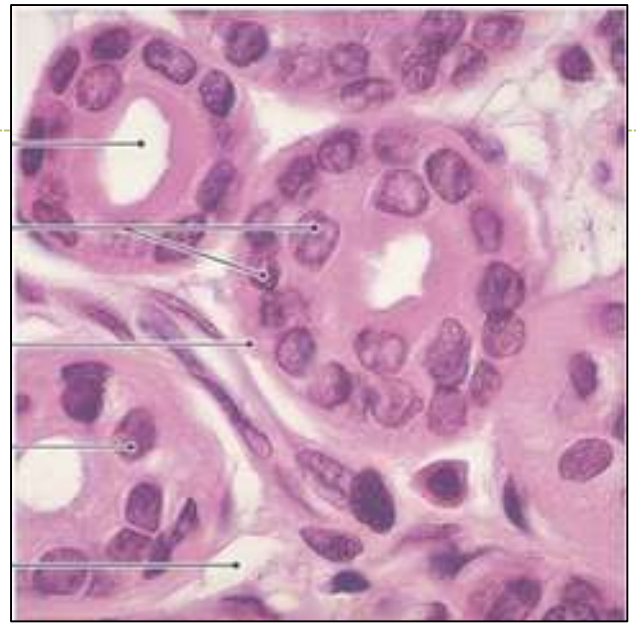
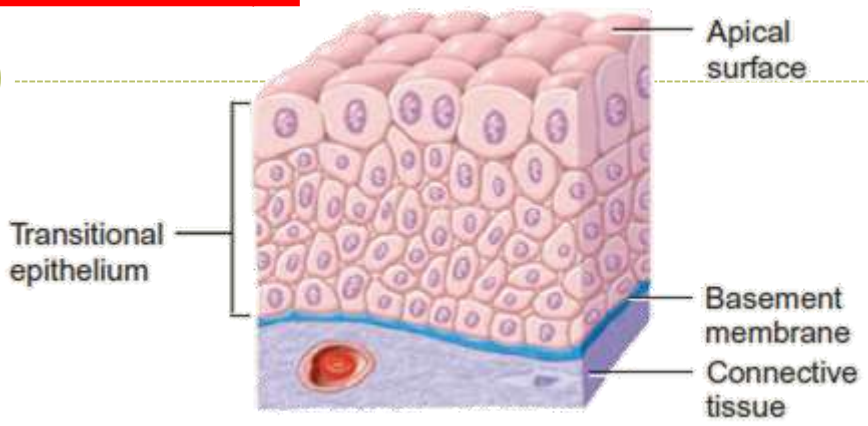


Fig.8: Above, stratified cuboidal epithelium in ducts of glands. To the left, stratified columnar epithelium of the conjunctiva

Transitional epithelium (Urothelium):



- The topmost cells of this stratified epithelium are dome-like (also called ***umbrella cells***).
- Found in: Urinary bladder, ureters and renal calyces.
- The umbrella cells are dome-shaped when the bladder is empty. Once it's full, these cells will become flattened (hence the name transitional).
- Functions: Protection against the adverse effects of urine. Allow the bladder to change size.

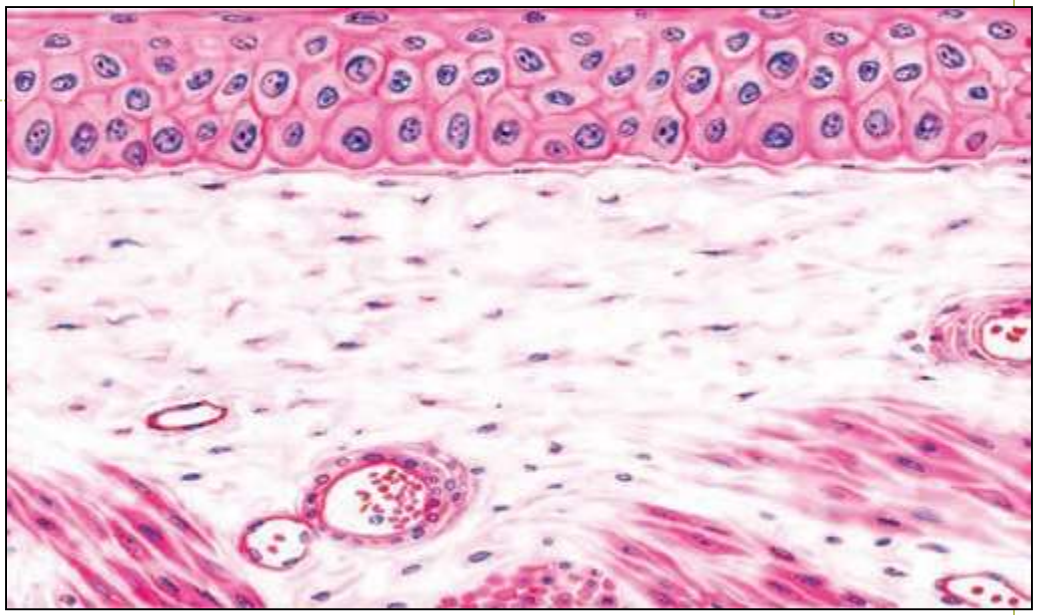
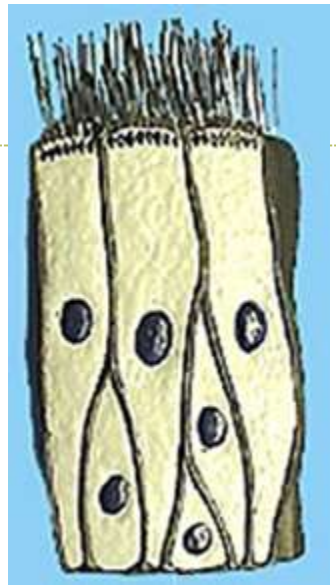


Fig.9: Transitional epithelium of the urinary bladder. To the left, when bladder is empty. Above, when the bladder is full. Note the change in shape of the upper most cells.

Pseudostratified epithelium:



- In this epithelium, the cells have different heights. All cells rest on the same basal lamina, but not all of them reach the surface. This makes the nuclei occupy different levels giving the epithelium a false stratified appearance.
- The ***Respiratory epithelium*** is a pseudostratified columnar ciliated epithelium found in the trachea, bronchi, and nasal cavity.
- Functions: Protection and secretion. Ciliary movement remove particles from the airway passages.

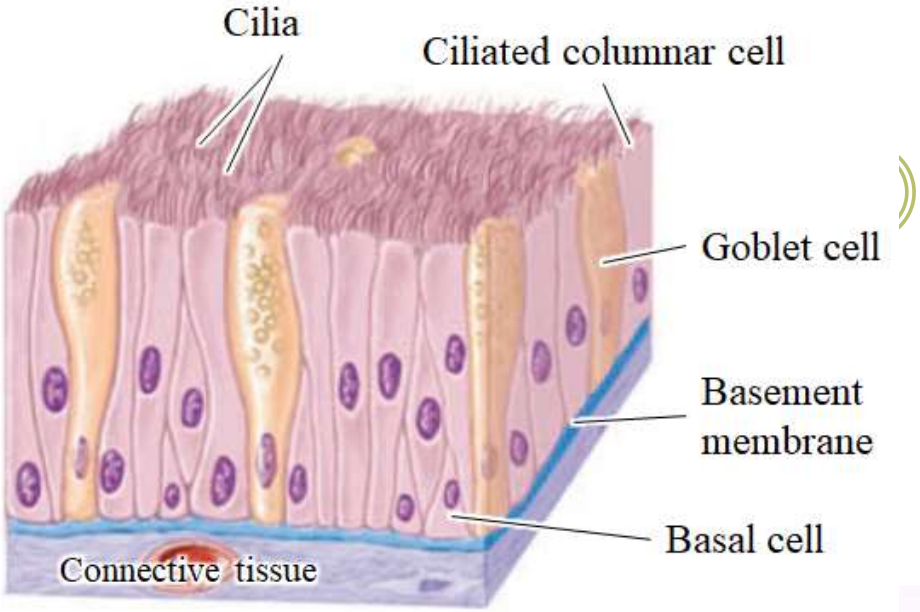


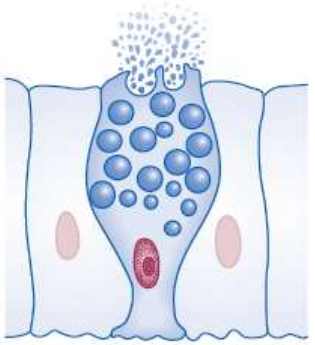
Fig.10: Respiratory epithelium. Note how the image below gives the impression that it's a stratified epithelium. Also note the presence of cilia and mucous secreting goblet cells (long white arrows)

Glandular Epithelium

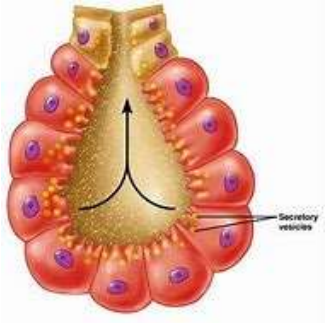
- Is an epithelium specialized in secretion.

Classification of glandular epithelium:

1) *According to number of cells*:



- **Unicellular** glands: formed of a single cell, like Goblet cells of the digestive and respiratory tracts.



- **Multicellular** glands: formed of clusters of cells, like: salivary and sweat glands.

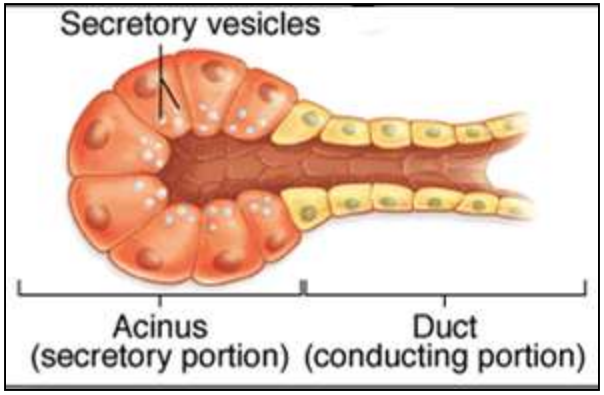
Uni- =one. Multi- = several.

2) *According to presence of ducts*:

- **Exocrine** glands: possess ducts that transfer the secretion to the outside of the body, like: salivary glands.
- **Endocrine** glands: they lack ducts. Their secretions are transferred to the target organs, usually, by blood. Example: Pancreatic Islets, Pituitary gland.

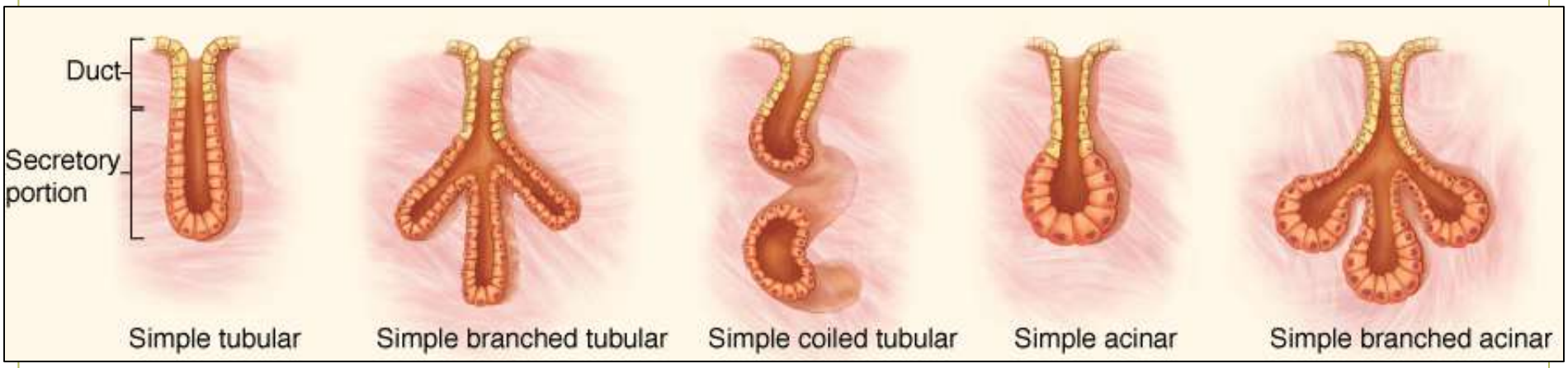
3) Exocrine glands classified *according to morphology of duct and secretory portion:*

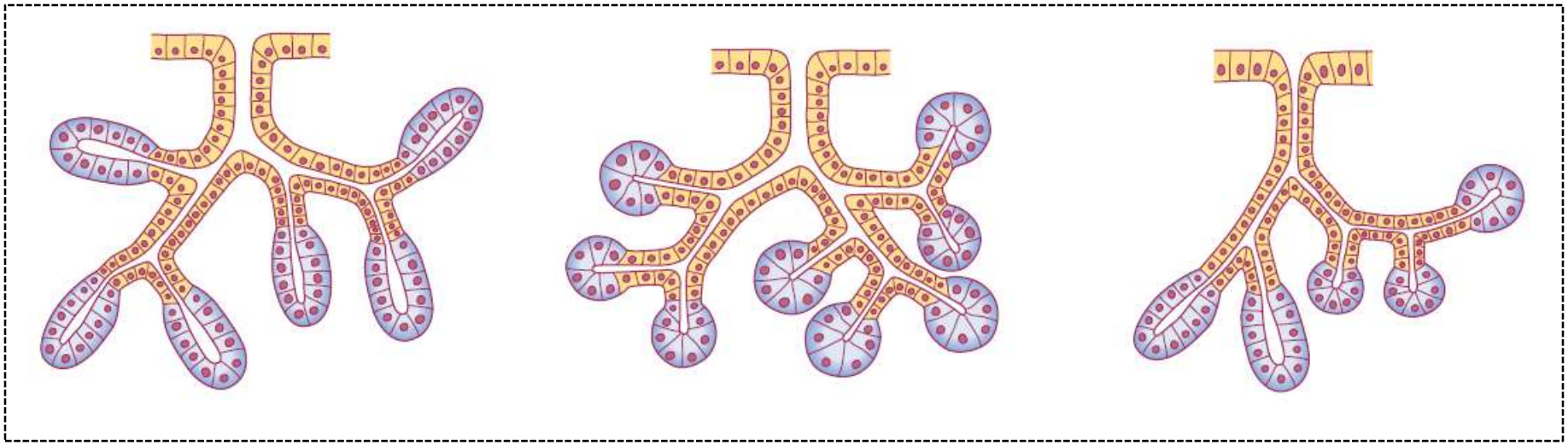
- Each exocrine gland has a secretory portion that produces the secretion and a duct that carries this secretion.



1. ***Duct***
   - If the duct is *unbranched*, the gland is called *Simple*
   - If the duct is *branched*, the gland is called *Compound*
2. ***Secretory portion***
   - If the secretory portion is *unbranched*, the gland is called *Unbranched*
   - If the sectetory portion is *branched*, the gland is called *Branched*
3. ***Secretory portion***
   - If the secretory portion is *tube-like* in shape, the gland is called *Tubular*. If the tube is spiral in shape, it's called *Coiled*.
   - If the secretory portion is *ball-like* in shape, the gland is called *Acinar*
   - If there are *both tubular and acinar* secretory portions, the gland is called *Tubuloacinar*

❖ Unbranched secretory portion = 1 secretory portion opens into 1 duct
❖ Branched secretory portion = Several secretory portions open into 1 duct





Compound tubular

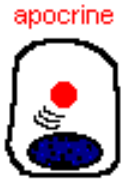
Compound acinar

Compound tubular-acinar

4) Exocrine glands classified according to method of secretion:

- **Merocrine**: only the product is secreted by exocytosis. As in salivary glands.

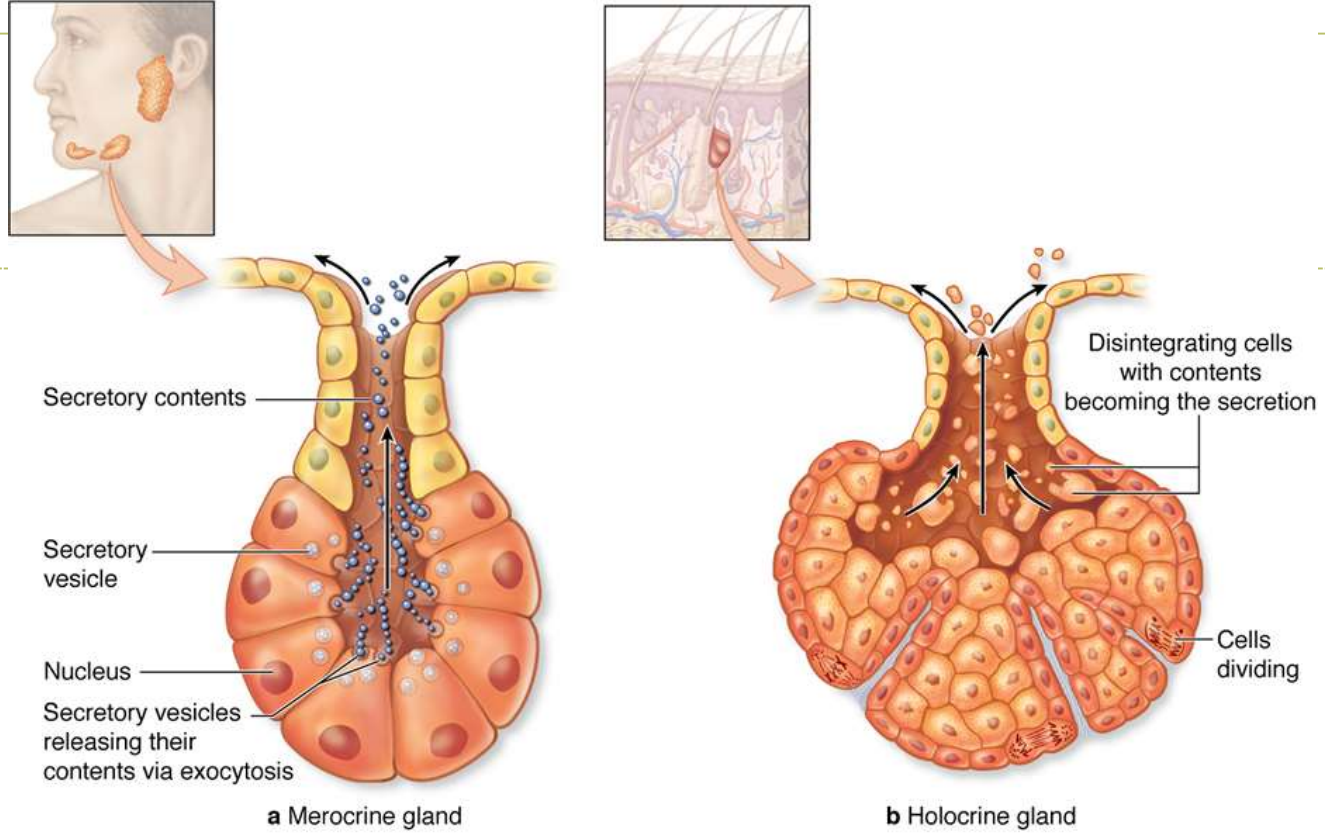
- **Apocrine**: the product and the apical part of the cell is shed. As in mammary gland.



- **Holocrine**: the whole cell disintegrates and is shed with the secretion. As in sebaceous glands of the skin.

- Merocrine glands are either serous or mucous.

Mero- = part. Apo- = away from. Holos = whole. –crine = separate.



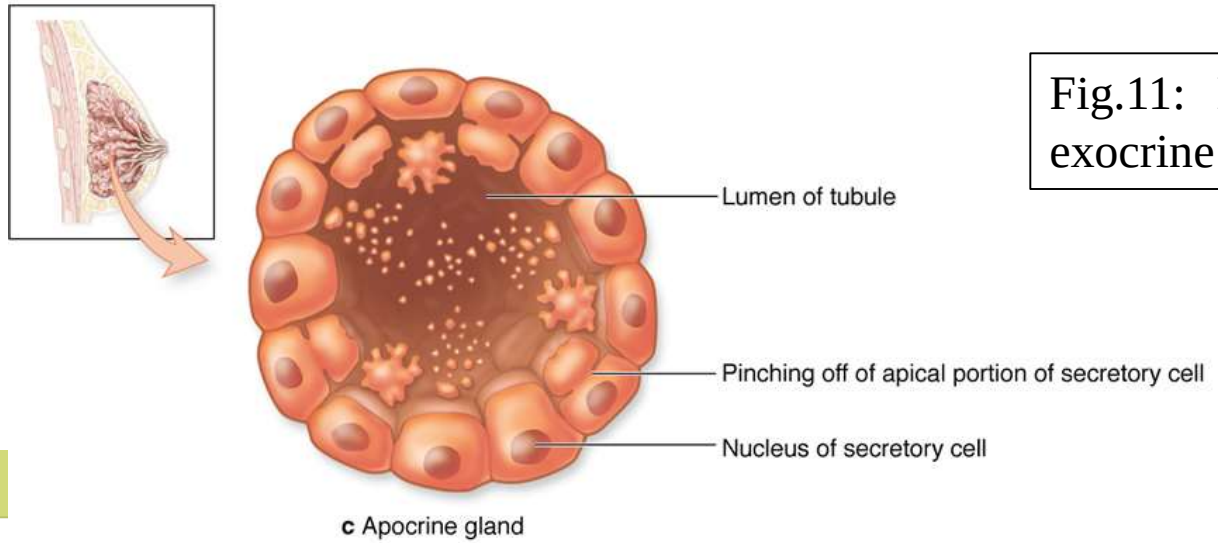
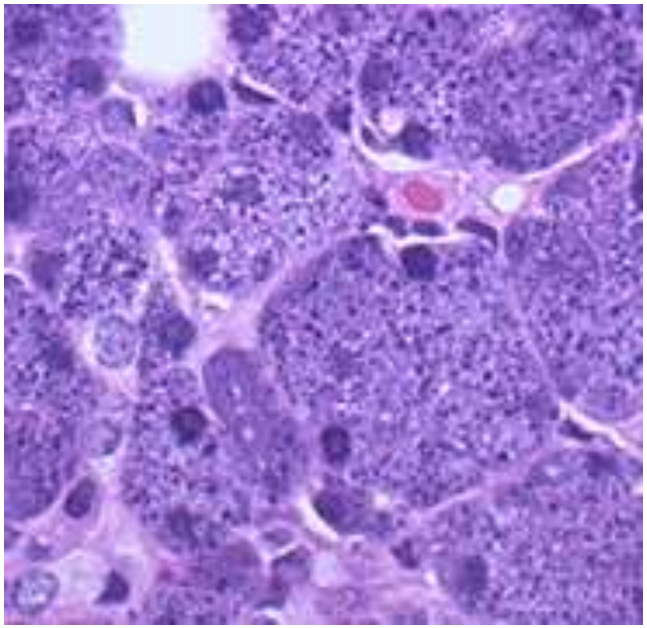


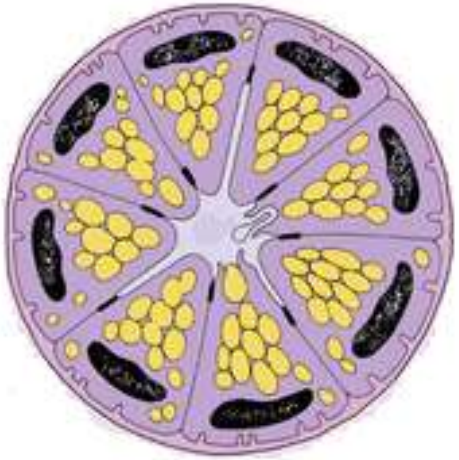
Fig.11: Methods of secretion of exocrine glands.

Serous cells: (Glands)

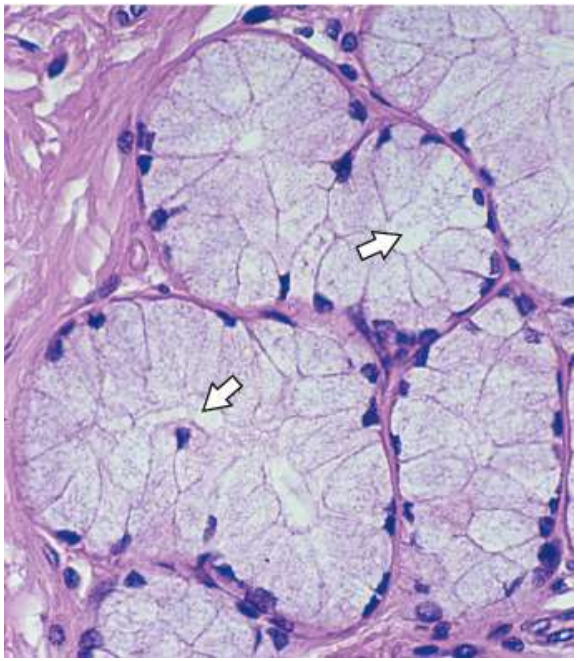
1. Pyramidal in shape.
2. Central, round nucleus.
3. Intense basophilia in the basal region due to abundance of rough endoplasmic reticulum (RER) and ribosomes.
4. Apical region less basophilic and more acidophilic due to presence of secretory granules.
5. Example: Parotid salivary gland



Mucous cells: (Glands)



1. Nucleus compressed in the basal region.
2. Basophilia in the basal region due to abundance of RER.
3. Apical region filled with several large mucin-containing granules that push the nucleus down.
4. The contents of the granules disappear during routine histological preparation → Cells appear vacant.
5. Example: Sublingual salivary gland and Goblet cells.



Myoepithelial cells:

- These are epithelial cells associated with glandular epithelium.
- They’re located between the secretory cells and the basal lamina.

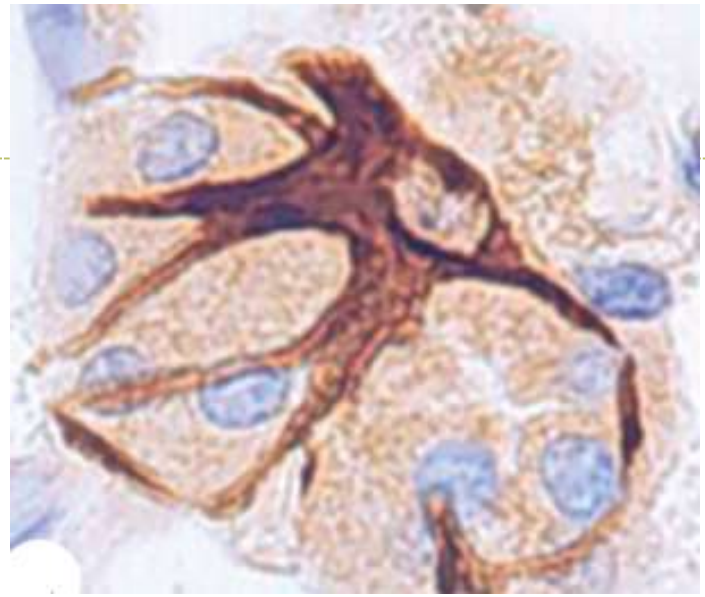


Fig.12: Myoepithelial cells. Stain for contractile elements.

- They contain contractile elements in their cytoplasm. When they contract, they compress the secretory portion of the gland pushing the secretion from its lumen to the duct.

Epithelial Cell Polarity

- Polarity of a cell means that various regions of the cell have specialized structural features because they perform different functions.

- Epithelial cells can be generally divided into 3 regions:
  1. **Apical (Luminal) region**: Facing the lumen of the organ.
  2. **Lateral regions**: adjacent to other cells.
  3. **Basal region**: Lying on the basal lamina.

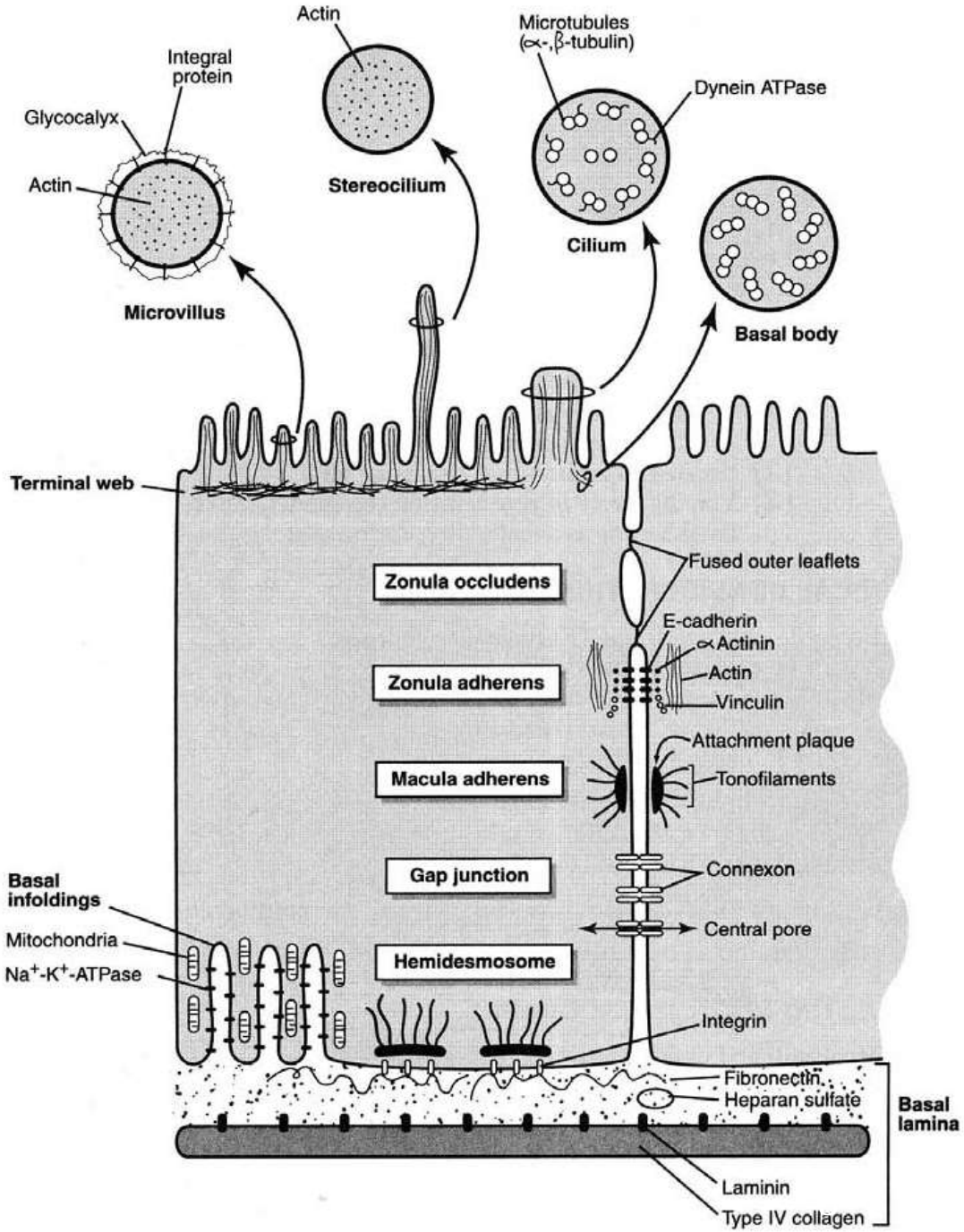
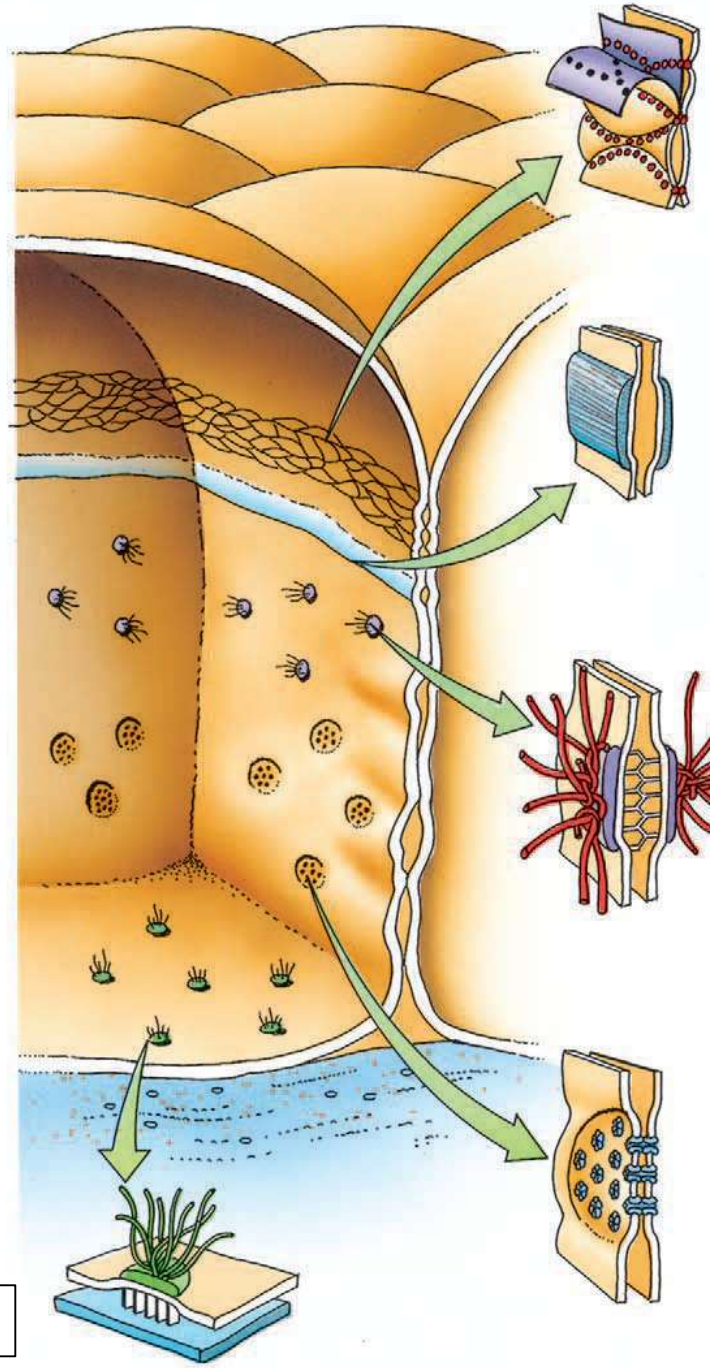


Fig.13: Polarity of epithelial cells. Note the various specialized structures in the different regions of the cell.

Cellular Junctions

- Several membrane-associated structures contribute to adhesion and communication between cells and between cells and nearby structures.
- They are present in several types of cells, but are most prominent in epithelial cells.
- They’re usually present in the lateral surface of the cell and their arrangement from the apical to basal parts is specific.

Fig.14: Various types of cellular junctions



1) Tight Junctions

- Areas in which there's ***fusion of the cell membranes of two adjacent cells*** due to the direct interaction between proteins of the cell membrane.

- They consist of several strands of fusion and they completely surround the cell forming a ring around it. That's why these junctions are also called **zonula occludens**.

- They're present in the apical region of the lateral wall of the cell.

Zonula = zone. Occludens = occlusion.

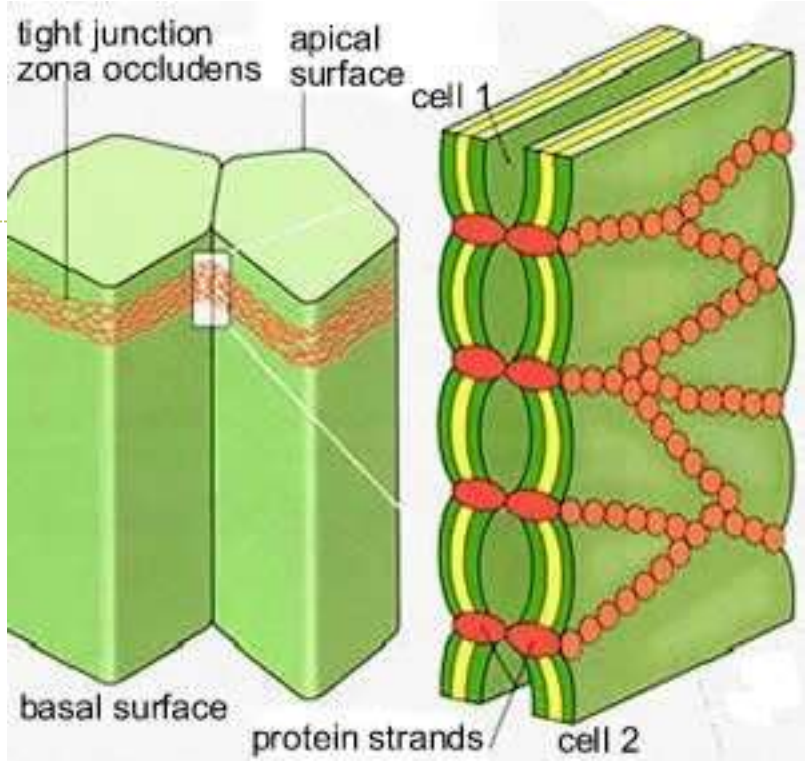
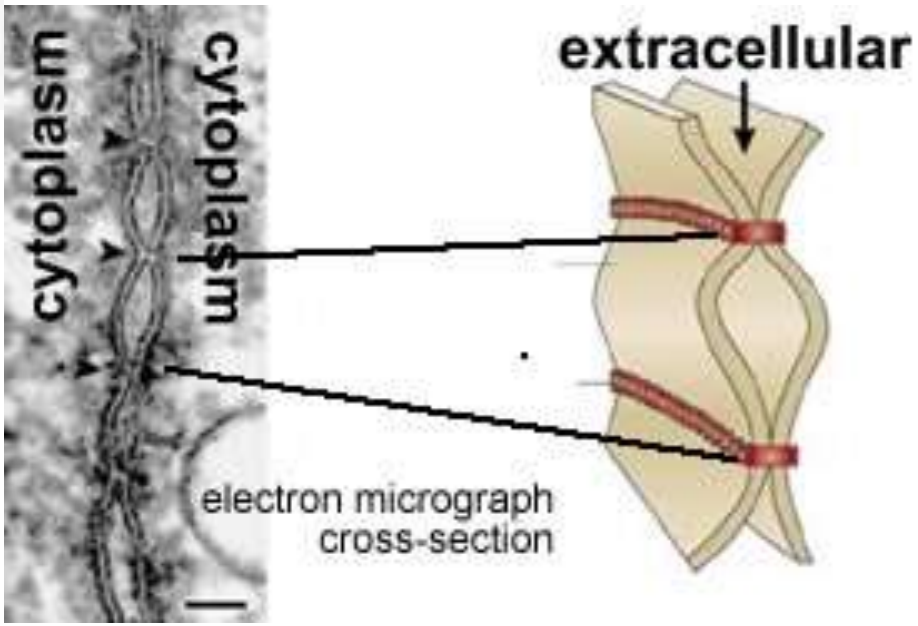
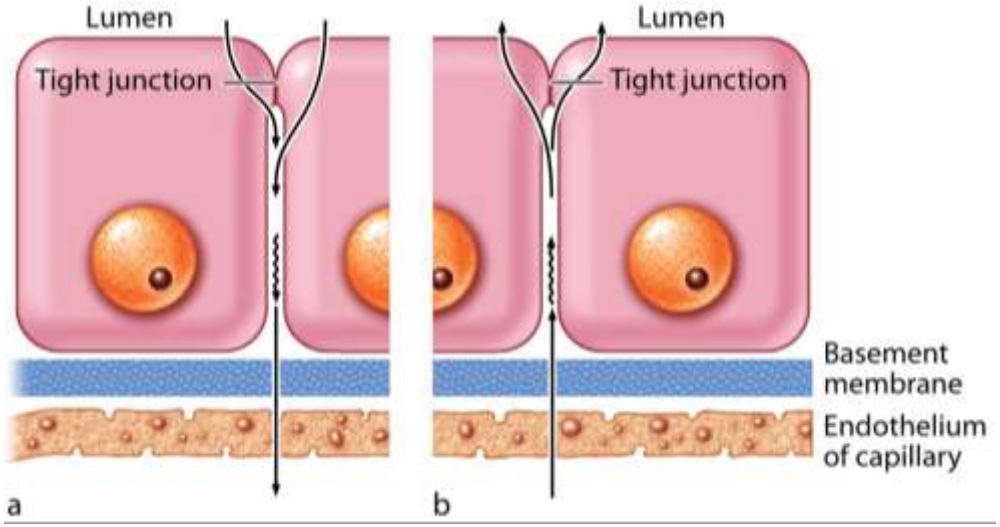


Fig.15: Tight junction. Image on the left shows how these junctions are formed of several strands that completely surround the cell. Fusion of cell membrane at these junctions is clear in the EM image below (arrow heads).



- *Functions of the zonula occludens*:

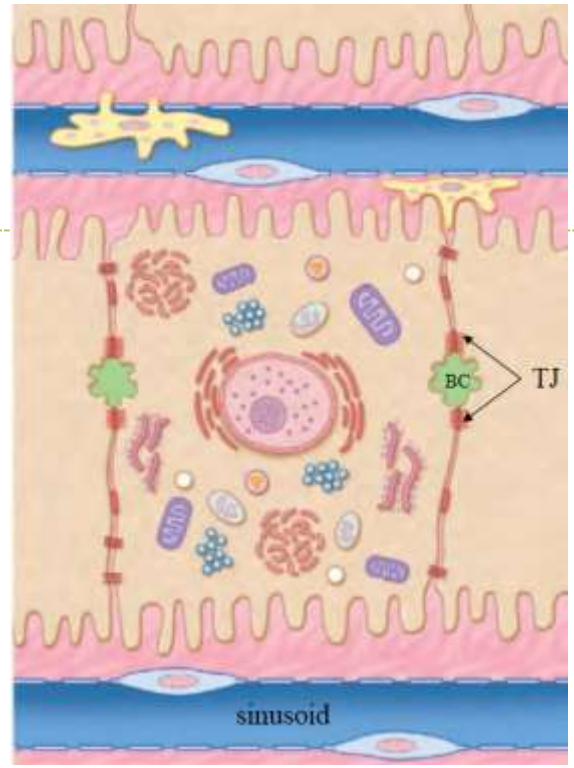
1. Prevention of passage of substances through the intercellular space (this sealing function depends on the number and complexity of the strands).

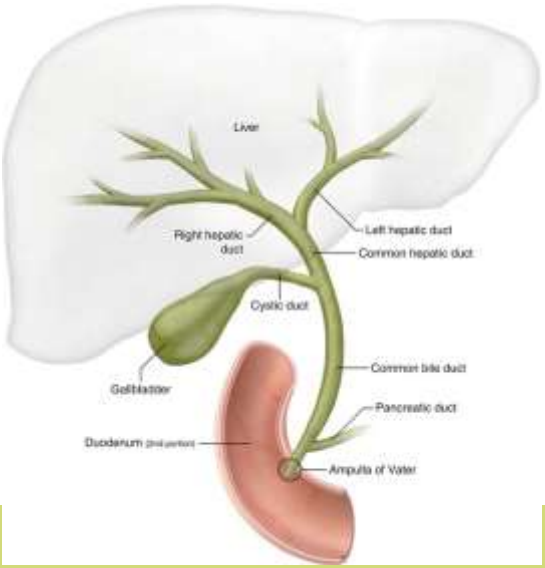


2. Prevention of movement of proteins between apical and basal surfaces of the cell, thus each region will maintain its characteristic protein structure.

Obstructive Jaundice

- One of the functions of hepatocytes (liver cells) is the synthesis and secretion of bile. Bile is first excreted into bile canaliculi, small intercellular channels bounded by hepatocytes cell membrane and closed off from the adjacent liver sinusoids by tight junctions.
- If there's an obstruction to the flow of bile for any reason, bile will accumulate, and the increased pressure in the canaliculi will cause rupture of the tight junctions. In this way, some bile will pass into the sinusoids and lead to jaundice and other complications.
- So, tight junctions here are considered part of the ***blood-bile barrier***.





2) Adherent Junctions

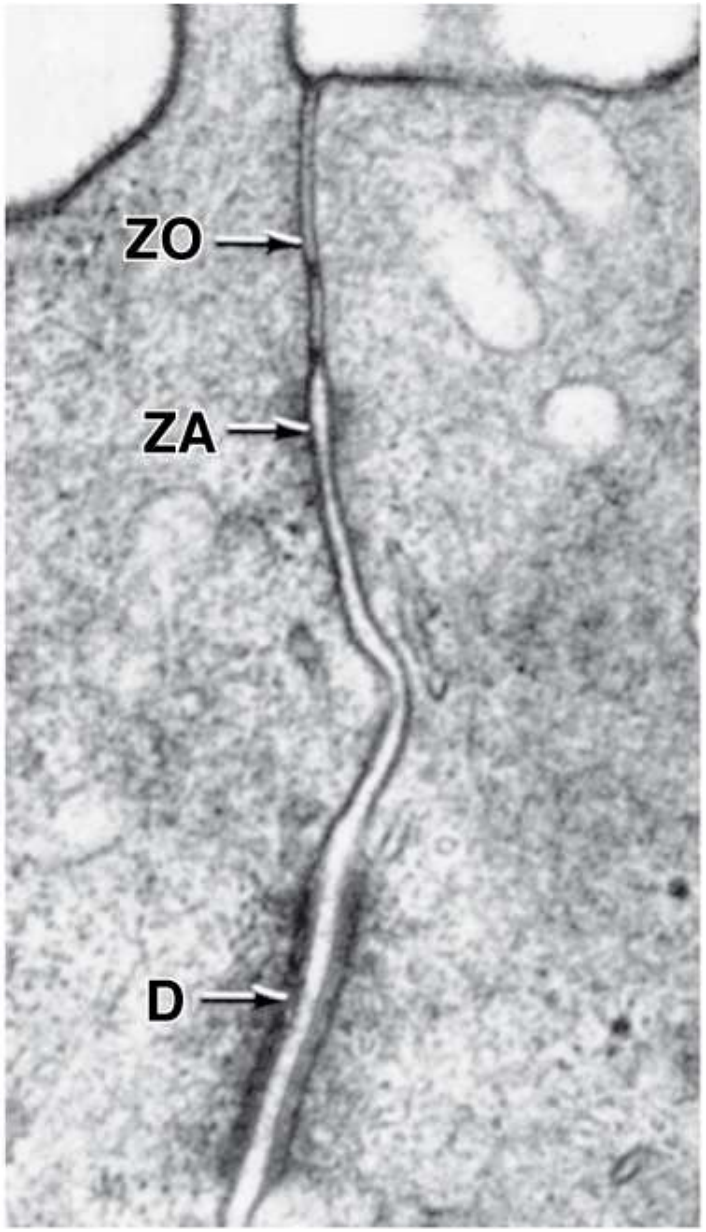
- Areas in which there's ***adhesion between two adjacent cells*** mediated by a Ca^{2+}-dependent transmembrane glycoprotein (The intercellular space is not closed off).

- These glycoproteins are attached to a protein plaque inside the cell that's connected to microfilaments.

- Adherent junctions also surround the cell usually below the zonula occludens forming another zone called **zonula adherens**.

- Function of adherent junctions is to provide for a firm adhesion between adjacent cells thus preventing their separation due to physical forces.

Zonula = zone. Adherens = Adhesion.



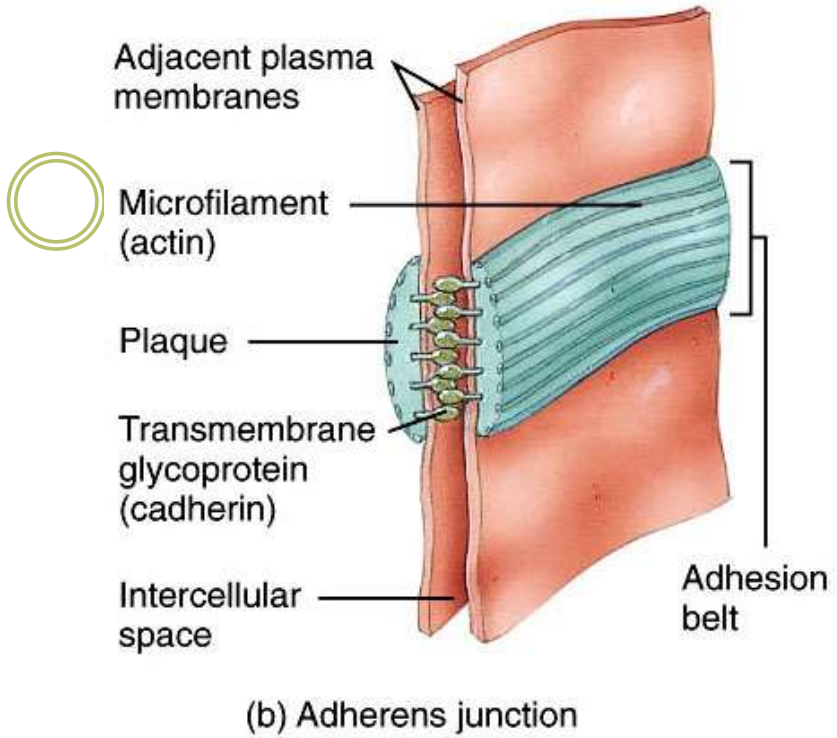


Figure 04.01 Tortora - PAP 12/e

Fig.16: Adherent junction. Image above shows the components of this junction. The EM image on the left shows that at this junction (ZA), the intercellular space is not closed off.

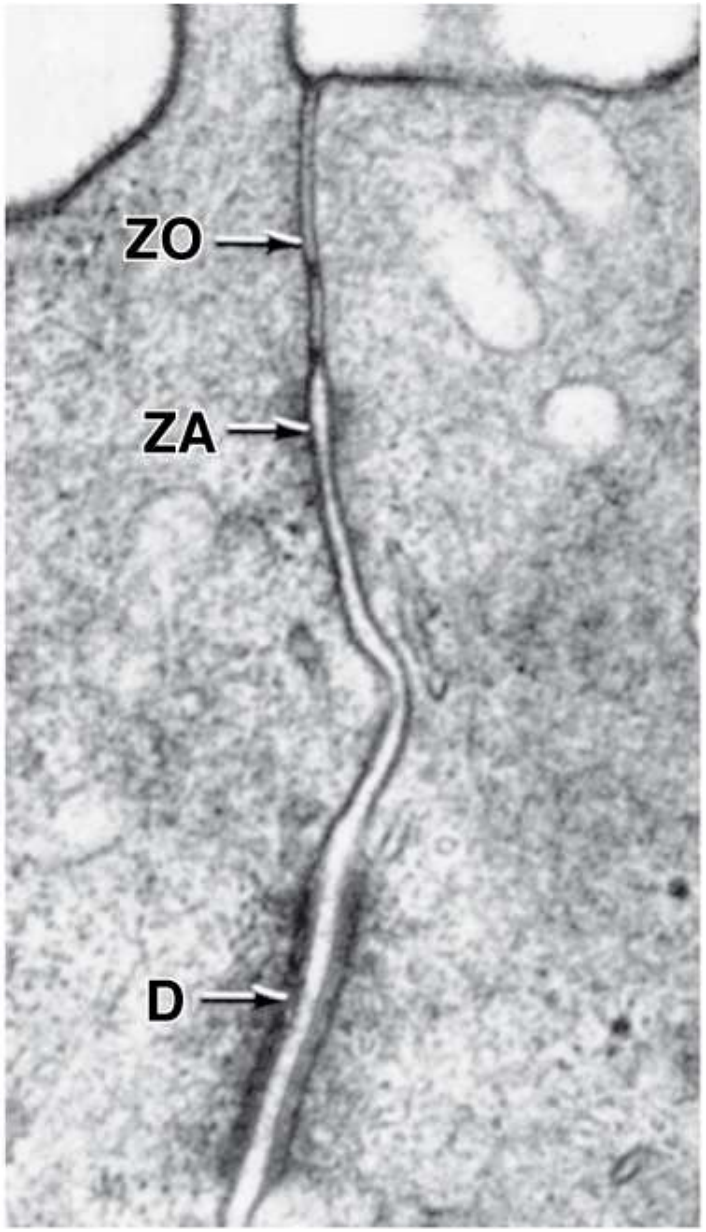
3) Desmosomes

- ✓ Here there is also cellular adhesion mediated by transmembrane glycoproteins. The glycoproteins are attached to protein plaques which are in turn attached to ***intermediate filaments***.

- ✓ Because the connection here is with intermediate filaments, the adhesion in desmosomes is stronger than the adhesion provided by the zonula adherens.

- ✓ Desmosomes do not form a ring around the cell, but are present as scattered single spots called **macula adherens**.

Macula = spot.



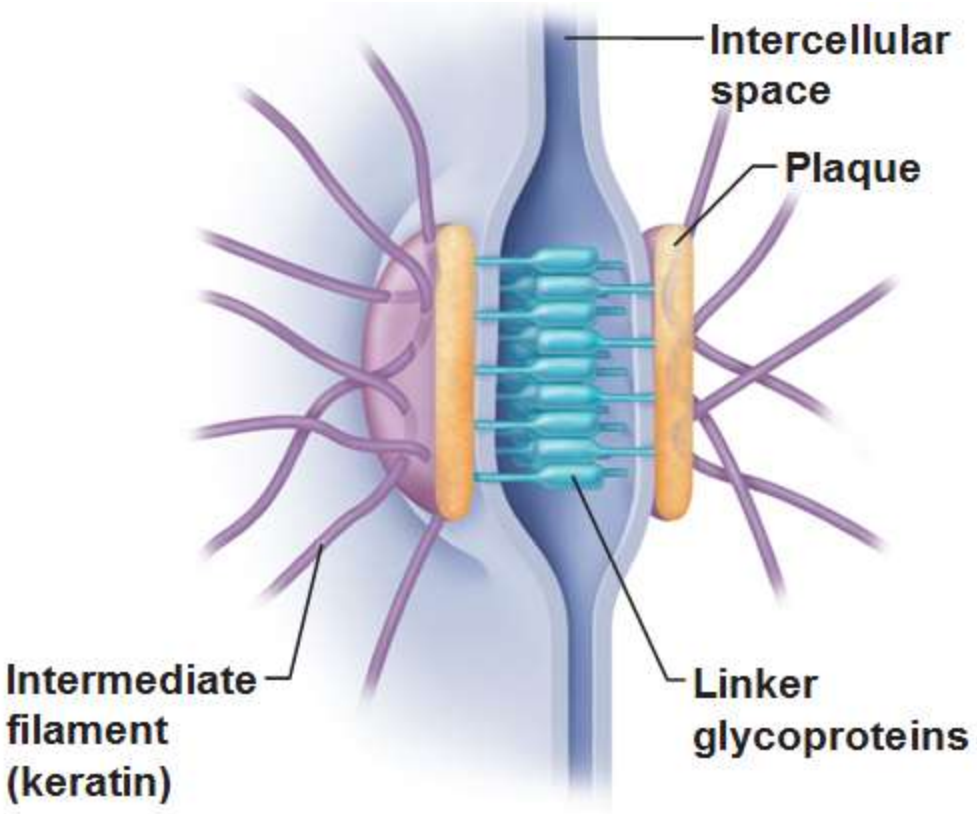


Fig.17: Desmosomes. Image above shows the components of this junction. The EM image to the left shows the position of these junctions.

- ✓ They are usually present in the lower part of the lateral wall of the cell.
- ✓ Function of desmosomes is to provide strong cell-to-cell adhesion.
- ✓ *Pemphigus vulgaris* is a condition involving the skin in which there are antibodies against epidermal desmosomal proteins. These cause disruption of the desmosomes and the loss of cellular adhesion leading to accumulation of fluid and formation of blisters.

Pemphigus = from pemphix = bubble. Vulgaris = common.

4) Hemidesmosomes

- These are similar to desmosomes. They're located in the basal surface of the cell and provide ***adhesion between the cell and the underlying basal lamina***.

- In hemidesmosomes, the adhesion molecules and the protein plaque are derived from the cell only.

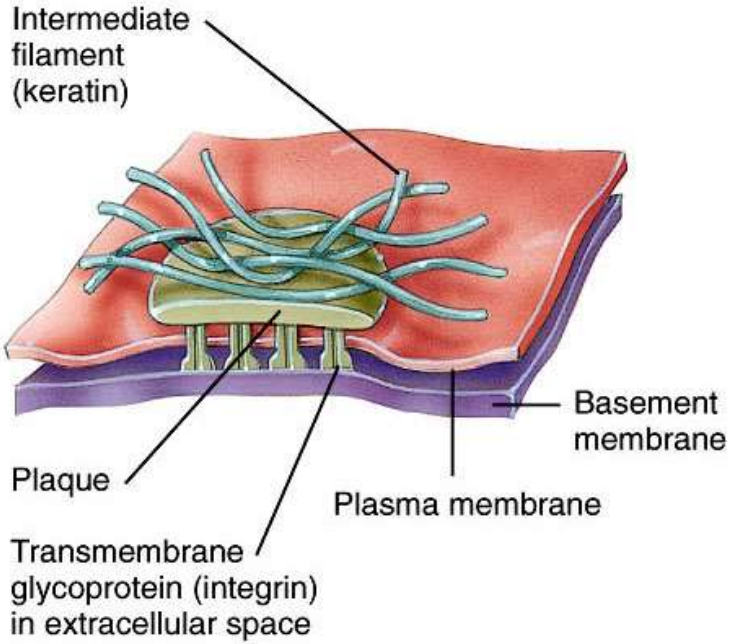


Fig.18: Hemidesmosomes. Note how this junction is present in the cell only.

Hemi- = half.

- *Bullous pemphigoid* is an autoimmune disease in which antibodies are directed against hemidesmosomes of the epidermis. Hemidesmosomes will lose their anchoring abilities leading to separation of epidermis from the dermis causing accumulation of fluid and formation of blisters.

Bulla = large blister. -oid = like.

5) Gap (Communicating) Junction

- At these junctions, the cell membrane of two adjacent cells are apposed. Each cell has a disc shaped structure that contains ***numerous protein complexes with central pores in them***.

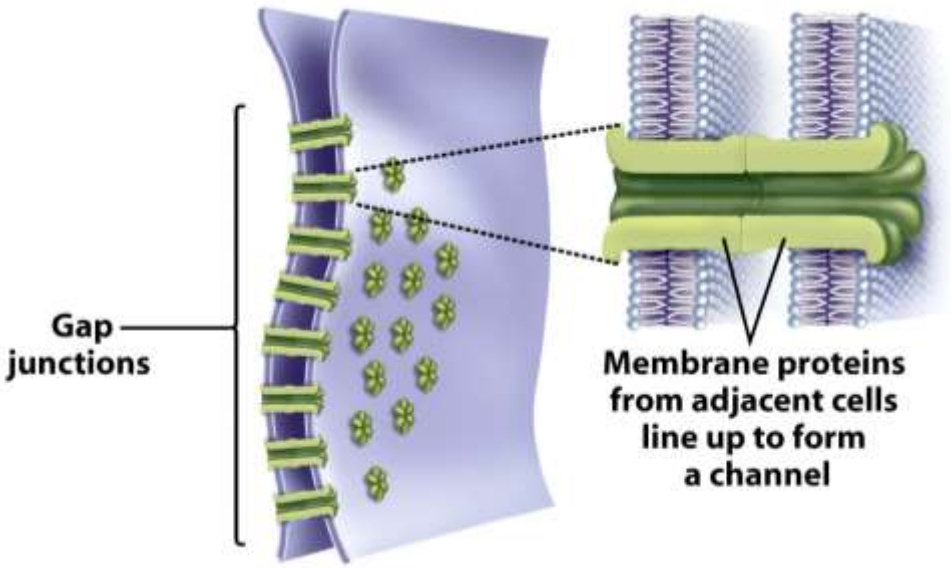


Fig.19: Gap junction

- Through these pores small molecules may pass from the cytoplasm of one cell to the other.

- It could be located anywhere along the lateral surface of cells.

- In cardiac and smooth muscles, the presence of such junctions allow the passage of Ca ions rapidly between cells ensuring their simultaneous contraction.

- In bones, the presence of such junctions between osteocytes ensures the passage of nutrients from one cell to another.

Osteo- = related to bone. –cyte = cell.

Specialization of the Basal surface

1. Hemidesmosomes: for anchoring into basal lamina.
2. Basal striation: infolding of the cell membrane to increase the surface area.
3. Several transporters and pumps.
4. Receptors for various signals.

Specialization of the Apical surface

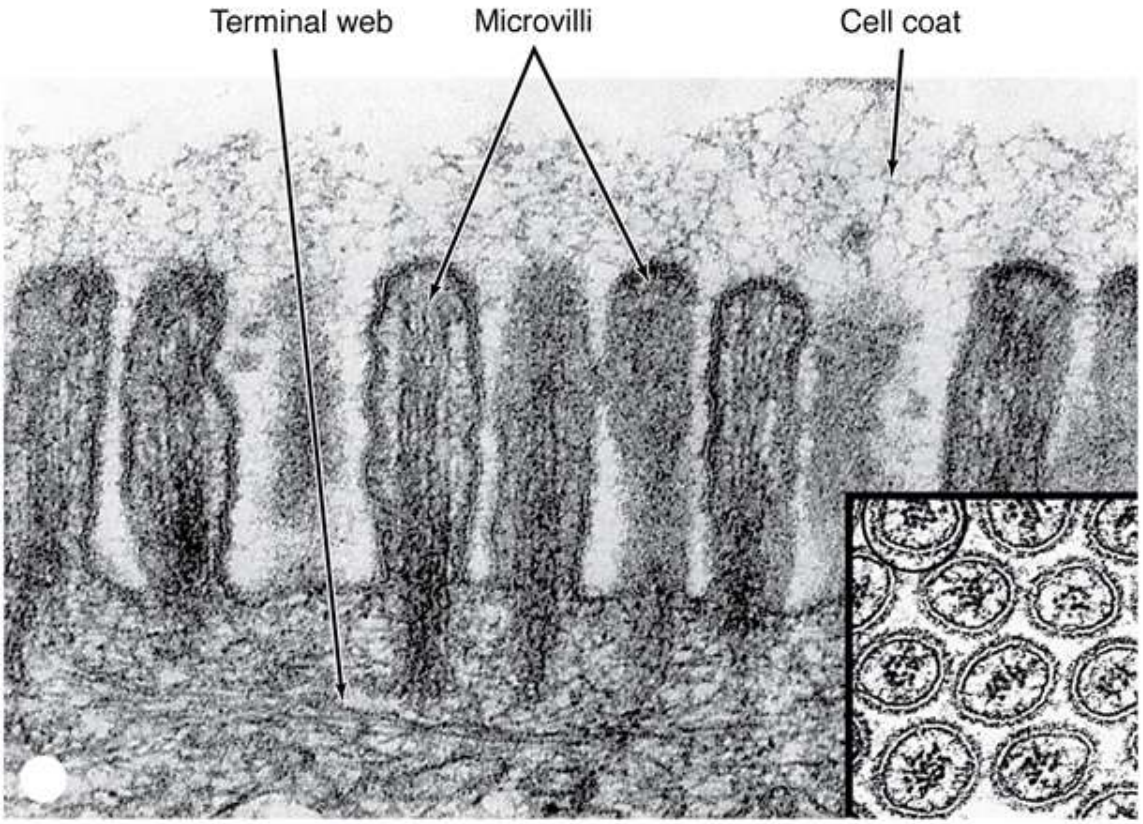
1) Microvilli (single = microvillus)

- Finger-like cytoplasmic projections that are present in absorptive epithelium, most prominently in the small intestine. They increase the surface area.

- They consist of a core of cytoplasm with a network of actin filaments cross-linked with each other and with the surrounding cell membrane and with the terminal web of the cell. They’re motile.

- They could be short or long, temporary or permanent.

Villus = Shaggy hair.



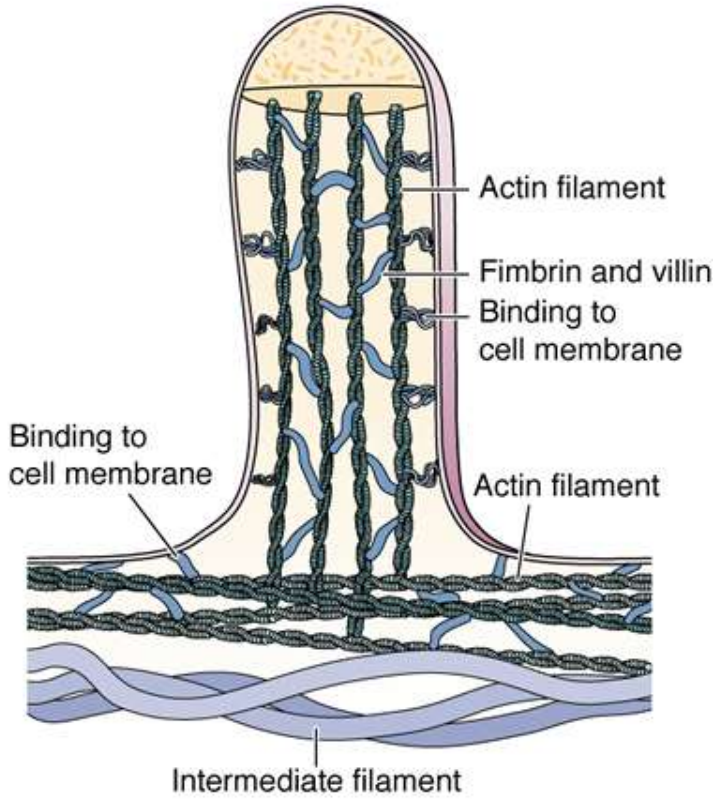


Fig.20: The EM image on the left clearly shows the structure of the microvilli.. The image on the right shows how the actin filaments are cross-linked with each other, with the cell membrane and the terminal web.

- Under light microscope, numerous microvilli form a brush border on the surface of the small intestinal epithelium. But, because they're small, their features can only be clearly identified by electron microscope.

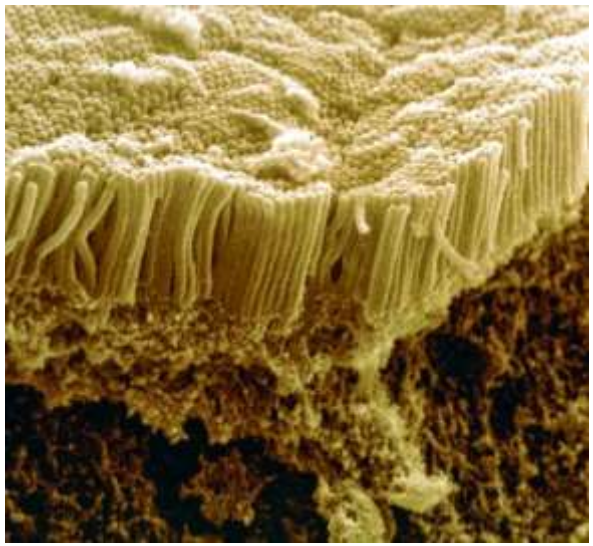


Fig.21: LM image of small intestinal wall. Note the Striated/Brush border formed by microvilli (Black arrow).

2) Stereocilia

- These are apical specialization in some absorptive cells like those of the epididymis and ductus deferens. They're also present on the hair-cells of the inner ear.

- They are similar in structure to microvilli. However, they're longer, less motile and branched.

- They increase the surface area. Stereocilia of the inner ear act as mechanoceptors.

Stereo- = Firm or solid. Cilium = eyelash.

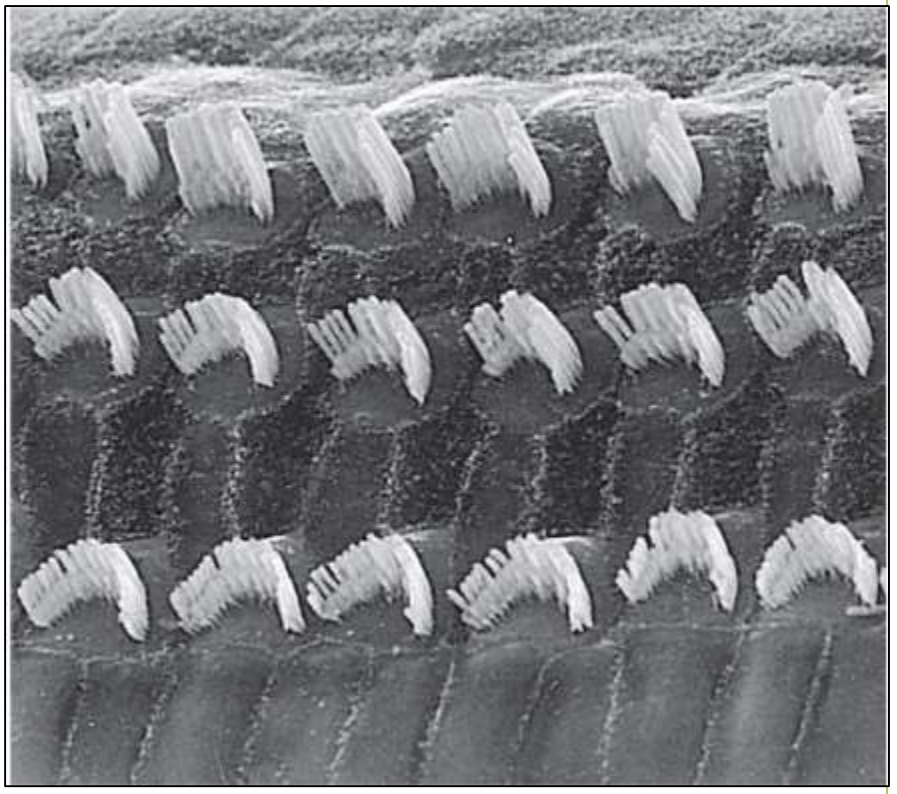


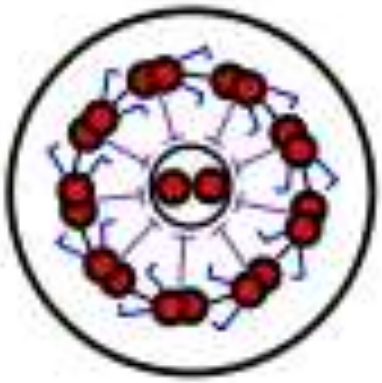
Fig.22: Above, LM image of stereocilia of the epithelium of the epididymis (arrows). The image to the right is a SEM image showing stereocilia of the inner ear.

3) Cilia (single = cilium)

- Elongated, motile structures on the surface of some epithelial cells, like those of the trachea. There are, usually, many cilia on the surface of a single cell.

- Cilia move in rhythmic fashion backwards and forwards removing fluid, debris, or various other materials in a certain direction.

- It's surrounded by cell membrane and is formed of microtubules arranged in a specific pattern.



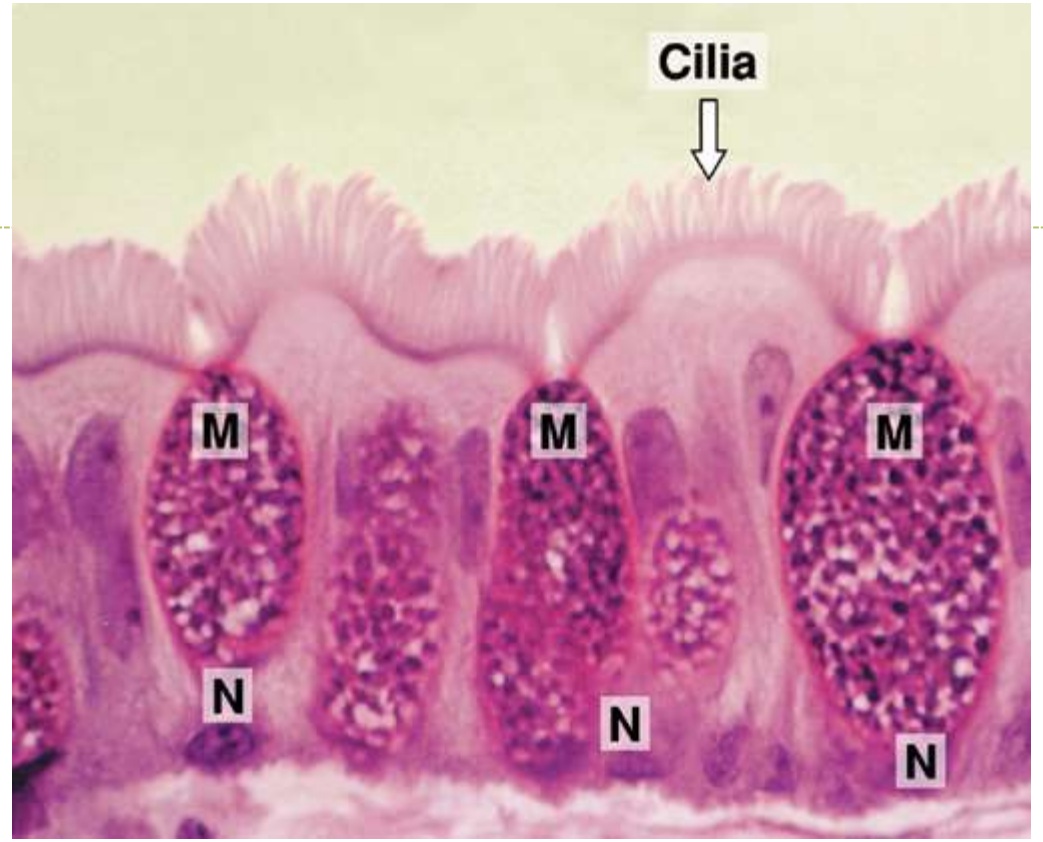


Fig.23: LM image above shows the cilia of the epithelium of the respiratory tract. In the EM image on the right, note how the cilia are much longer and thicker than the microvilli.

- Flagella (single = flagellum) are structurally like cilia but are much longer and, usually, only one flagellum is present on a cell. The movement of the flagellum is rotational.

- The only cell in the human body that has a flagellum is the sperm. Here, it's used for movement of the sperm.

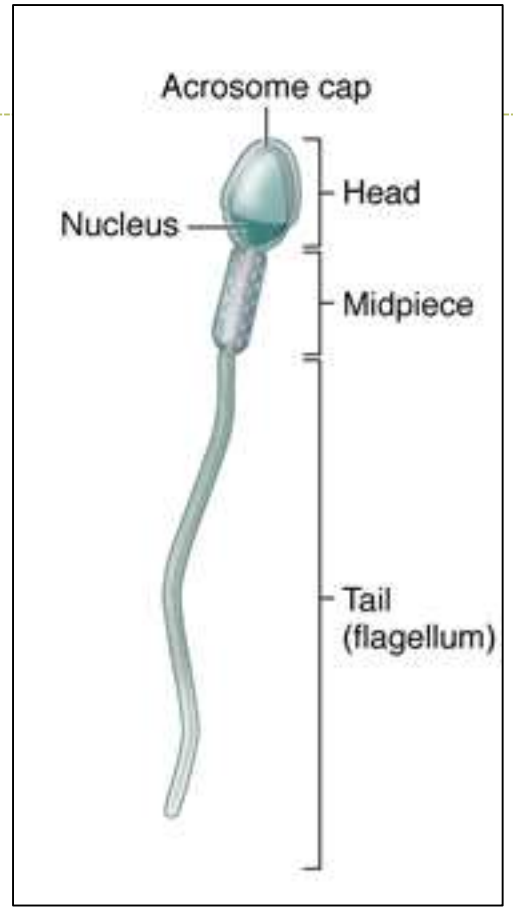
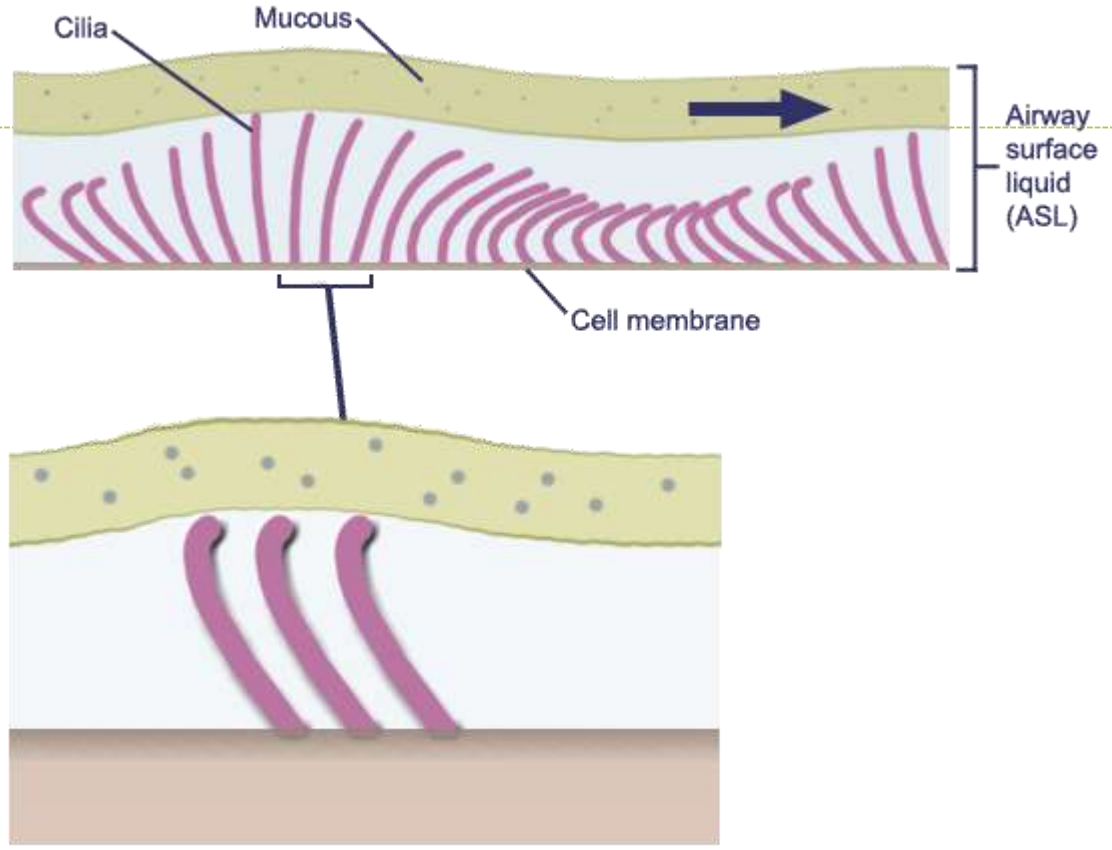


Fig.24: The tail of the sperm is a flagellum.



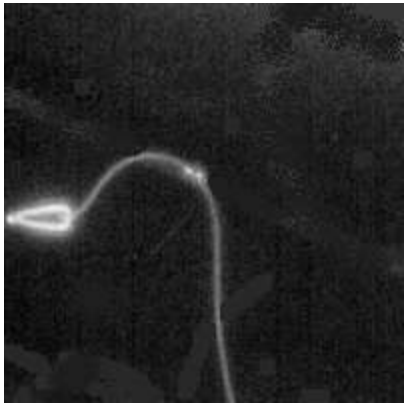


Fig.25: The left animated image shows the forwards and backwards ***sweeping*** motion of cilia. Compare it with the rotational propulsive movement of the flagellum (tail) of a sperm shown in the right animated image.

Primary Ciliary Dyskinesia (Immotile Cilia Syndrome)

- It’s a genetic disorder in which there is abnormality in the movement of cilia and flagella.
- Mucus is not easily removed form the respiratory system leading to repeated infections.
- Sperms cannot move easily leading to male infertility.
- The cilia of the uterine tubes may also be affected leading to infertility in females.

THANK YOU

It's better to know one thing about everything and everything about one thing