Topic 2. Epithelial tissue

Control questions

1. Definition the term «tissue», elements of the tissues. Classification of the tissues.
2. Classification of epithelium and its functions.
3. General characteristic of epithelial tissues.
4. Polarity of epithelial cells and their surface modifications.
5. Types of the cell junctions.
6. Basement membrane structure and functions.
7. Morphological classification of covering epithelium.
8. Types of simple epithelium. Structure and distribution.
9. Types of stratified epithelium. Structure and distribution.
10. Regeneration of epithelium.
11. Glands. Sources of development. Classifications. Types of secretion.
12. Ultrastructure of the glandular cell. Gland as an organ.

Question 1. Definition the term «tissue», elements of the tissues. Classification of the tissues.

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

Tissues consist of cells and intercellular substance or extracellular matrix.

The human body is composed of 4 basic types of tissues:

1) Epithelial tissue (epithelium) that covers body surfaces, lines body cavities, and forms glands;

2) Connective tissue that underlies or supports structurally and functionally the other three basic tissues;

3) Muscle tissue that is made up of contractile cells and is responsible for movement;

4) Nerve tissue that receives, transmits, and integrates information from outside and inside the body to control the activities of the body.

Question 2. Classification of epithelium and its functions.

All epithelia are classified into 3 main groups according to their functions:

1. Covering or lining;
2. Glandular;
3. Sensory.

The basic functions of epithelial tissue are:

1) Protection (e.g., skin and esophagus);
2) Absorbtion (e.g., tubules of kidney, small and large intestines);
3) Transportation (e.g., cilia-mediated transport in the respiratory organs) and between blood and loose connective tissue (e.g., endothelium of vessels);
4) Secretion of mucus, hormones, proteins (e.g., in glands);
5) Gases exchange (e.g., alveoli of the lungs);
6) Lubrication between two surfaces (e.g., mesothelium of the pleural, peritoneal and pericardial cavities);
7) Sensation (e.g., in some sensory organs);
8) Contractility (e.g., myoepithelial cells of some exocrine glands).

Question 3. General characteristic of epithelial tissues.

All epithelial tissues possess some general characteristics:

1) Epithelia are continuous sheet-like cellular layers with little amount of intercellular substance separating the underlying connective tissue from the external environment or environment of internal cavities;

2) Epithelial cells are closely apposed and adhere to one another by means of specific cell-to-cell adhesion molecules that form specialized cell junctions;
3) Epithelial cells rest on a basement membrane;
4) Epithelia are avascular tissue because do not contain blood vessels. They are nourished by diffusion of substances from underlying capillaries of the loose connective tissue;
5) Epithelial cells exhibit polarity;
6) Epithelial tissues receive a rich supply of sensory nerve endings;
7) Epithelia have a high ability to regeneration. Epithelial tissues are labile structures whose cells are renewed continuously by means of mitotic activity;
8) Some epithelial cells display surface modifications on their apical domain.

Question 4. Polarity of epithelial cells and their surface modifications.

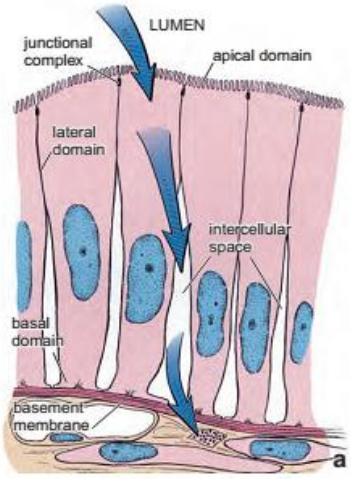


Figure 2.1. Diagram of small intestine absorptive epithelial cells [13].

Epithelial cells exhibit distinct polarity. It means the epithelial cells have an apical domain and opposite a basal domain. Except them, there are two lateral domains in epithelial cells.

The free or apical domain is always directed toward the exterior surface or the lumen of an enclosed cavity or tube. The lateral domain communicates with adjacent cells and is characterized by specialized attachment areas. The basal domain rests on the basal lamina anchoring the cell to underlying connective tissue [13].

Surface modifications of some epithelial cells

In many epithelial cells, the apical domain exhibits special structural surface modifications to carry out specific functions. They are:

1) Microvilli;
2) Stereocilia (stereovilli);
3) Cilia.

Microvilli

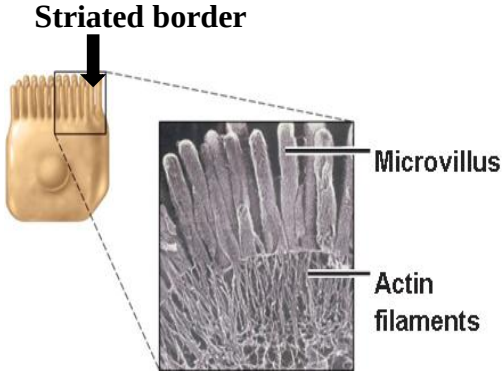


Figure 2.2. Electron micrograph of microvilli

Microvilli are fingerlike cytoplasmic projections on the apical surface of some epithelial cells. The microvilli greatly increase the cell apical surface area and absorptive capacity of epithelial cells. Thus, the cells that principally transport fluid and absorb metabolites (e.g., those of the intestine and kidney tubules) have many closely packed, tall microvilli producing together a structure called striated or brush border on their apical part.

The internal structure of microvilli contains a core of actin filaments. Actin filaments extend down to produce the terminal web laying just below the base of the microvilli [13].

Stereocilia (stereovilli)

Stereocilia are modified microvilli of epithelial cells in some sensory organs where they are sensitive to the odorous molecules or to the sound waves; and in some parts of the genital duct where they facilitate an absorption.

Silium in transverse section

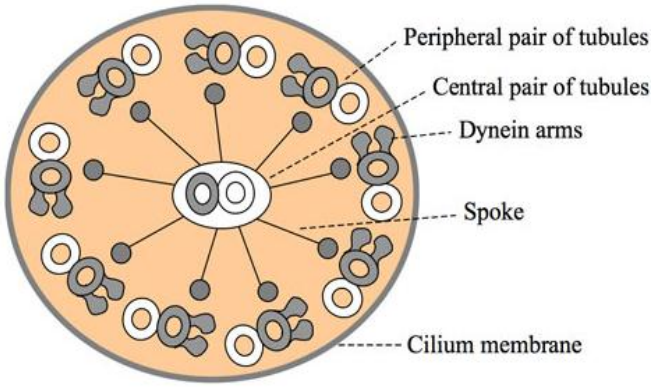


Figure 2.3. Diagram of a cilium (cross-section).

Cilia are hair like extensions of the apical plasma membrane of ciliated cells. Cilium contains an inner core called axoneme. The axoneme extends from the basal body, laying on the base of cilium.

Cilia

Both axoneme and basal body of cilia consists of microtubules. In axoneme the microtubules are arranged as circular nine peripheral pairs or doublets and a single central pair (formula is (9×2)+2 of microtubules). In basal body the microtubules are arranged as circular nine peripheral triplets with no central microtubules (formula is (9×3)+0 of microtubules).

Each doublet of microtubules exhibits a pair of "arms" that contain a motor protein called dynein. Cilia movement originates from the sliding of microtubule doublets, which is generated by the ATPase activity of the dynein arms. Cilia beat in a synchronous pattern. Motile cilia are capable of moving fluid and particles along epithelial surfaces [5].

Question 5. Types of the cell junctions.

Lateral domain of epithelial cells exhibit several specializations that form intercellular junctions. There are three principle types of specialized junctions or junctional complexes:

I. Anchoring;
II. Occluding;
III. Communicating.

Classification of anchoring or adhesive junctions

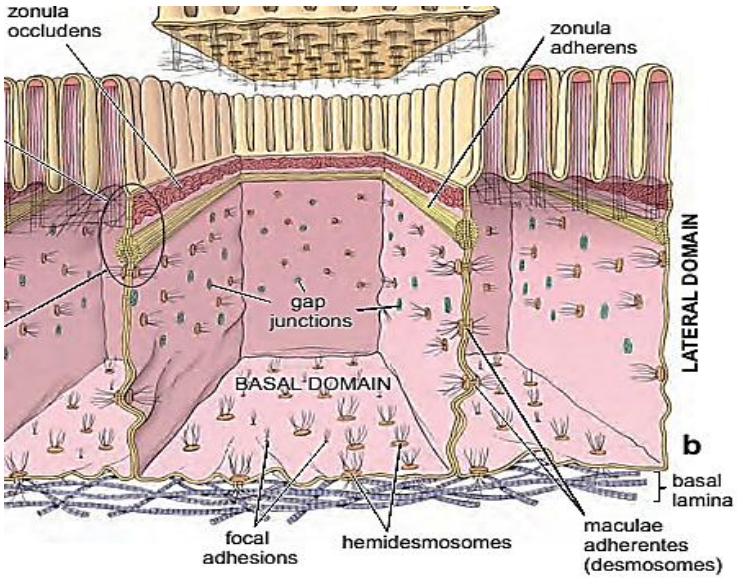
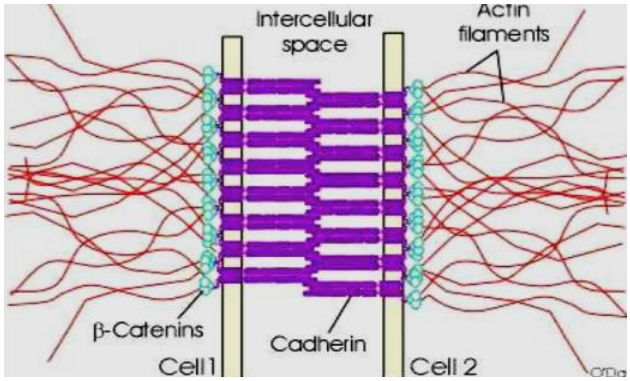


Figure 2.4. Diagram of cell junctions [13].

Anchoring junctions may be classified into:

1. **Anchoring junctions on the lateral cell domain,** binding cells together and providing mechanical stability to epithelial cells:
   a) Zonula adherens or adhesive belt, which interacts with the network of actin filaments inside the cell;
   b) Macula adherens or desmosome, which interacts with intermediate filaments.
2. **Anchoring junctions on the basal cell domain,** binding cells with basal membrane:
   c) Hemidesmosomes;
   d) Focal adhesions.

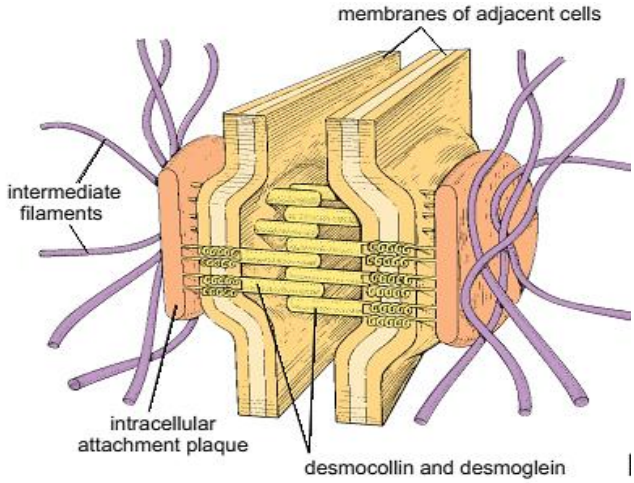
Zonula adherens (adhesive belt)



Zonula adherens is a continuous band or belt like configuration around the apical part of the epithelial cell. The zonula adherens is composed of the transmembrane protein molecules called cadherin, forming a complex with catenin molecules presenting on the cytoplasmic side of cell. Actin filaments of adjacent cells are attached to the cadherin–catenin complex [13].

Figure 2.5. Diagram of zonula adherens.

Macula adherens (desmosome)



The desmosome is a spot like junction between lateral domains of adjacent epithelial cells. In the intercellular area of the desmosome, the proteins called desmogleins and desmocollins provide the linkage between the plasma membranes of adjacent cells.

On the cytoplasmic side of the plasma membrane of each of the adjoining cells there is a disc-shaped structure called the desmosomal attachment plaque, which serve to anchor the intermediate filaments [13].

Figure 2.6. Diagram of desmosome [13].

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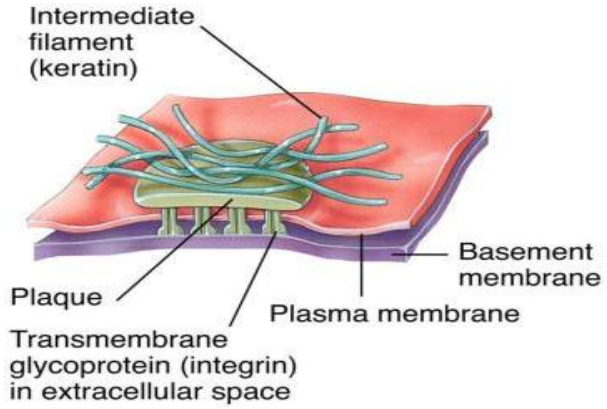
Hemidesmosome

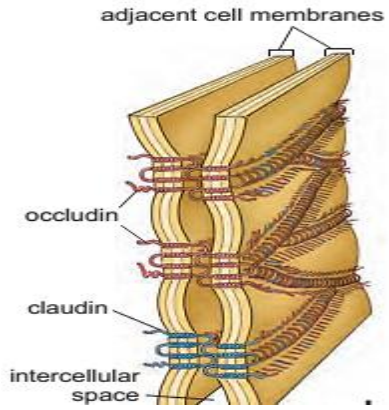


Hemidesmosomes provide the attachment of the epithelial cell to the basal lamina.

Hemidesmosome looks like a half of desmosome. The majority of transmembrane proteins found in the hemidesmosomes belong to the integrin class.

Figure 2.7. Diagram of hemidesmosome.

Occluding junctions (zonula occludens) or tight junctions



Occluding junctions are impermeable for most molecules and allow epithelial cells to function as a barrier. Occluding junctions or zonula occludens are therefore, also called tight junctions.

Tight junction is a series of focal fusions between the cells, created by transmembrane proteins of adjoining cells called occludin, claudin [13].

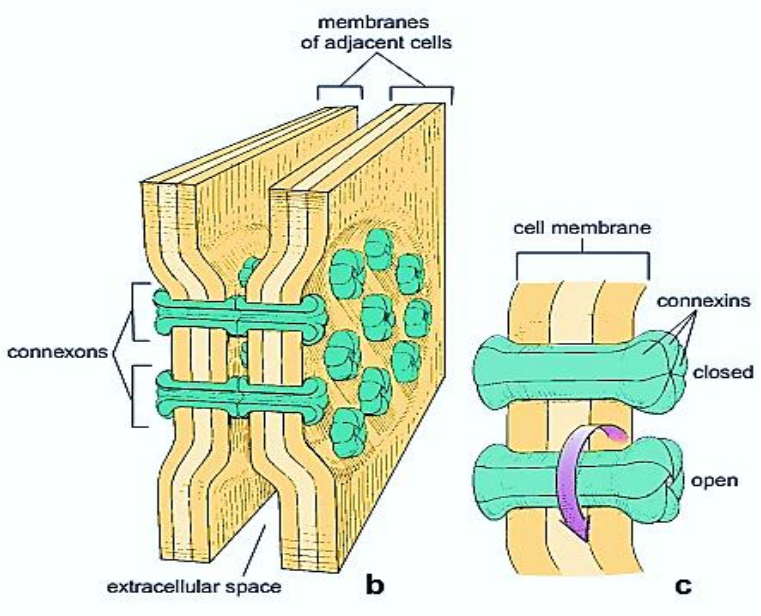
Figure 2.8. Diagram of zonula occludens [13].

Communicating junctions

Communicating junctions are:

1) **Synapses.** They are junctions binding the neurons;
2) **Gap junctions or nexuses.** They there are in epithelia, smooth and cardiac muscles.

Gap junctions or nexuses



Gap junction is membranes channels between two adjoining cells. These channels are represented by pairs of connexons with a central opening that bridge the extracellular space between adjacent cells.

Each connexon is made up of six subunits of an integral membrane protein called connexin. Gap junction allow molecules to pass in both directions [13].

Figure 2.9. Diagram of zonula occludens [13].

Question 6. Basement membrane structure and functions.

All epithelia rest on a sheet-like extracellular structure called the basement membrane. It is a specialized structure located next to the basal domain of epithelial cells and the underlying connective tissue stroma. The thickness of basement membrane is 20 to 100 nm.

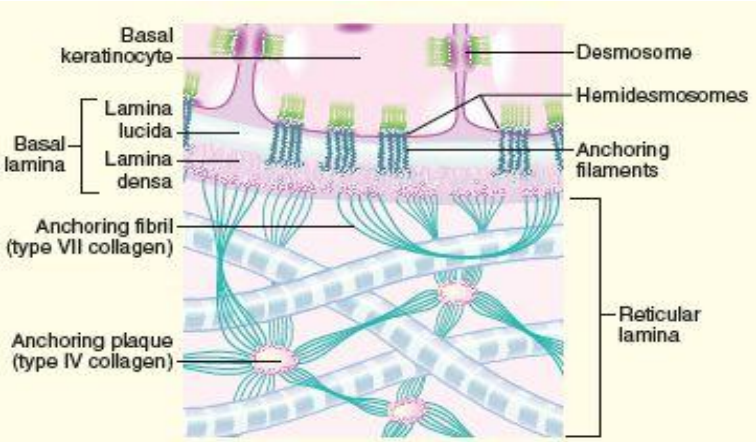


Figure 2.10. Diagram of basal specialization beneath an epithelium.

Basement membrane consists of three laminae:

1) a lamina lucida;
2) a lamina densa (basal lamina);
3) a fibroreticular lamina.

The fibroreticular lamina consist of reticular fibrils that merge with under laying connective tissue.

The lamina densa exhibits a network of filaments composed of laminins, a type IV collagen molecule, and various associated proteoglycans and glycoproteins. Lamina densa is attached to the under laying connective tissues by anchoring fibrils consisting of type VII collagen.

Between the basal lamina and the epithelial cell there is a clear or electron-lucent area called the lamina lucida which is represented by the integrin family of transmembrane proteins mainly fibronectin and laminin [13].

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Functions of basement membrane

1. Supportive function because the basement membranes are structural bases and attachment sites for epithelial cells;
2. Barrier function because the basement membranes are selective barriers, limiting epithelia from the connective tissue and regulating the exchange of macromolecules between them.
3. Regulatory function because the basement membranes influence on epithelial cells proliferation, differentiation and matabololism.

Question 7. Morphological classification of covering epithelium.

According to the number of cell layers and the shape of surface cells the covering epithelia can be classified into:

I. **Simple epithelium** containing only one layer of cells:
  a) squamous;
  b) cuboidal;
  c) columnar

II. **Stratified epithelium** containing more than one layer of cells:
  1) Keratinized squamous;
  2) Non-keratinized:
    a) squamous;
    b) cuboidal;
    c) columnar

III. **Special epithelia:**
  1) Pseudostratified **(simple)**;
  2) Transitional **(stratified)** [13].

Question 8. Types of simple epithelium. Structure and distribution.

There are four types of simple epithelium in our organism:

1) Simple squamous;
2) Simple cuboidal;
3) Simple columnar;
4) Pseudostratified.

Simple squamous epithelium

Simple squamous epithelium is composed of a single layer of uniform flat cells, which all rest on the basement membrane. The nuclei of cells appear flattened.

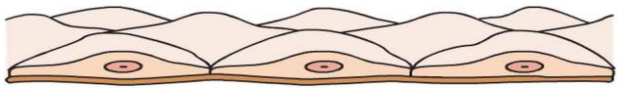


Figure 2.11. Diagram of simple squamous epithelium [5].

This type of epithelium is found:
1) Lining the alveoli of the lung;
2) Lining the vessels and hurt chambers **(endothelium)**;
3) Lining the serous body cavities (pericardial, pleural and peritoneal) and the serous coats of inner organs **(mesothelium);**
4) Lining the thin segments of loops of Henle of the kidney;
5) Lining the smallest excretory ducts of some glands;
6) Lining the posterior surface of the cornea.

Simple squamous epithelium (mesothelium of peritoneum) (slide)

Stain: silver impregnation

Using this slide you must perform the exercise 2 of album (topic "Epithelial tissue")

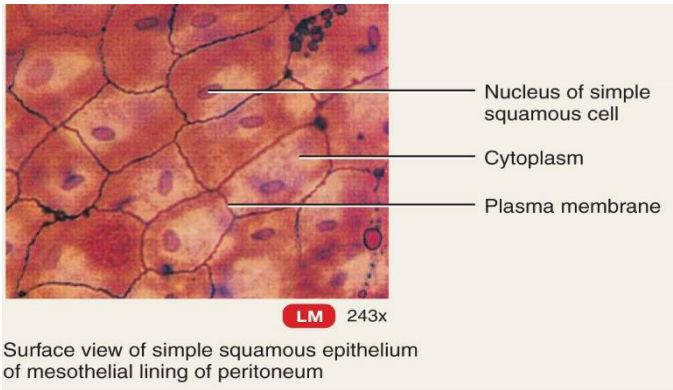


Figure 2.12. Photomicrograph of mesothelium.

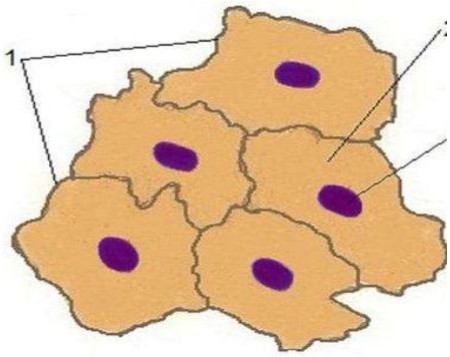


Figure 2.13. Diagram of mesothelium [18].
Draw 4-5 cells

Simple cuboidal epithelium

Simple cuboidal epithelium is composed of a single layer of uniform cuboidal cells, which all rest on the basement membrane. The nuclei of cells are centrally placed and spherical in shape.

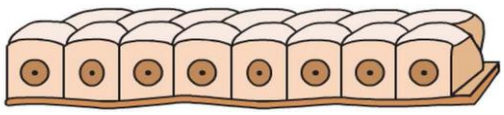


Figure 2.14. Diagram of simple cuboidal epithelium [5].

This type of epithelium is found:
1) Lining the most tubules of the kidney;
2) Lining the thyroid follicles walls;
3) Lining the excretory ducts of some glands;
4) Pigment epithelium of the retina;
5) Subcapsular epithelium of the lens.

Simple cuboidal epithelium in kidney of a rabbit (slide)

Stain: hematoxylin-eosin

Using this slide you must perform the exercise 3 of album (topic "Epithelial tissue")

Kidney tubules in cross section

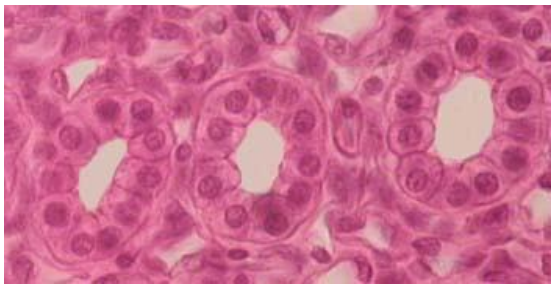


Figure 2.15. Photomicrograph of kidney tubules (cross section).

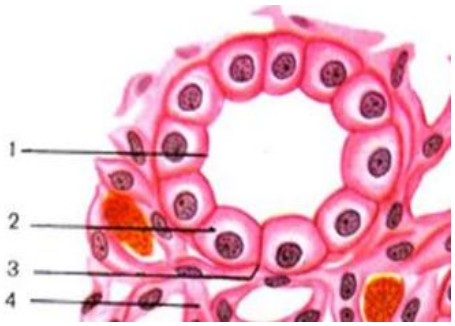


Figure 2.16. Diagram of kidney tubule (cross section) [15].

2. Epithelial cells
3. Basal membrane
4. Loose connective tissue

Simple columnar epithelium

Simple columnar epithelium is composed of a single layer of uniform columnar cells, which all rest on the basement membrane. The elongated ovoid nuclei is most often located in the basal part of the cells.

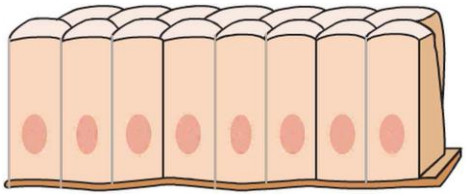


Figure 2.17. Diagram of simple columnar epithelium [5].

This type of epithelium is found:
1) Lining the gall bladder;
2) Lining the uterus and oviducts;
3) Lining the ducts of some glands;
4) Lining the stomach, small and large intestines.

Simple columnar epithelium in small intestine (jejunum) of a dog (slide)

Stain: hematoxylin-eosin

Using this slide you must perform the exercise 4 of album (topic "Epithelial tissue")

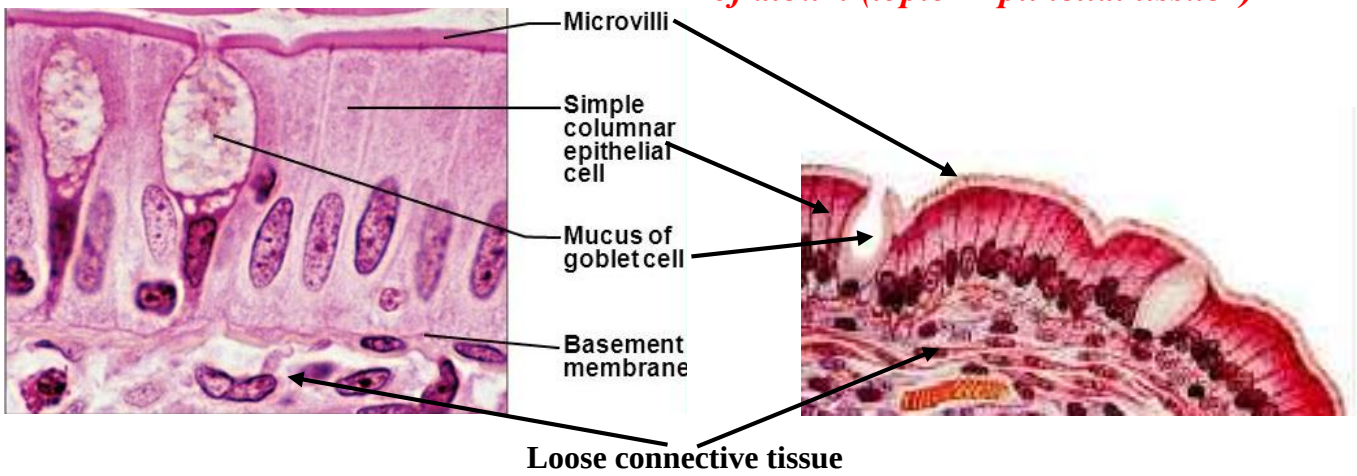


Figure 2.18. Photomicrograph of small intestine epithelium.

Figure 2.19. Diagram of simple columnar epithelium in small intestine [15].

Pseudostratified epithelium

Pseudostratified columnar epithelium is composed of a single layer of nonuniform cells, which all rest on the basement membrane. The cells of this epithelium are different shape and height and their nuclei occupy varying positions. In pseudostratified epithelium, the most widespread cells are ciliated columnar shaped cells. Except them, there are also goblet (mucus-secreting) cells and basal cells.

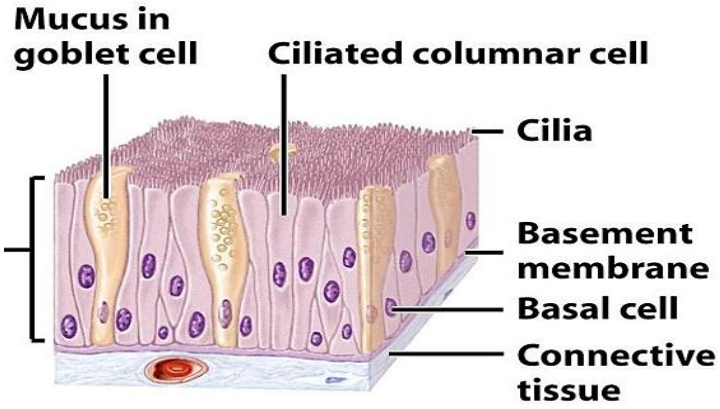


Figure 2.20. Diagram of pseudostratified columnar epithelium.

This type of epithelium is found:
1) Lining the respiratory tract;
2) Lining the some parts of male and female reproductive tract.

Pseudostratified columnar ciliated epithelium in trachea of a dog (slide)

Stain: hematoxylin-eosin

Using this slide you must perform the exercise 5 of album (topic "Epithelial tissue")

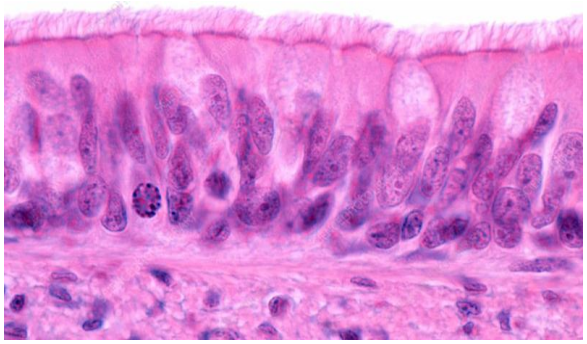


Figure 2.21. Photomicrograph of trachea epithelium.

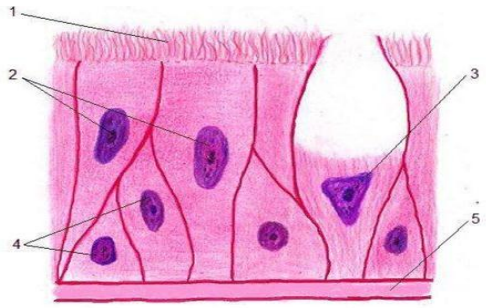


Figure 2.22. Diagram of trachea epithelium [18].

1. Cilia
2. Ciliated cells
3. Goblets (mucus-secreting) cells
4. Basal cell
5. Basal membrane
6. Loose connective tissue

Question 9. Types of stratified epithelium. Structure and distribution.

There are five types of stratified epithelium in our organism:
1) Stratified non-keratinized squamous;
2) Stratified non-keratinized cuboidal;
3) Stratified non-keratinized columnar;
4) Stratified keratinized squamous;
5) Transitional.

Stratified non-keratinized squamous epithelium

All stratified epithelia contain several layers of cells, but only the deepest layer of cells there is in contact with basement membrane. There are three types of stratified non-keratinized epithelium

according to the shape of cells in the superficial layer: squamous, cuboidal and columnar. However, in our organism more distributing type of stratified non-keratinized epithelia is squamous. Stratified non-keratinized cuboidal and stratified non-keratinized columnar epithelia have a limited distribution and can be found in some large ducts of the exocrine glands.

Stratified non-keratinized squamous epithelium consists of tree cell layers:

1) Basal layer presenting by one row of the cuboidal or columnar shape basal cells resting on the basement membrane;
2) Intermediate layer presenting by several rows of polyhedral shape cells;
3) Superficial layer presenting by 2-3 rows of flattened shape cells.

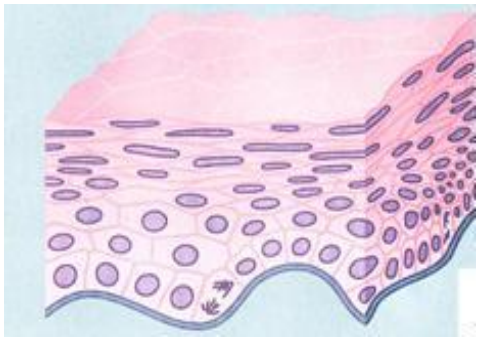


Figure 2.23. Diagram of stratified non-keratinized squamous epithelium [14].

This type of epithelium is found:

1) Lining the oral cavity organs;
2) Lining the esophagus;
3) Lining the vagina;
4) Lining the true vocal cords of larynx;
5) Lining the lower third of the anal canal;
6) Anterior epithelium of the cornea;

Stratified non-keratinized squamous epithelium in esophagus of a dog (slide)

Stain: hematoxylin-eosin

Using this slide you must perform the exercise 6 of album (topic "Epithelial tissue")

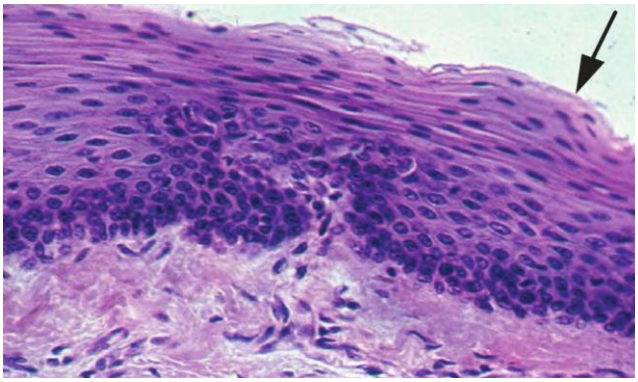


Figure 2.24. Photomicrograph of esophagus epithelium [5].

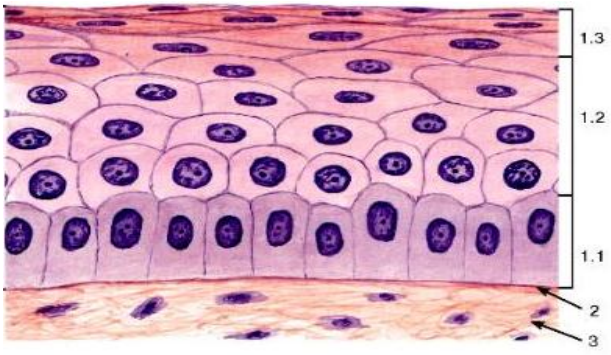


Figure 2.25. Diagram of esophagus epithelium [18].

1.1. Basal layer of columnar cells
1.2. Intermediate layer of polyhedral and cuboidal cells
1.3. Surface (superficial) layer of squamous cells
2. Basal membrane
3. Loose connective tissue

Stratified keratinized squamous epithelium

Stratified keratinized squamous epithelium is similar to stratified non-keratinized squamous except that surface cells are nonnucleated instead of nucleated and presentation of five cells layers instead of three. Stratified keratinized squamous epithelium is found in the skin to produce skin epidermis. It consists of layers called:

1) Stratum basale;
2) Stratum spinosum;
3) Stratum granulosum;
4) Stratum lucidum;
5) Stratum corneum.

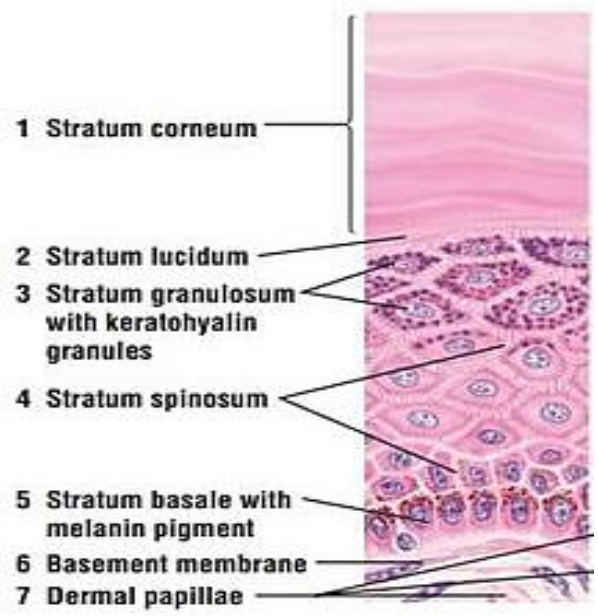


Figure 2.26. Diagram of stratified keratinized squamous epithelium [4].

The stratum basale is one-cell-deep layer of the cuboidal or columnar shape basal cells resting on the basement membrane.

The stratum spinosum is characterized by several rows of polyhedral shape cells binding with each other by desmosomes presenting within their spiny projections.

The stratum granulosum is characterized by 1-3 rows of flattened cells containing the centrally located flattened nuclei and cytoplasm filling by basophilically staining keratohyalin granules.

The stratum lucidum is characterized by several layers of flattened eosinophilic cells, but due to the highly refraction index, the cells of stratum lucidum are not visible and this layer looks like a wavy, translucent, clear strip.

The stratum corneum is characterized by 15-20 layers of flattened nonnucleated cells (horny cells), whose cytoplasm is filled with protein called keratin.

Stratified keratinized squamous epithelium (epidermis) of the humans finger skin (slide)

Stain: hematoxylin-eosin

Using this slide you must perform the exercise 7 of album (topic "Epithelial tissue")

Figure 2.27. Photomicrograph of skin epidermis.

1.1 Stratum basale
1.2 Stratum spinozum
1.3 Stratum granulosum
1.4 Stratum lucidum
1.5 Stratum corneum
2. Basement membrane
3. Loose connective tissue

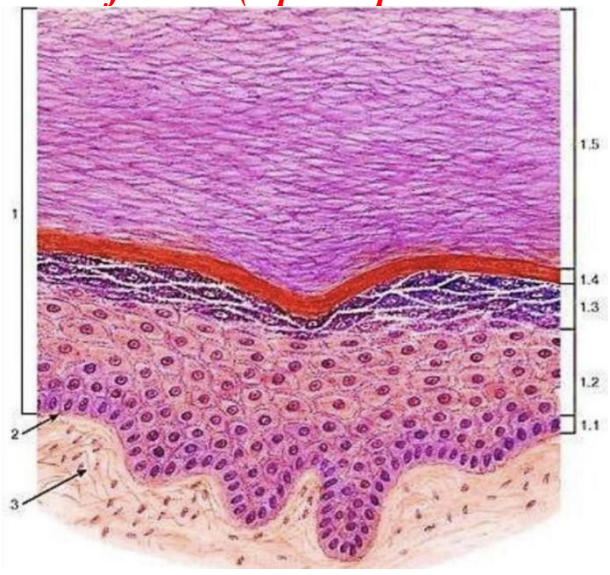


Figure 2.28. Diagram of skin epidermis [18].

Transitional epithelium (urothelium)

Transitional epithelium has specific morphological characteristics that allow it to distend. Transitional epithelium belongs to stratified type because it consists of three cell layers - basal, intermediate and surface.

The basal layer is represented by the smallest cuboidal cells resting on the basement membrane.

The intermediate layer is represented by average size polyhedral or pear shaped cells.

The surface or superficial layer is represented by the largest, sometimes binucleate, dome shaped cells called dome cells or umbrella cells. Surface umbrella cells change their shape in response to stretching and to relaxing. They become flattened, when an organ is filled by the urine.

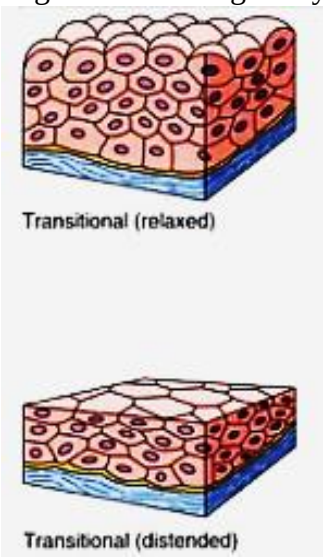


Figure 2.29. Diagram of transitional epithelium.

This type of epithelium is found:

1) Lining the kidney calyces and pelvises;
2) Lining the ureter;
3) Lining the urinary bladder;
4) Lining the proximal part of the urethra.

Transitional epithelium (urothelium) in urinary bladder of a dog (slide)

Stain: hematoxylin-eosin

Using this slide you must perform the exercise 11 of album (topic "Epithelial tissue")

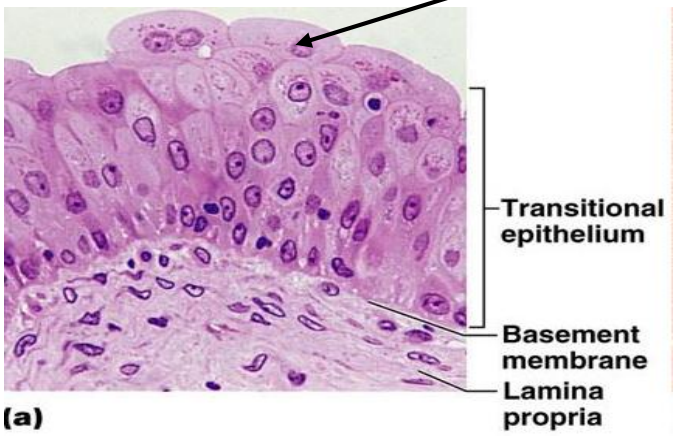


Figure 2.30. Photomicrograph of transitional epithelium.

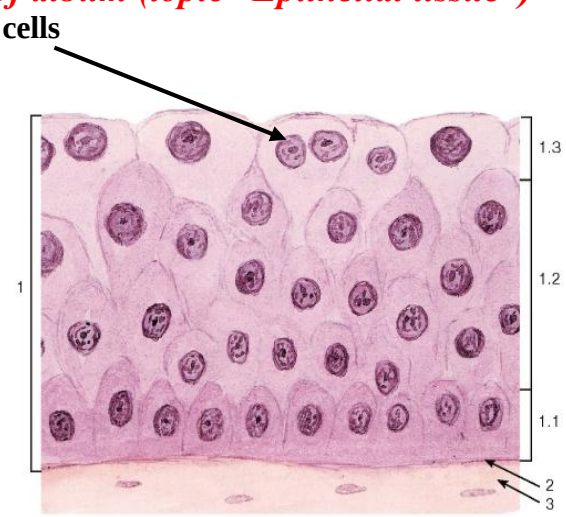


Figure 2.31. Diagram of transitional epithelium [18].

1.1 Basal layer
1.2 Intermediate layer
1.3 Superficial layer
2. Basement membrane
3. Loose connective tissue

Question 10. Regeneration of epithelium.

Epithelia have a high ability to regeneration and belong to the category of continuously renewing cell populations. The replacement cells are produced by mitotic activity of self-maintaining stem cells. They are located in sites called niches. For example, in the small intestine, niches of stem cells are located in the lower portion of the intestinal glands called crypts.

In all stratified epithelia the stem cells, providing their regeneration are located in basal layer (stratum basale) appropriately named the stratum germinativum.

After mitosis in stratum germinativum, the cells start to differentiate and they are pushed toward the surface of the epithelium to rich it and, than sloughed off [13].

Question 11. Glands. Sources of development. Classifications. Gland as organ.

Glands are composed of glandular epithelial tissue and classified into exocrine and endocrine according to how the secretory product leaves the gland. Ductless endocrine glands release their products called hormones directly into bloodstream or lymph. Exocrine glands secrete their products either through ducts into the lumen of an organ or directly onto the body surface [3].

Both exocrine and endocrine glands are developed from covering epithelia by the cell proliferation and invasion into subjacent loose connective tissue. In developing exocrine gland, the distal part of the epithelial invasion is developed into secretory part, while the proximal part of epithelial invasion forms a duct of exocrine gland. Thus, the exocrine glands have two parts - the secretory part (portion), which responsible for the secretory process and the duct. The duct is responsible for releasing of secrets into the surface of the body or lumens of body cavities.

Endocrine glands are produced the same fashion to exocrine glands, but in further they lose the contact with the epithelial surface. Therefore, the endocrine gland consists of only a secretory part, presenting by the cords and clumps of secretory endocrine cells or by follicle like structures.

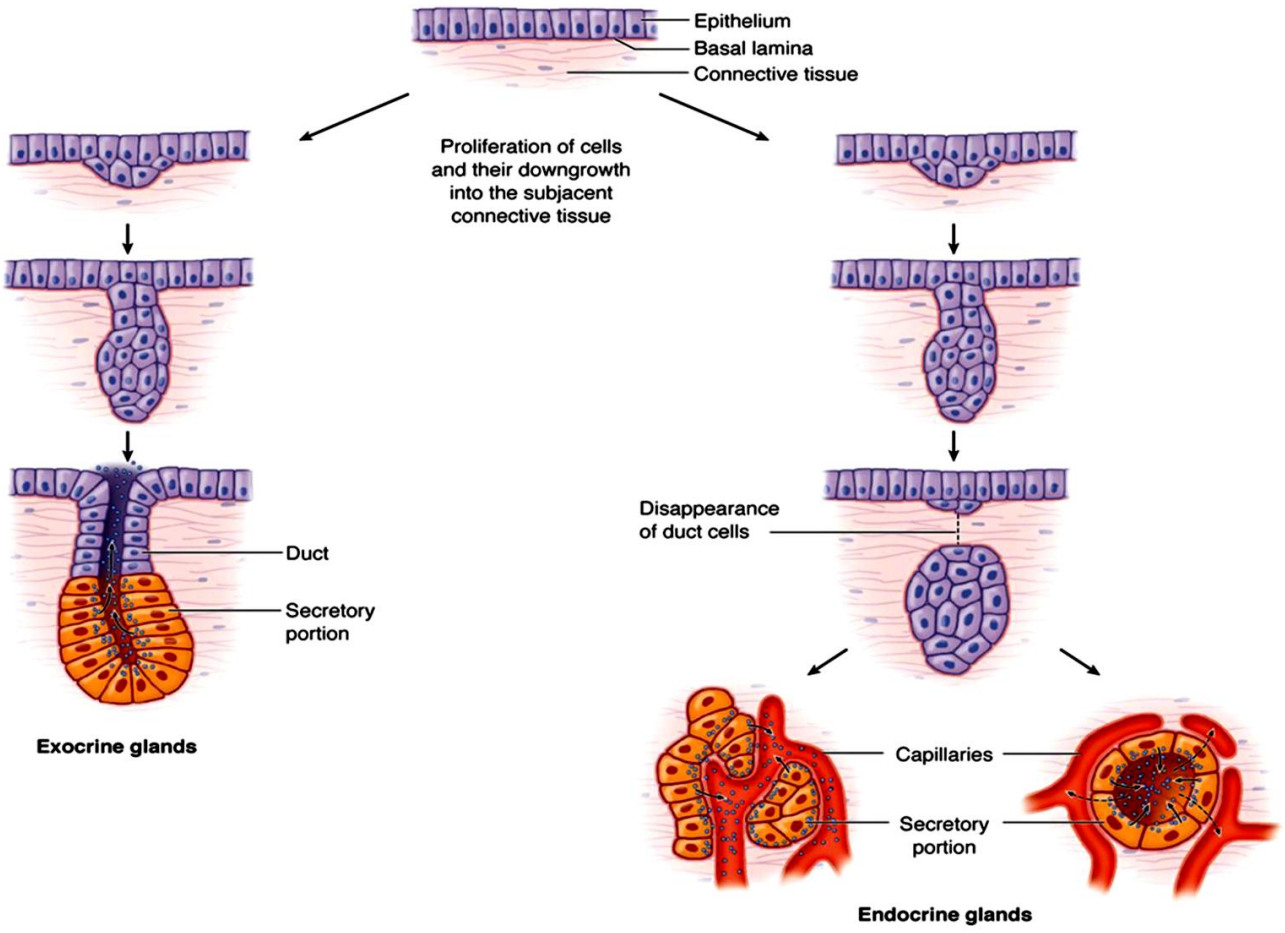


Figure 2.32. Diagram of glands development [9].

Classifications of exocrine glands

Exocrine glands can be classified into several categories according to the:

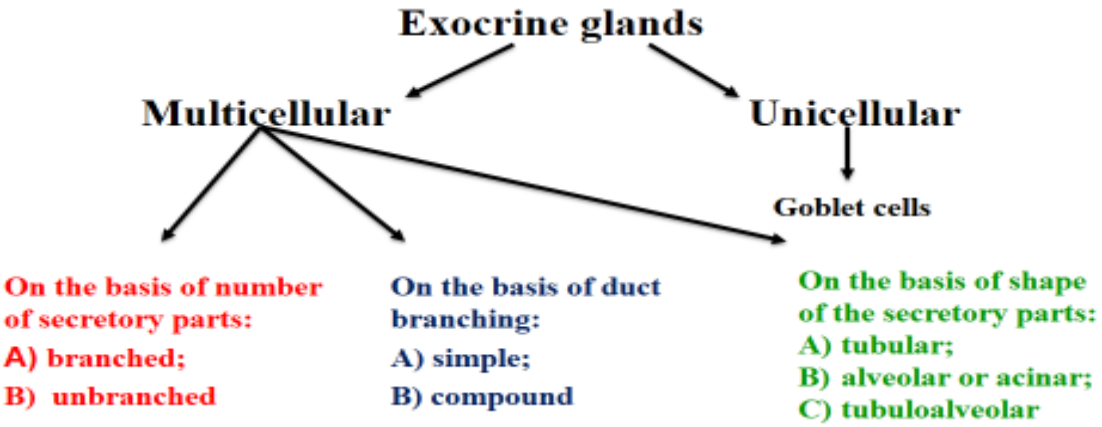
1) Nature of their secretory products;
2) Morphology of glands;
3) Mechanisms of secretion.

Classification of exocrine glands according to the nature of secretory product

On the basis of nature of secretory product the exocrine glands can be classified into:

1) Serous. They are protein secreting glands (parotid gland, pancreas);
2) Mucous. They are mucous secreting glands (goblet cells and sublingual salivary gland);
3) Mixed (seromucous). They are both protein and mucous secreting glands (submandibular and sublingual salivary glands, glands of the trachea and esophagus);
4) Sebaceous. They are lipid producing glands of the skin [3].

Morphology classification of exocrine glands



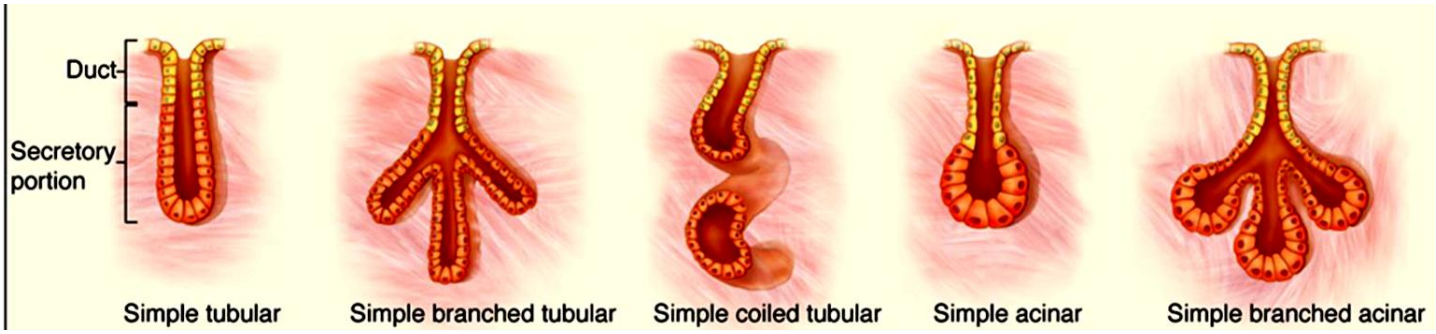
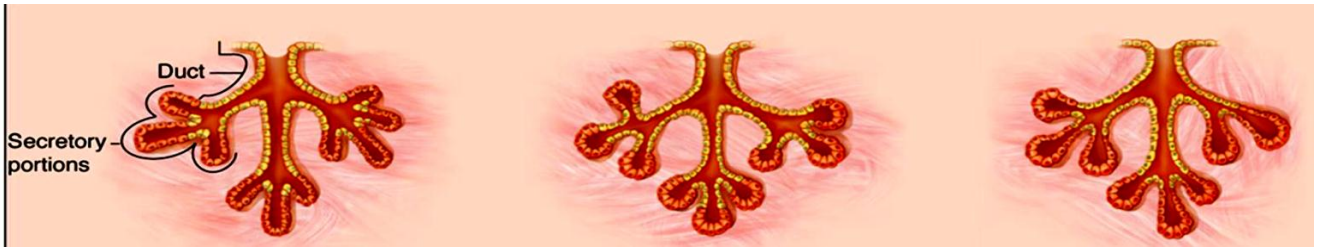


Figure 2.33. Diagram of simple exocrine glands.



Compound branched tubular **Compound branched acinar** **Compound branched acinar**

Figure 2.34. Diagram of compound exocrine glands [9].

Classification of exocrine glands according to the mechanisms of secretion

Exocrine glands are classified by the mechanisms of secretion into 3 types:

1) Merocrine;
2) Apocrine;
3) Holocrine.

In merocrine secretion, the secretory product is released from the cell by exocytosis without the distraction of cell cytoplasm. Secretory cells of the parotid glands and pancreas are examples of merocrine type of secretion.

In apocrine secretion. the secretory product is released together with part of the apical cytoplasm of the secretory cell. Secretory cells of the mammary glands are example of apocrine type of secretion.

In holocrine secretion the secretory product is released by disintegration of the entire cell. Secretory cells of the sebaceous glands are example of holocrine type of secretion [3].

Question 11. Ultrastructure of the glandular cell. Gland as an organ.

The secretory cells also known as glandular epithelial cells have a well developed synthetic apparatus and numerous secretory granules. Ultrastructure of secretory cells depends on the nature of secret producing by them. There are 3 types of secretory cells:

1) Protein secreting cells. They have a well developed r-ER and a supranuclear Golgl complex. Spherical nucleus disposes at basal part of cell. Secretory granules fill the apical part of these cells;

2) Mucus secreting. They cells have a well developed r-ER, where the protein component of mucus is synthesized, and a very well developed Golgl complex where proteins are glycosylated. Mucus secreting cell contains a flattened nucleus at the base of cell and mucinogen granules filling its cytoplasm;

3) Steroid producing cells are characterized by the presence of extensive smooth endoplasmatic reticulum, and predominance mitochondria with vesicular cristae.

Gland as an organ

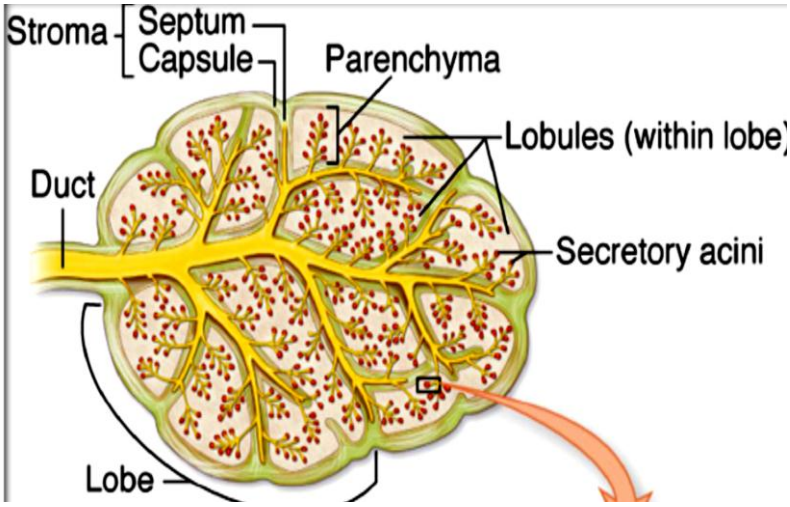


Figure 2.35. Diagram of gland structure as an organ [9].

All large exocrine glands consist of parenchyma, stroma and duct system. The secretory cells of a gland constitute its parenchyma and perform the essential functions of gland.

Stroma is supporting fibrous connective tissue with blood vessels and nerves forming a capsule surrounding the gland from outside and connective tissue septa penetrating from the capsule into the organ to divide gland into lobules.

Ducts of glands are classified into intralobular (lying within lobules) and interlobular (lying between lobules within connective tissue septa) types.