EPITHELIA

Epithelia forms continuous sheets of cells that line internal surfaces (lines the large internal body cavities) where it is termed mesothelium Furthermore, the internal surfaces of blood and lymph vessels are lined by epithelium, here called endothelium**.** and cover the external surface of the body. It is a selective barrier that protects tissues and is often involved in absorption or secretion.

Epithelium, consisting of closely apposed cells without intervening intercellular substances. Epithelia are avascular, but all epithelia "grow" on an underlying layer of vascular connective tissue. The connective tissue and the epithelium are separated by a basement membrane.

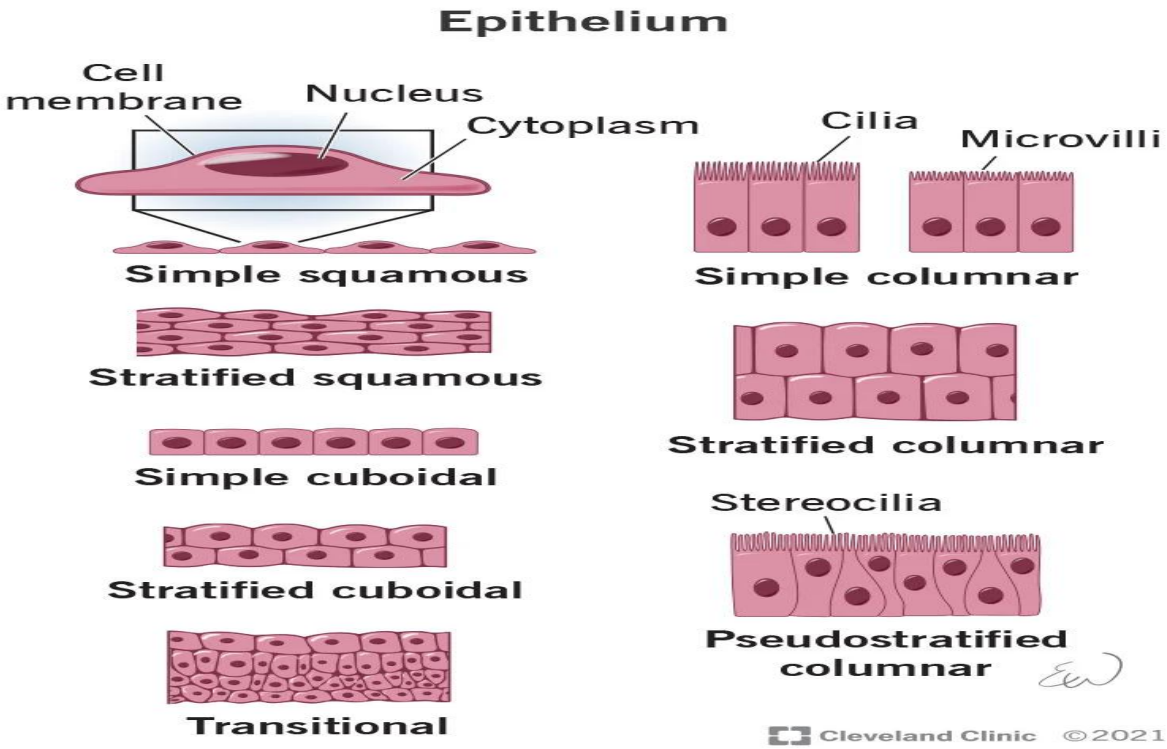
Epithelia are classified on the basis of the number of cell layers and the shape of the cells in the surface layer.

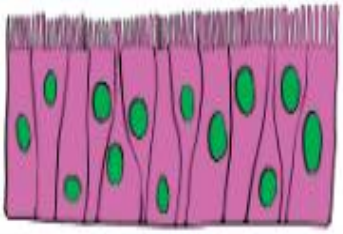
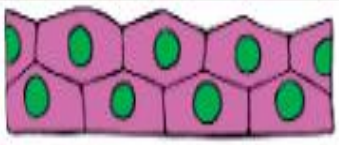
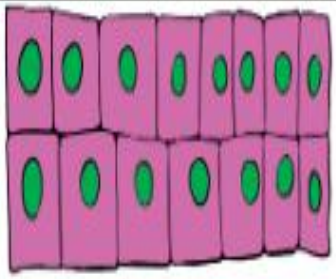
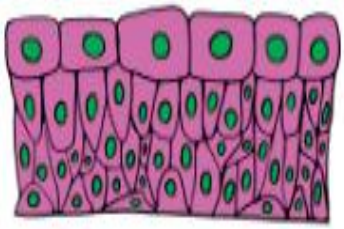
Epithelia are classified based on three criteria:

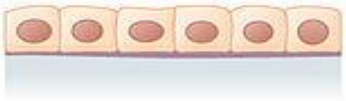
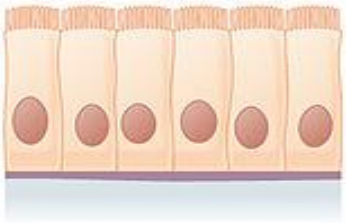
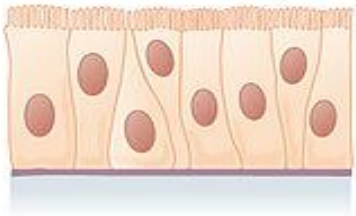
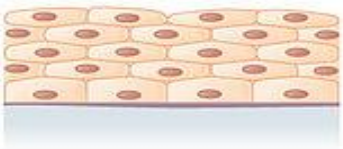
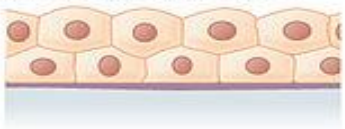
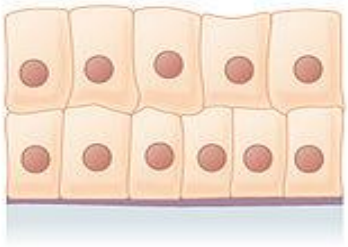
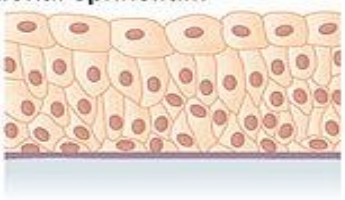
- Number of cell layers (**simple** or **compound**)
- Shape of surface cells (**squamous**, **cuboidal** or **columnar**)
- Specializations (**cilia**, **keratin** or **goblet cells**)

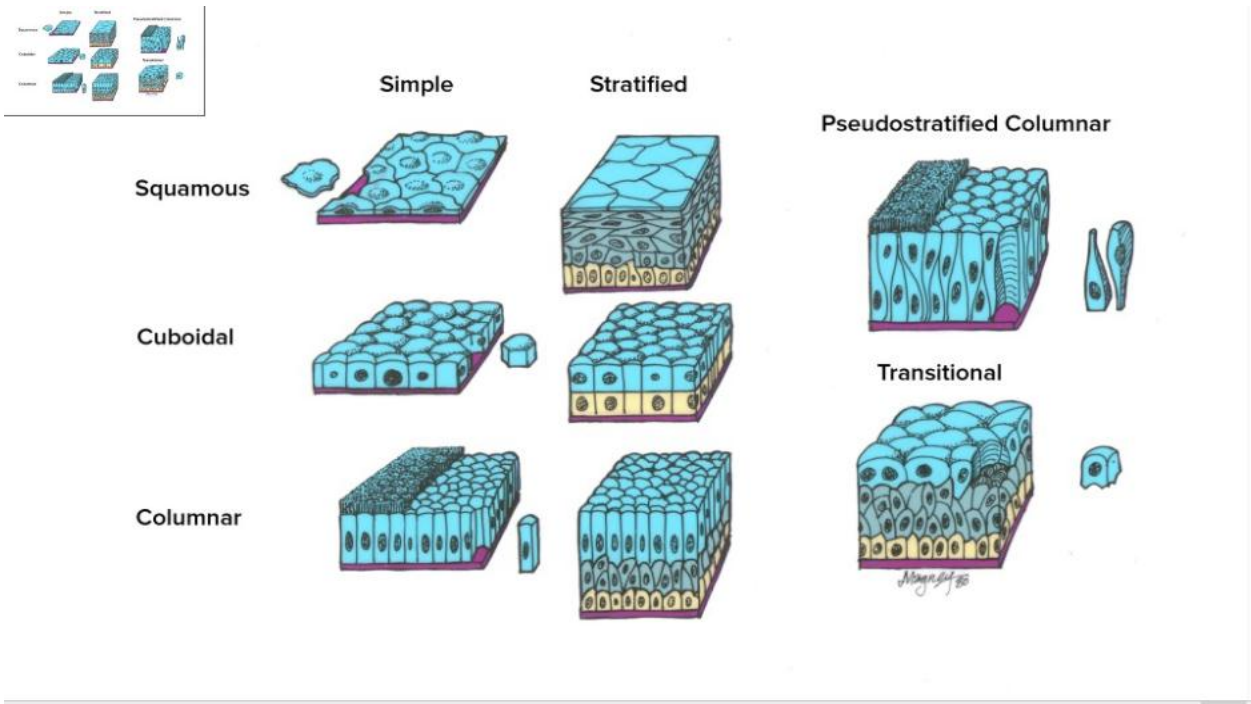
- If there is only one layer of cells in the epithelium, it is designated simple.
- If there are two or more layers of cells, it is termed stratified.
- Cells in the surface layer are, as a rule, described according to their height as squamous (scale- or plate-like), cuboidal or columnar.

Simple Epithelia



Epithelial Cells		Location	Function
Simple squamous		Lungs, lining of heart, blood vessels, lymphatic vessels	Semi-permeable. Secretes lubricating substance
Simple cuboidal		Ducts, secretory portions of glands in kidneys	Secretes, absorbs
Simple columnar		Ciliated: bronchi, uterine tubes, uterus Smooth: digestive tract, bladder	Absorbs. Secretes mucous and enzymes
Pseudostratified columnar		Lining of trachea, upper respiratory tract	Secretes mucus; cilia move mucus
Stratified squamous		Lining of esophagus, mouth, vagina	Protection from abrasion
Stratified cuboidal		Sweat glands, salivary glands, mammary glands	Protective tissue
Stratified columnar		Male urethra, glandular ducts	Secretes, protects
Transitional		Lining of bladder, urethra, ureters	Expansion and stretch of organs

Cells	Location	Function
Simple squamous epithelium 	Air sacs of lungs and the lining of the heart, blood vessels, and lymphatic vessels	Allows materials to pass through by diffusion and filtration, and secretes lubricating substance
Simple cuboidal epithelium 	In ducts and secretory portions of small glands and in kidney tubules	Secretes and absorbs
Simple columnar epithelium 	Ciliated tissues are in bronchi, uterine tubes, and uterus; smooth (nonciliated tissues) are in the digestive tract, bladder	Absorbs; it also secretes mucous and enzymes
Pseudostratified columnar epithelium 	Ciliated tissue lines the trachea and much of the upper respiratory tract	Secretes mucus; ciliated tissue moves mucus
Stratified squamous epithelium 	Lines the esophagus, mouth, and vagina	Protects against abrasion
Stratified cuboidal epithelium 	Sweat glands, salivary glands, and the mammary glands	Protective tissue
Stratified columnar epithelium 	The male urethra and the ducts of some glands	Secretes and protects
Transitional epithelium 	Lines the bladder, uretha, and the ureters	Allows the urinary organs to expand and stretch



Epithelia

Epithelia are classified by the shape of the surface cells and whether it has single or multiple layers of cells.

Shape of surface cells:

- **Squamous** - flattened cells whose width is greater than their height
- Nuclei are often taller than the flattened cells and bulge into the lumen
- Difficult to see their thin cytoplasm
- **Cuboidal** - cells appear as high as they are wide
- Spherical nuclei are centrally positioned
- **Columnar** - cells are taller than they are wide
- Oval nuclei located near the base of the cells

Number of layers:

- **Simple** - a single layer of cells
- All cells contact the basement membrane (purple)
- **Stratified** - two or more layers of cell
- Only the lowest layer of cells (yellow) contact the basement membrane (purple)

Specialized epithelia:

- **Pseudostratified Columnar**
- Single layer of cells
- Nuclei appear being to be different levels
- Not all cells reach the surface
- All cells contact the basement membrane (purple)
- **Transitional** - used where the epithelium is stretched
- Multiple layer of cells
- Only the lowest layer of cells (yellow) contact the basement membrane (purple)
- Morphology varies depending on whether it is relaxed or stretched
- Relaxed - surface layer of large, dome-shaped cells
- Stretched - surface layer of flattened cells

Simple squamous epithelium

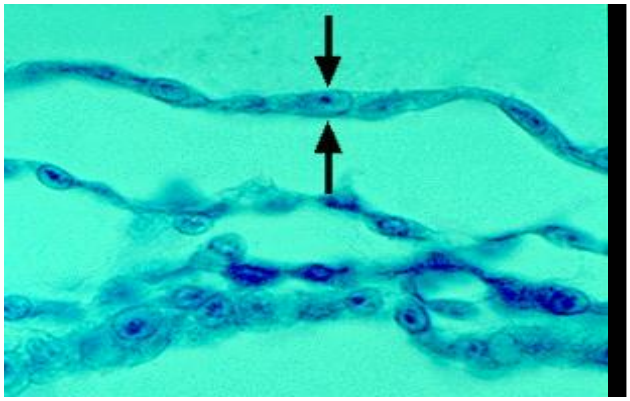
This type is composed of a single layer of flattened, scale- or plate-like cells. It is quite common in the body. The large body cavities and heart, blood vessels and lymph vessels are typically lined by a simple squamous epithelium. The nuclei of the epithelial cells are often flattened or ovoid, i.e. egg-shaped, and they are located close to the center of the cells. Epithelial cells are polarized:

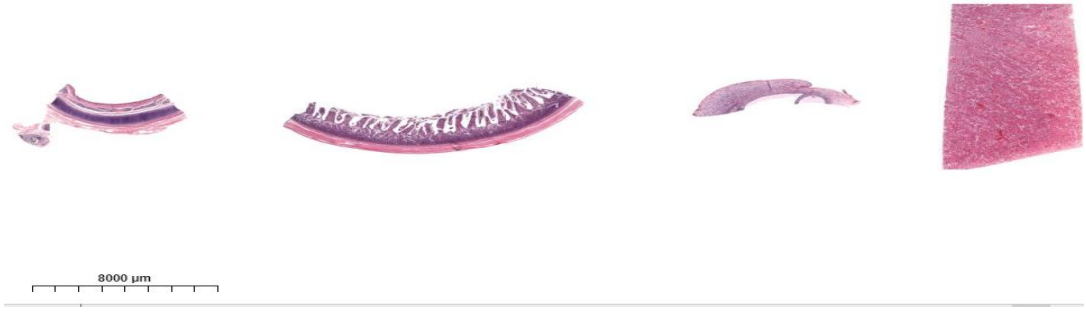
- **Apical surface** - faces the lumen or the external environment
  - Microvilli, cilia, stereocilia
- **Lateral surface** - faces the sides of adjacent cells
  - Tight junctions (zonula occludens), adherens junction (zonula adherens), desmosomes (macula adherens), gap junctions
- **Basal surface** - attaches to the basement membrane
  - Basement membrane, hemidesmosomes

An epithelium does not contain blood vessels and receives nourishment via diffusion from the underlying connective tissue.

Glands are formed by the down growth of an epithelium into the underlying connective tissue

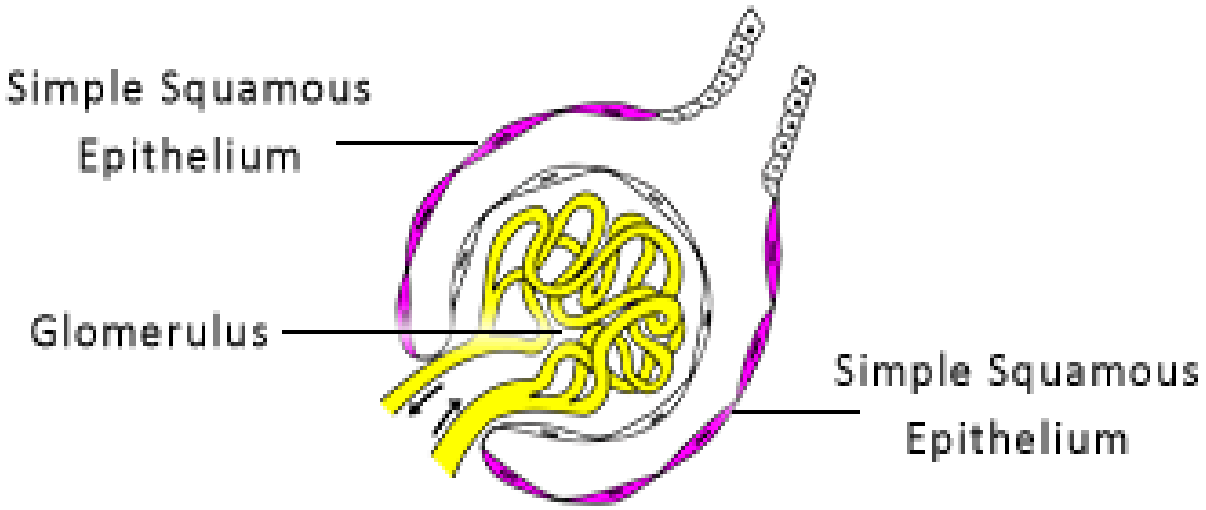
It is not necessary to learn the names of specific tissues for this chapter, but rather learn to recognize variations in epithelia.





Simple Squamous Epithelium

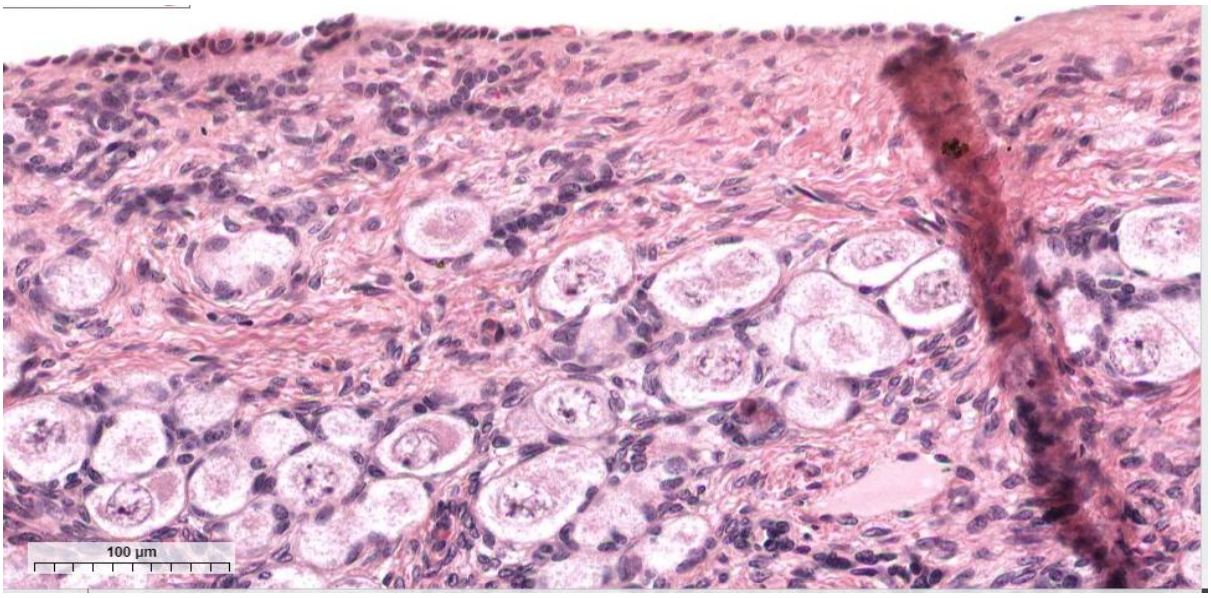
The kidney contains many different types of epithelia. However, the focus here is only on a simple squamous epithelium.

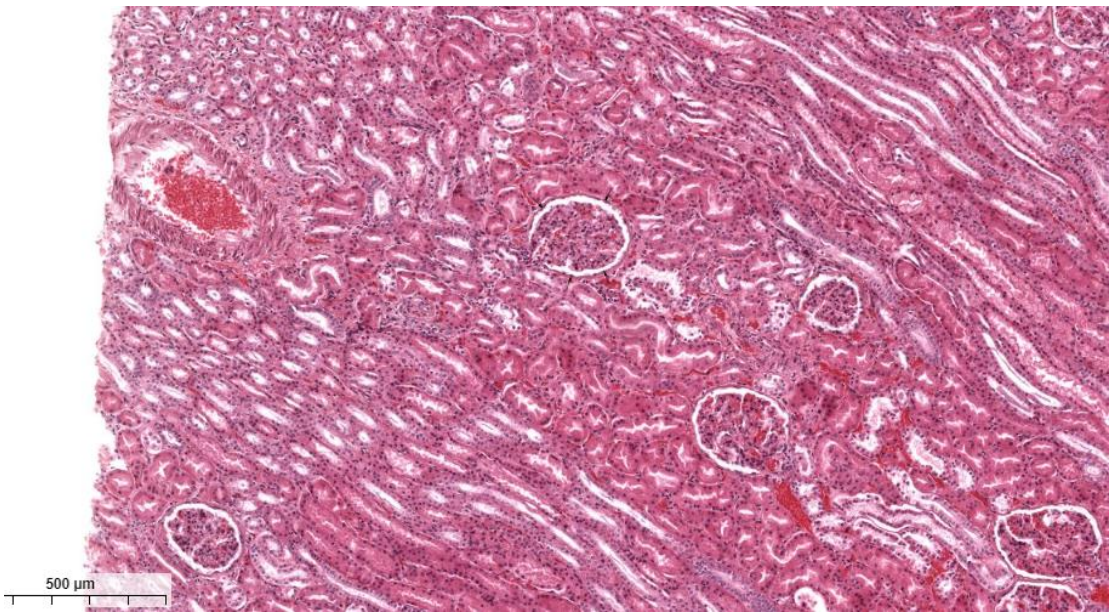


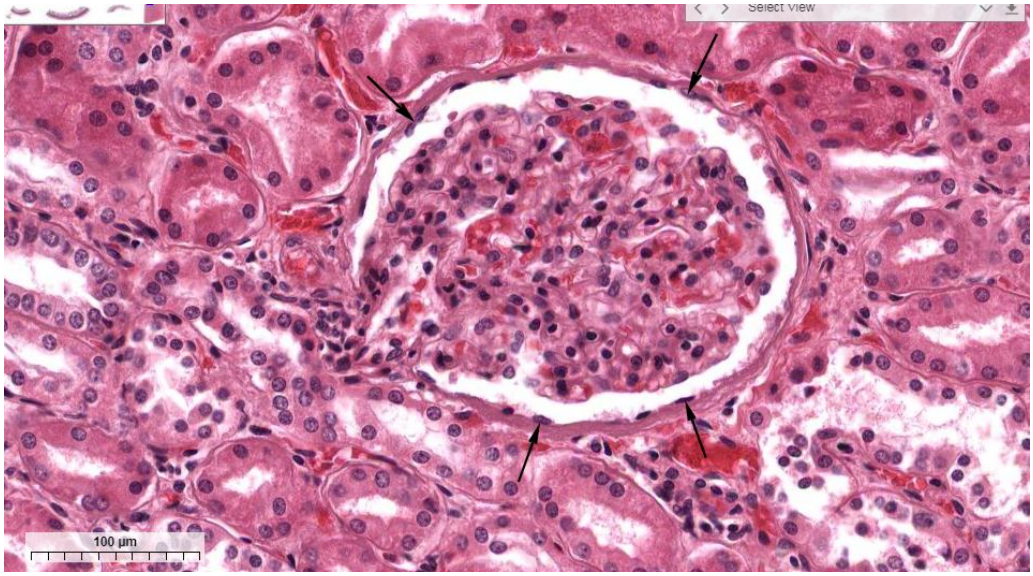
Find one of the round structures (~250 µm diameter) known as renal corpuscles. Each contains a glomerulus (a tuft of capillaries) surrounded by Bowman's capsule.

The interior of the capsule is lined by a simple squamous epithelium that rests on a thick basement membrane. The only part of these cells that can be seen are their nuclei bulging into the interior.

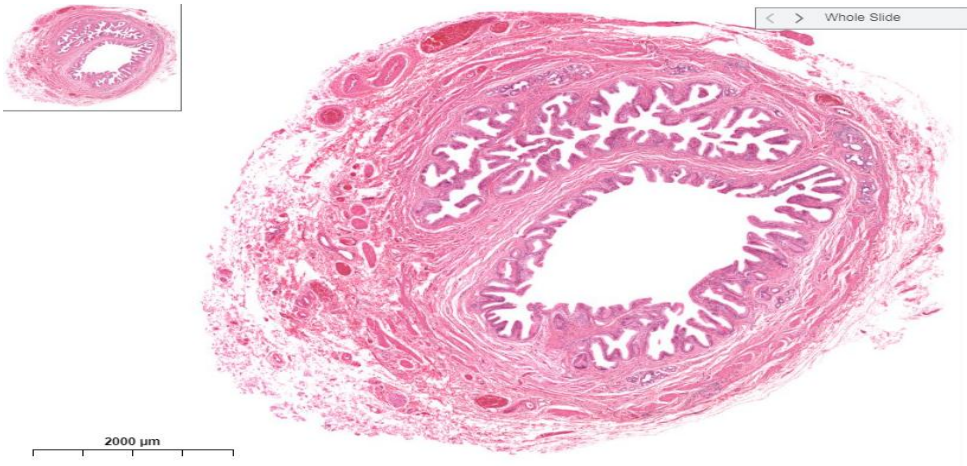
This epithelium is shown better in EM 080 Bowman's Capsule by scanning electron microscopy.




500 µm


100 µm


Select View
50 µm

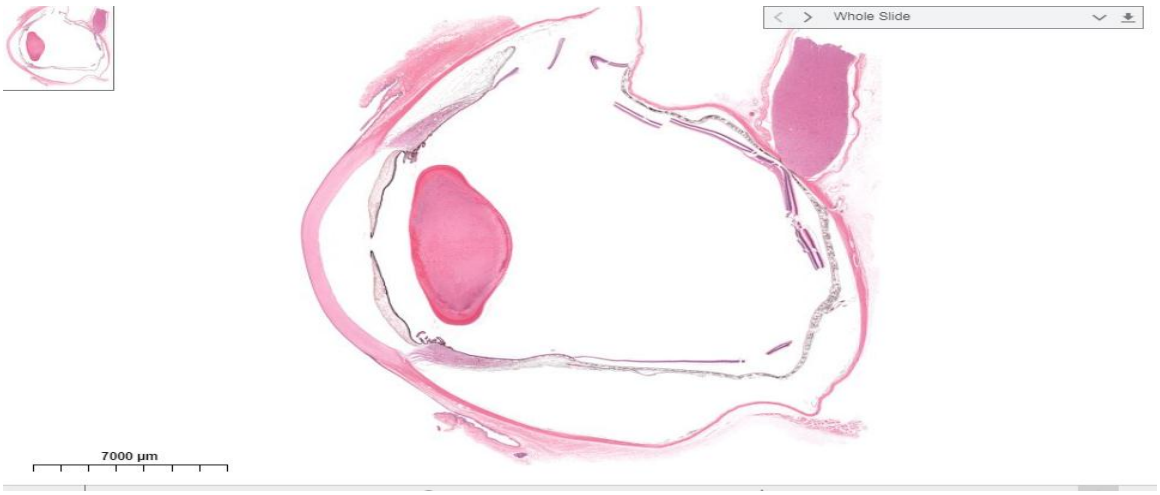


Simple Squamous Epithelium

This cross section of the bile duct contains many blood vessels in the surrounding connective tissue.

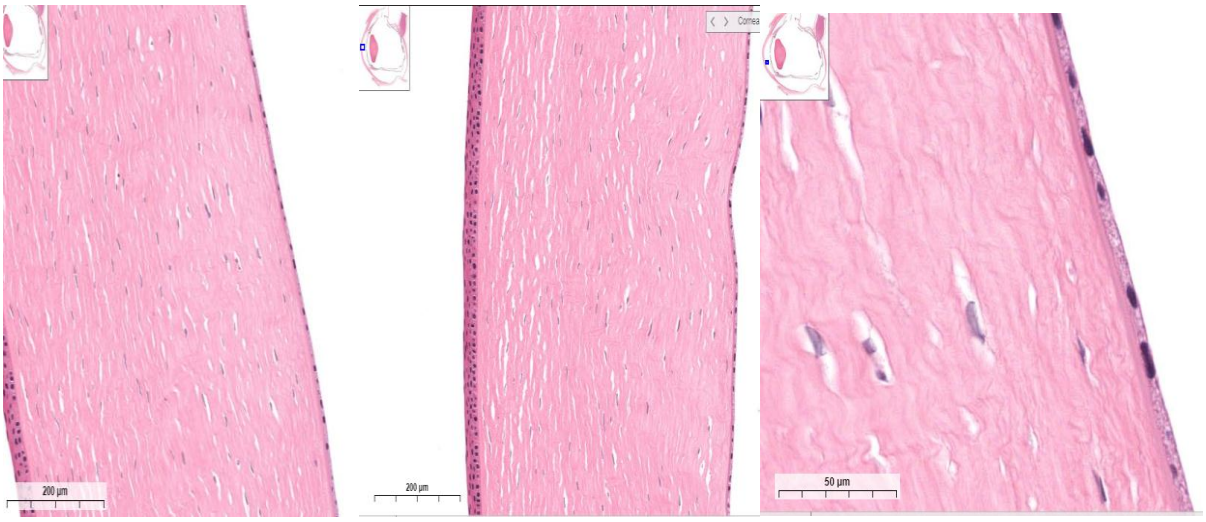
Blood vessels are lined with a simple squamous epithelium. The only part of these cells that can be seen are their flattened nuclei.

Epithelium that line blood vessels, the heart, and lymphatic vessels is also known as an **endothelium**.



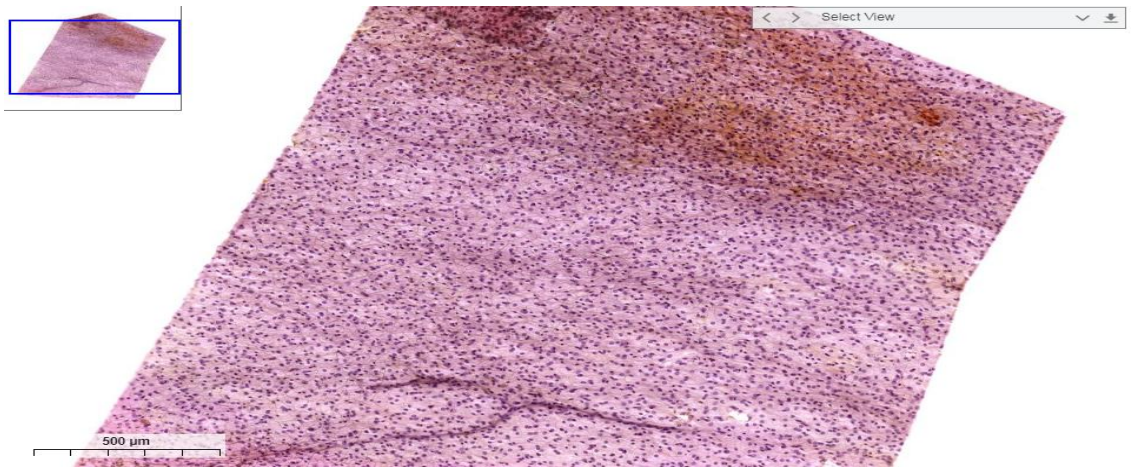
Simple Squamous Epithelium

The cornea is the transparent front part of the eye that covers the iris, pupil, and anterior chamber.



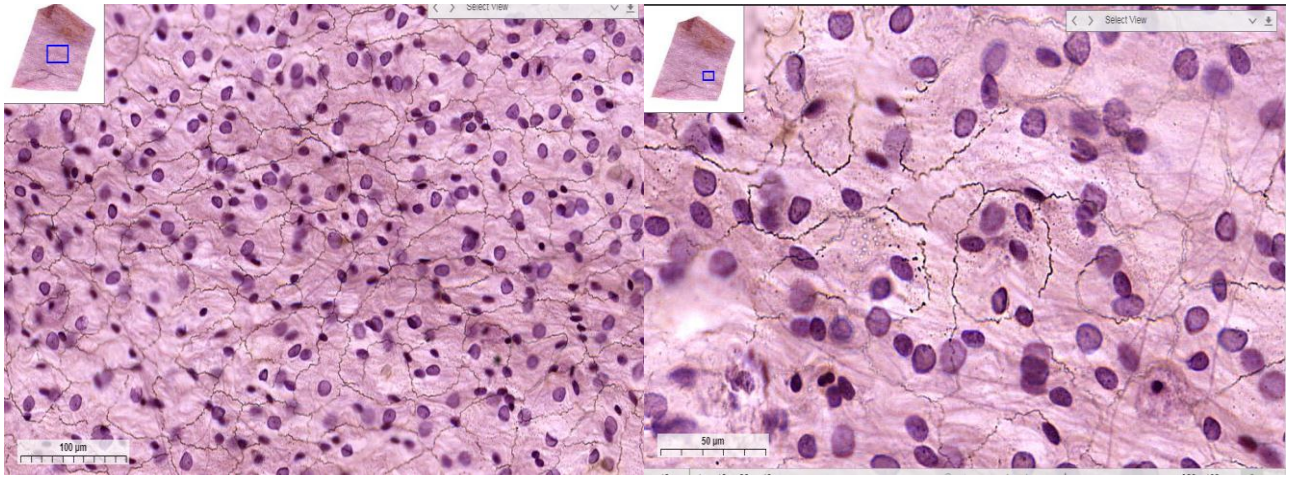
The posterior surface of the cornea is covered by a simple squamous epithelium. Note the thick basement membrane supporting the epithelium.

These squamous cells are unusual in that they are thicker (approximately 5 µm) than the typical flattened squamous cells. This makes their cytoplasm easy to see in cross-section.

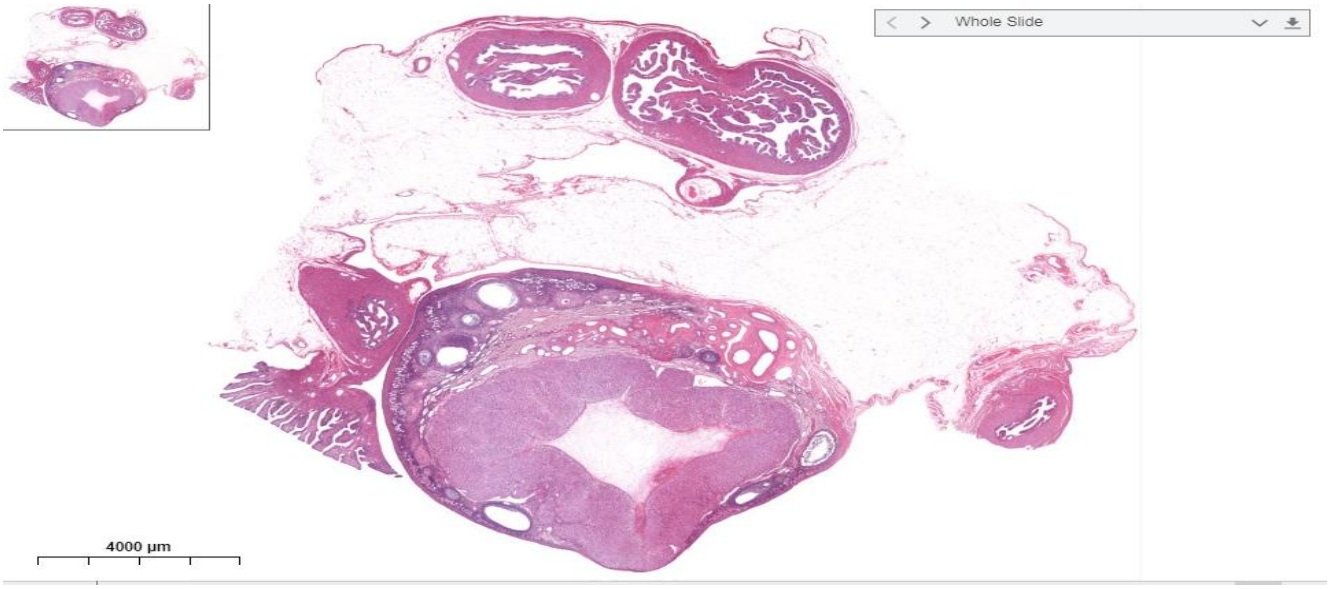


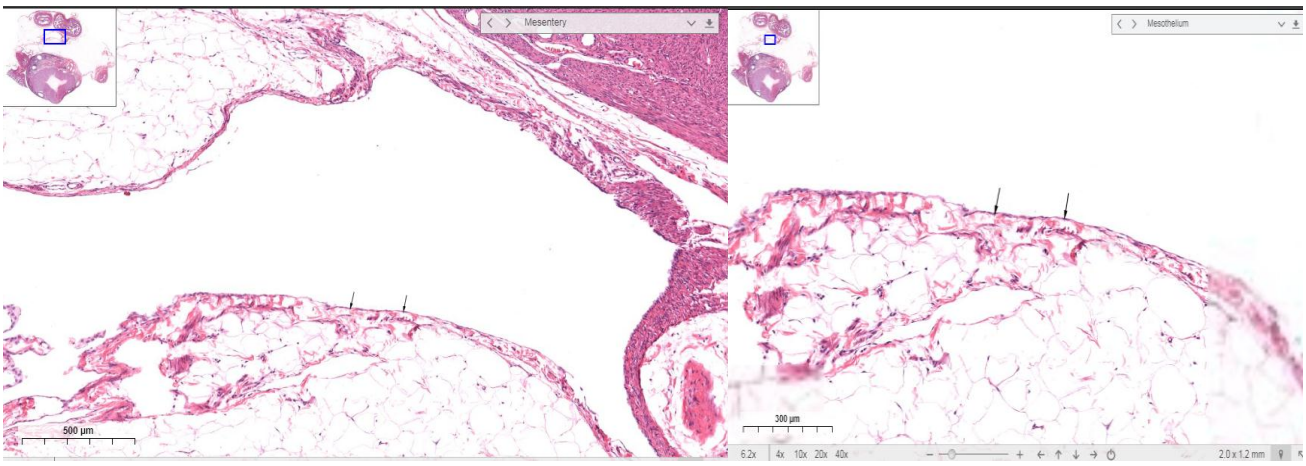
Simple Squamous Epithelium

A simple squamous epithelium consisting of flattened cells is also called pavement epithelium. This type of epithelium, for example, occurs on the mesentery (mesothelium) and lining blood vessels (endothelium)



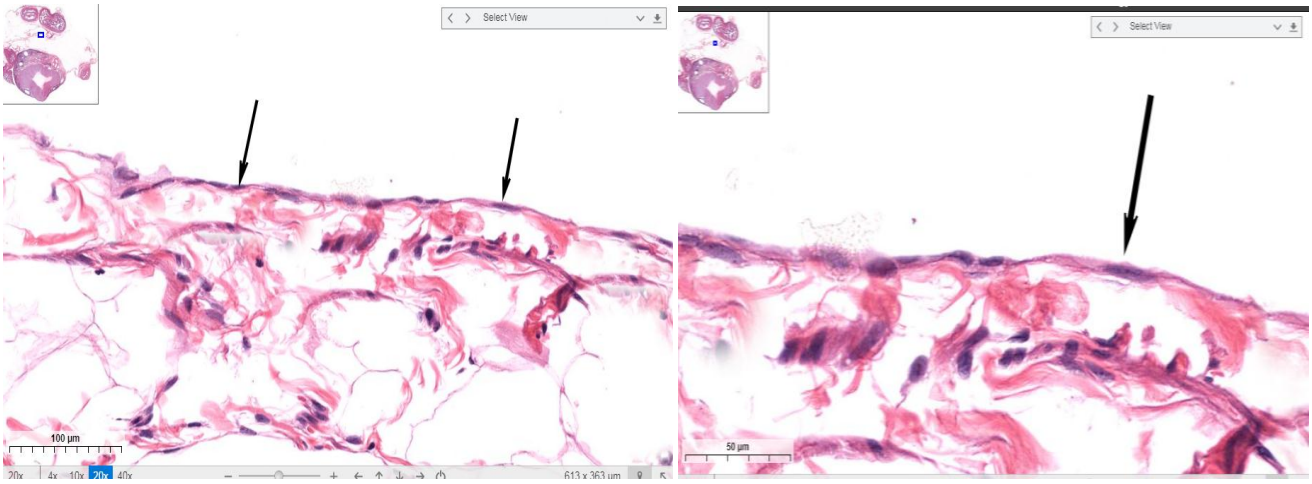
This specimen is a whole mount of thin mesentery stained with silver to outline individual cells and hematoxylin to show the nuclei. The mesentery is covered on both sides with simple squamous epithelium. The thinness of the specimen allows both surfaces to be seen giving the false impression that cells are multinucleated.



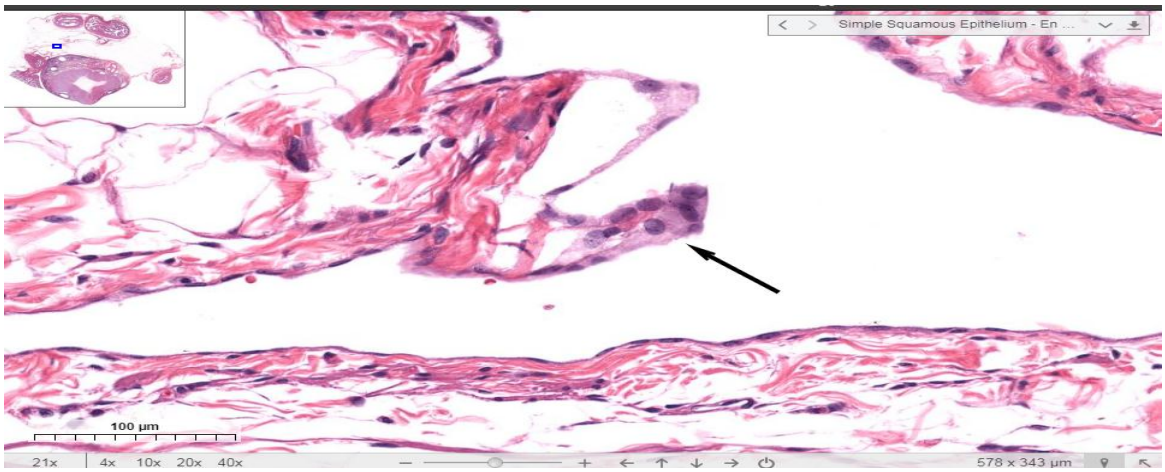


Simple Squamous Epithelium

Although cross sections of the ovary and oviduct are seen, examine the mesentery composed of connective tissue found between these tissues.
The mesentery is covered by a simple squamous epithelium known as the mesothelium.

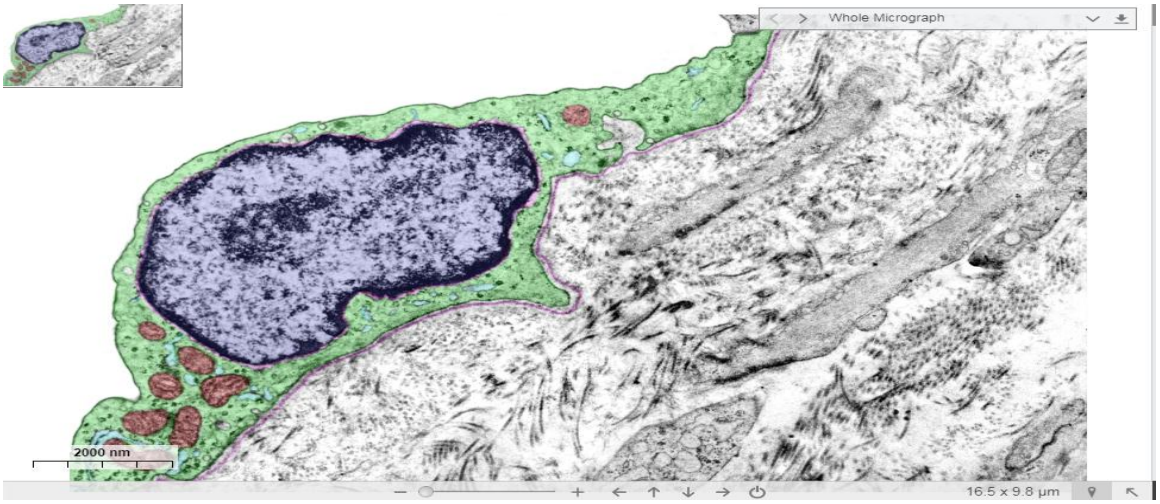


- Cross-section - most of the mesothelium is sectioned in cross-section in which only the nuclei are seen.



- En face - a fortuitous tangential section of the mesothelium allows an en face view of individual squamous cells. The nuclei surrounded by cytoplasm are seen in these cells.

The thinness of these epithelial cells can be seen in EM 072 Mesothelium by transmission electron microscopy.



Simple Squamous Epithelium

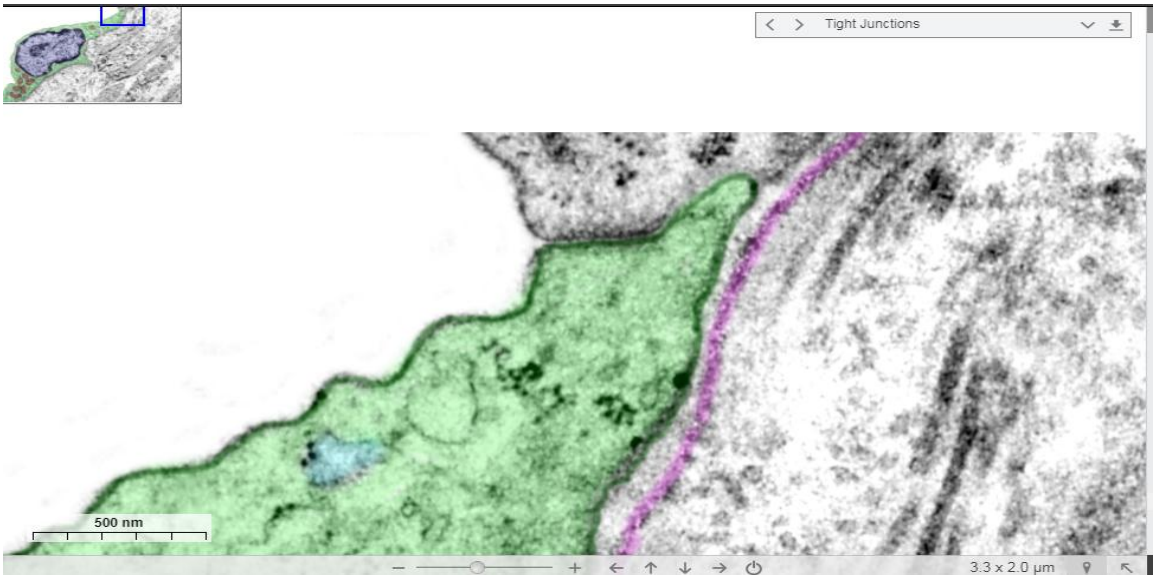
The mesothelium is a simple squamous epithelium that lines several body cavities (pleura around the lungs, pericardium around the heart, peritoneum in the abdominal cavity, and tunica vaginalis that covers the testes).

This micrograph shows a cross-section of the mesothelium that covers the peritoneum.

- Plasma Membrane (dark green)
- Nucleus (blue) - bulge from the flattened cells
- Nuclear Envelope (purple)
- Mitochondria (red)
- Endoplasmic Reticulum (cyan) - ribosomes (black dots) are found on its surface
- Cytoplasm (green) - clusters of ribosomes (black dots) are found in many regions

The mesothelium rests on the basal lamina supported by a thin layer of connective tissue.

- Basal Lamina (dark purple) - contains a network of reticular collagen IV fibrils. It appears as a dark line that separates the epithelium from the underlying connective tissue.
- Connective Tissue (grayscale) - collagen fibers are seen in both cross-sections and longitudinal sections.



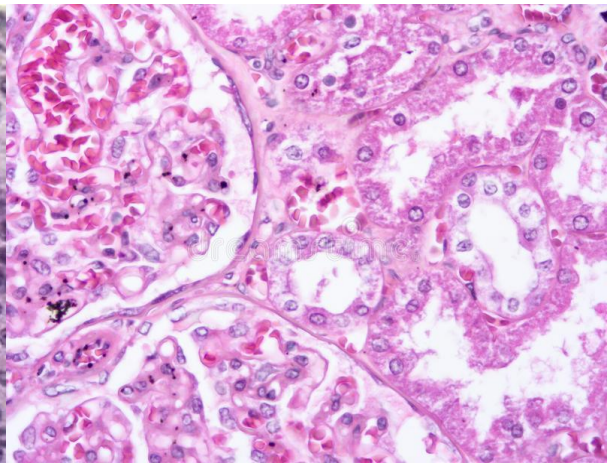
Tight Junctions

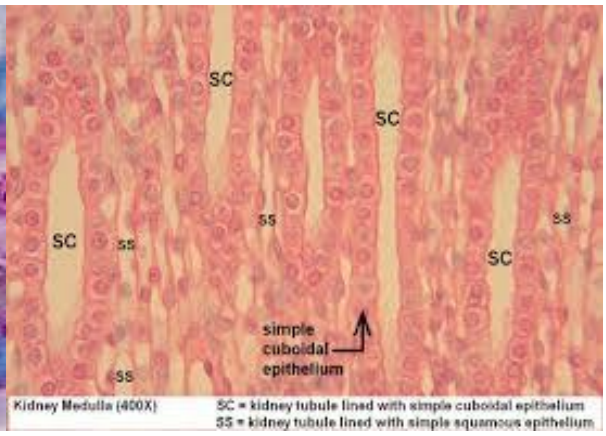
Tight junctions (also known as zonula occludens) are areas where the plasma membranes of adjacent cells come very close together.

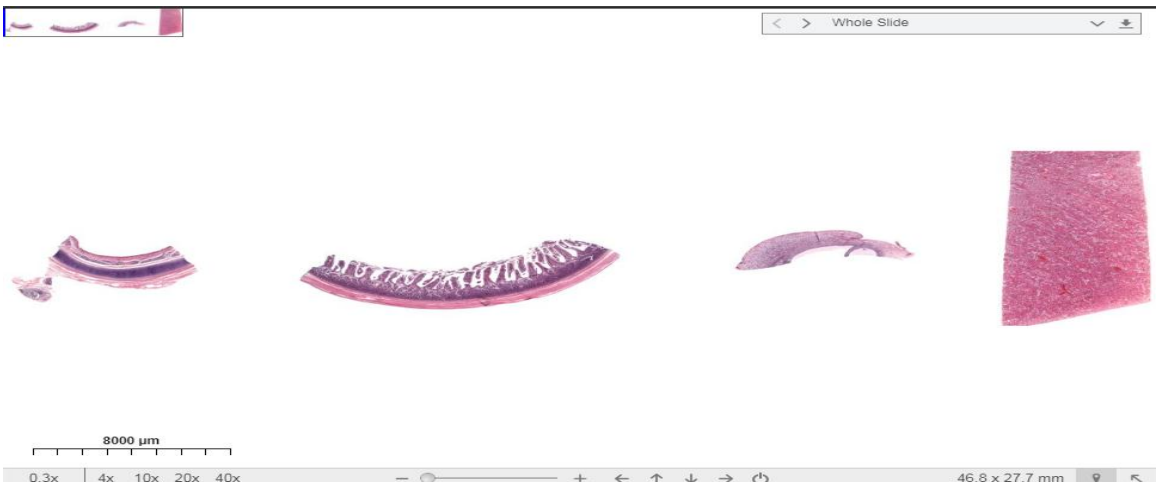
A small portion of another cell can be seen at the top of this image. The tight junctions appear as darker material along the plasma membranes of the two cells.

Simple cuboidal epithelium

Cells appear cuboidal in sections perpendicular to the surface of the epithelium. Viewed from the surface of the epithelium they look rather like small polygons. Simple cuboidal epithelium occurs in small excretory ducts of many glands, the follicles of the thyroid gland, the tubules of the kidney and on the surface of the ovaries.
Can there be "low cuboidal" epithelia?

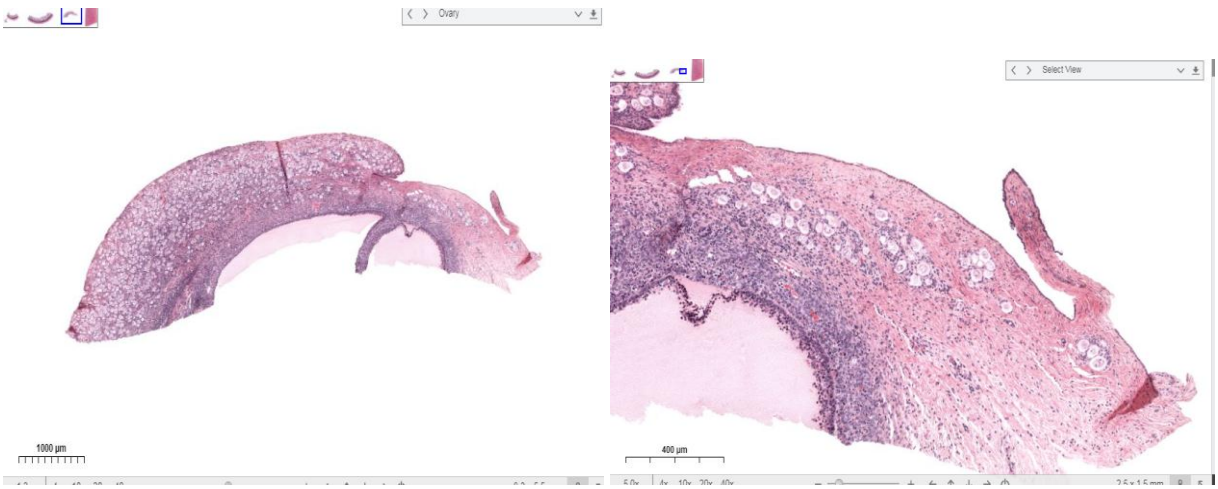




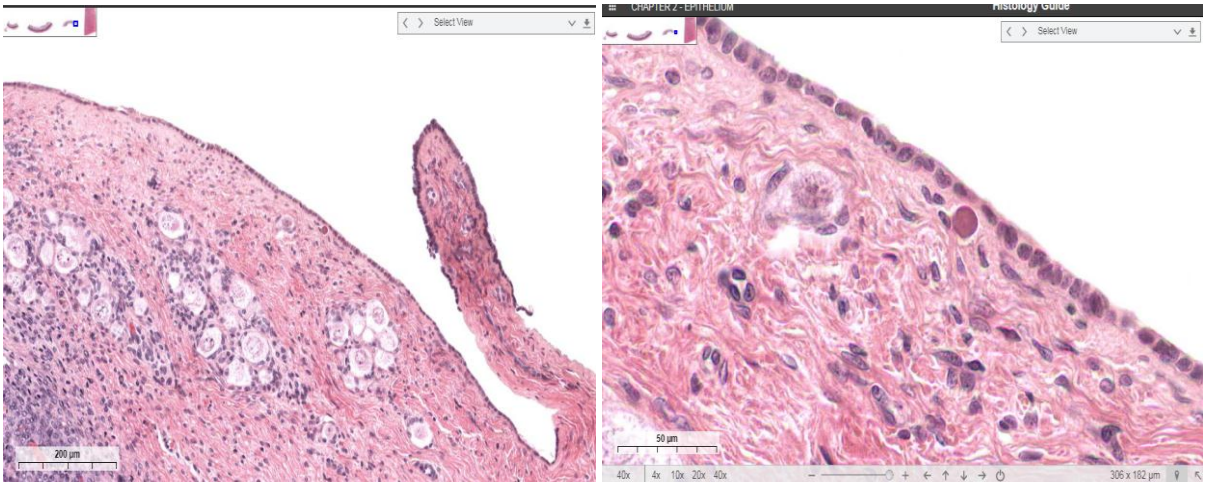


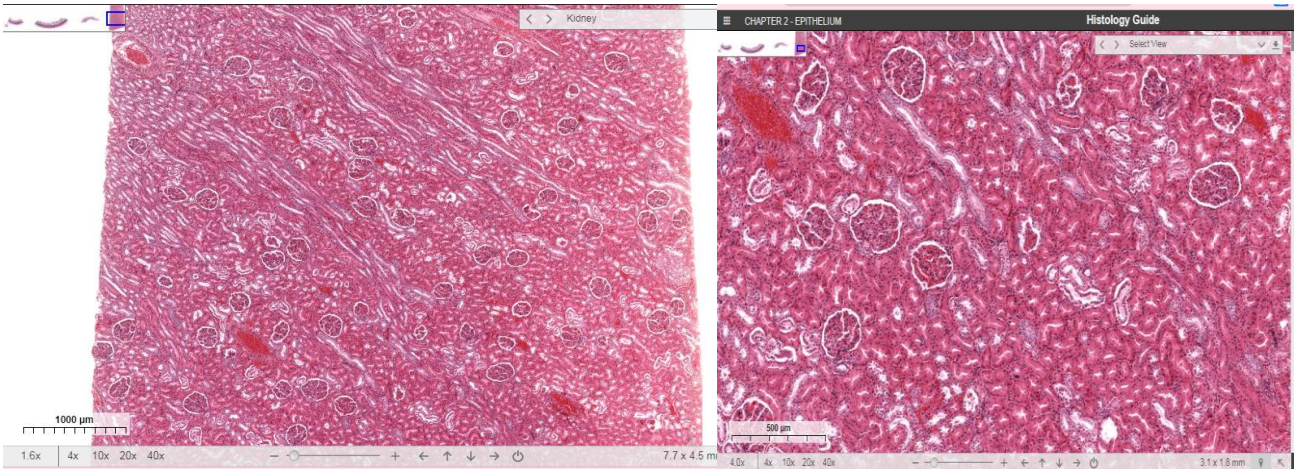
Simple Cuboidal Epithelium

The ovary and kidney contain examples of simple cuboidal epithelia.

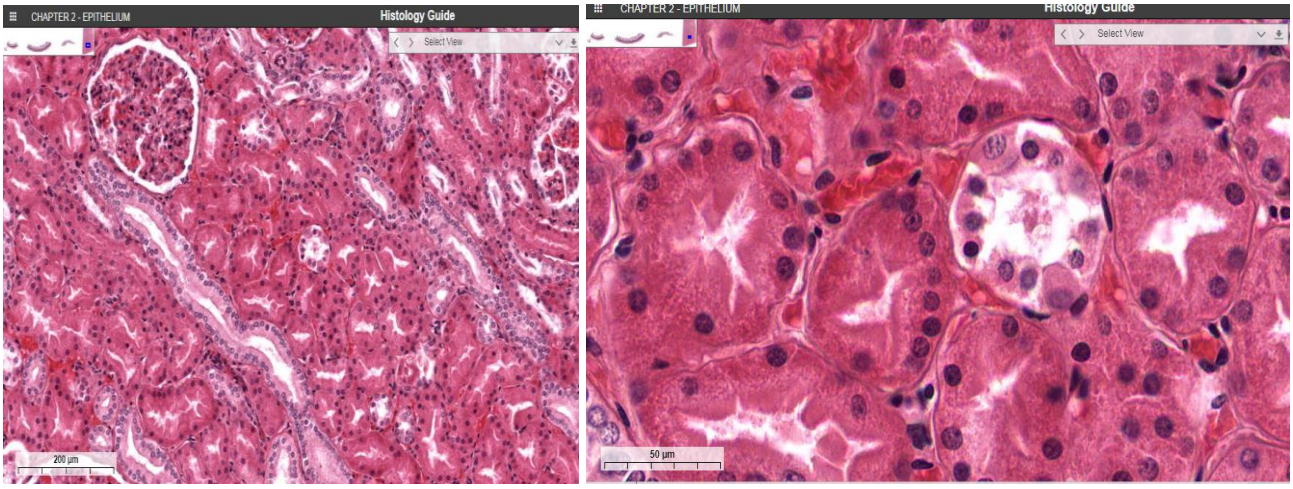


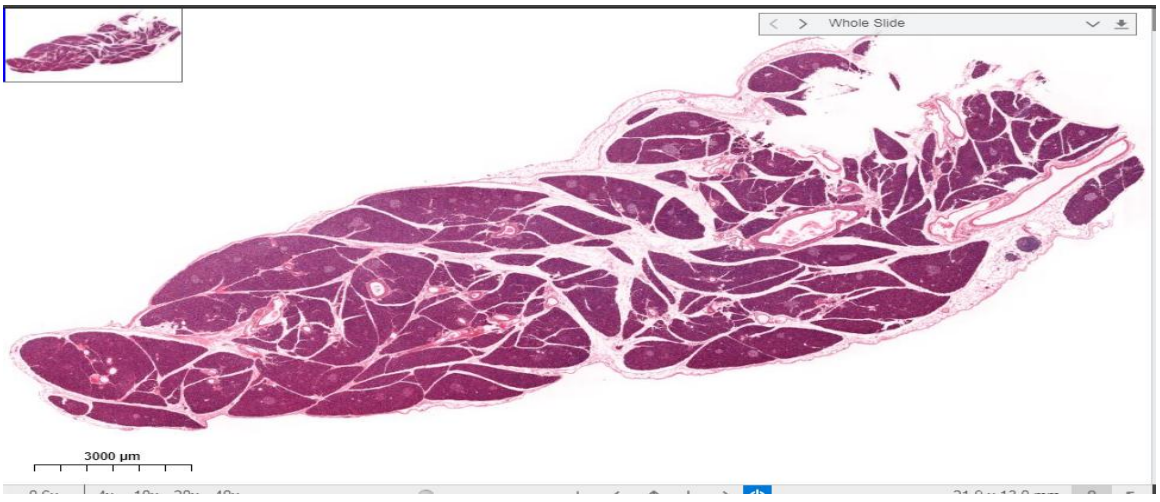
- Ovary - the outer surface of the ovary is covered with a simple cuboidal epithelium. It is very fragile and you may have to search for a region where it is intact.





- Kidney - the area around renal corpuscles usually contains many cross-sections of tubules with a simple cuboidal epithelium.

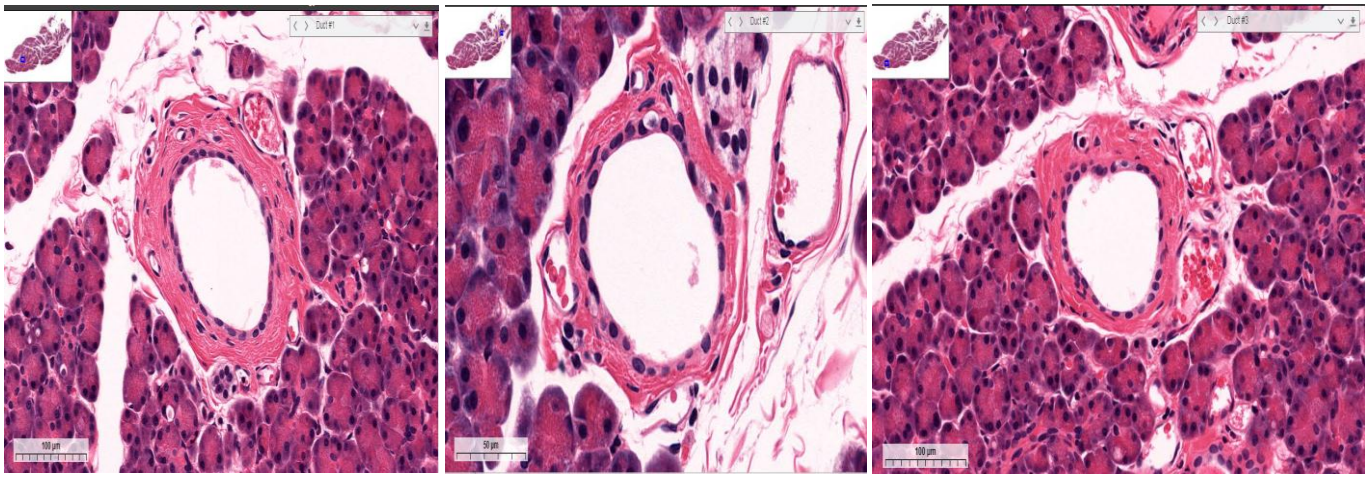




Simple Cuboidal Epithelium

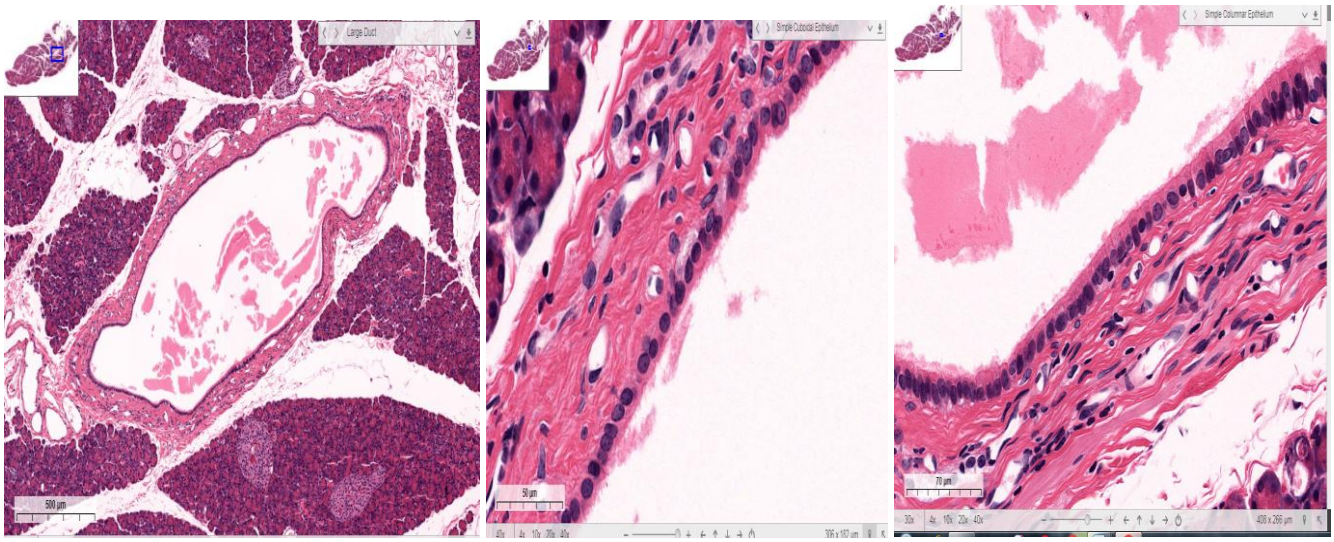
This pancreas section contains the profiles of many ducts.

The ultrastructure of these epithelial cells can be seen in EM 074 Intralobular Duct by transmission electron microscopy.

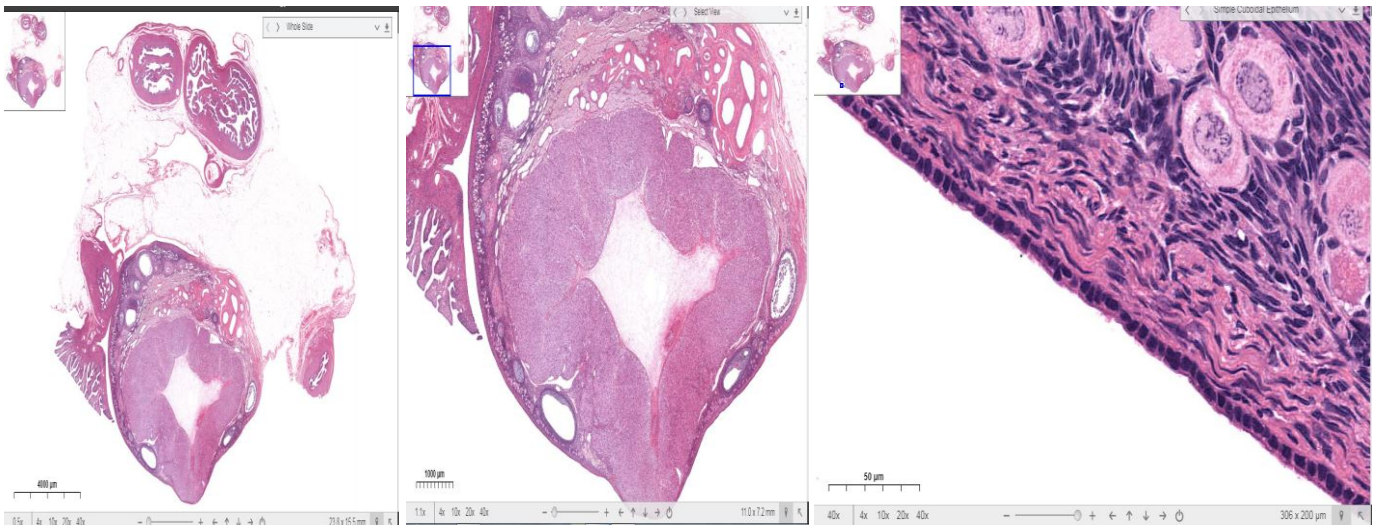


The ducts usually have a simple cuboidal epithelium as seen in these examples:

- Duct #1 Duct #2 Duct #3

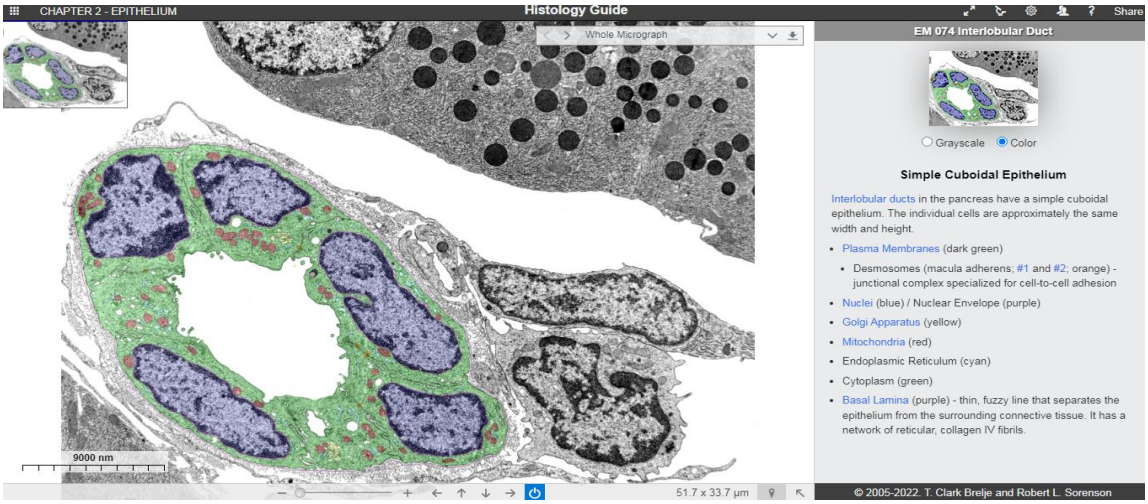


The height of the epithelial cells can increase in larger ducts. The epithelium can vary from cuboidal to columnar.



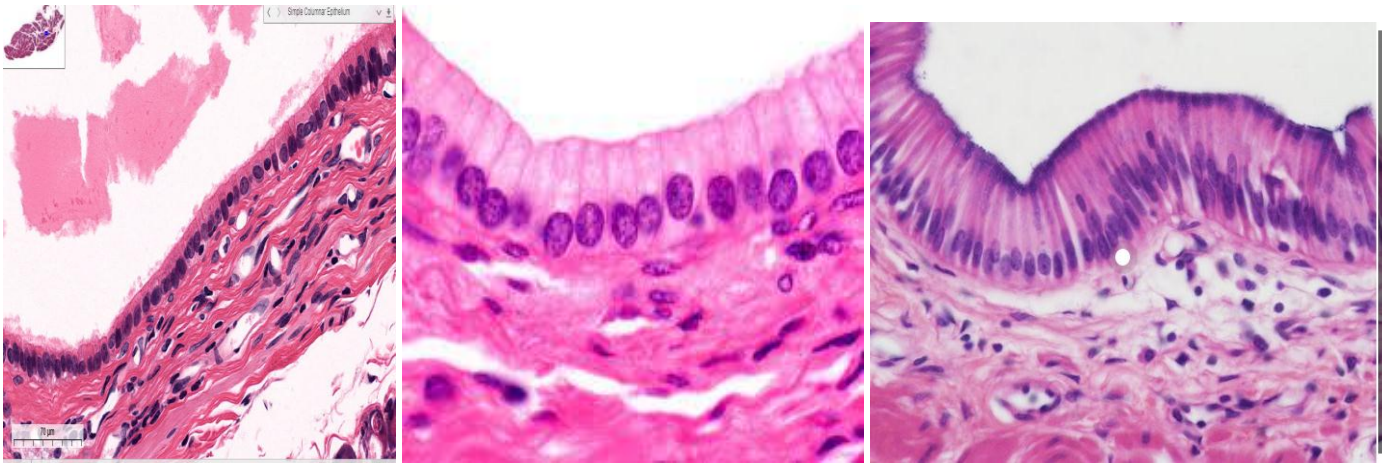
Simple Cuboidal Epithelium

The outer surface of the ovary is covered by a simple cuboidal epithelium. There is some variation in shape of the cells ranging from low cuboidal to tall cuboidal.

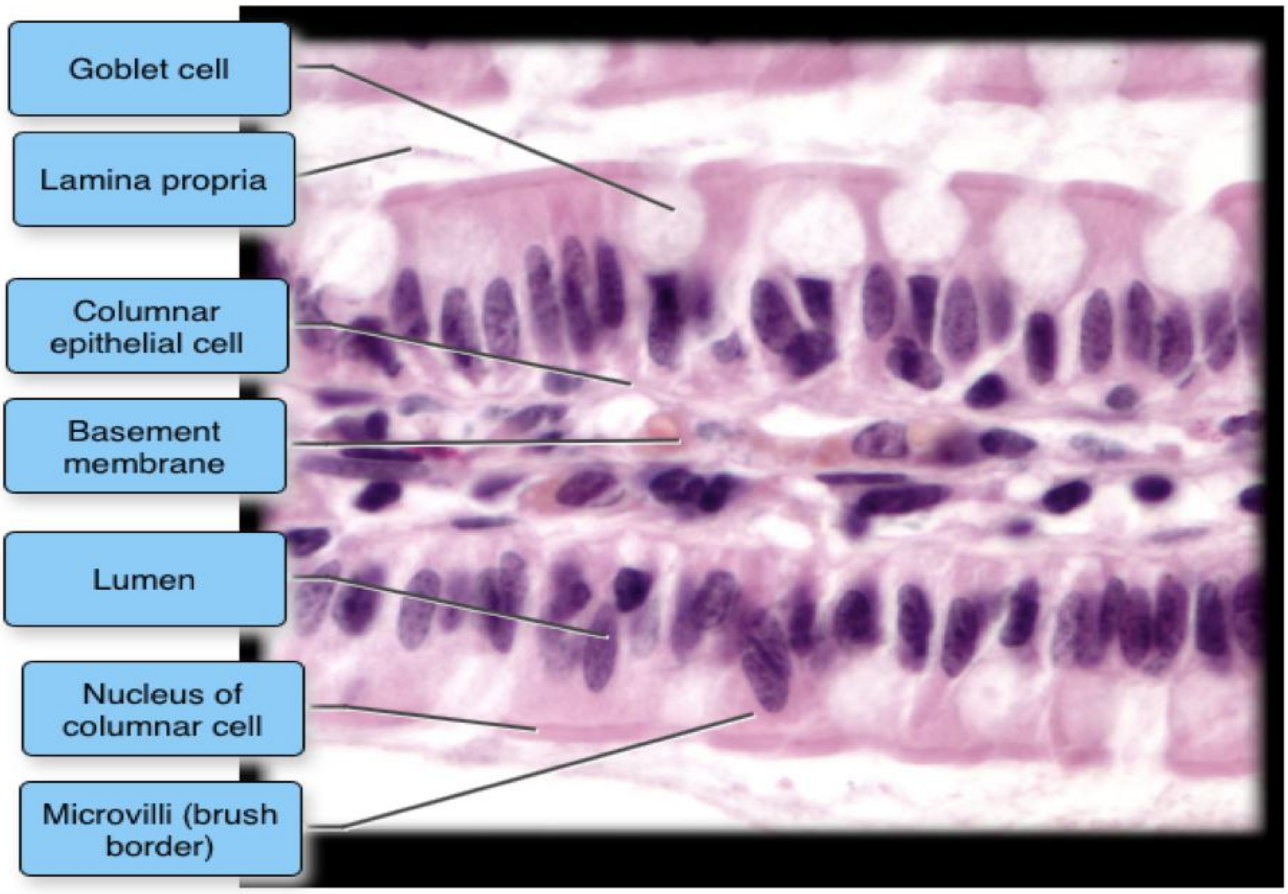


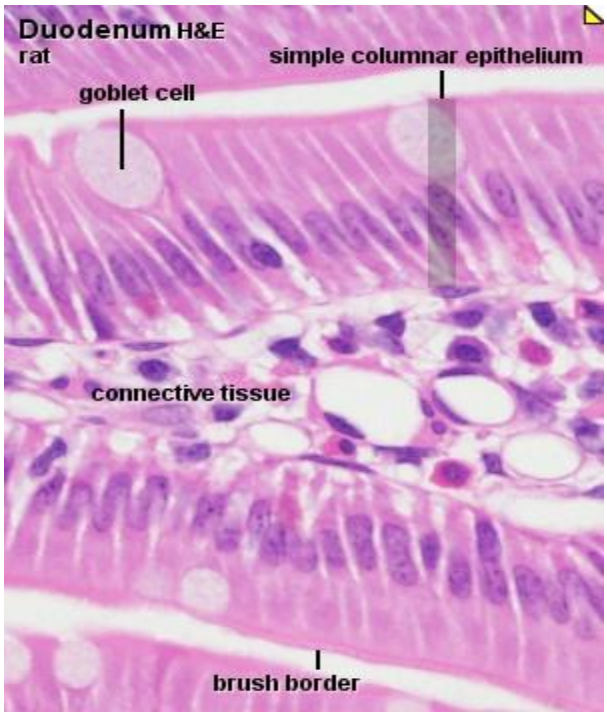
Simple columnar epithelium

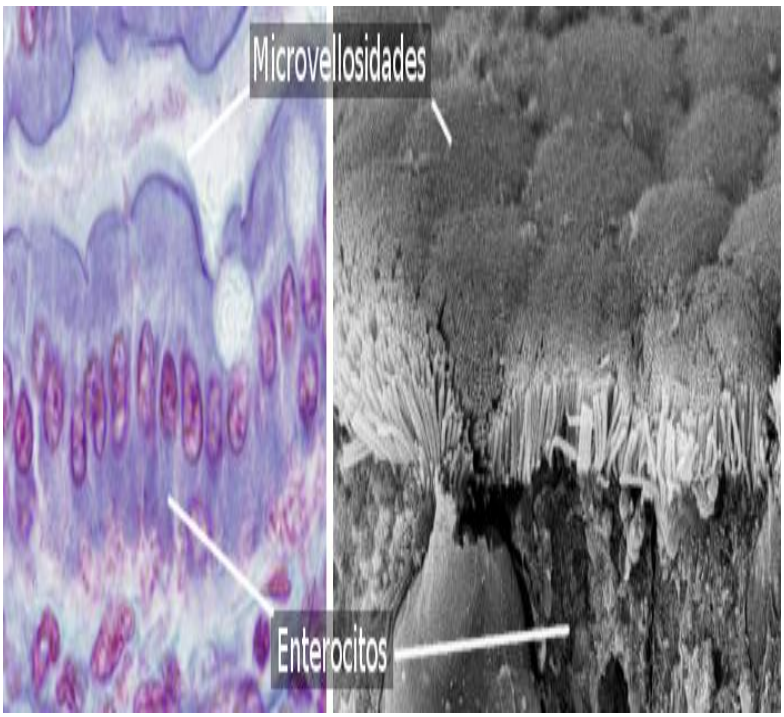
The cells forming a simple columnar epithelium are taller than they are wide. The nuclei of cells within the epithelium are usually located at the same height within the cell - often close to the base of the cell. An example is the simple columnar epithelium which lines the internal surface of the gastrointestinal tract (GIT) from the cardia of the stomach to the rectum.



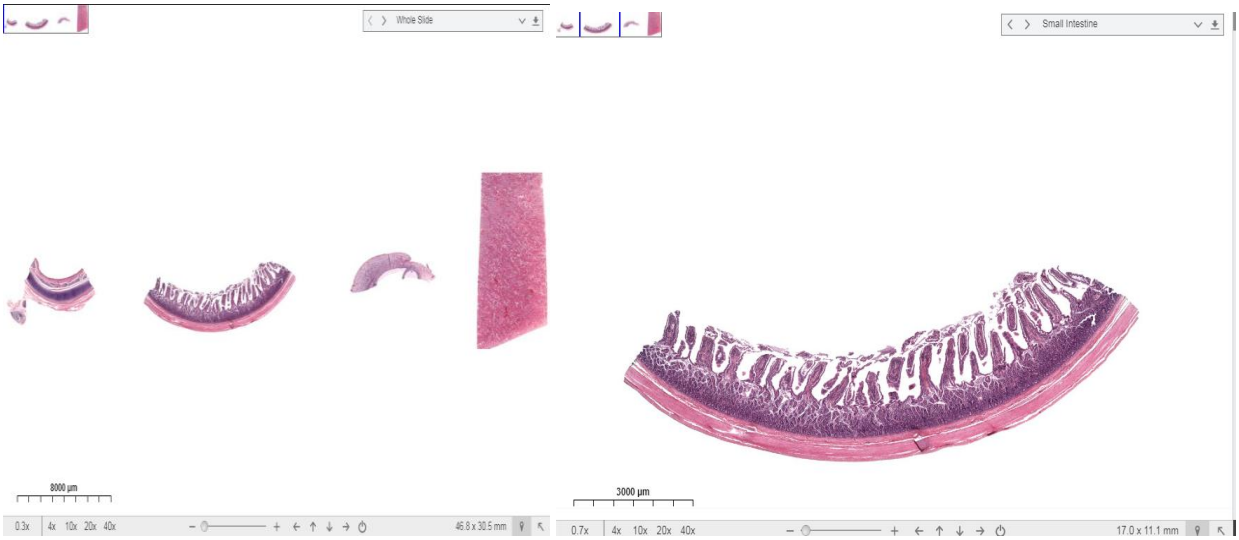
Simple ciliated columnar Light microscope picture simple columnar epi.





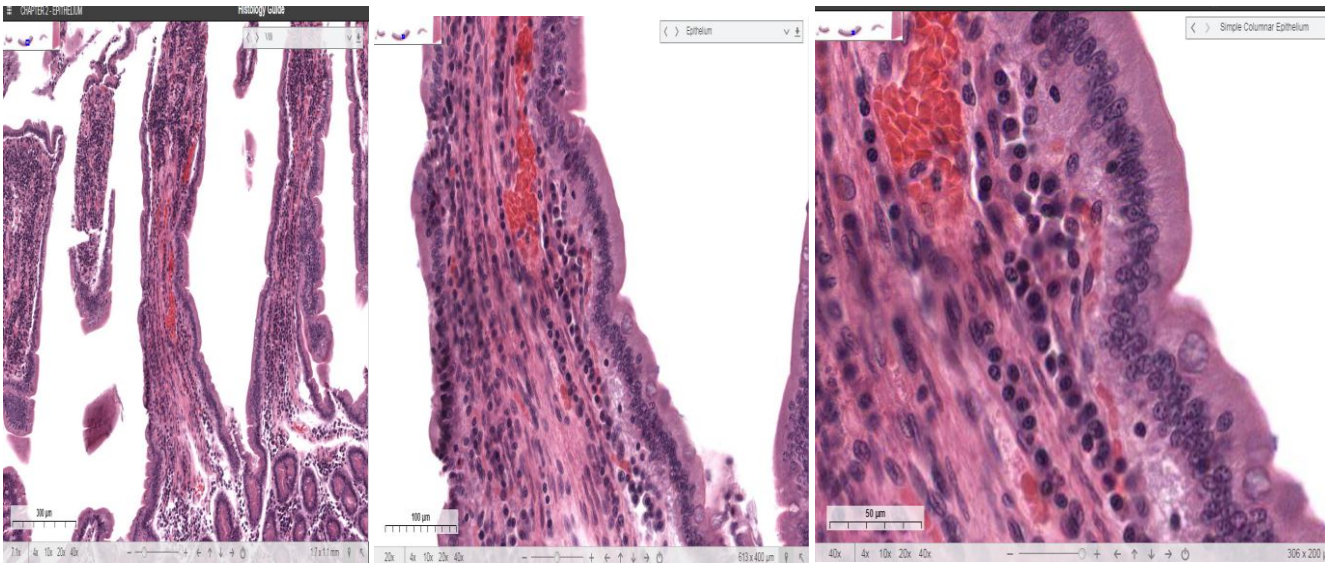


Duodenum, rat, H&E and Ileum, human - H&E



Simple Columnar Epithelium with Goblet Cells

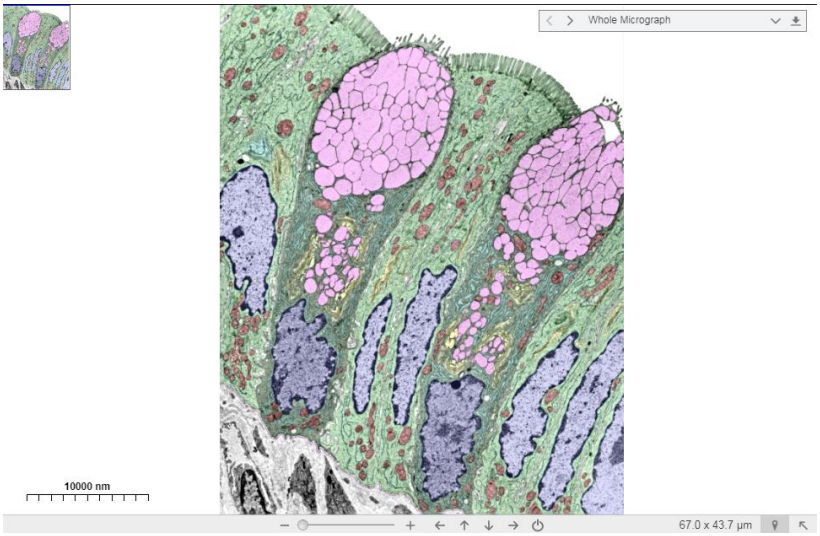
This section of the small intestine is poorly preserved with most of the epithelium detached from the underlying connective tissue..



The surface area of the small intestine is increased by finger-like projections called villi. Examine a villi in which the epithelium is still attached to the underlying tissue The epithelium is a single layer of cells that are taller than they are wide. However, this is difficult to see because this section is cut tangential to the surface of the villi. It passes through adjacent cells resulting in multiple nuclei appearing at different levels. This simple columnar epithelium contains:

- Surface Absorptive Cells (or enterocytes) - their apical surface has tightly packed microvilli to increase their surface area. This is known as a brush border. The dark line underneath the brush border is the terminal web in which the microvilli are anchored.
- Goblet Cells - scattered cells that secrete mucus. The basophilic secretion granules form circular clusters near the apical surface.

The ultrastructure of these two cell types can be seen in EM 034 Small Intestine by transmission electron microscopy.



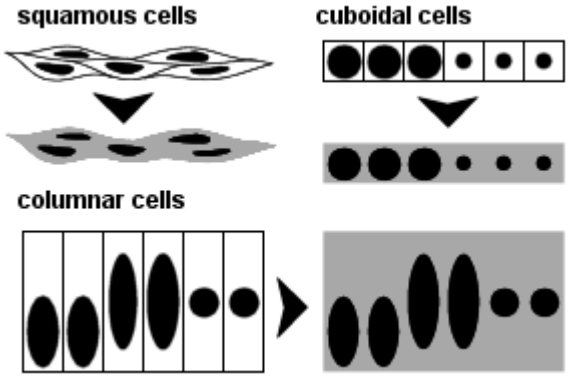
Simple Columnar Epithelium

A simple columnar epithelium with goblet cells lines the small intestine.

- Goblet Cells (dark green) - secrete mucins (the main component of mucus). Their goblet shape is due to secretion granules expanding the apical region of the cell.
- Secretion Granules (purple) - large, densely packed in the apical region of the cell.
- Golgi Apparatus (yellow) - well developed in this secretory cell.
- Endoplasmic Reticulum (cyan) - abundant in the basal region of the cell
- Intestinal Absorptive Cells (enterocytes; light green) - most common type of cell in the small intestine. They are specialized for the absorption of nutrients.
- Microvilli (green) - thin extensions that increase the surface area of the apical membrane.
- Terminal Bar - complex of tight junctions (zonula occludens), zonula adherens and desmosomes (maculae adherens).
- Mitochondria (red) - provide energy for the transport of molecules

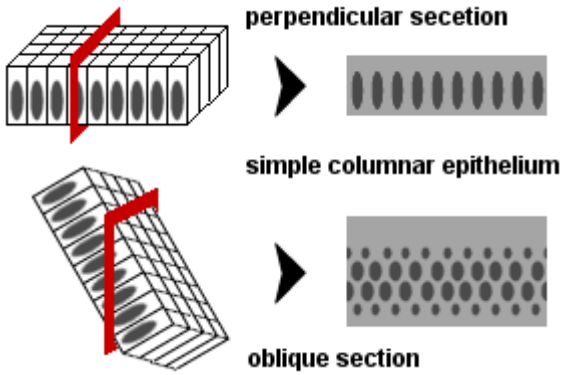
The lateral plasma membranes of adjacent cells have extensive interdigitations.

The basal lamina (dark purple) is the thin, fuzzy line that separates the epithelium from the underlying connective tissue. It has a network of reticular, collagen IV fibrils.



Identifying Epithelia?

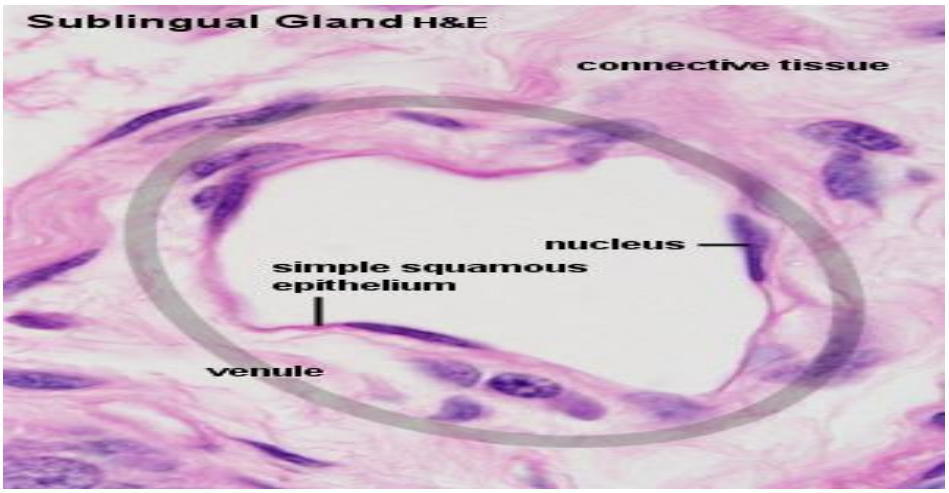
The outlines of individual epithelial cells are not always visible, and it may be difficult to identify the shape of the cells. It is often helpful to look at the shape, location and spacing of the nuclei in the epithelium, which together will allow a very good guess at the shape of the cells forming the epithelium.



How many cell layers are visible in a section depends very much on the angle between the section plane and the surface of the epithelium. Oblique sections of epithelium will be visible in almost all slides of organs in which epithelium lines a surface with a very irregular profile. A single surface is usually not lined by several types of epithelia. The number of epithelial cell layers will usually be the smallest number of layers visible anywhere along the surface lined by the epithelium.

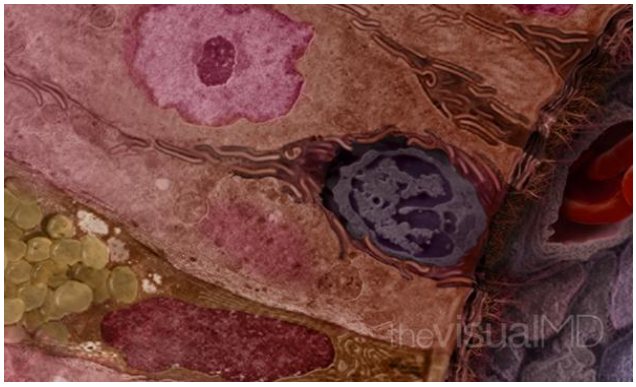
Suitable Slides

- **simple squamous epithelium:** any section containing blood vessels or sections of organs which include the serosa of the organs - H&E
- **simple cuboidal epithelium:** sections of ovaries, thyroid gland, kidney or large glands (e.g. parotid gland) with well preserved small ducts
- **simple columnar epithelium:** sections of the small intestine (duodenum, jejunum or ileum), uterus (uterine glands), liver (large bile ducts) or gall bladder - H&E, trichromeSublingual Gland, human, H&E



Blood vessels are probably present in all sections you will ever see. With very few exceptions, they are lined by a simple squamous epithelium. The individual epithelial cells are extremely fattened and form a much larger part of the surface than individual cuboidal or columnar cells. The nuclei of the epithelial cells are also flattened. Not every epithelial cell nucleus will be included in the plane of the section, and if the vessel is very small (e.g. a capillary), there may be no visible nuclei in the epithelial lining. Capillaries and other small vessels are easily deformed during tissue processing and the epithelium of larger vessels may be damaged or look corrugated. It may therefore take a little more patience than you expect to find a "good" simple squamous epithelium.

Draw a small vessel with its epithelial lining, label the features visible in your drawing and include a suitable scale.

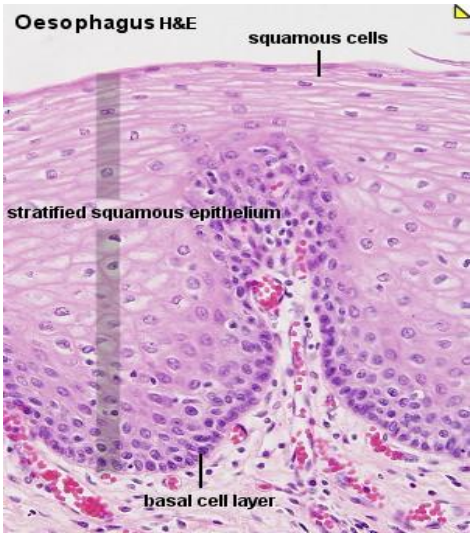


The small intestines are lined by a simple columnar epithelium. Most of the epithelial cells (enterocytes) are involved in the absorption of components of the digested food in the lumen of the intestines. Complex folds of the intestinal lining increase the surface area available for absorption. The sections plane will therefore often pass at an oblique angle through the epithelium. The epithelium may look stratified where this happens. Scan along the epithelium until you find a spot where it is cut perpendicular to its surface, i.e. where it looks like a simple columnar epithelium. Mucus producing goblet cells are a second cell type of this epithelium. Mucus stains only weakly or not at all in H&E stained sections. Round, light "hollows" in the epithelium represent the apical cytoplasm of the goblet cells, which is filled with mucin-containing secretory vesicles.
Microvilli extend from the apical surface of epithelial cells into the intestinal lumen. They increase surface area by a factor of ~20 and thereby facilitate absorption. Together, the microvilli are visible as a light red band along the upper limit of the epithelium - the brushborder.

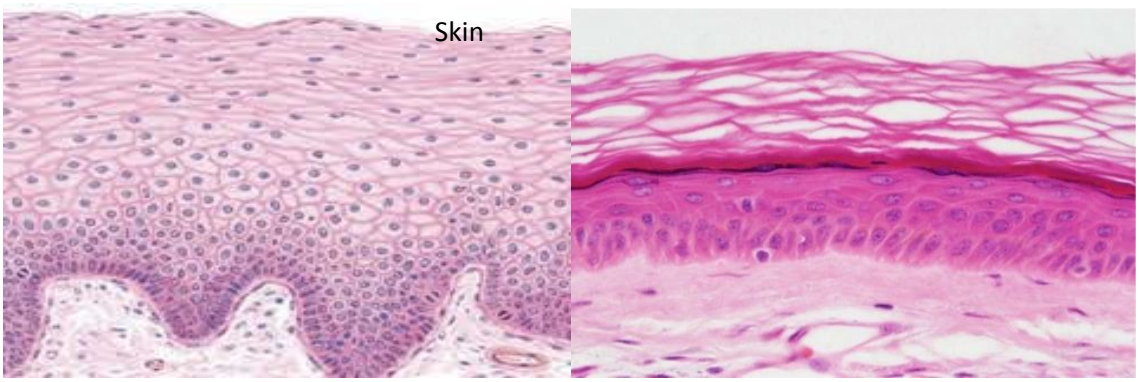
Draw and label the epithelium. Include goblet cells in your drawing.

Stratified Epithelia

Stratified squamous epithelium

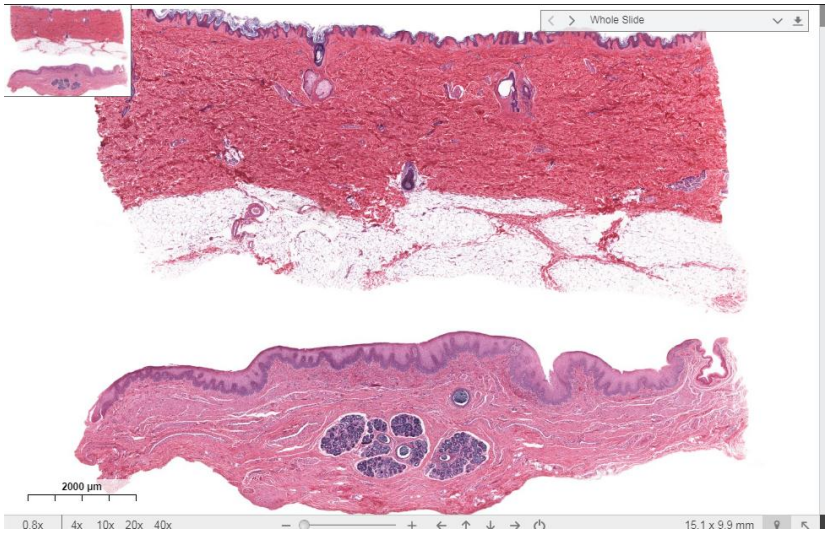


Stratified squamous epithelia vary in thickness depending on the number of cell layers present. The deepest cells, which are in contact with the basement membrane, are cuboidal or columnar in shape. This layer is usually named the basal cell layer, and the cells are called basal cells. Basal cells are mitotically active and replace the cells of the epithelium which are lost by "wear and tear". The basal cell layer is followed by layers of cells with polyhedral outlines. Close to the surface of the epithelium, cells become more flattened. At the surface of the epithelium, cells appear like flat scales - similar to the epithelial cells of simple squamous epithelia. Remember that it is the shape of the cell which form the surface of the epithelium which gives the name to the epithelium!



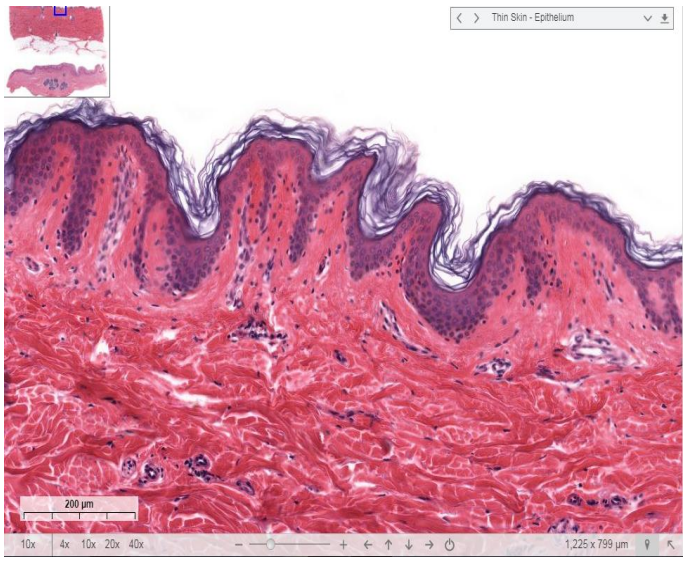
Oesophagus, human - H&E The oesophagus is lined by a stratified squamous epithelium consisting of many cell layers. Basal cells often form a well defined layer at the border of the epithelium to the underlying connective tissue. The underlying connective tissue forms finger-like extensions towards the lumen of the oesophagus, which are called papillae. The border between epithelium and connective tissue may appear quite irregular because of the papillae. This irregular border aids in anchoring of the epithelium to the connective tissue. If these extensions are not cut exactly along their long axis, they may look like isolated small islands of connective tissue and blood vessels within the epithelium.

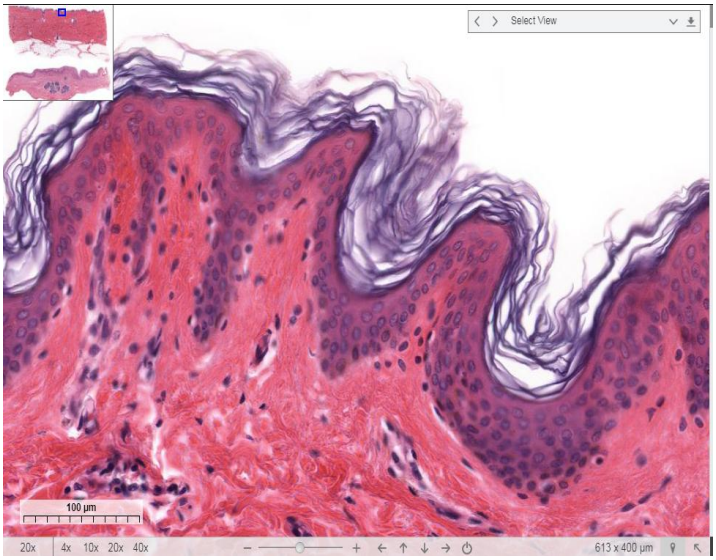
Draw the stratified squamous epithelium of the oesophagus and label your drawing. Try to draw a little schematic illustration which shows how the plane of section would effect the appearance of the connective tissue extensions.



Stratified Squamous Epithelia

A stratified squamous epithelium has multiple layers of cells. It is continuously replacing itself by division of the basal layer of cells. These cells change shaped as they move toward the surface and are eventually shed. Its name arises from the squamous appearance of the outermost layer of cells.

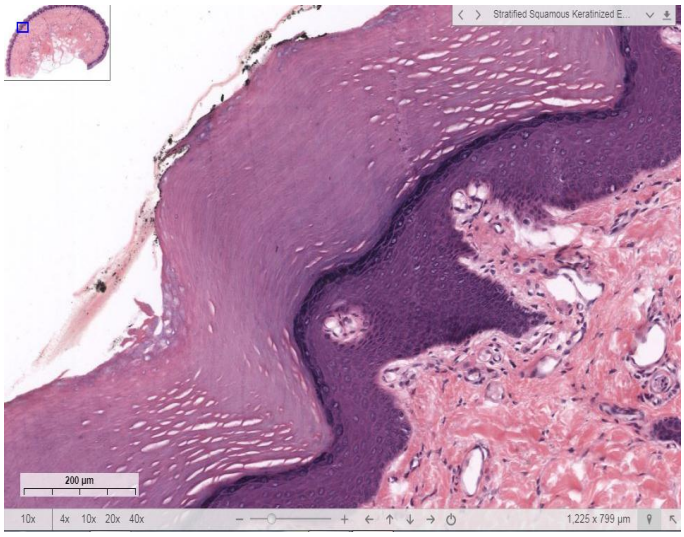




Stratified squamous epithelium is further classified by the presence or absence of keratin, a tough protective protein, at its apical surface.

- Thin Skin - covered by a stratified squamous keratinized epithelium.
- Number of cell layers in skin ranges from a few (thin skin) to many (thick skin)
- Because skin is exposed to air, it is keratinized to protect the surface from abrasion and is lubricated by glycolipids to avoid desiccation
- Esophagus - lined by a stratified squamous non-keratinized epithelium.
- Keratin is not necessary because it is constantly kept moist

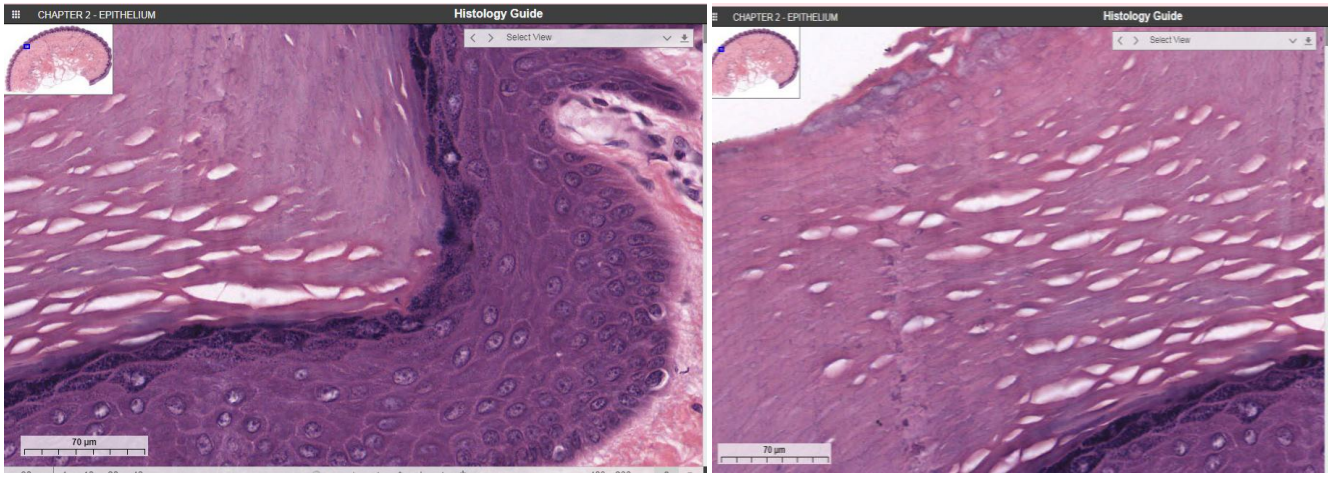
The ultrastructure of thin skin is shown in EM 084 Thin Skin by transmission electron microscopy.



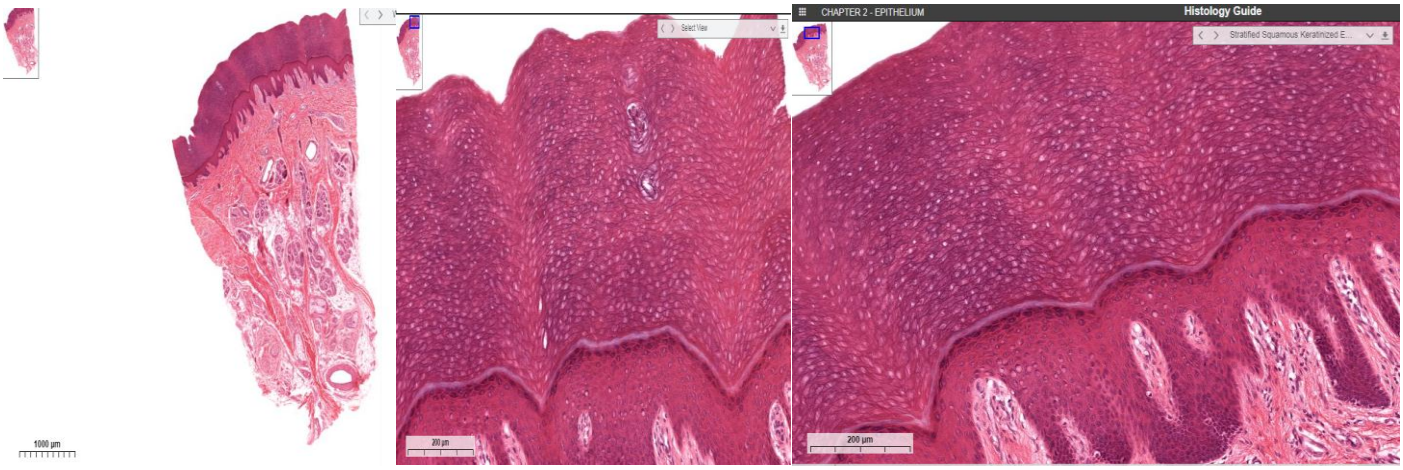
Stratified Squamous Keratinized Epithelium

There are two types of skin - thin and thick. Thick skin only occurs on the palmar and plantar surfaces hands and feet, whereas thin skin occurs on all other parts of the body.

Thick skin is covered by a stratified squamous keratinized epithelium.



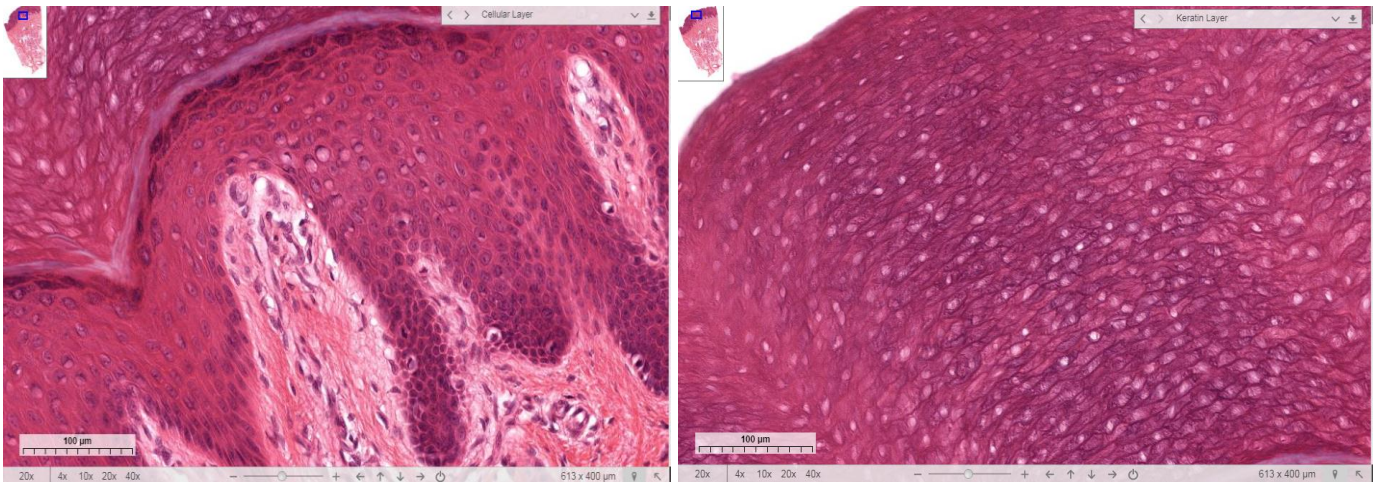
- The epithelial cells form between 10 and 20 layers.
- The keratin layer is thicker than the cellular layer (which is the opposite of thin skin.)
- Because skin is exposed to air, it is keratinized to protect the surface from abrasion and is lubricated by glycolipids to protect it from dehydration.
- The basement membrane is too thin to be identified in this specimen.



Stratified Squamous Keratinized Epithelium

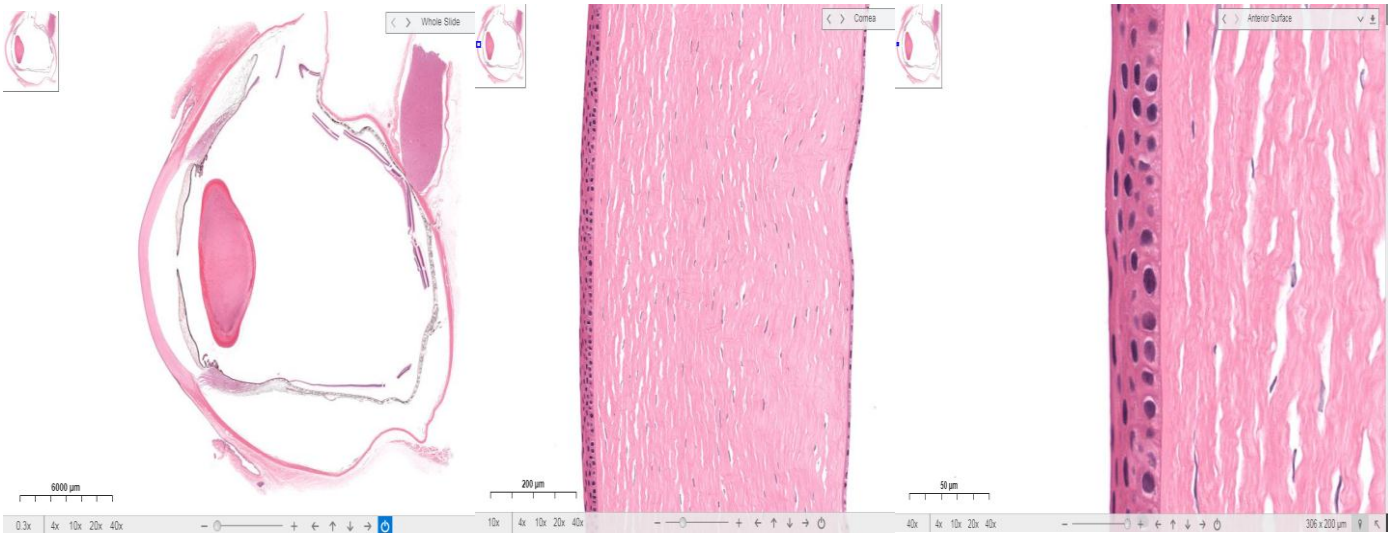
This specimen has a well preserved epithelium with excellent cellular definition.

Thick skin is covered by a stratified squamous keratinized epithelium.



- The epithelial cells form between 10 and 20 layers.

- The keratin layer is much thicker than the cellular layer. A closer examination reveals the outlines of cells within the keratin. This reflects the cellular origins of the keratin. These cells are dead and do not have nuclei.
- Because skin is exposed to air, it is keratinized to protect the surface from abrasion and is lubricated by glycolipids to protect it from dehydration.
- The basement membrane is too thin to be identified in this specimen.

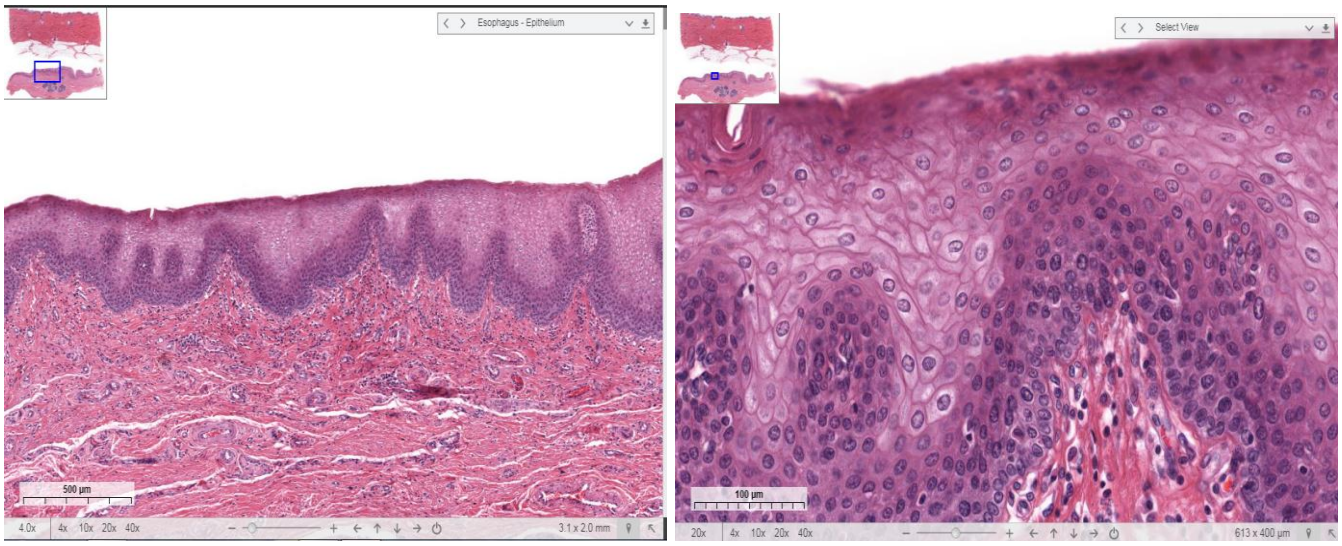


Stratified Squamous Epithelium

The anterior surface of the cornea is covered by a very thin stratified squamous non-keratinized epithelium.

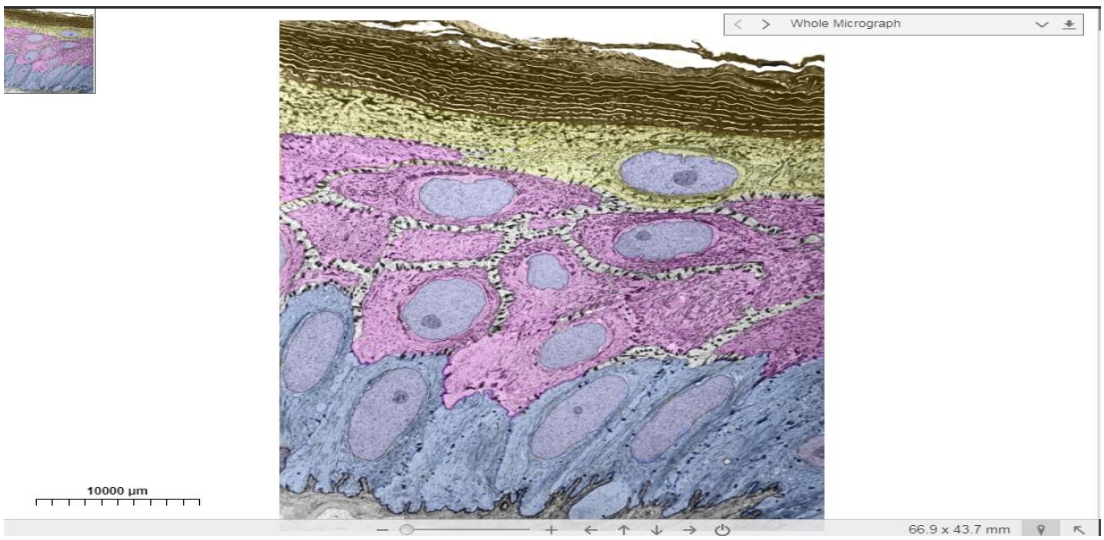
Because this surface is exposed to air and is non-keratinized, the epithelium must be kept constantly moist with tears.

Irregularity or edema of the corneal epithelium disrupts the smoothness of the air-tear film interface reducing visual acuity.



- Esophagus - lined by a stratified squamous non-keratinized epithelium.
- Keratin is not necessary because it is constantly kept moist

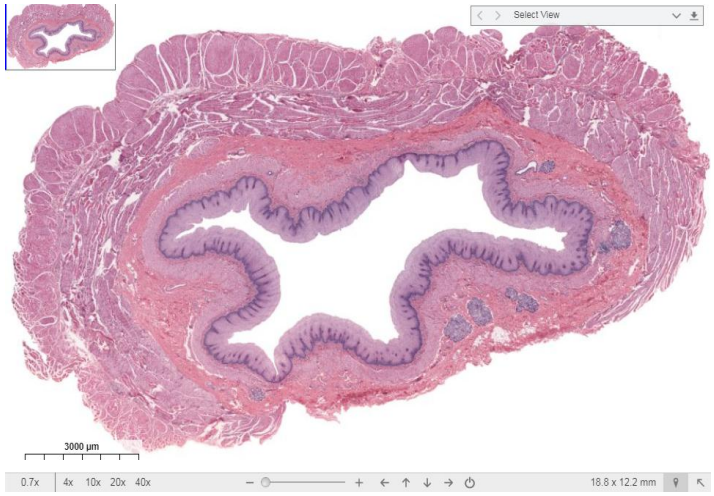
The ultrastructure of thin skin is shown in EM 084 Thin Skin by transmission electron microscopy.



Stratified Squamous Epithelium

Skin is covered by a stratified squamous keratinized epithelium.

- Basal layer (blue) is the deepest layer of the epithelium and rests on the basal lamina
- Keratin layers (orange) is the outermost layer
- Because skin is exposed to air, it is keratinized to protect the surface from abrasion and is lubricated by glycolipids to protect it from dehydration
- Less thick than the cellular layer in thin skin
- Basal Lamina - not visible

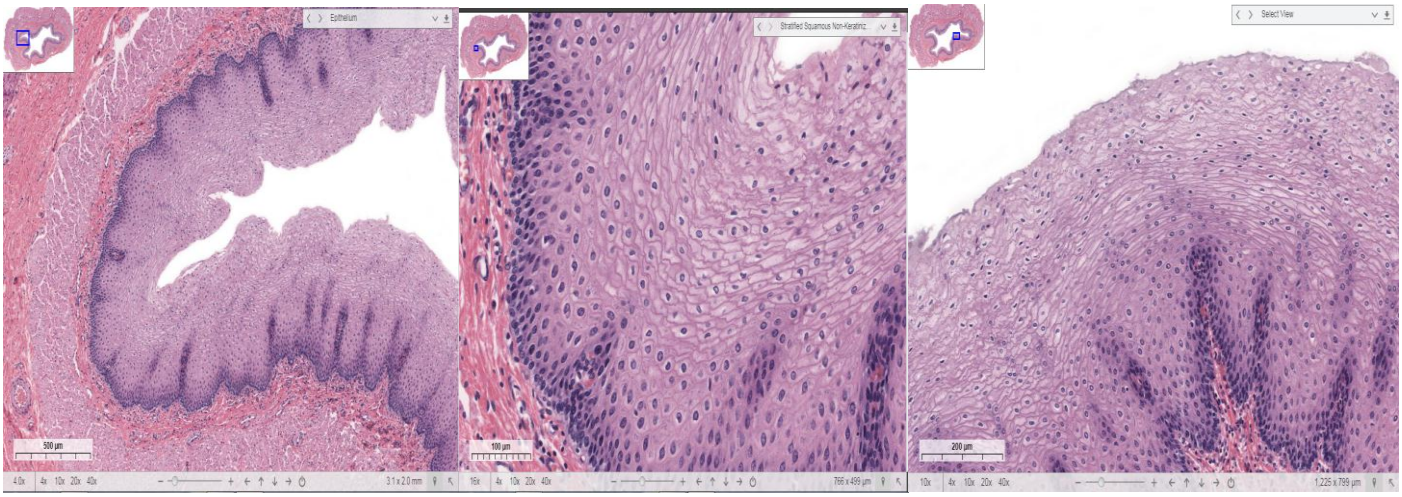


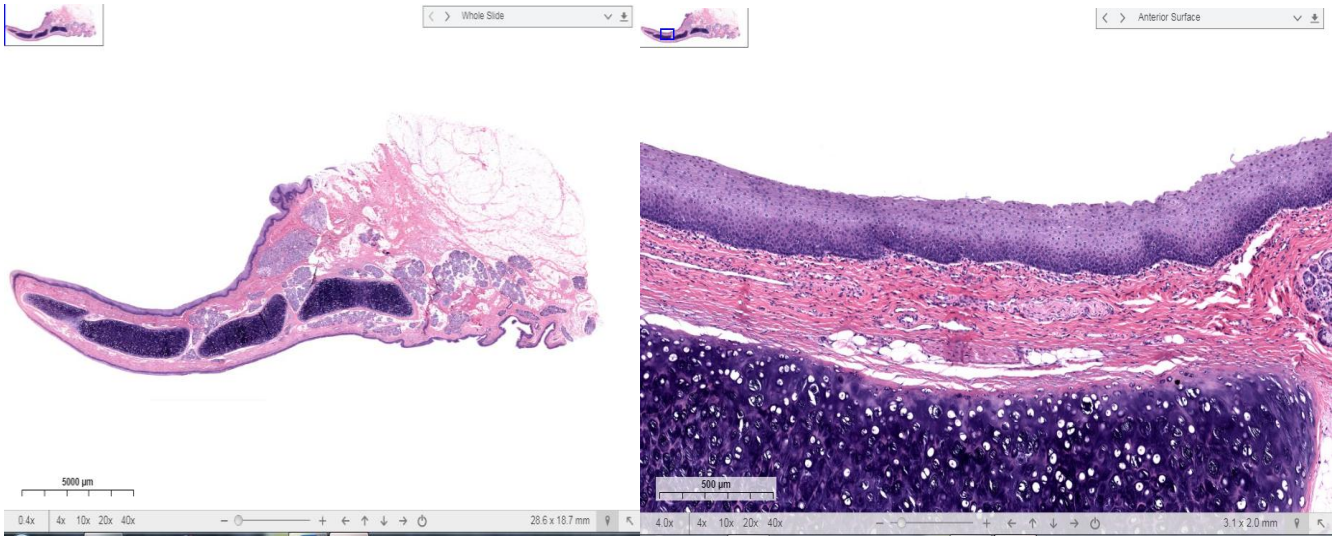
Stratified Squamous Non-Keratinized Epithelium

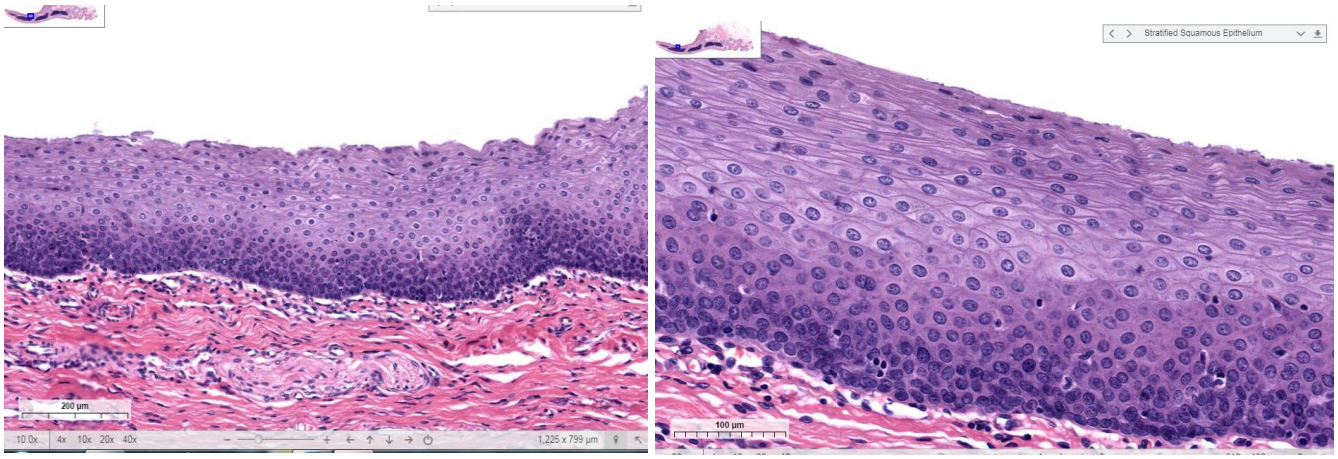
This esophagus is lined by a stratified squamous non-keratinized epithelium.

Features of this epithelium:

- This epithelium has 40 to 50 layers of cells. They change shape as they migrate from the basal layer to surface: cuboidal cells in the basal layers, round cells in the middle layers, and flattened (squamous) in the upper layers.
- The epithelium is separated from the underlying connective tissue by a thin basement membrane. It is seen as a dark band beneath the epithelium.
- Keratin is not necessary because this epithelium is not exposed to the desiccating effects of air and is constantly kept moist.

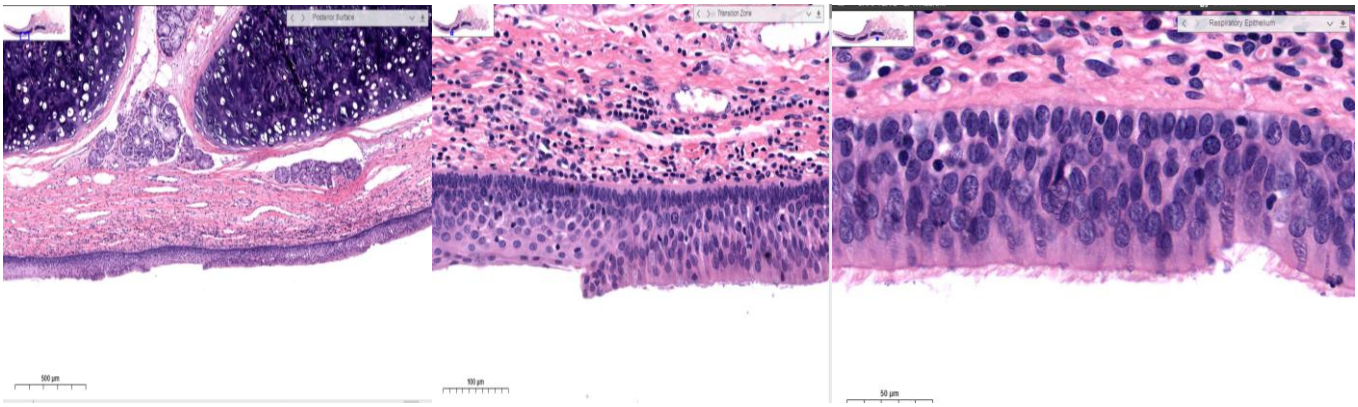






Stratified Squamous Epithelium

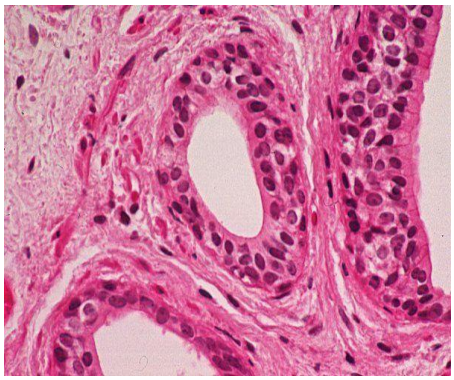
The entire anterior surface (the part facing the tongue) and apical portion of the posterior surface (the part facing the larynx) of the epiglottis is covered by a stratified squamous epithelium. These areas are vulnerable to abrasion due to the passage food.

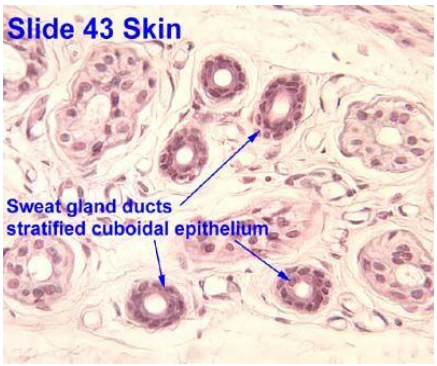


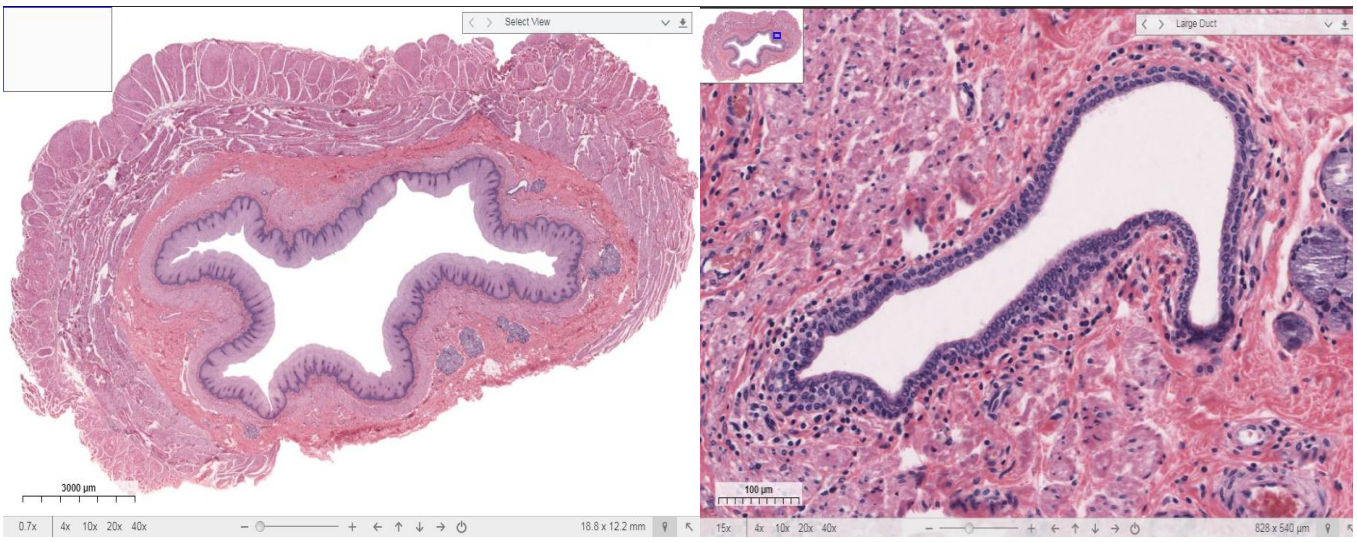
The rest of the posterior surface is covered by respiratory epithelium. The epithelium abruptly transitions from a stratified squamous epithelium to a pseudostratified columnar epithelium (respiratory epithelium).

Respiratory epithelium is a pseudostratified columnar epithelium with ciliated columnar cells and goblet cells.

Stratified cuboidal and columnar epithelia : are not common. A two-layered cuboidal epithelium is, for example, seen in the ducts of the sweat glands. Stratified columnar epithelia are found in the excretory ducts of the mammary gland and the main excretory duct of the large salivary glands.

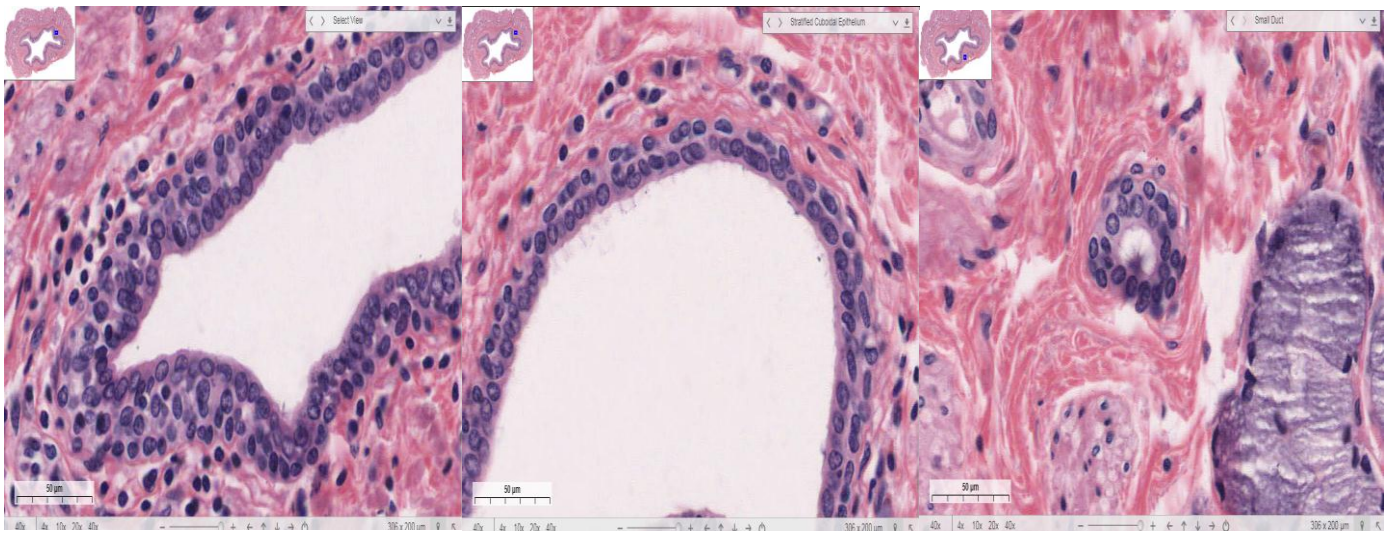






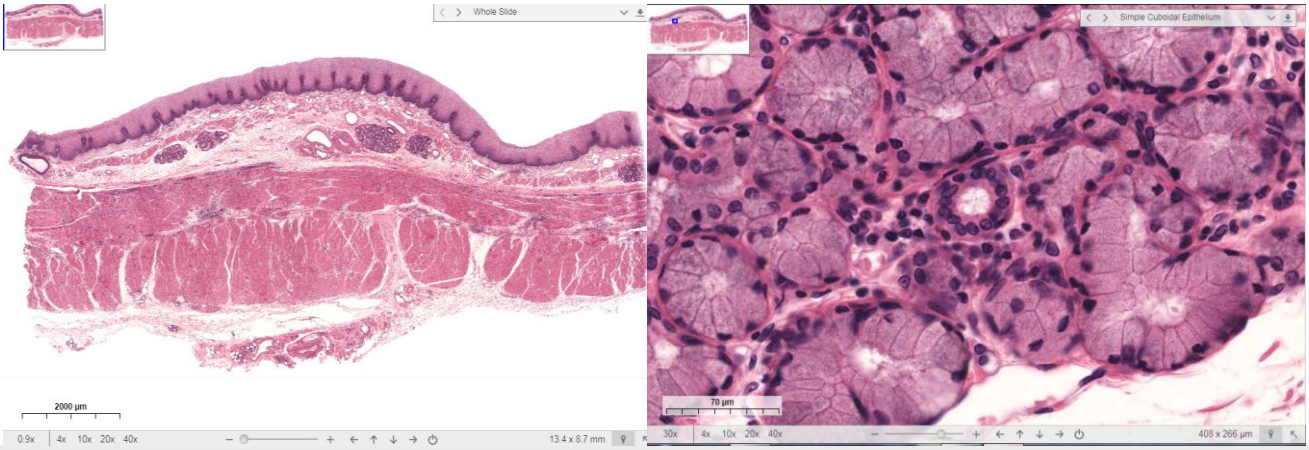
Stratified Cuboidal Epithelium

Stratified cuboidal epithelium has a limited distribution. It is most often found in large ducts from exocrine glands. Typically, it has only two layers of cuboidal cells.



This esophagus has an example of a large duct with a stratified cuboidal epithelium.

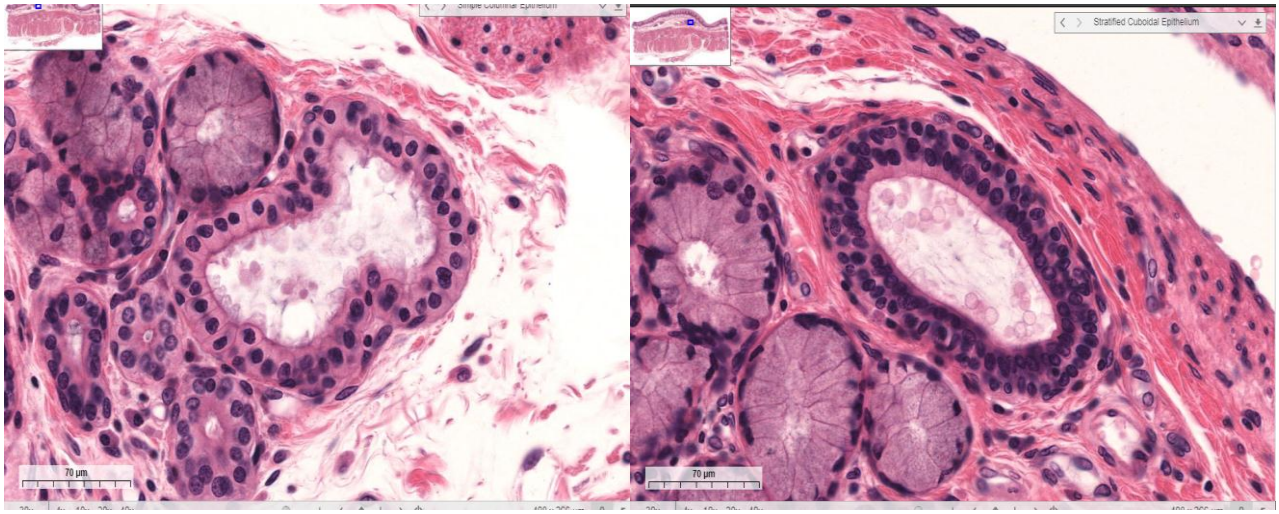
Smaller ducts with a stratified cuboidal epithelium are also present.



Cuboidal and Columnar Epithelia

Cuboidal epithelium has a limited distribution. It is most often found in the ducts from exocrine glands. These ducts range from simple cuboidal, simple columnar, to stratified cuboidal epithelia.

- Simple cuboidal epithelium - often found in small ducts.



- Simple columnar epithelium - found in intermediate size ducts.
- Stratified cuboidal epithelium - usually found in both small and large ducts. It most often has only two layers of cuboidal cells.

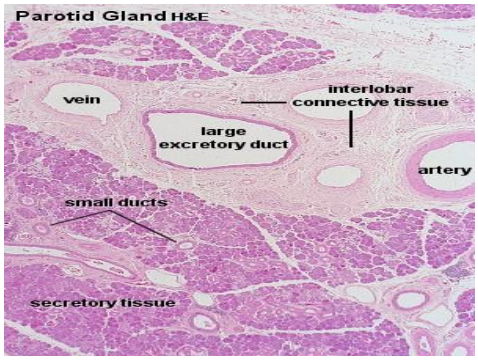
Suitable Slides

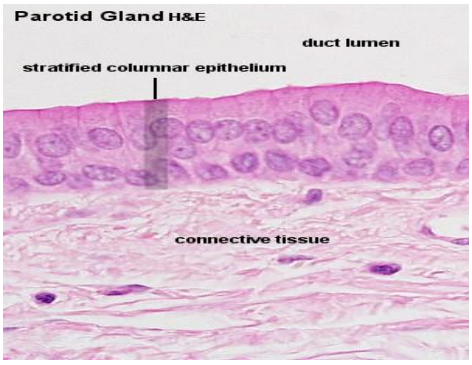
stratified squamous epithelium: sections of the oesophagus or tongue - H&E, van Gieson
stratified cuboidal epithelium: skin (excretory ducts of sweat glands) - H&E
stratified columnar epithelium: sections of the parotid gland or mammary gland - H&E

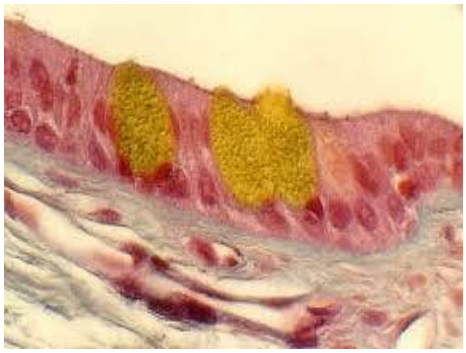
Parotid Gland, human - H&E

Stratified columnar epithelia are found in the largest excretory ducts of some glands. The parotid gland, a large salivary gland, is one of them. Several epithelial types are found in the duct system of the parotid. The smallest ducts, which are embedded in the secretory tissue (intralobular ducts), are lined by cuboidal or columnar epithelia. Small ducts, which are embedded in connective tissue located between areas of secretory tissue (interlobular ducts), are lined by columnar or pseudostratified epithelia. These ducts finally coalesce to form the main excretory duct of the parotid which is lined by a stratified columnar epithelium.

Draw the stratified columnar epithelium seen in the largest ducts and label your drawing.





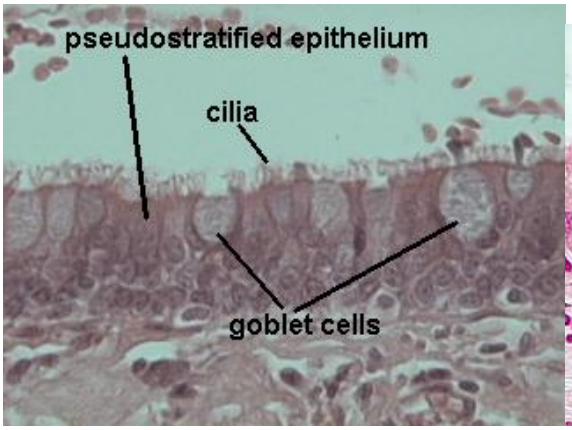


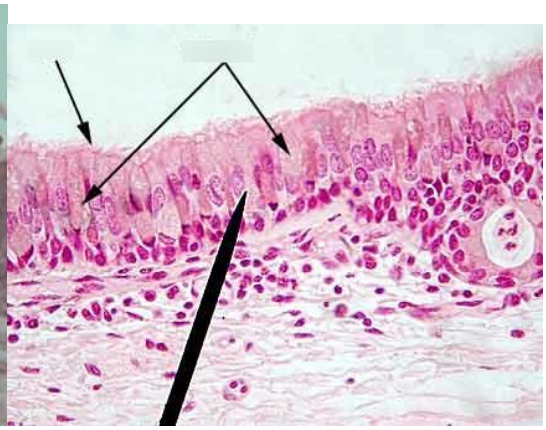
Pseudostratified and Transitional Epithelia

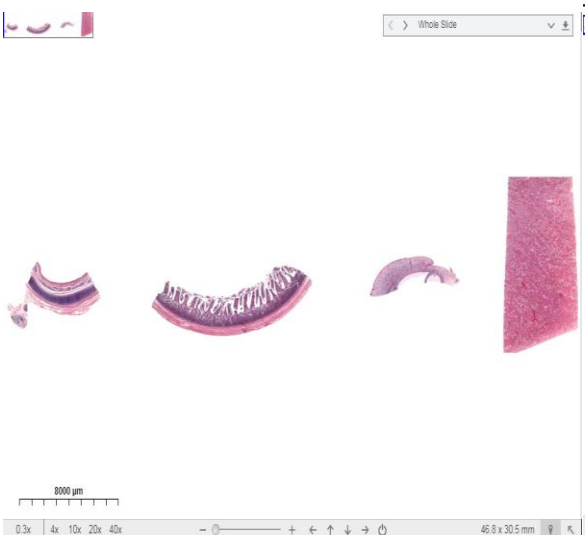
These two types of epithelia are difficult to classify using the shape of the cells in the surface layer and the number of the cell layers as criteria.

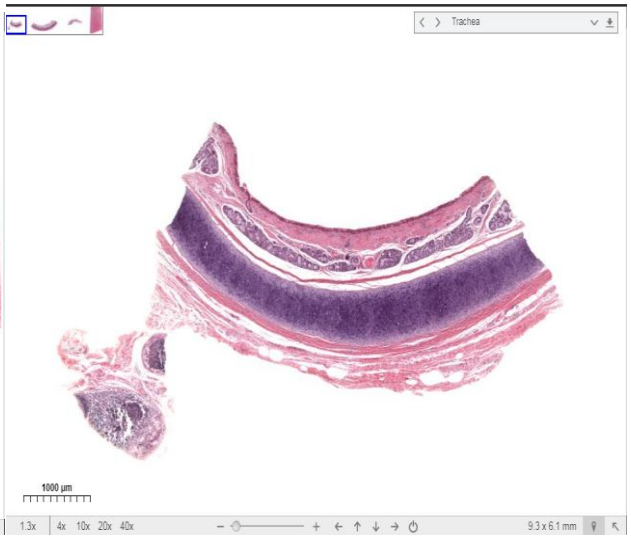
Pseudostratified columnar epithelium

All cells of this type of epithelium are in contact with the basement membrane, but not all of them reach the surface of the epithelium. Nuclei of the epithelial cells are typically located in the widest part of the cell. Consequently, the nuclei of cells which do or do not reach the surface of the epithelium are often located at different heights within the epithelium and give the epithelium a stratified appearance. The epithelium will look stratified but it is not - hence its name "pseudostratified". Pseudostratified columnar epithelia are found in the excretory ducts of many glands.









Pseudostratified Columnar Epithelium

The trachea is a tube that connects the larynx to the lungs allowing the passage of air. It is lined with a pseudostratified columnar epithelium.

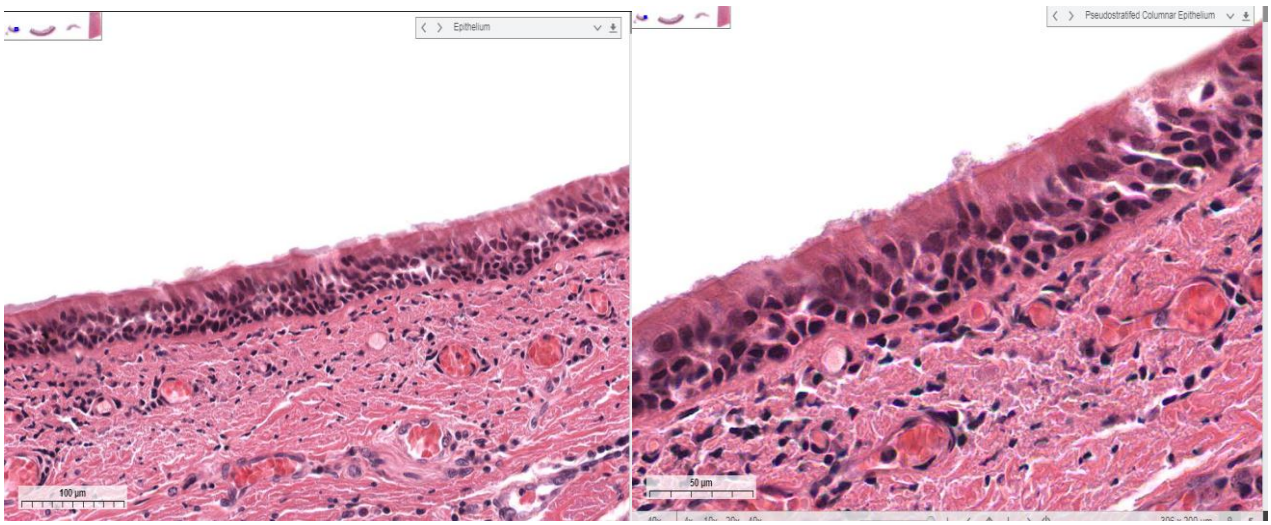
As its name implies, this epithelium appears to be stratified (*i.e.*, has multiple layers of cells) but in fact all of the cells are attached to the basement membrane. Therefore, it is a simple epithelium. The stratified appearance is due to the nuclei of individual cells being present at different levels.

Features of this pseudostratified epithelium:

- Cilia - extend 5 to 7 µm from the surface of the epithelial cells. The dark line at their base is from their basal bodies.
- Goblet Cells - scattered cells that secrete mucus. They are difficult to identify in this specimen, but a thick layer of mucus covers some regions of the epithelium.
- Basement Membrane - the epithelium is separated from the underlying connective tissue by a thick basement membrane. It is seen as an acidophilic band beneath the epithelium.

Since it lines the respiratory tract, a pseudostratified ciliated, columnar epithelium with goblet cells is referred to as the "respiratory epithelium".

The ultrastructure of these epithelial cells is also shown in EM 070 Respiratory Epithelium by transmission electron microscopy.



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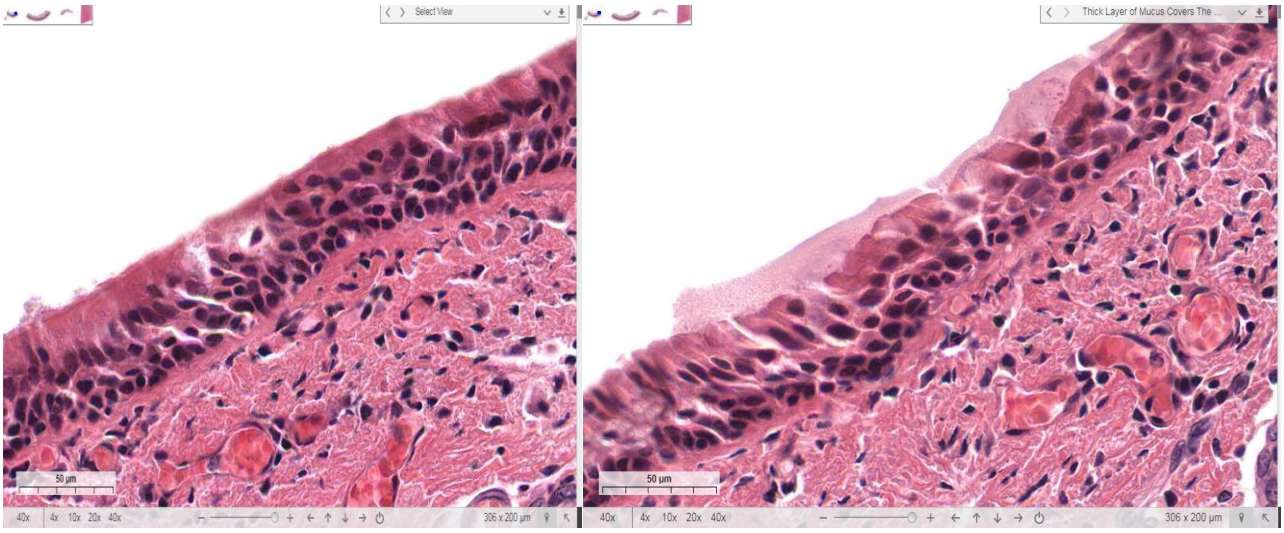

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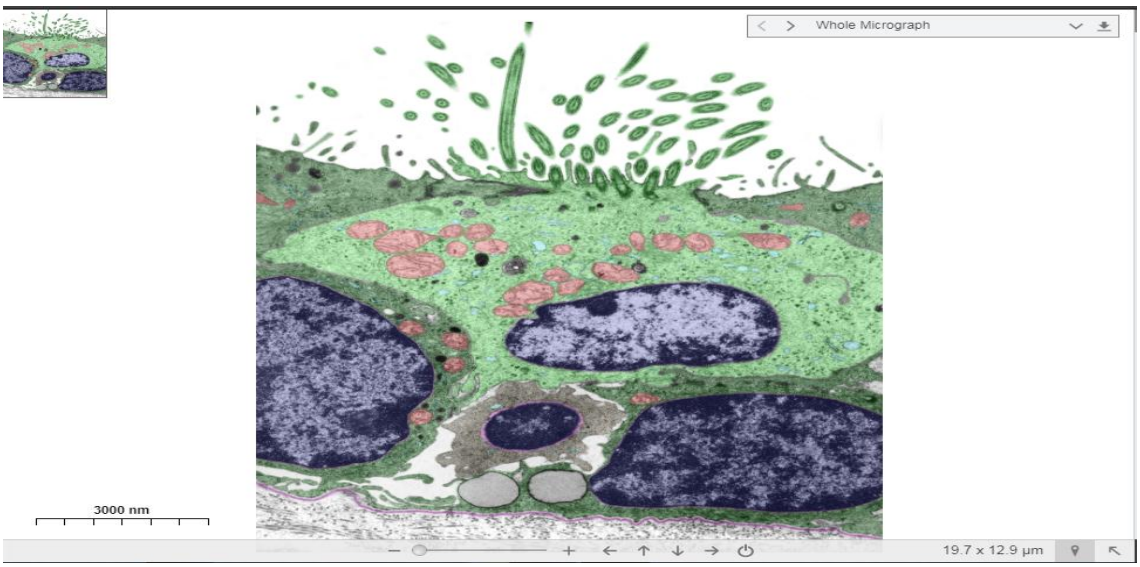


Pseudostratified Columnar Epithelium

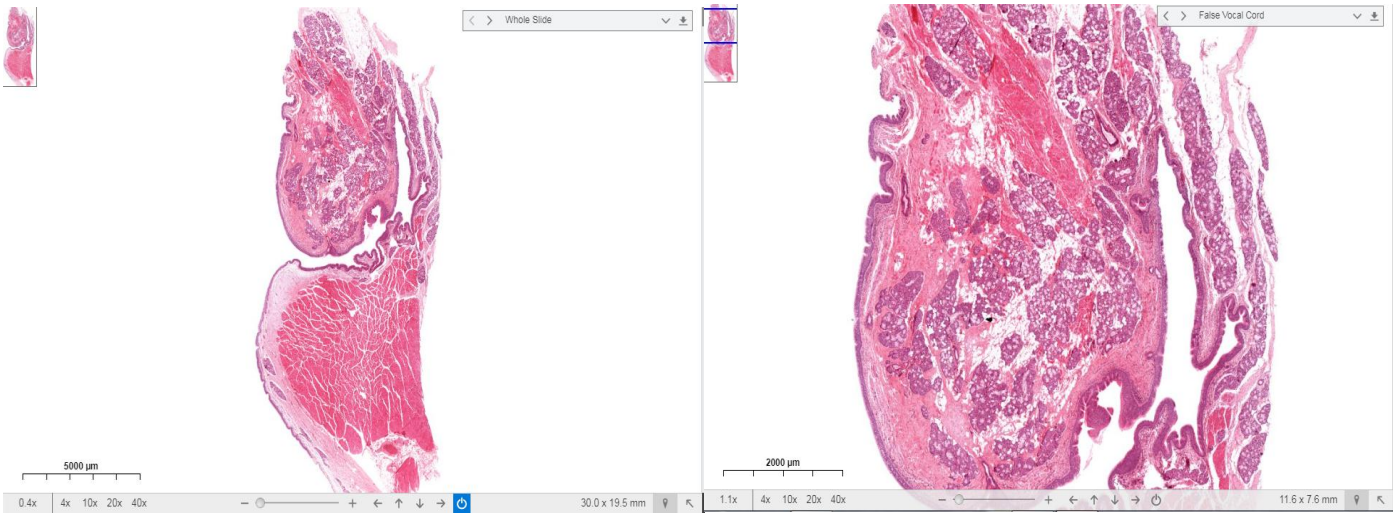
Although a pseudostratified columnar epithelium is a single layer of cells, the nuclei are not aligned in the same plane. This can give the appearance of several layers of cells.

The pseudostratified columnar cells with cilia and goblet cells found in airways is also known as **respiratory epithelium**.

This thin section is from the trachea but no goblet cells are seen in this micrograph. The base of the ciliated cell is not visible.

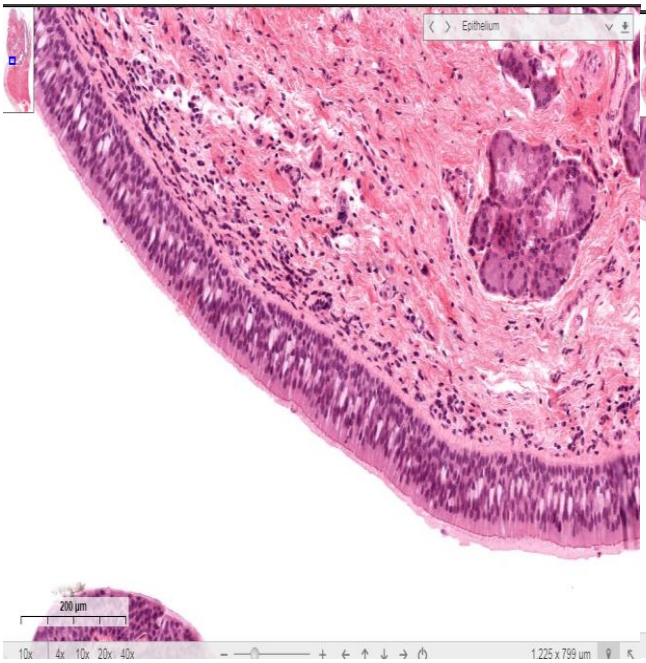
- Nuclei (blue) / Nuclear Envelope (purple)
- Mitochondria (red)
- Endoplasmic Reticulum (cyan)
- Cytoplasm (green)
- Cilia (green) - outer nine doublets and central pair of singlet microtubules are seen in cross sections of cilia
- Basal Lamina (purple) - thin, fuzzy line that separates the epithelium from the underlying connective tissue. It contains a network of reticular, collagen IV fibrils.

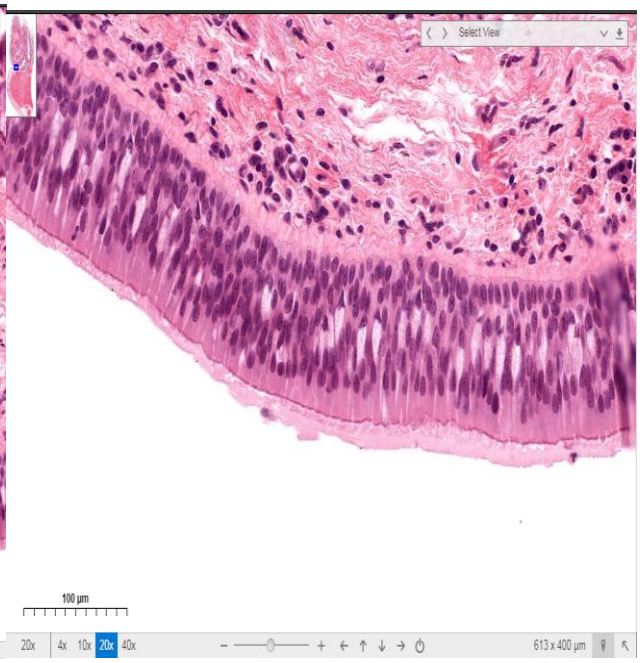
An immune cell (tan) can be seen at the bottom of the epithelium. (Lymphocytes can cross the basal lamina and move into an epithelium.)



Pseudostratified Columnar Epithelium

The upper fold of the larynx, the false vocal cord, is covered by a pseudostratified columnar epithelium.

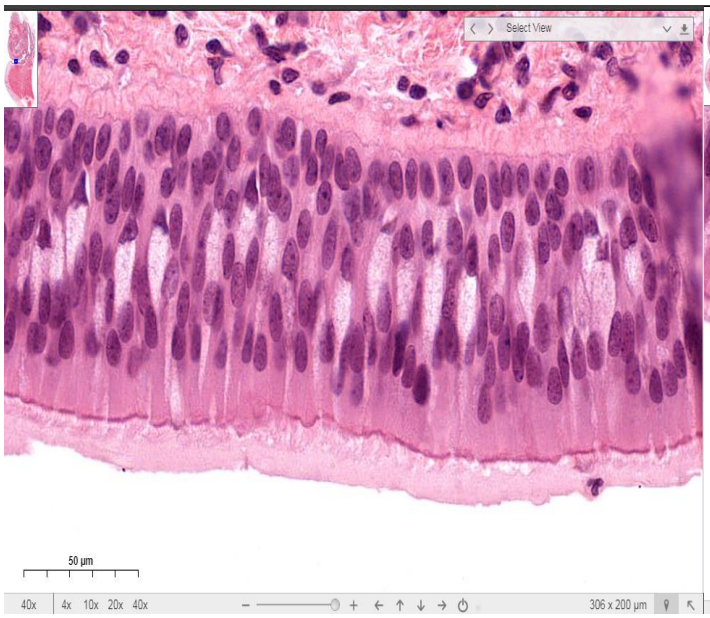


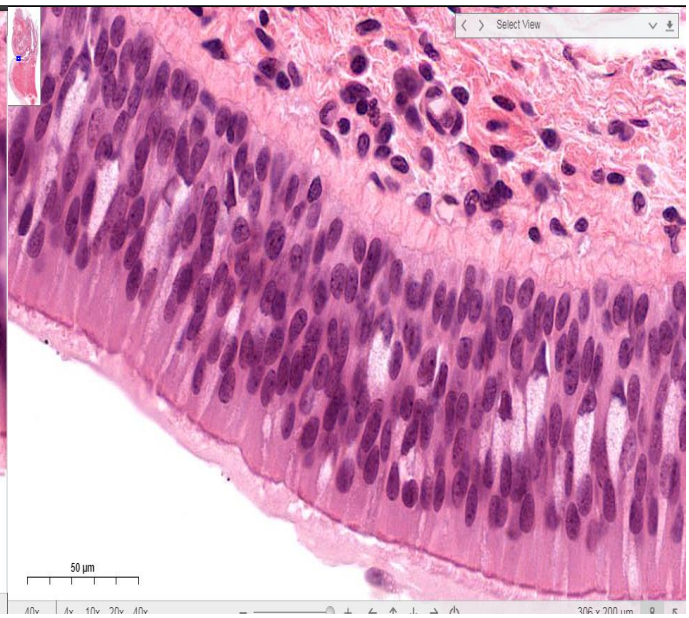


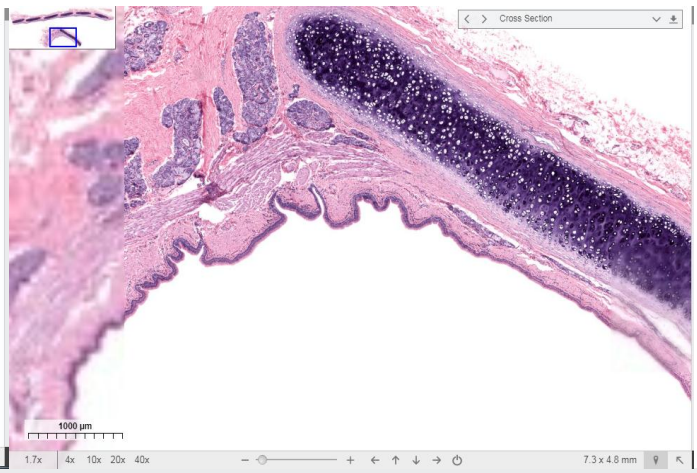
Features of this epithelium:

- Cilia - extend 5 to 7 µm from the surface of the epithelial cells. The dark line at their base is from their basal bodies.
- Goblet Cells - scattered cells that secrete mucus. The secretion granules are clustered within the cells. This is seen as a clear circular area due to the mucus being extracted during preparation of the specimen.
- Basement Membrane - the epithelium is separated from the underlying connective tissue by a thick basement membrane. It is seen as an acidophilic band beneath the epithelium.

Since it lines the respiratory tract, a pseudostratified ciliated, columnar epithelium with goblet cells is referred to as the "respiratory epithelium".

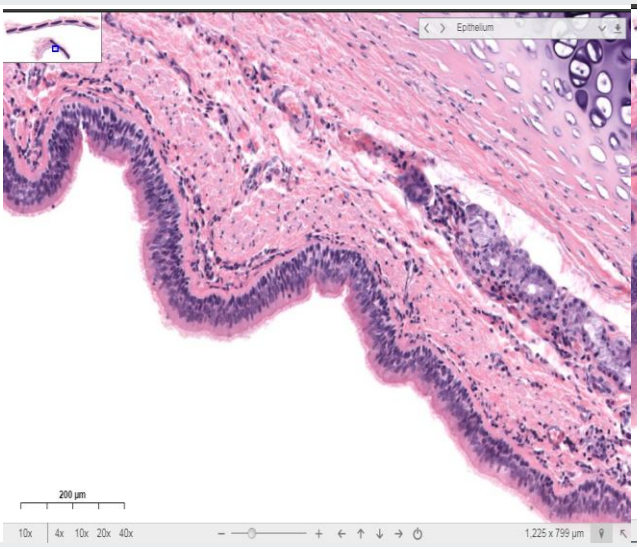


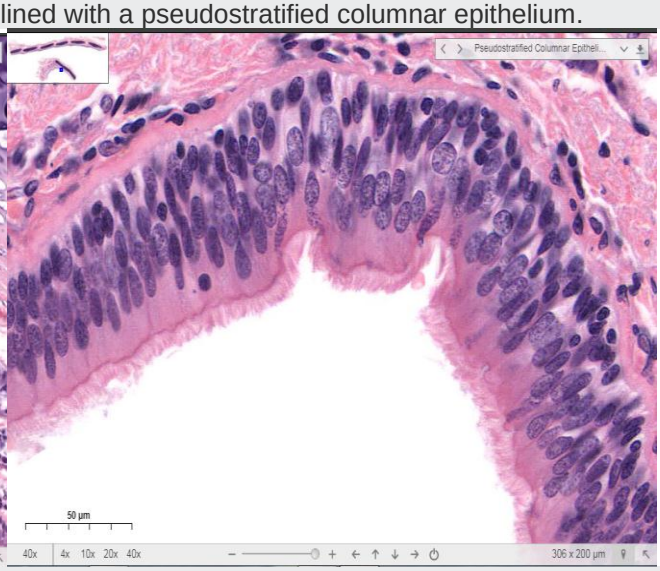




Pseudostratified Columnar Epithelium

Examine the luminal surface of the cross section which is lined with a pseudostratified columnar epithelium.





Features of this epithelium:

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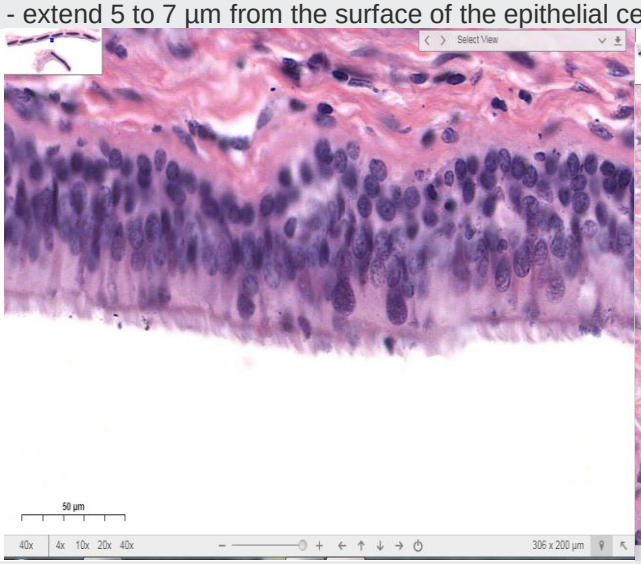
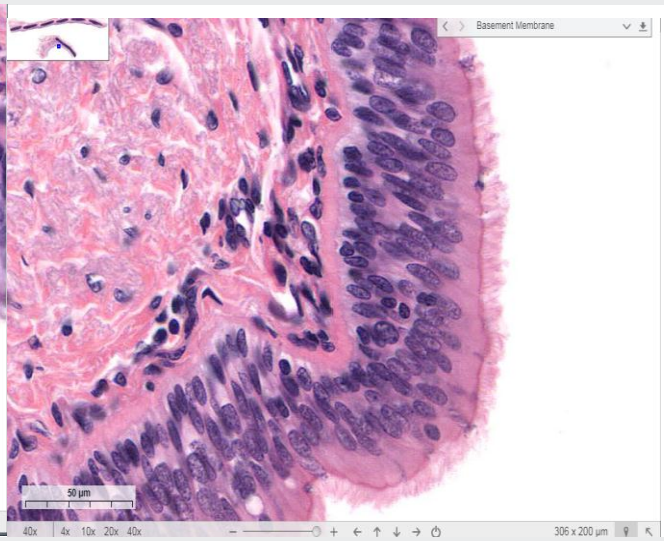
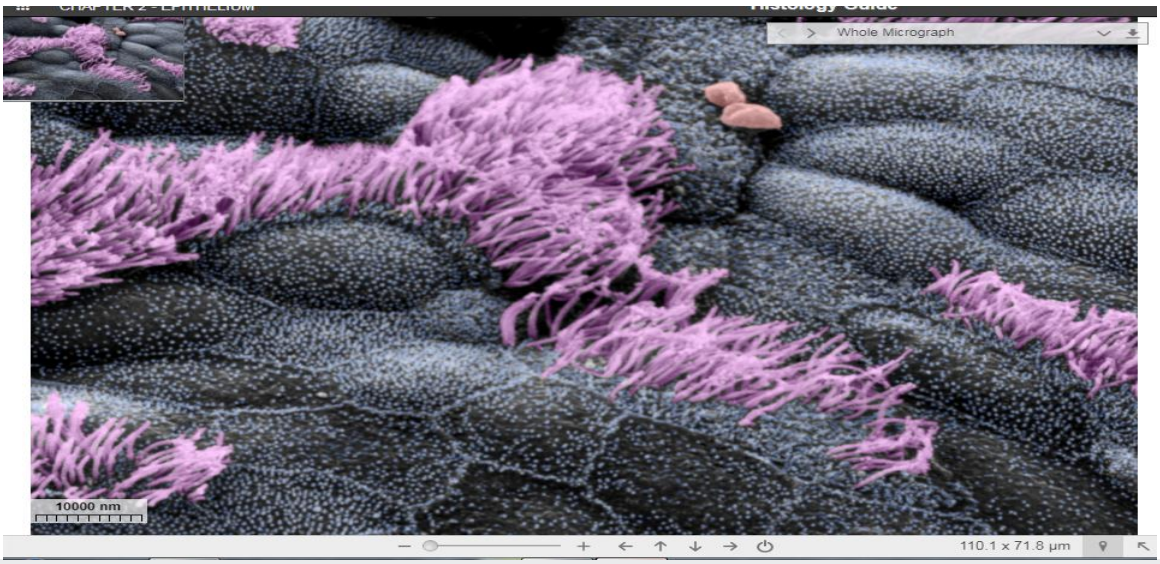




- Goblet Cells - scattered cells that secrete mucus. They can be identified by their cluster of basophilic secretion granules near their luminal surface.
- Basement Membrane - the epithelium is separated from the underlying connective tissue by a thick basement membrane. It is seen as an eosinophilic band beneath the epithelium.

Since it lines the respiratory tract, a pseudostratified ciliated, columnar epithelium with goblet cells is referred to as the "respiratory epithelium".

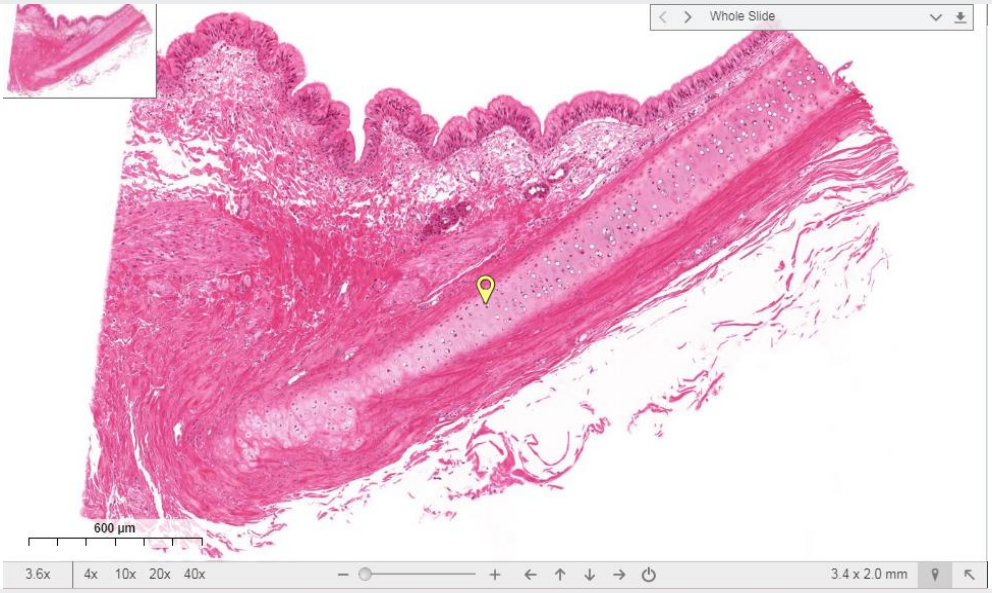


Pseudostratified Columnar Epithelium

Surface of the pseudostratified columnar epithelium that lines the lumen of the trachea.
Although this is a pseudostratified columnar epithelium, the shape of the cells and the number of layers can not be determined from this micrograph.

- Cilia (purple) - only seen on some of the cells (~8 to 10 µm in length and 250 nm in diameter)
- Microvilli (blue) - seen on all cells (~1 µm in length and 100 nm in diameter)

Several red blood cells (red) are seen on the surface of the epithelium.
The pseudostratified columnar cells with cilia and goblet cells found in airways is also known as **respiratory epithelium**.

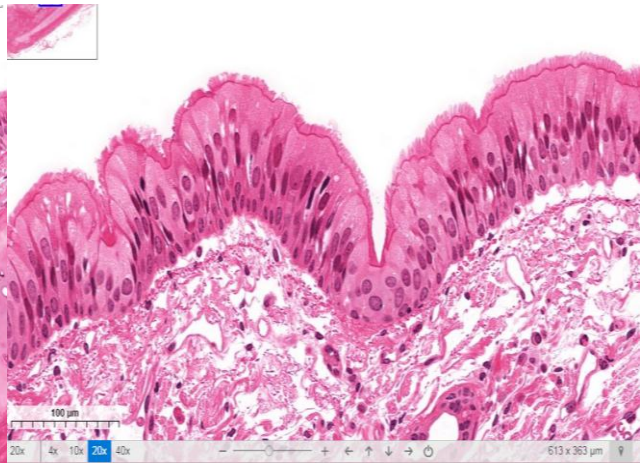


Pseudostratified Columnar Epithelium

The luminal surface of the trachea is lined with a pseudostratified columnar epithelium. In some areas, individual epithelial cells can be identified in this semi-thin section.
Features of this epithelium:

- Cilia - extend 5 to 7 µm from the surface of the epithelial cells. The dark line at their base is from their basal bodies.
- Goblet Cells - scattered cells that secrete mucus. They are difficult to identify in this specimen.
- Basement Membrane - the epithelium is separated from the underlying connective tissue by a thick basement membrane. Difficult to identify in this specimen.

Since it lines the respiratory tract, a pseudostratified ciliated, columnar epithelium with goblet cells is referred to as the "respiratory epithelium".

Transitional epithelium

The shape of the cells varies with the degree of distension of the organ in the epithelium which lines the excretory passages of the urinary system - transitional epithelium. In the "relaxed" state of the epithelium, it seems to be formed by many cell layers. The most basal cells have a cuboidal or columnar shape. There are several layers of polyhedral cells, and, finally, a layer of superficial cells, which have a convex, dome-shaped luminal surface. In the distended state of the epithelium only one or two layers of cuboidal cells are followed by a superficial layer of large, low cuboidal or squamous cells. In the distended state the epithelium will resemble a stratified squamous epithelium.

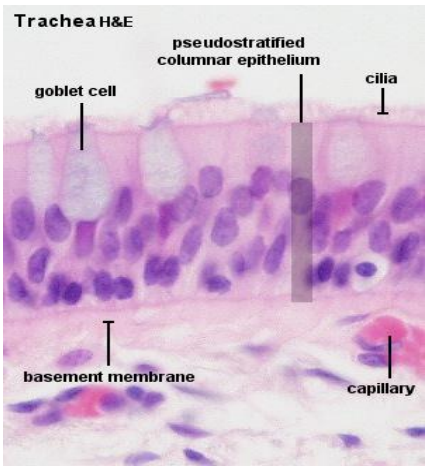
Transitional epithelium is found exclusively in the excretory urinary passages (the renal calyces and pelvis, the ureter, the urinary bladder, and part of the urethra).**Suitable Slides**

transitional epithelium: sections of ureter or urinary bladder - H&E
pseudostratified epithelium: sections of the trachea - H&E
Ureter, monkey - H&E
At a first glance a transitional epithelium looks like a stratified cuboidal epithelium. Several layers of nuclei appear to be topped by a layer

of dome-shaped cells which bulge into the lumen of the ureter. The shape of the surface cells and the number of layers change if the ureter is distended. The number of layers decreases. This decrease should tell us that many of the nuclei located in different layers of the epithelium belong to cells which are all in contact with the basement membrane. With distension, the shape of the cells in the surface layer will become squamous.

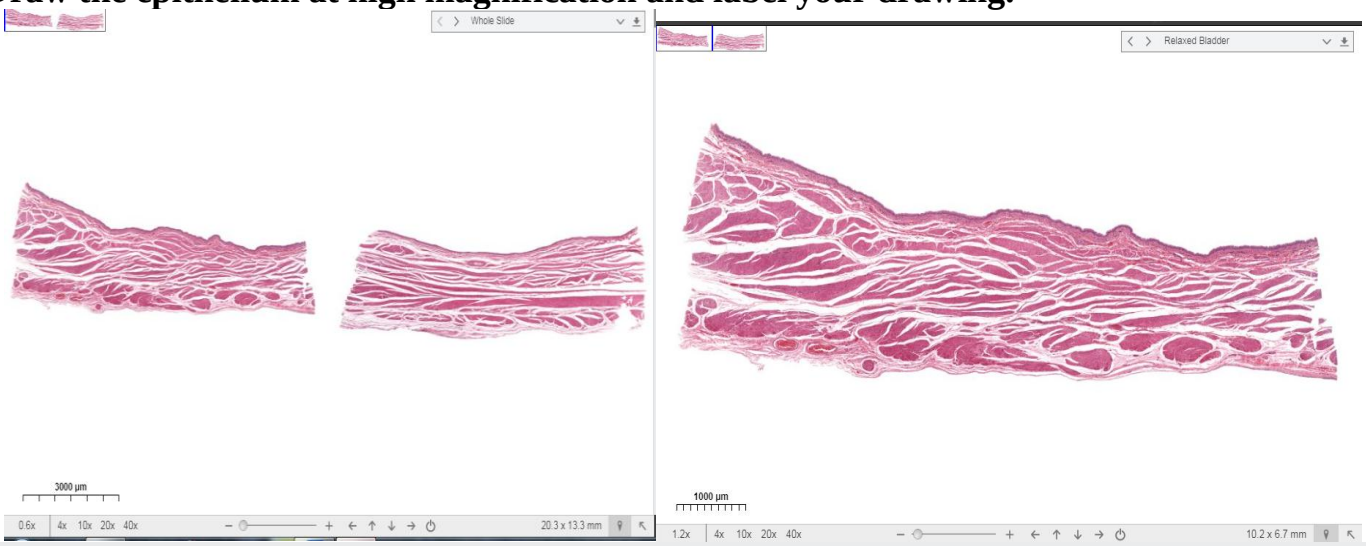
Draw the epithelium and label the features you can see. Add a simple schematic drawing of how you expect the epithelium to look like if the ureter is distended.

It has not yet been resolved if all the epithelial cells are in contact with the basement membrane. Some texts consider transitional epithelium as a specialised stratified epithelium while others group it with pseudostratified epithelia. Maybe it is best to also consider it "transitional" in this regard.



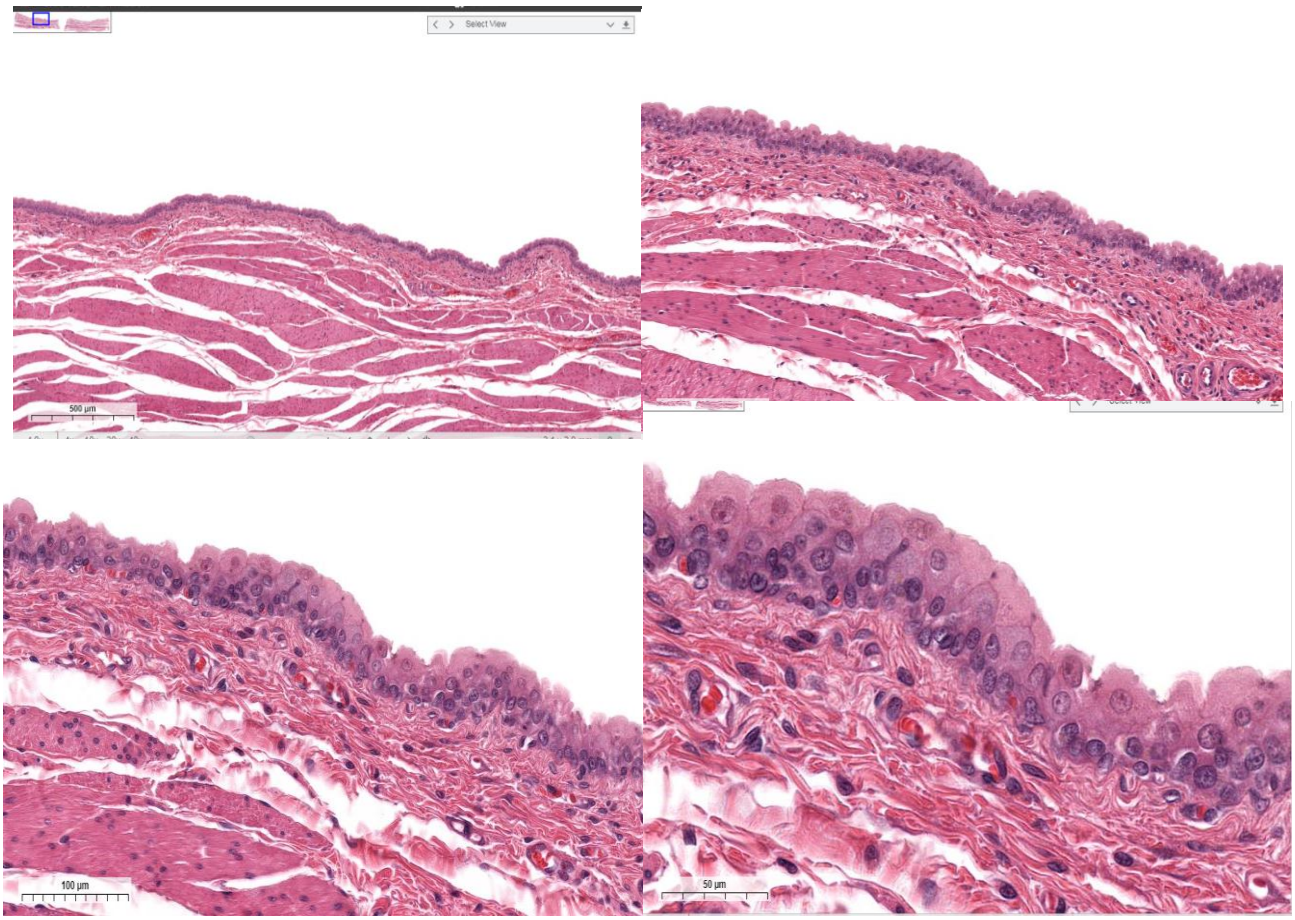
Trachea, human - H&E At least two, sometimes three layers of nuclei are seen in the pseudostratified columnar epithelium lining the trachea. The nuclei belong to cells which are all in contact with the basement membrane. The epithelial lining of the trachea is also one of the few examples of a basement membrane visible in H&E stained sections. Epithelial cells can be ciliated or they can be goblet cells (unicellular exocrine glands). Capillaries and small vessels are visible in the connective tissue beneath the epithelium. A ciliated pseudostratified columnar epithelium with goblet cells is a characteristic feature of parts of the respiratory system, where it is call respiratory epithelium. It contains several cell types in addition to ciliated cells and goblet cells.

Draw the epithelium at high magnification and label your drawing.

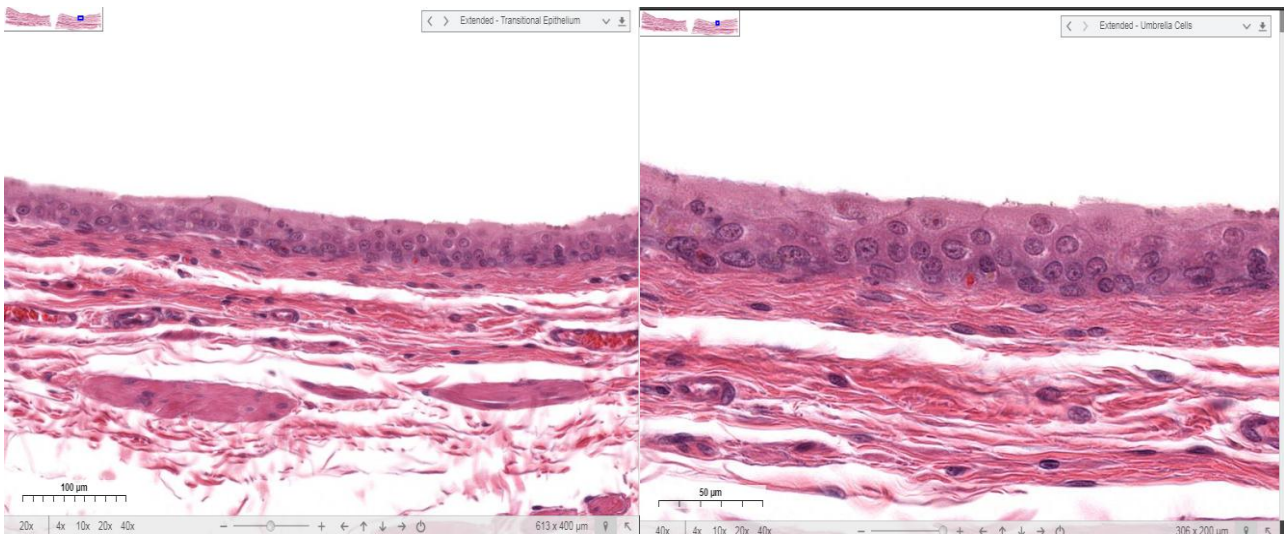


Transitional Epithelium

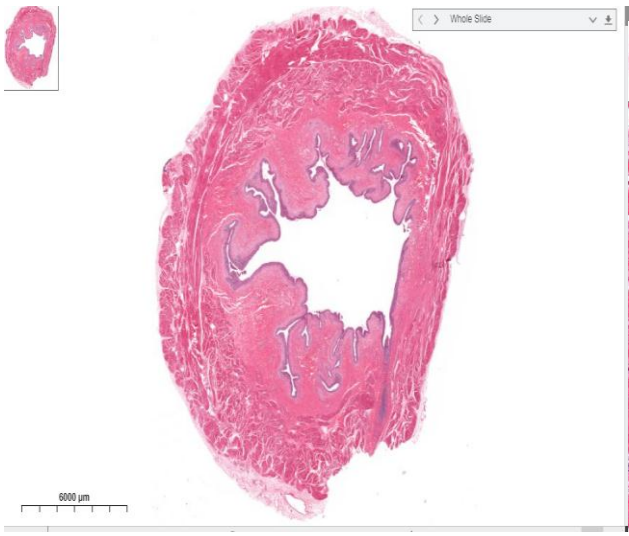
Transitional epithelium (urothelium) is a specialized stratified epithelium found in the lower urinary tract. It rapidly adapts to distention and contraction by changing from a taller to thinner epithelium. Umbrella cells are highly dynamic cells at the luminal surface.



- Relaxed (non-stretched)
  The transitional epithelium has several layers of cells and large, dome-shaped umbrella cells on its surface. (They are called umbrella cells because they cover several underlying epithelia cells.)



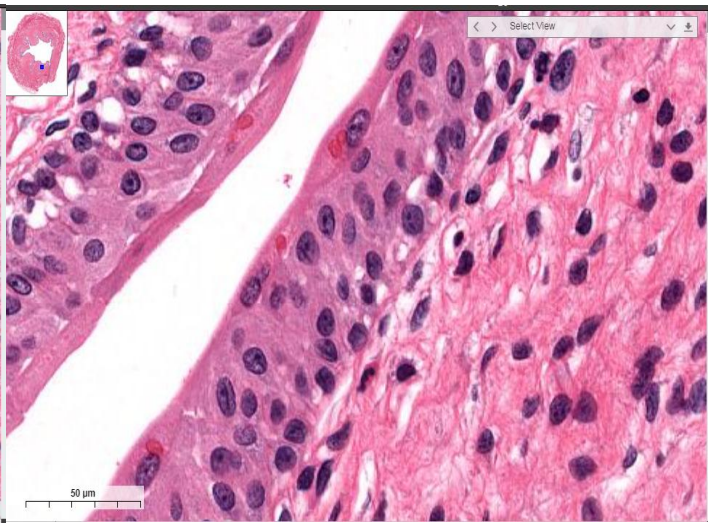
- Extended (stretched)
  The transitional epithelium has become thinner. The umbrella cells have become elongated and flattened.

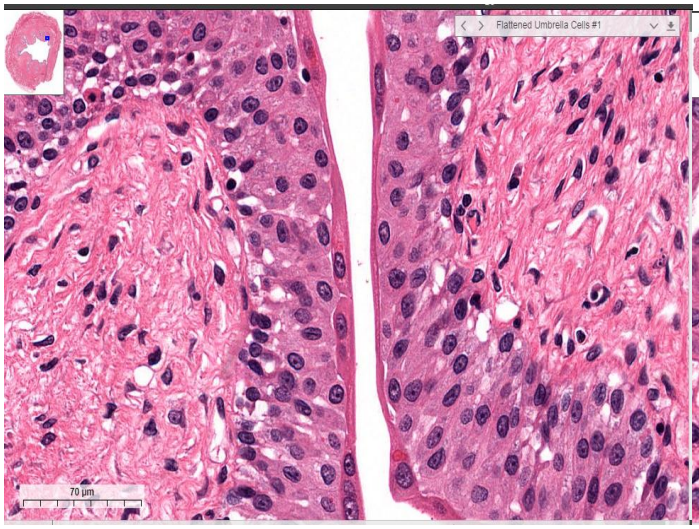


Transitional Epithelia

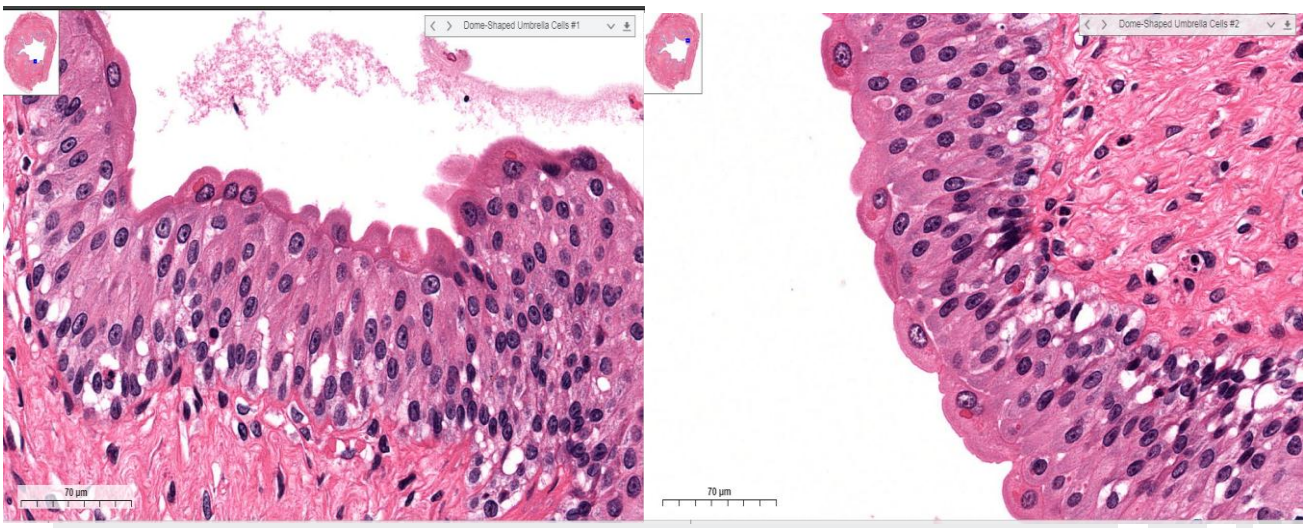
The bladder is lined with a transitional epithelium (urothelium).

This empty bladder contains umbrella cells that are elongated and flattened and others that are round and dome shaped. Their conformation depends on their location within the folds of the bladder.

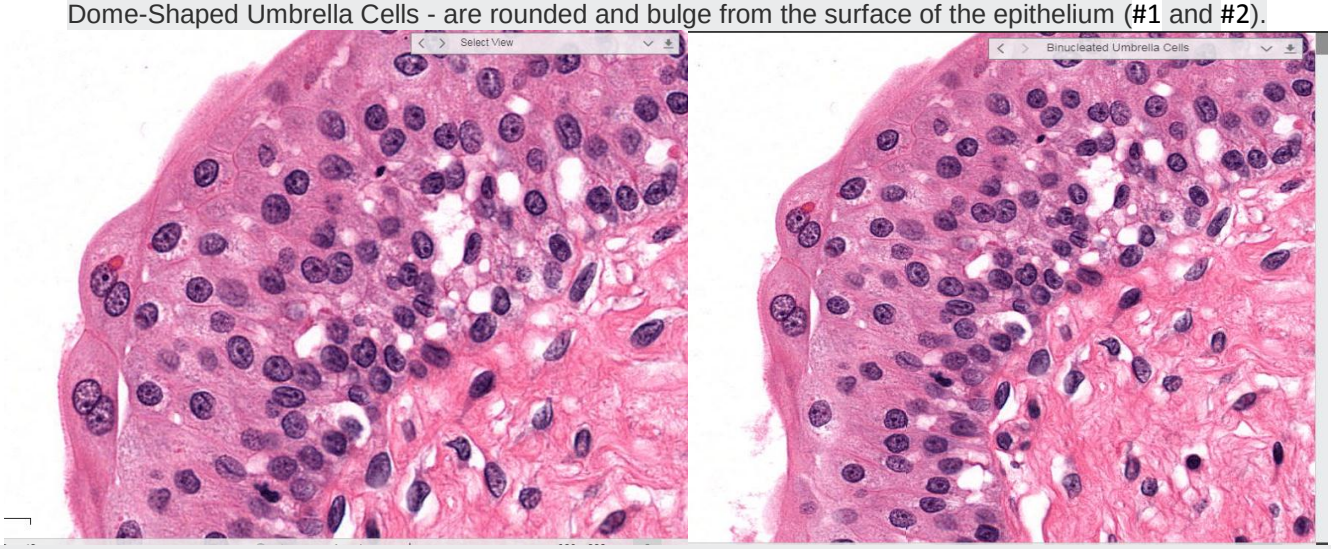




- Flattened Umbrella Cells - stretch over several underlying epithelial cells (#1 and #2).



Dome-Shaped Umbrella Cells - are rounded and bulge from the surface of the epithelium (#1 and #2).



- Bi-Nucleated Cells - have two nuclei.

Special Cytological Features of Epithelia

Basement membrane

Epithelia are separated from the underlying connective tissue by an extracellular supporting layer called the basement membrane. The basement membrane is composed of two sublayers. The basal lamina (about 100 nm thick) consists of fine protein filaments embedded in an amorphous matrix. It is produced by the epithelial cells. The reticular lamina consists of reticular fibres embedded in ground substance. The components of the reticular lamina are synthesised by cells of the connective tissue underlying the epithelium. In addition to its function as support of the epithelium, the basal lamina acts as a selectively permeable filter between epithelium and connective tissue.

Unless special stains are used, the basement membrane is rarely visible using light microscopy. You can read more about reticular fibres and ground substance on the "Connective Tissues" page.

Specialisations of the apical surface Microvilli and stereocilia are finger- or thread-shaped extensions of the epithlial cells. Their main function is to increase the surface area of epithelial cells. They are typically found in epithelia active in absorption. Microvilli contain actin filaments, which are in contact with the terminal web of the cell. The only difference

between microvilli and stereocilia is their length. Microvilli are much shorter than stereocilia. Stereocilia are, despite their name ("cilia"), not actively moving structures.

Using light microscopy, stereocilia are difficult to discern from cilia.

Specialisations of the lateral and basal surfaces
Connective tissue is responsible for the structural integrity of most organs. As mentioned above, it is absent from epithelia and cell-to-cell contact, and tissue integrity has to be taken care of by the epithelial cells. Several specialisations in the lateral and basal parts of the cell membranes of the epithelial cells mediate these functions.

Desmosomes : are specialisations of the lateral cell membranes which mediate cell adhesion. Proteins inserted into the cell membrane of the adjacent cells form a protein-"zipper" linking the cells. Fibers of the cytoskeleton attach to the cytoplasmic side of the desmosome to stabilise the area of contact. Hemi-desmosomes mediate the attachment of the epithelial cells to the basement membrane.
A group of glycoproteins (cadherins) inserted into the opposing plasma membranes mediate cell-to-cell adhesion at desmosomes and also at the adhesion zones or patches mentioned below. Integrins, another group of proteins, allow the cell to attach to the matrix proteins of the basement membrane.
A zone of adhesion (zonula adherens) : is structurally not as well-characterised as the desmosomes. The zonula adherens typically appears as a close and consistent apposition (15-20 nm) of the cell membranes close to the apical cell surface and surrounding the entire cell. Again, fibres of the cytoskeleton insert into the cytoplasmic side of this membrane specialisation.
Additional patches of adhesion (maculae adherentes), which structurally resemble the zonula adherens, are found scattered over the lateral surfaces of the epithelial cell.
The above mentioned membrane specialisations mediate cell-adhesion but are less well suited to support one of the essential functions of epithelia - the isolation of the interior of the body from the outside world. A tight junction (zonula occludens) between epithelial cells mediates this aspect of epithelial function.

Proteins inserted into the cell membranes of adjacent cells "stitch" the membranes of the cells together and provide an effective barrier to the diffusion of substances from the outside of the epithelium (called luminal side if the epithelium covers the surface of a tubular structure). Several "rows of stitches" may be found. Their number depends on the demand to reduce diffusion across the epithelium. Each of these rows reduces diffusion by about a factor 10 of what it was "before".