COVERING EPITHELIUM

The **covering epithelium** falls under the surface epithelium. Their cells are connected by intercellular contacts, so that they closely adhere to each other (the space between the cells almost contains no extracellular matrix). The basal layer of epithelial cells is anchored to the basal lamina, which separates the overlying epithelium from the adjacent connective tissue. Epithelia are avascular; their nourishment occurs through the basal lamina. Epithelial cells are polarized, i.e. their surfaces differ morphologically (basolateral and apical surfaces have different roles), reflecting the functional specialization of the cells. Different organs performing diverse functions are lined by different covering epithelium. Correct identification of the epithelium allows both the diagnosis of the organ and the determination of its function. For the **classification of covering epithelia** it is essential:
- to determine the number of layers or rows of epithelial cells;
- to determine the shape of the superficial (i.e., the most specialized) cells;
- to define the relationship of uppermost cells to the basal lamina.

According to the number of layers/rows, covering epithelia are divided into simple, pseudostratified and stratified.

SIMPLE EPITHELIUM

Simple epithelia are made up of a single layer of cells of the same size, and therefore all cells sit on the basal lamina (and all nuclei are arranged in a single row). According to the cell shape they are classified as:
- Simple squamous epithelium,
- Simple cuboidal epithelium,
- Simple columnar epithelium.

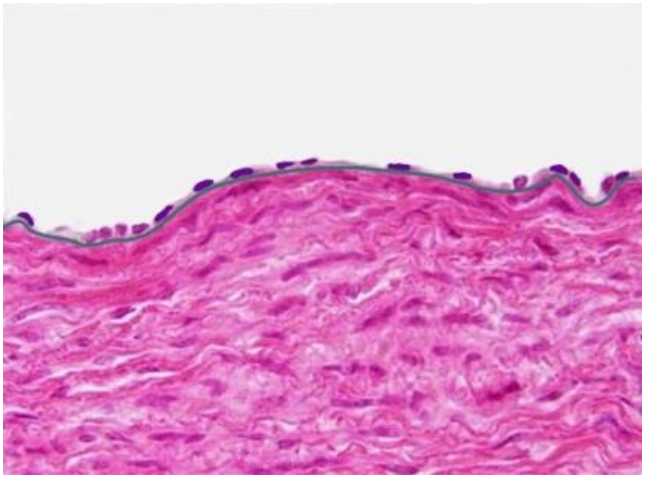
Fig. 1. Scheme of simple epithelia. The description is given on the left of the figure; the basal lamina is shown by the black line under the epithelia.

SIMPLE SQUAMOUS EPITHELIUM

The **simple squamous epithelium** consists of a single layer of flat cells spread over an area. The height of the cells is minimal; the cells are spread out to cover as much surface area as possible. The shape of the cells corresponds to the shape of the nucleus - the nucleus of the cells is also flattened. In light microscopy, the boundaries between the cells are not clearly visible, but the nuclei arranged in a single layer are clearly visible. Below the epithelial cells is the **basal lamina** (visible at electron microscopy level).

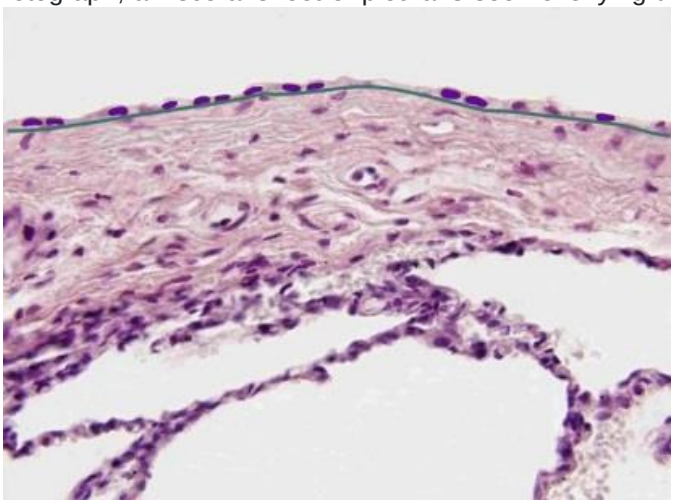
Examples:

Endothelial cells line the lumen of blood vessels. In the microphotograph of the wall of a muscular artery, the covering epithelium - endothelium - is seen on the inner surface (top). The cells are arranged in a single layer and their cytoplasm is flattened - it is a **simple squamous** (flatenned) **epithelium**. The highest point in the cell is the region of the cell nucleus, which protrudes into the lumen. The nuclei are also flattened (marked in blue in the interactive image). At the point of contact between adjacent cells, the cytoplasmic protrusion is the thinnest and difficult to see at the light microscopy. For detailed observation of the epithelial cells, the highest magnification should be chosen. The course of the basal lamina (which is not visible in the optical microscope) is indicated by the green line below the epithelium.



Note: Endothelial cells are very heterogeneous and in some vessels they may have different morphology, e.g. in venous sinuses of the spleen they are spindle-shaped, venules in the paracortex of the lymph node have a high nucleus and on the transverse section they have the appearance of high cuboidal endothelial cells.

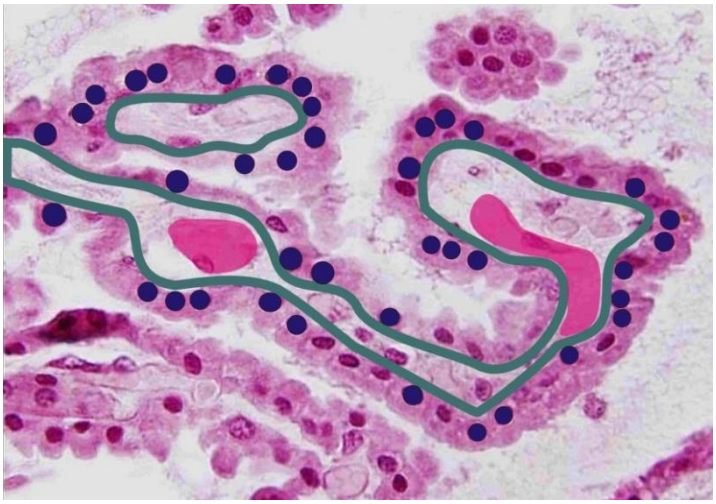
Another example of a simple squamous epithelium is the lining of the serous membranes - the **mesothelium**. In the interactive microphotograph, a visceral sheet of pleura is seen overlying the surface of the lung (lung alveolis are seen in the lower half of the microphotograph). The mesothelium has the appearance of a **simple squamous epithelium**, i.e. its squamous cells are arranged in a single layer. In contrast to the endothelium, the cells of the mesothelium are always the same height and their flattened nucleus (blue) is embedded in the cytoplasm without buldging into the lumen. The boundaries between the cells are not clearly visible. An important feature seen at light microscopy is the single layer of flat nuclei that do not protrude above the surrounding cytoplasm. The **basal lamina** is indicated by the green line. Underneath is the loose connective tissue.



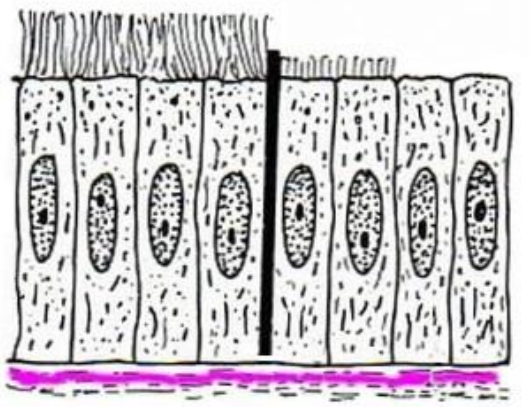
SIMPLE CUBOIDAL EPITHELIUM

The **simple cuboidal** (isoprismatic) **epithelium** consists of a single layer of cuboidal cells lining the surface. The height of the cells is the same as their width. The shape of the cells corresponds to the shape of the nucleus, which is spherical. At light microscopy, the boundaries between the cells are not clearly visible, but the spherical cell nuclei arranged in a single layer are clearly visible. Below the epithelial cells is the **basal lamina** (visible at electron microscopy).

Example: The surface of the choroid plexus is lined by a simple layer of **cuboidal** (isoprismatic) **cells**. Inside the cytoplasm there is a clearly visible **spherical nucleus**. The apical cytoplasm of the cells is slightly convex. The epithelium sits on the basal lamina (its course is indicated by the green line), which separates it from the loose connective tissue of the stromal villi; inside, numerous **blood capillaries** can be seen (two are shown in red), which are lined by a simple squamous **endothelium** with flattened cell nuclei.



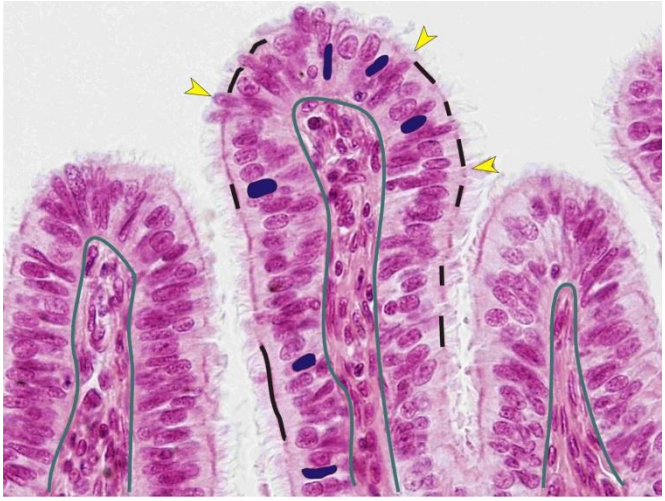
SIMPLE COLUMNAR EPITHELIUM



The **simple columnar** (prismatic) **epithelium** consists of a single layer of elongated cells. The height of the cells is greater than their width. The shape of the cells corresponds to the shape of the nucleus - the nucleus is also elongated along the cell axis (or in secretory cells it can be pushed to the basis). In light microscopy, the boundaries between the cells are not well seen, but the elongated nuclei arranged in a single layer are clearly visible. At higher magnification, structural differentiations of the apical surface such as cilia (kinocilia - in epitehlial cells lining uterus and fallopian tube) or brush border (in enterocytes) are also visible. Some cells lack these structures on their apical surface (e.g., the striated ducts in large salivary glands). Identification of these surface specializations is important for differential histological diagnosis. Beneath the epithelial cells is the **basal lamina**.

Examples of a lining epithelium consisting of a simple columnar epithelium can be found in the mucosa of the intestine or fallopian tube.

The surface of the duodenal villi (and other parts of the small **intestine**) is covered by a **simple columnar epithelium**. The epithelium sits on the basal lamina (its position is indicated by the green line), which separates it from the loose connective tissue of the villi stroma. Note: the basal lamina is not visible at light microscopy; it is an electronmicroscopic structure. Slender **enterocytes** (some stained blue) with elongated nuclei can be found in the lining of the intestinal villi. At the apical pole of the enterocytes, the **brush border** (outlined in black) is clearly visible at higher magnification. Between the enterocytes are bright and broad **goblet cells** (asterisk); their nuclei tend to be pushed towards the cell basis.



The mucosa of the fallopian tube produces numerous abundant folds (three are seen in Fig.). The lining consists of a **simple columnar epithelium**. The cell bodies are slender and elongated; they sit on the basal lamina (the course of which is indicated by the green line). There is one elongated **nucleus** in the cytoplasm of the cells (some nuclei are marked in blue in the interactive figure). Numerous **ciliated cells** can be recognized inside the epithelium. At high magnification, cilia are

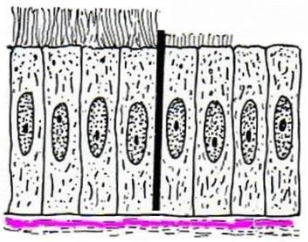
visible as fine tufts protruding from the apical plasmalemma. Just below the plasmalemma, a dark line can be seen (indicated by the black line), which is formed by the **basal bodies** of the ciliated cells being bought up. In **secretory cells** that do not have cilia, this line is absent (arrows) - this is the easiest way to distinguish secretory cells from ciliated cells.

PSEUDOSTRATIFIED EPITHELIA

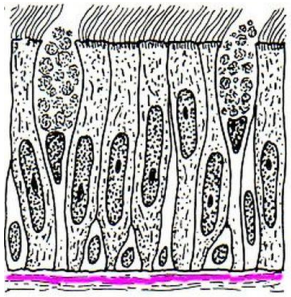
Pseudostratified epithelia are thicker (taller) than simple epithelia. All the cells of the covering epithelium sit on the basal lamina, but the cells reach different heights: the basal cells are the smallest (they are pyramidal or cubic in shape), if there are intermediate cells they are elongated (spindle or tennis racket shaped) and the longest cells reach the surface. Due to the different cell sizes, their nuclei are arranged in multiple rows. For the resulting classification, it is most important to describe the shape of the superficial cells, i.e. the uppermost layer, as these cells are the most specialised and have the most typical morphology; it is also important to register the presence of structural differentiations on the apical cell surface (i.e. the presence of kinocilia or stereocilia). According to the shape of the superficial cells, the following types of cells are distinguished:

- Pseudostratified columnar epithelium
- Pseudostratified cuboidal epithelium

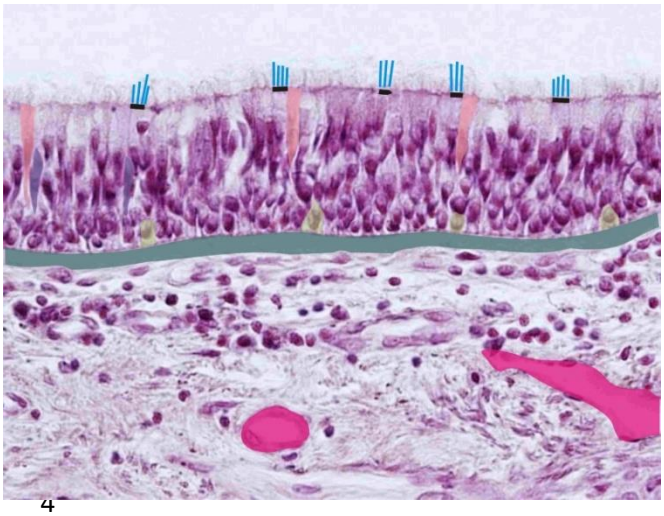
PSEUDOSTRATIFIED COLUMNAR EPITHELIUM



Pseudostratified columnar epithelium consists of both lower basal cells (often triangular in section) and tall columnar cells (i.e. cells of different heights). The cell nuclei are therefore distributed in multiple rows. However, all cells are anchored to the basal lamina. The most common example consists of one row of basal cells and one row of columnar cells. The columnar cells of multi-row epithelia may then have a **free apical surface** (right) or may bear **stereocilia** (left) or kinocilia.



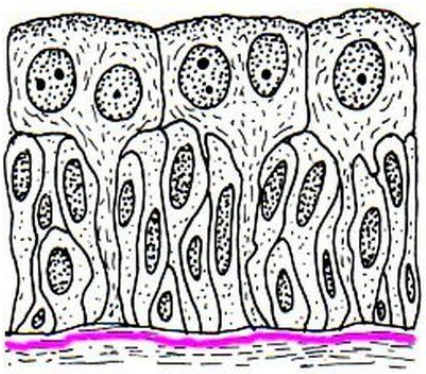
A **pseudostratified columnar epithelium with cilia** lines the respiratory tract and is therefore referred to as the respiratory epithelium. The **respiratory epithelium** is taller and contains more rows of cells and its cells vary significantly in height - but all cells are anchored to the **basal lamina** (magenta). Under the cilia, a dark line is clearly visible under light microscopy by the accumulation of the basal bodies. Another characteristic feature of respiratory epithelia is the presence of **goblet cells** (unicellular intraepithelial glands) producing mucus (normal staining does not stain the mucus and therefore these cells appear bright).



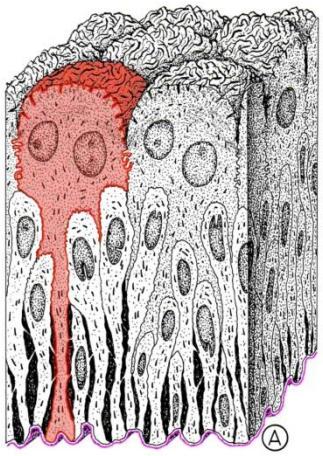
The covering epithelium lining the mucosa of the respiratory tract, including the bronchi, has the character of a pseudostratified columnar epithelium **with cilia**. The epithelium is relatively thick and consists of several rows of cells. The basal cells tend to be triangular (shown in light green) and sit at the base of a thick **basement membrane** that is clearly visible in the light microscope (its course is shown in dark green). The other cells are taller (purple) and their nuclei are located higher up. The most typical cells are those whose apical pole

reaches the surface (pink). These most specialized cells line the surface, are columnar in shape, and therefore their nuclei are elongated. Cilia are located on the apical plasmalemma of these cells (some are shown with blue lines to show their height). Below the cilia, a dark line (shown by the black line) is visible, corresponding to the **kinetosomes**. Numerous blood vessels (red) lined with endothelial cells can be seen in the adjacent loose connective tissue.

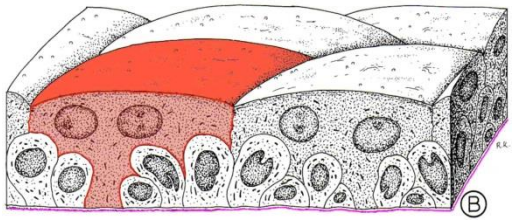
PSEUDOSTRATIFIED CUBOIDAL EPITHELIUM



The **pseudostratified cuboidal epithelium** is composed of cells of varying height and shape (small basal cells, medium tennis racket-shaped cells and huge covering cells), all of which are atteched to the lamina basalis (burgundy). The cell nuclei are thus arranged in several rows; the superficial cells can also be binucleated.In light microscopy, the shape of the large superficial cells resemble a cube (a thin cytoplasmic processus contacting the basal lamina is not clearly visible).

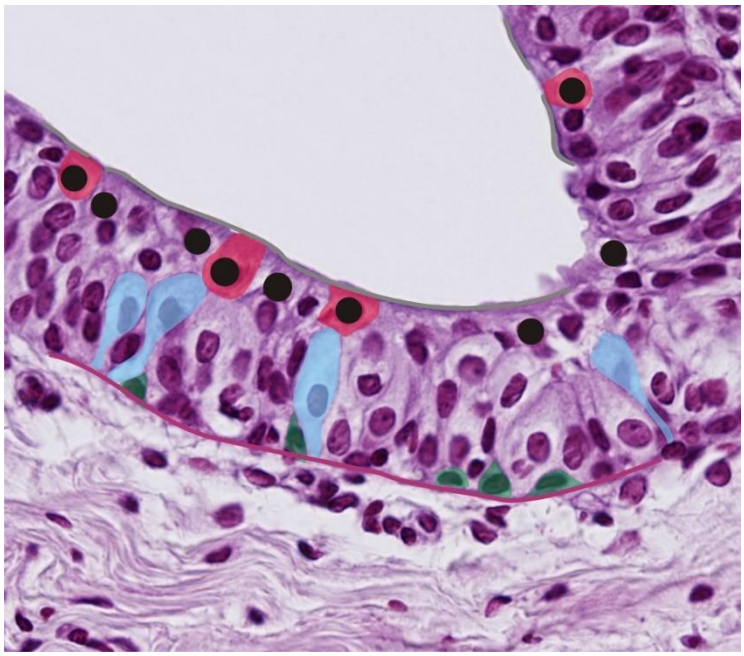


In the empty urinary passages, the epithelial cells have a columnar form (Fig. A). In this state, it is possible to count eight to ten rows of nuclei in the urothelium. The basal epithelial surface is infolded as well as thri lateral and apical surfaces and the apical surfaces of superficial cells are convex. When the urinary tract is filled, the epithelium becomes thinner. In this state, only two to three rows of nuclei are evident (Fig. B). The coherence of the surface is maintained by the reserve folds of the plasmalemma and the discoid vesicles, which fuse with the apical cell membrane upon distension. The name "**transitional**" **epithelium** is derived from these changes that take place in its structure. The name "urothelium" reflects the localization of this epithelium. The basal lamina of the epithelium is coloured in burgundy. For better understanding, one of the superficial epithelial cells is marked red.



The pseudostratified cuboidal epithelium is the covering epithelium of the urinary passages (renal pelvises, calyces, ureters, urinary bladder and part of the male urethra) and is therefore also referred to as the **urothelium**.

Urothelium is classified as **pseudostratified epithelium** because all its cells anchored to the **basal lamina** (coloured burgundy). In the epithelium we find tiny basal cells (one of the basal cells is coloured green), and also elements of the middle zone of the epithelium, which are shaped like a tennis racket (blue), and outermost cells (red), the apical part of which reaches the luminal surface of the organ; with a narrow endfeet attached to the basal lamina. The apical membrane of the superficial cells of the urothelium is reinforced to resist the action of urine. The apical cytoplasm contains spindle-shaped vesicles; these structures are visible in light microscopy as a crust, which is visible as a dark line, the course of which is shown by the grey line.

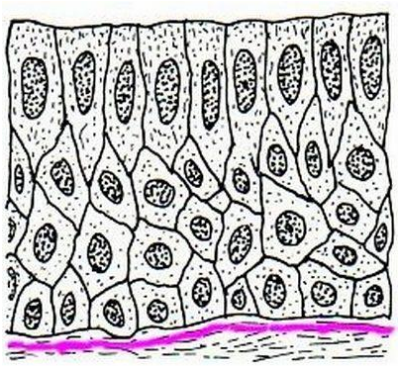


STRATIFIED EPITHELIUM

Stratified epithelium consists of several cell layers, with only the lower layer attached to the basal lamina; the layers deposited above have lost contact with the basal lamina. For the resulting classification, it is most important to describe the shape of the superficial cells, i.e. the uppermost layer, as these cells are the most specialized and have the most typical morphology. According to the shape of the superficial cells, the covering epithelia are classified as:

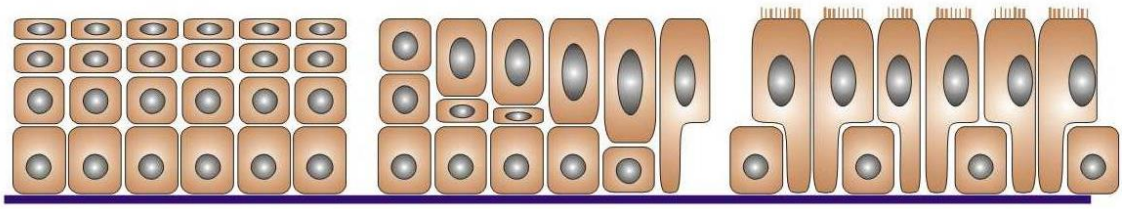
- Stratified columnar epithelium
- Stratified cuboidal epithelium

STRATIFIED COLUMNAR EPITHELIUM



The **stratified columnar epithelium** is composed of multiple layers of cells, of which only the basal cell layer rests its base on the basal lamina. Cells of higher layers always lie only on the cell layer immediately preceding them. The cells of the superficial layer acquire a columnar shape.

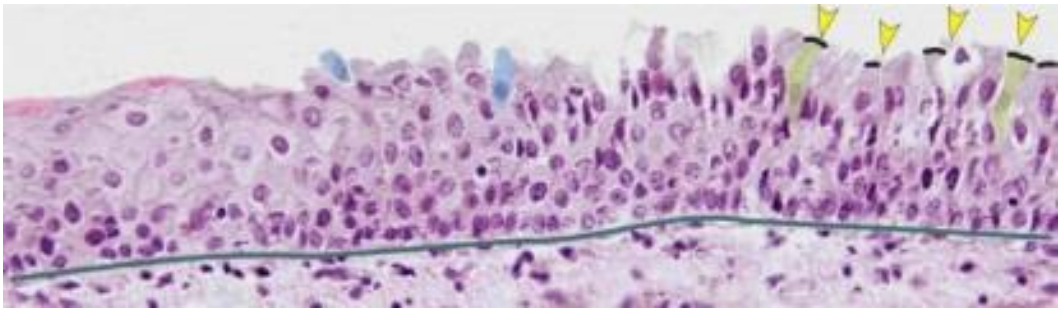
Stratified columnar epithelium is relatively rarely found in the organism. It is mainly the epithelium of the transition zones. It is sandwiched between structurally distinct covering epithelia and allows their mutual connection. An example is the epiglottis of the larynx, which is located at the interface between the respiratory tract (lined by respiratory epithelium, i.e. stratified columnar epithelium) and the upper part of the digestive tract (lined by stratified squamous non-keratinized epithelium). The two epithelia are so structurally distinct that they cannot be joined: in the respiratory epithelium, all cells are seated on the basal lamina (purple), whereas in the stratified squamous non-keratinized epithelium, only the cells of the basal layer are in contact with the basal lamina. The stratified columnar epithelium bears the



Stratified squamous non-keratinized ep. | **Stratified columnar epithelium** | **Pseudostratified columnar epithelium**

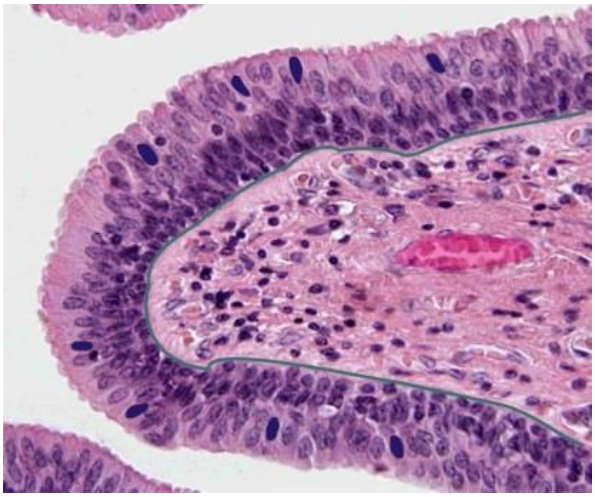
features of both epithelia: it is composed of columnar cells like the respiratory epithelium, while being stratified like the non-keratinized epithelium. By gradually changing the size of the superficial cells, the transition of the stratified squamous epithelium into a respiratory epithelium can be made. Because of this property, the stratified columnar epithelium is referred to as **transition zone epithelium.**

The lining of the epiglottis consists of three epithelia. The **stratified squamous non-keratinized epithelium** (left) is composed of layers of progressively flattening cells (superficial squamous cells shown in pink) and is adjacent to the **stratified columnar epithelium**, the superficial cells of which acquire a columnar shape (blue).



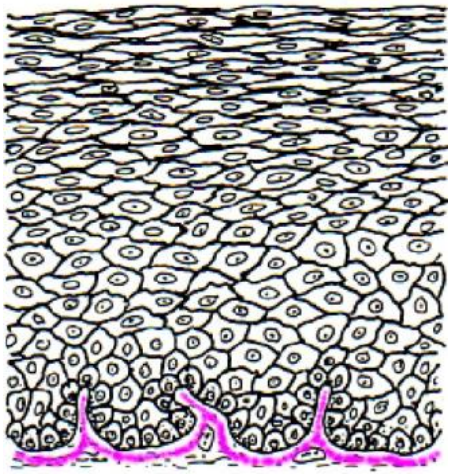
This columnar epithelium transitions into a **pseudostratified columnar epithelium** (right), the superficial cells of which (light green) extend to reach the basement membrane (shown by the green line), which is not clearly visible in the short section shown. However, this epithelium can be clearly distinguished from the stratified columnar epithelium by the presence of columnar cells with cilia (arrows); a thickened dark line (black line) is visible below the base of the cilia, corresponding to the accumulation of the basal bodies.

The spongious part of the male urethra is covered by mucosal epithelium. A detailed view allows unambiguous classification of the epithelium. The nuclei of the lining cells are arranged in several layers, with the superficial cells being columnar (their nuclei are elongated in the longitudinal axis of the cell - some nuclei are coloured blue in the interactive image). This is a **stratified columnar epithelium**. Straight borders between adjacent tall columnar cells are clearly visible. Beneath the basal lamina (indicated by the green line) lies the lamina propria mucosae, composed of loose connective tissue, which contains numerous **blood capillaries** (one capillary lined with endothelium



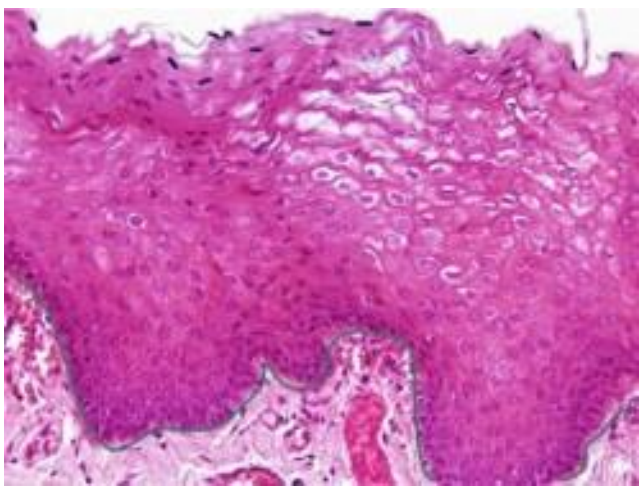
is shown in red). Numerous cells (fixed and wandering cells, especially lymphocytes) can be found around the capillaries.

STRATIFIED SQUAMOUS EPITHELIUM



The **stratified squamous non-keratinized epithelium** forms a lining of mucosal surfaces composed of multiple cell layers that gradually transform into flat cells. Only the basal layer of relatively thick covering epithelium atteached to the basal lamina. The layer of cells distributed above the basal layer no longer has contact with the basal lamina. Towards the surface, the cells gradually become flattenned as well as their nuclei, which are most often visible in the outermost cells (as opposed to cornified epithelia - see below). This type of epithelium is mechanically resistant and therefore lines those parts of the mucosal surfaces that are exposed to certain stress (oral cavity, tongue, oesophagus, vocal cords, etc.).
The **stratified squamous non-keratinized epithelium** covers the outer surface of the cornea and is therefore referred to as the anterior corneal epithelium. Only the lower layer of epithelial cells is in contact with the **basement membrane** (purple). The other cells, which are arranged higher up, are larger and contain tonofilaments in the cytoplasm. The superficial cells become flattened (some are shown in pink), as does their nucleus; eventually the cells lose their nucleus. The covering epithelium shown does not keratinize, i.e. it is of the mucosal type. Other examples of non-keratinized epithelia include the lining of the oral cavity, pharynx, oesophagus, parts of the epiglottis, plica vocalis of the larynx, anus and vagina. The surface of mucosal epithelium is moistened by the secretions of the respective glands, in the case of the cornea by the lacrimal gland.

The **stratified squamous keratinized epithelium** has the basic cell arrangement as the non-keratinized epithelium (see Fig.). The uppermost cell layers are not in contact with the basal lamina (purple) and as the cells mature (differentiate), they progressively become flattened. Basophilic keratohyalin granules accumulate in the cytoplasm of the upper layer of flat cells with flattened nuclei, giving these cells a dark appearance. With further transformation, the cells cornify, lose their nuclei, and transform into mechanically resistant scales that cover the outer surface of the skin, i.e., form the **epidermis**. Depending on the thickness of the stratum corneum, two modifications can be distinguished: thinly keratinized and thickly keratinized epithelium. The **stratified squamous thinly keratinized epithelium** covers most of the surface of the skin; its keratinized layer is thinner than the layers formed by living cells (i.e. containing cell nuclei). The **stratified squamous thickly keratinized epithelium**, covers the surface of the palms of hands and the soles of feet; its keratinized layer exceeds the thickness of the live cell layers.



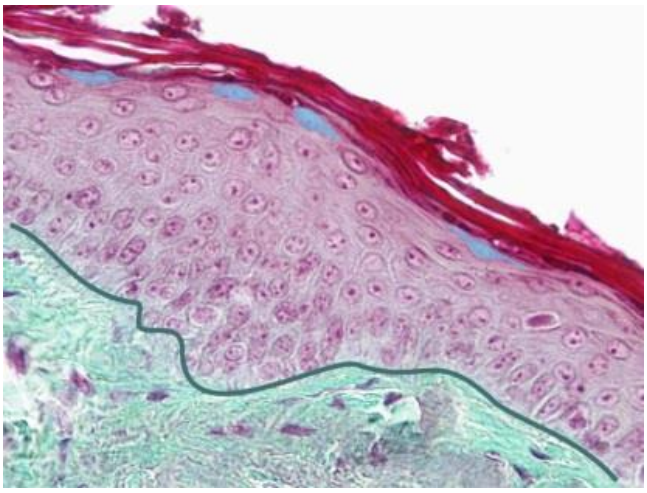
Stratified squamous non-keratinized epithelium

The mucosa of the **lip** is lined by a strikingly thick epithelium, which is composed of a large number of cell layers to provide mechanical resistance and coverage. The individual cell layers are not in contact with the basal lamina (its course is shown by the green line) except for the basal layer. The cells of the middle layer are relatively large, have an oval

nucleus, and the boundaries between the cells can be nicely distinguished. Already these cells begin to flatten and as they move upwards they turn into squamous cells. The cells on the surface have a distinctly **flattened nucleus** whose condensed chromatin is distinctly basophilic and therefore dark (these cell nuclei are shown in blue). Cell nuclei can also be found (in contrast to the keratinized epithelium) in the superficial layer of squamous cells. Under the basal lamina (green), a loose connective tissue (lamina propria mucosae) with numerous blood capillaries (one of which is coloured red) can be found.

Stratified squamous thinly keratinized epithelium

The surface of the **nasal ala** is covered by the **epidemis**. Its epithelium reaches a relatively high thickness because it is made up of many cell layers. The basal layer of epithelial cells is anchored to the basal lamina (its course is outlined in green in the interactive figure), which separates the epithelium from the adjacent loose connective tissue (stained green by trichrome). Epithelial cells and their nuclei are stained purple by haematoxylin-eosin. The cells of the middle layers are polygonal and their nuclei are round or oval. The higher up the cells move, the more they become specialized and flattened (shown in blue in the interactive figure). The flattened cells in the granular layer are stained dark due to the presence of keratohyalin granules. Above this layer is the keratinized layer, which turns red; the cells (scales) lack a cell nucleus. This layer is on the very surface of the epidermis; its thickness is less than that of the cell layers with cell nuclei. Therefore, the epithelium is classified as **stratified squamous thinly keratinized**.



Stratified squamous thickly keratinized epithelium

The depicted covering epithelium reaches an unusual thickness due to a thick **keratinized layer** (red) formed by keratinized **scales** (not containing cell nuclei). Spiral pores pass this layer (shown in blue) representing the terminal compartments of the duct of sweat gland. The gaps (marked with an asterisk) are arteficial. Under the keratinized layer, a dark layer (due to the accumulation of basophilic keratohyalin granules) of **granular layer** can be seen, whose cells, which still contain the nucleus, become flattened (some are shown in yellow). Underneath them, up to the basal lamina (green line), other cell layers (purple) can be seen. The course of the basal lamina is considerably undulating due to the presence of dermal papillae, which strengthen the anchorage of the **epidermis** to the **dermis** and which, through their blood capillaries, provide nutrition to the higher layers of epidermal cells. The papillae contain loose connective tissue and are relatively pale (lower part of Fig.).