

# **EPITHELIUM**

## **INTRODUCTION TO THE CONCEPT OF EPITHELIUM**

Single celled organisms (Protozoa) have very little control of their internal environment. If a group of single-celled organisms become linked together to form a multicellular colony, then there is the possibility for mutual cooperation of cells involving cellular differentiation and specialization for specific functions. The cells at the exterior of the colony can be modified to assume functions related to their position close to the external environment, whereas the cells deeper in the colony can assume different functions. This specialization of function provides added advantages to the multicellular organism. The layer of cells near the periphery can be modified for protection or defence and can prevent fluid loss or desiccation. These cells can also be modified for metabolic purposes such as control of substances taken up by the organism or excreted and for the collection of information or signals from the external environment. These cells at the border between the external and internal environments, the epithelial cells, are extremely important in many aspects of physiological homeostasis.

## **FEATURES OF EPITHELIUM**

Epithelium lines the surfaces of the body and is mainly located on the borders between the external and internal environments. Epithelium also lines all the internal body spaces that have a connection with the external environment at some stage.

Epithelium plays an important role in homeostasis of the body and in maintaining the physiological parameters of the internal environment different from those outside the body.

Epithelium is a tissue composed of cells, tightly-bound to each other, with no intercellular connective tissue. There are specializations of the cell membranes that play roles in maintaining the integrity of the tissue.

Epithelium is an avascular tissue and has no integral blood supply.

Epithelium develops in the embryo from all the three germ layers (Ectoderm, Mesoderm, Endoderm). For example, the epidermis of the skin is ectodermal in origin, the epithelium lining the serous cavities (peritoneum, pleura, pericardium) is derived from mesoderm (and is often referred to as

mesothelium), whereas the epithelium lining most of the intestinal tract is endodermal. The endothelium, lining the blood vessels, is not a true epithelium, as it is derived from mesenchyme (and should be considered as belonging to connective tissue. Moreover, endothelium has no connection at any stage with the external environment.)

## **FUNCTIONS OF EPITHELIUM**

Owing to the strategic location of epithelium at the border between the internal and external environments, the functions of epithelium are many and varied, but can be conveniently divided into two major categories: **protective** or **metabolic**.

**Protective functions** of epithelium include protection against :

- mechanical damage
- loss of fluids (desiccation) - waterproofing
- invasion of foreign bodies

**Metabolic functions** of epithelium include :

- **Exchange of metabolites**, typically described as **ion-transport**. All the substances entering or leaving the body must pass through epithelium and are under its control. The ion-transporting epithelium may become highly specialized for **absorption** or **excretion**.
- The **glandular secretions** of the body by glands (exocrine and endocrine) are mainly a function of specialized epithelium.
- Some epithelia are modified for **sensory reception** including recognition of sensory stimuli such as pain or as chemoreceptors (such as taste buds).

## **Polarity**

Epithelial cells are polarized cells and we can distinguish different areas of the cells (apical, basal, lateral) with specific structural modifications (unlike other tissues, where structural polarity is not found).

Specific structures found on the **apical surface** (the free surface facing the lumen or external environment) include : **microvilli**, **stereocilia**, **cilia** or **flagella**.

The **lateral surfaces** (between adjacent epithelial cells) typically have "junctional complexes" including :

- **tight junctions** (impermeable, enabling the organism to maintain the integrity of its internal environment)
- **adhering junctions (desmosomes)** promoting adhesion and reinforcing the structural integrity and sites for stress fibers
- **communicating junctions (gap junctions or nexuses)**, which allow the exchange of nutrients, ions, signals between adjacent cells).

Epithelial cells are separated from the underlying connective tissue by a **basal lamina**, secreted by the cells themselves. The plasmalemma at the base of epithelial cells, especially those with metabolic function (ion-transporting epithelia) may be modified by having marked invaginations to increase the surface area.

## **MORPHOLOGICAL CLASSIFICATION OF EPITHELIA**

Epithelia are described according to the number of layers they possess and the appearance of the cells at the border adjacent to the external environment.

**Simple epithelia** are composed of a single layer of epithelial cells.

**Stratified epithelia** are composed of more than one layer of epithelial cells.

The histological appearance describing the various epithelia is that seen in vertical sections. It is customary when drawing epithelia to show the free surface directed to the top of the page, whereas the basal surface is depicted in the direction of the bottom of the page.

### **SIMPLE EPITHELIA**

**Simple epithelia consist of a single layer of cells.**

When seen in vertical sections the epithelial cells are described as :

- **squamous** (flattened)
- **cuboidal** (more square or cube-like)
- **columnar** (tall and thin)

If all the cells in the epithelium consist of a single cell type, the epithelium is described as being **homogeneous**. If the epithelium has more than one cell type, the epithelium is described as being **heterogeneous**.

If the apical edge of the epithelium has cilia, the epithelium is described as being **ciliated**.

Epithelial cells that have large numbers of microvilli on the apical or luminal surface (such as the columnar absorptive cells of the small intestine) are described as possessing a **brush border**.

If histological sections of the simple epithelium are cut tangentially, they may give a false impression of being composed of more than one layer (stratified).

## EXAMPLES OF SIMPLE EPITHELIA

**Simple squamous epithelia** line the serous cavities of the body (peritoneum, pleura, pericardium). These epithelia are also known as **Mesothelia** (because of their mesodermal origin). If a small piece of the omentum is removed and examined as a total preparation (thin enough not to need sectioning) it can be seen to be composed of a mosaic of tightly-connected cells. In vertical sections these simple squamous epithelia are seen as very flat, elongated cells.

**Simple cuboidal epithelia** line many small ducts in the body. Examples include the urinary ducts of the kidney, the bile ductules of the liver, or the cells lining thyroid follicles.

**Simple columnar epithelia** line the gallbladder, the larger ducts near the urinary papilla of the renal pyramids and the absorptive cells of the small intestine.

Ion-transporting (metabolic) epithelia are typically simple epithelia.

## STRATIFIED EPITHELIUM

**Stratified epithelia** consist of more than one layer of cells. These typically are at sites needing a more defensive, rather than a metabolic function.

Stratified epithelium is described as squamous when the cells nearest to the external environment are flattened. In typical multilayered epithelium, the cells nearest to the base of the epithelium are more columnar or cuboidal, whereas

the cells nearer to the surface are flatter. The more basal areas are sites of cell proliferation (mitosis) and there is a continuous movement of cells in the direction of the free surface, with the flattened surface cells being sloughed off. **Stratified squamous epithelium** is found in the esophagus and epidermis of the skin. The stratified epithelium of the skin (epidermis) has a layer of keratin and is called a **keratinized** (or dry) epithelium.

### **Pseudostratified columnar epithelium**

Some epithelia give the false appearance of being stratified, but in effect consist of a single layer of irregular columnar cells, all in contact with the basal lamina. Pseudostratified columnar epithelium is the typical epithelial type of much of the respiratory tract. This epithelium also is ciliated and is an example of a heterogeneous epithelium owing to an additional cell type (mucus-secreting unicellular goblet cells). One additional characteristic feature of pseudostratified epithelium is that the nuclei of adjacent cells are not orderly arranged but appear at different levels.

### **Transitional epithelium**

Transitional epithelium is a form of stratified epithelium lining the urinary bladder and part of the urinary tract. This epithelium is subjected to large mechanical changes and can adapt accordingly. If the bladder is empty, the epithelium appears to be thicker and have more layers, than when the bladder is full and distended, in which case, the cells appear more stretched. Transitional epithelium can be recognized by the large rounded epithelial cells lining the lumen (in contrast to other stratified epithelia, where such surface cells are squamous).

### **Basal lamina**

All epithelia lie on a basal lamina, separating them from the underlying connective tissue (*lamina propria*). The basal lamina provides structural support and acts in part as a selective barrier for the epithelial layer. The basal laminae are formed by the cells themselves. In some cases the basal laminae are greatly thickened (as in the glomeruli and filtration system of the kidneys). (The older term "basement membrane" should be avoided). The basal laminae, as seen by transmission electron microscopy, are seen to be formed from an electron-dense layer (50-80 nm thick) composed of **non-fibrous type IV collagen** and the proteoglycan, **heparan sulfate**, surrounded on both sides by a less-dense layer containing the glycoprotein, **laminin**.

Basal laminae are not exclusive features of epithelia, but are also found associated with endothelia and some other cell types.

The border between epithelia and the underlying connective tissue is sharp and distinct. In the case of stratified epithelium this border may be ridged or consist of papillae.

Epithelia are avascular. Blood vessels of the underlying connective tissue (*lamina propria*) supply the necessary nutrients and metabolites, which are transported to and from the epithelial cells by diffusion.

Some epithelia, especially the stratified epithelia of the epidermis and the nasal mucosa may have sensory nerve endings. These help transmit information from the external environment.

### **Proliferation and regeneration**

Epithelia are present in vulnerable sites of the body, where they are continually exposed to the hazards of the external environment. Epithelial cells are constantly subjected to mechanical damage, destroyed, or sloughed off. Epithelia have remarkable proliferative properties and typically show many dividing cells (**mitoses**) in order to replace the cells lost and maintain the integrity of the tissue. In cases of trauma or wounds, the epithelia need to cover the lesion as rapidly as possible, repair the lining tissue and prevent damage to the underlying tissues.

Most of the cancers of the body are the result of uncontrolled proliferation of epithelial cells (aden).

### **GLANDULAR EPITHELIUM**

One of the specialized functions of epithelia is **secretion**.

**Glands consist of groups of epithelial cells modified to synthesize and secrete.**

Glands are classified as:

- **exocrine glands**, which secrete to the external environment via ducts.
- **endocrine glands**, which secrete directly into the blood (**ductless glands**)
- **mixed glands**, which have both exocrine and endocrine secretion.

**Secretion of exocrine glands** is classified as :

(a) **Merocrine (or eccrine) secretion**

This is the most common type of exocrine secretion. Secretory granules (packaged in the Golgi bodies) migrate to the apical surface of the cell. The membranes of the secretory granules fuse with the apical membrane and the secretion is released to the external environment by exocytosis.

(b) **Apocrine secretion**

With apocrine secretion the apical portion of the cells, together with the secretory contents, are budded off and released to the lumen or external environment. Examples of such apocrine secretion are found in the apocrine sweat glands of the armpits.

(c) **Holocrine secretion**

Holocrine secretion involves the secretion of whole cells and their contents. This is best seen in the sebaceous glands associated with hairs of thin skin.

## **CLASSIFICATION OF EXOCRINE GLANDS**

Exocrine glands are classified into two groups:

- **unicellular glands**
- **multicellular glands.**

### **Unicellular exocrine glands**

The main example of a unicellular exocrine gland is the **goblet cell**. Goblet cells are found scattered in the heterogeneous epithelium of mucous membranes, for example, in the pseudostratified epithelium of the respiratory tract or in the absorptive epithelium of the small and large intestine. These glands synthesize and secrete mucin (the precursor of mucus) to the epithelial surface. This mucoid secretion helps lubricate and maintain the moistness of the epithelium, and may also be involved in trapping dust or particulate material and in responding to infection. The nuclei of goblet cells are basally situated and usually are very flattened.

The secretory contents of goblet cells are stained weakly acidophilic (pink staining after H&E) and are stained intensely by the PAS technique owing to their proteoglycan (polysaccharide) content.

### **Multicellular exocrine glands**

Multicellular exocrine glands develop by proliferation and invagination of epithelial cells into the underlying connective tissue. The initial portions develop into the **secretory duct**, whereas the terminal portions develop into the **secretory units**. In cases where the gland develops from simple epithelium, the duct and secretory units are also single-layered (e.g. the exocrine glands of the small and large intestine). In cases where the gland develops from stratified epithelium, the duct and secretory units usually have more than one layer of cells.

The cells of the secretory ducts are typically less poorly differentiated than the cells of the secretory units. All the epithelial cells of both the ducts and secretory units show marked polarity.

Multicellular exocrine glands are classified as **simple** or **compound glands**.

- **Simple exocrine glands** have unbranched secretory ducts.
- **Compound exocrine glands** have branched secretory ducts. The branching is often complex and similar to that of branches of a tree.

The morphology of secretory units in both simple and compound glands is very varied and is described as:

- **tubular (e.g. intestinal crypts of Lieberkuhn)**
- **coiled tubular (e.g. sweat glands)**
- **branched tubular (e.g. Brunner's glands of the duodenum)**
- **alveolar**
- **acinar (e.g. exocrine pancreas)**

and various combinations such as **tubulo-alveolar**

The epithelial components of glands are often referred to as **parenchyma**, whereas the connective tissue components are called the **stroma**. The connective tissue of glands provides support and typically many exocrine glands are surrounded by a **capsule** of connective tissue, which may send out



septa of connective tissue that divides the gland into **lobes** (larger anatomical structures) and smaller functional units, the **lobules**.

### **Secretory cells of exocrine glands**

The secretory cells (of secretory units) of exocrine glands are classified into two histological categories based on their secretory characteristics.

- **Mucous cells.** These are rounded acidophilic cells (typically with basal flattened nuclei), that are rich in glycoproteins (PAS-positive) and produce a mucoid secretion.
- **Serous cells.** These are basophilic cells that are more cuboidal or columnar. The serous cells synthesize and secrete polypeptides or proteins. Their nuclei are fairly centrally located, and the secretory granules may be visible in the apical portion of the cells. The basal region of the cells have accumulations of rough endoplasmic reticulum (RER) that provide the basophil staining.

The secretory units of some exocrine glands are entirely serous in nature (e.g. pancreas, parotid gland), whereas other glands may be mixed with both mucous and serous cells (e.g. submaxillary gland, glands of the fundus of the stomach).

The process of synthesis, storage and secretion in serous cells illustrates the structural and functional polarity of the cells. The RER in the basal region synthesizes the polypeptide or protein molecules, which are transported to the Golgi bodies and packaged into membrane-bound granules. These granules accumulate in the apical region of the cells and as a result of the necessary secretory signals are discharged at the apical surface to the external environment by exocytosis.

Several types of multicellular exocrine glands (of ectodermal origin) have an additional cell type known as the **myoepithelial cells**. These are contractile cells surrounding the secretory units, and when they receive a signal to contract, result in secretory discharge from the secretory cells. Examples of glands with myoepithelial cells include the salivary glands and the mammary glands.

### **ENDOCRINE GLANDS**

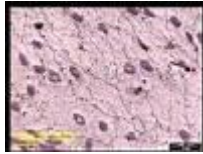
Endocrine glands develop initially in the embryo like the multicellular exocrine glands, however their ducts degenerate and disappear (ductless glands) and the

glands secrete directly into the blood capillaries in the surrounding connective tissue. Endocrine secretions are known as hormones and the endocrine glands form part of a major regulatory system, known as the endocrine system. Endocrine glands, which will be considered later, are very variable in histological appearance and owing to their great structural diversity are hard to classify according to morphology, though the secretory cells may be classified into two major groups:

- **polypeptide (or protein)-secreting cells**
- **steroid-secreting cells.**

The endocrine **polypeptide (or protein)-secreting cells** are typically characterized by well-developed RER (rough endoplasmic reticulum), Golgi bodies and membrane-bound secretory granules. These endocrine cells may be isolated or in small groups (the **diffuse endocrine system**) and include many of the endocrine cells of the intestine. The **APUD concept** was originally conceived owing to the fact that most of the polypeptide-secreting endocrine cells have several common ultrastructural and biochemical characteristics and were thought to have a common embryological origin. It is nowadays accepted that APUD cells of the intestinal tract and respiratory tract are derived from endoderm, whereas the other APUD cells are of neural crest origin. The name APUD is derived from *A*mine *P*recursor *U*ptake and *D*ecarboxylase. This concept is now superseded by the **diffuse neuroendocrine system**, though the term **apudoma** is still used to describe tumors of APUD cells. Polypeptide or protein-secreting endocrine cells are also present in many of the classical endocrine glands.

The **endocrine steroid-secreting cells** (e.g. in the testis, ovary, suprarenal cortex) are characterized by well-developed SER (smooth endoplasmic reticulum) and abundant lipid droplets. The mitochondria of these cells have tubular cristae (unlike the typical lamellar cristae of other cell types).



Ep. Simple Squamous Epithelium  
Simple Columnar Ep.

Simple Cuboidal Ep.

Simple Cuboidal



Ep. S. Columnar Heterogeneous Ep.  
Stratified Squamous Ep

Pseudostratified Columnar Ep.

Stratified Squamous



Transitional Epithelium

Goblet Cells

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