

Chapter 3

Epithelial Tissues

3.1. General Features

Epithelia are single or multiple sheets of cells where the cells are closely opposed to one another with little intercellular material. All surfaces of the body, excepting the joint cavities, are covered or lined by epithelium. Epithelium then serves as a barrier to seal and to separate the organism from various external and internal environments. It covers all of the body's exterior surfaces (ex; epidermis, cornea). It lines all passageways which connect either directly or indirectly to the exterior (ex; digestive, respiratory, and urogenital tracts). Epithelium lines the blood vessels and the heart's interior (i.e.; Endothelium). It lines all of the closed coelomic cavities (e.g.; pleural, pericardial, and peritoneal). This epithelium is called Mesothelium. Epithelium lines all invaginations of the body's surface epithelia (e.g.; glands). Epithelia rest on a Basement Membrane and an underlying layer of loose connective tissues. The basement membrane is acellular.

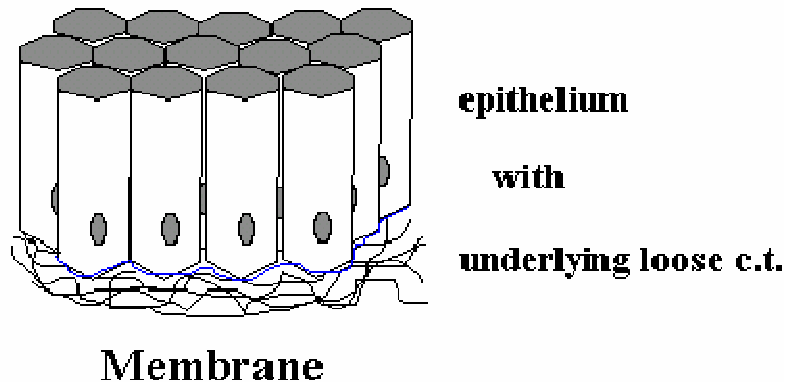


Fig.3.1. General Features of Epithelium

Epithelial are, generally, avascular. Blood vessels from the underlying connective tissues do not penetrate the epithelium. Instead materials diffuse between the epithelial cells and the blood. The majority of the body's glands develop as invaginations of epithelia into the underlying connective tissues.

There are two classes of glands: Exocrine and Endocrine. All bodily surfaces are more or less "active" with a continuous flux of materials across the epithelium in either one or two directions. Virtually everything that enters or exits the body passes through, is synthesized by, or is modified by the epithelium. Epithelial tissues have a strong regenerative capability. Epithelial tissues are "plastic" being able to undergo Metaplasia when local environmental conditions become chronically altered.

Metaplasia is the morphological and/or functional transformation from one type of tissue into another type of the same class. Epithelia are diverse in origin. They are derived from all three of the primordial germ layers. This property helps to contribute to the diverse structures of epithelium. Epithelial tissues have a diversity of functions including: protection, lubrication, digestion, absorption, transport, excretion, sensory reception and transduction, reproduction and secretion (ex; sweat, oil, milk, HCl, mucus,

enzymes, hormones, bile salts, urine, and gametes).

3.2. The Classes of Epithelia

Epithelial tissues are broadly divided into three superclasses which, in turn, are subdivided. The three superclasses are: surface epithelia, glandular epithelia and special epithelia

3.2. 1. Surface Epithelia

The surface epithelia are distinguished and classified primarily on the basis of two criteria: the number of cell layers and the height/shape of the cells. Also, in certain epithelia, the free surface of the outermost cells may be structurally specialized for particular functions. In such cases these surface specializations are also used to classify the epithelium.

a) The Types of Surface Epithelia

1) Simple Epithelia - simple epithelia consists of a single layer of epithelial cells over a basement membrane.

a] Simple Squamous Epithelium - a single sheet of flattened, scale-like cells. "Squamous" means scale-like and refers to the fact that these cells are much wider than they are tall. Simple squamous epithelium is found in areas such as small glandular ducts, the mesothelium lining the closed coelomic cavities (e.g.; pleural, pericardial, and peritoneal), the endothelium lining the blood vessels, heart, and lymph vessels, respiratory bronchioles and alveoli, Bowman's capsules and loops of Henle in the kidneys. Functionally simple squamous epithelium is well suited for sites of fluid, metabolite, and gas exchange.

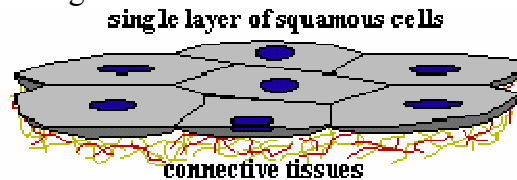


Fig.3.2. Simple Squamous Epithelium

b] Simple Cuboidal Epithelium - a single sheet of hexagon-shaped cells. These cells are called "cuboidal" because they appear to be cube-shaped under the light microscope being of equal height and width. Cuboidal epithelial cells will typically have a centrally positioned nucleus.

Simple Cuboidal Epithelia

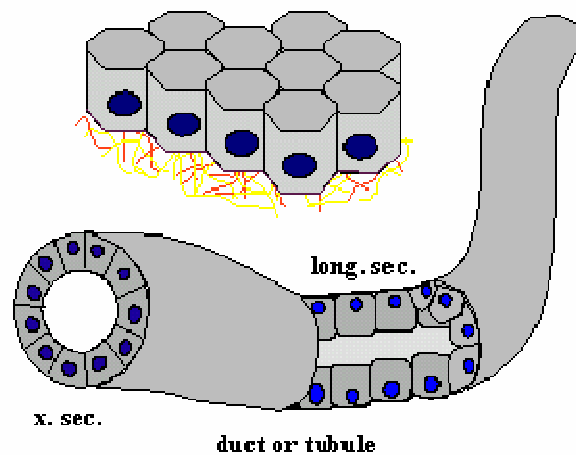


Fig.3.3. Simple Cuboidal Epithelium

Simple cuboidal epithelium is found in areas such as glandular termini and ducts, the parenchyma cells of the liver (i.e.; hepatocytes), rete testis, covering the free surface of the ovary (i.e.; germinal epithelium) and certain portion of the renal tubules (i.e.; thick segments). Functionally simple cuboidal epithelium may simply line conducting passageways (ex; glandular ducts) or may be structurally adapted to play important roles in secretion or absorption (ex; the proximal and distal convoluted tubules of the kidneys).

c] Simple Columnar Epithelium - a single sheet of polygon shaped cells. These cells are called "columnar" because they appear to be column-shaped under the light microscope being of a much greater height than width. Typically, columnar epithelial cells will typically have a basally positioned, ovoid nucleus. Simple columnar epithelium is found in places such as, the ducts of many glands, lining the stomach, intestines, and gall bladder, some of the small respiratory passageways and portions of the oviducts and uterus.

Functionally simple columnar epithelium is well designed for absorption (ex; intestinal epithelium) and secretion (ex; uterine secretory cells). In some cases simple columnar epithelial cells will have cilia on their apical surfaces.

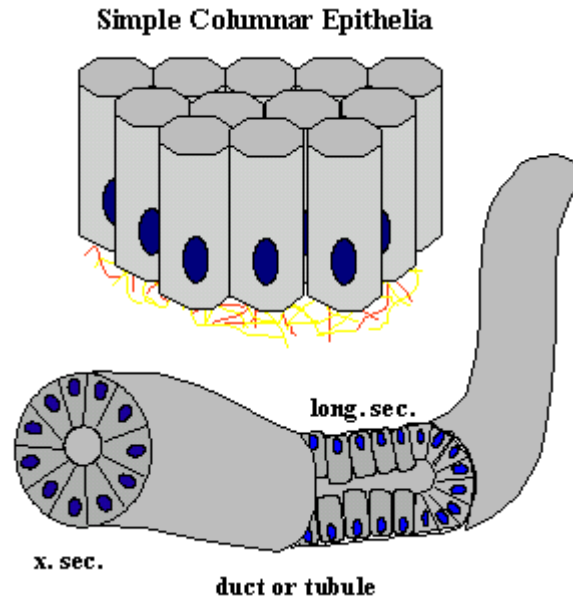


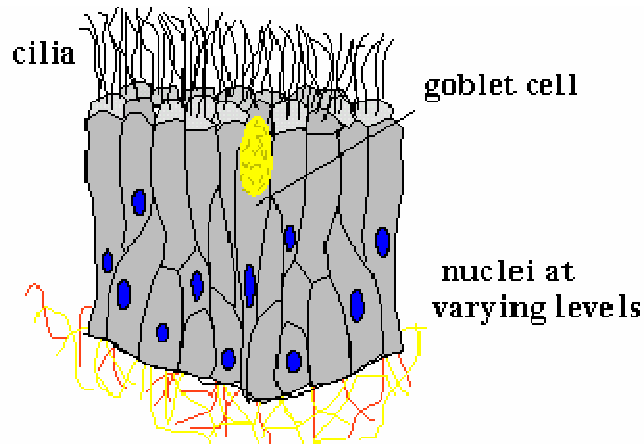
Fig.3.4. Simple Columnar Epithelium

d] Pseudostratified Columnar Epithelium - a single sheet of irregularly shaped cells giving the appearance of more than one cell layer. Pseudostratified epithelium is not truly stratified. It only appears to be since not all of the cells reach the free surface of the tissue, the nuclei of the cells are on two or three levels, the cells appear to be crowded due to their varying shapes.

However, if observed closely, all of the cells are in contact with the basement membrane and so are only one layer. Pseudostratified columnar epithelium can be found in places such as: most of the respiratory passageways, eustachian tube and portions of the middle ear, portions of the male urethra, portions of the male accessory sex organs

Functionally pseudostratified columnar epithelium is designed for lining, secretory, and absorptive roles. The pseudostratified columnar epithelium lining the respiratory tract are ciliated and the tissue will contain mucus producing goblet cells. So, this epithelium is called pseudostratified ciliated columnar epithelium with goblet cells. The cilia will move substances across the surface of the tissue adding to its functionality.

The pseudostratified columnar epithelium of the ductus epididymides and of the ductus deferens possess numerous elongated microvillae called stereocilia and so the tissue is termed pseudostratified columnar epithelium with stereocilia.



3.5. Pseudostratified Epithelium

2) Stratified Epithelia – They consist of two or more sheets of epithelial cells with only the basal layer being in contact with the basement membrane. This is largely a protective group guarding the body from wear and stress.

i} Stratified Squamous Epithelium - this multilayered tissue's outermost cells have a flattened, squamous appearance. The deeper cells may be less squamous in appearance, being cuboidal or even columnar in shape in certain cases, but classification is based on the outermost layer in stratified epithelia. There are two groups of stratified squamous epithelia:

a} Stratified Squamous Nonkeratinized, or Mucus Type : The surface cells contain visible nuclei and lack keratin. It is found on the surfaces of moist cavities or passageways which open onto the body surface such as the: mouth, pharynx, esophagus, vagina, and anal canal.

non-keratinized stratified squamous

living, nucleated cells at surface

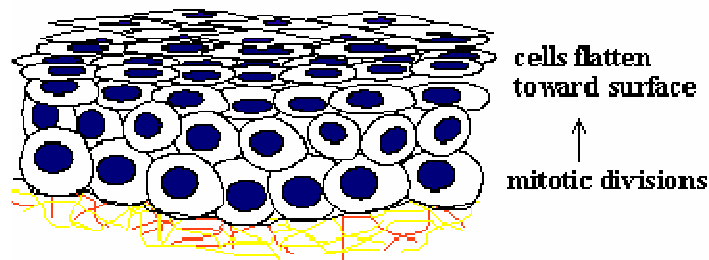


Fig.3.6a. Nonkeratinized Stratified Squamous Epithelium

b} Stratified Squamous Keratinized, or Cutaneous Type: The surface cells are dead, being anucleated and filled with keratin. It covers the entire exposed surface of the body (except for the cornea). It is well designed to deal with abrasion and desiccation.

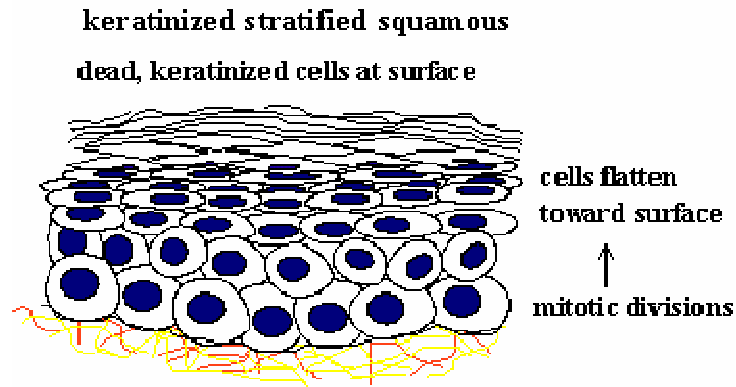


Fig.3.6b. Keratinized Stratified Squamous Epithelium

ii] Stratified Cuboidal Epithelium – These are multiple layers of epithelial cells where at least the surface cells are cuboidal. Stratified cuboidal epithelium is of limited distribution throughout the body. Where it is found it is typically only two layers thick. It is found in areas such as larger glandular ducts.

iii] Stratified Columnar Epithelium - These are multiple layers of epithelial cells where at least the surface cells are columnar (the cells of the deeper layers are typically cuboidal in shape). Stratified columnar epithelium is of limited distribution throughout the body. Where it is found it is typically only two layers thick. It lines small portions of the pharynx, larynx, the largest glandular ducts, and portions of the male urethra. It also occurs in certain regions of transition between two different types of epithelia.

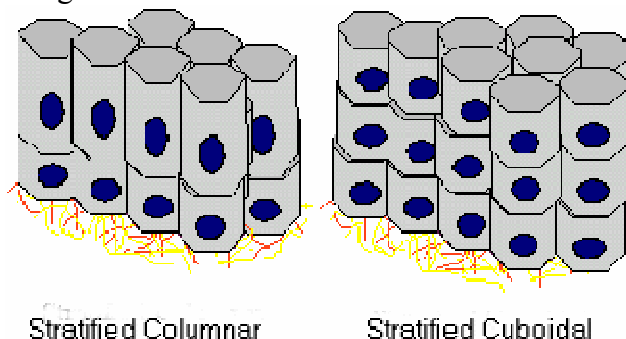


Fig.3.7. Stratified Columnar and Cuboidal Epithelia

iv] Transitional Epithelium - These are multiple layers of variable appearing cells. The appearance of the cells is based upon the tissue's location and action. It is a flexible layer which can expand and contract which is responsible for the variable appearance of the cells. The surface cells are typically dome-shaped while the underlying cells may be columnar, cuboidal, or even squamous in appearance. Occasionally two nuclei per surface cell is observed. Transitional epithelium is specifically adapted for flexibility and for stretching. The distribution of transitional epithelium is limited primarily to the urinary system. It lines the renal pelvis, ureters, bladder, and portions of the urethra (based on gender).

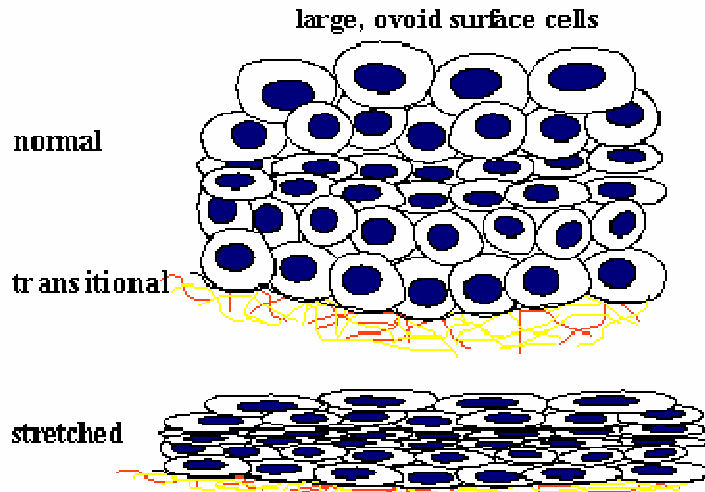


Fig.3.8. Transitional Epithelium

3.2.2. Glandular Epithelia

Single cells or groups of cells designed for secretion are defined as Glands. The products of glands may either be secreted into ducts in the case of the Exocrine Glands or into the blood in the case of Endocrine Glands. Not all endocrine glands are of epithelial origin and so will be studied in their respective organ systems.

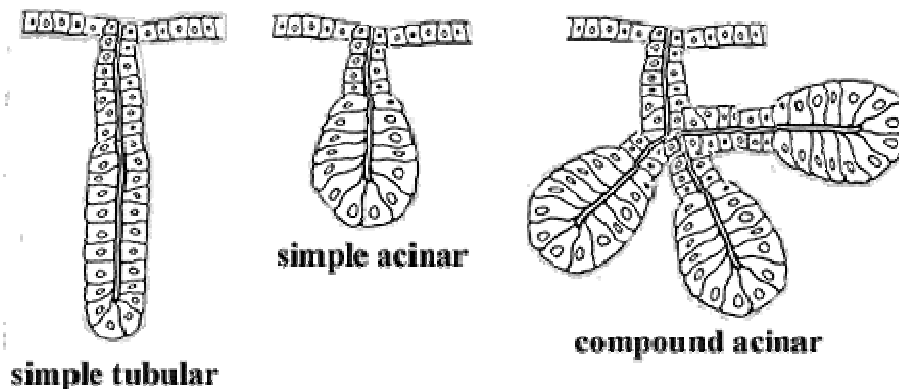


Fig.3.9. Glandular epithelia

a) Exocrine Glands

Exocrine glands can be classified based on four factors:

1. cell number (i.e.; multicellular vs. unicellular)
2. duct system (i.e.; simple vs. compound) and secretory portion (i.e.; tubular, acinar, or tubuloacinar)
3. nature of secretion (i.e.; mucus, serous, or seromucus)
4. mode of secretion (i.e.; merocrine, apocrine, or holocrine).

i) Types of Exocrine Glands

a) Types of Exocrine Glands Based on Cell Number

1] Unicellular Glands - are composed of a single secretory cell interposed in an epithelium of cells having other functions (ex; a goblet cell).

2] Multicellular Glands - a multicellular gland is composed of many cells and will vary in complexity occurring as: Epithelial Sheet Glands (ex; surface mucus glands of the stomach), Intraepithelial Glands (ex; urethral mucus glands) and Complex Glands with

Ducts - by far the most numerous, these glands are distinguished by their duct systems and by their secretory portion.

b] Types of Exocrine Glands Based on Duct System and Secretory Portion

Based on duct system, glands can be considered to be Simple if the duct is unbranched or Compound if the duct branches. Based on secretory portion, glands can be considered to be Tubular if the secretory portion is "test tube" shaped or Alveolar/Acinar if the secretory portion is "flask" shaped Tubuloacinar/Tubuloalveolar is the secretory portions of the gland are of both types.

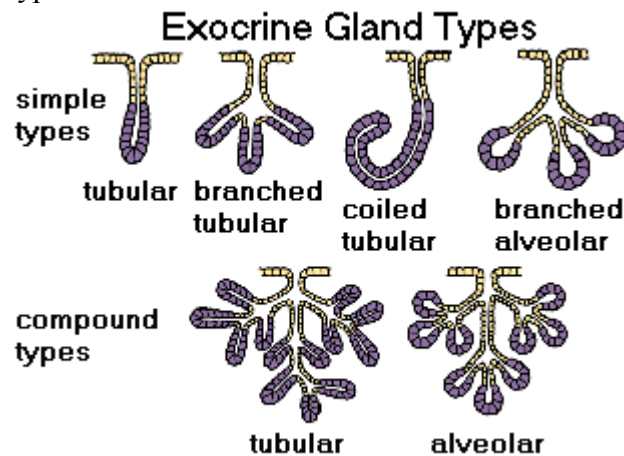


Fig.3.10. Types of Exocrine Glands

c] Classifications

a} Simple Glands - these are glands whose ducts are unbranching. 1} Simple Tubular Glands (ex; crypts of Leiberkuhn of the small intestine). 2} Simple Coiled Tubular (ex; eccrine sweat glands). 3} Simple Branched Tubular (ex; Brunner's glands, fundic glands). 4} Simple Acinar/Simple Alveolar. These glands are not found in humans (or possibly in mammals at all). Ex; poison glands in certain amphibians. 5} Simple Branched Acinar/Alveolar Glands (ex; sebaceous glands)

b} Compound Glands - these are glands whose ducts display definite branching. 1} Compound Tubular Glands (ex; cardiac glands of the stomach). 2} Compound Acinar/Alveolar (ex; salivary glands). 3} Compound Tubuloacinar/Tubuloalveolar (ex; pancreas)

c] Types of Exocrine Glands Based on The Nature of the Secretion

1] Mucus Glands - secrete the glycoprotein mucin which forms mucus when combined with water. Due to the high quantity of mucinogen present in these cells, mucus glands stain poorly.

2] Serous Glands - secrete serous fluid, a watery clear fluid containing a proteinaceous component.

3] Seromucus (or Mixed) Glands - have both a serous and a mucus component to their secretion. Both types of secretory units occur as either: 1} Mixed Alveoli. 2} Demilunes - mucus units with serous "caps" having a half moon appearance (ex; submandibular gland).

d] Types of Exocrine Glands Based on the Mode of Secretion

1] Merocrine Glands - release their secretory product by typical exocytotic

techniques. The entire cell remains intact, only the product is released. Merocrine secretion is typical for glands involved in protein or mucus release.. Ex; exocrine pancreas, salivary glands

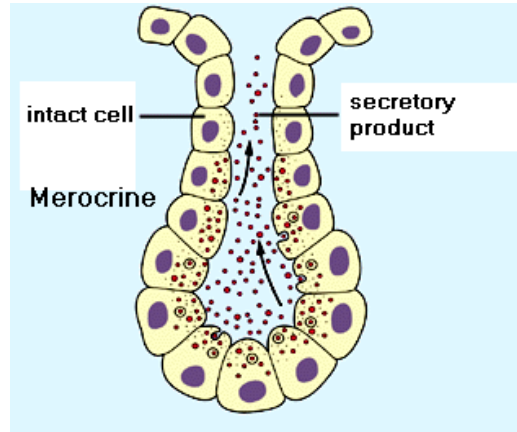


Fig.3.11a. Merocrine Glands

2] Apocrine Glands - release their products with the loss of a portion of the cell. The product is released from the apical surface of the cell along with either a thin rim of cytoplasm or a larger cap of luminal cytoplasm. Ex; certain sweat glands, ceruminous glands, and the lipid secretions of the mammarys.

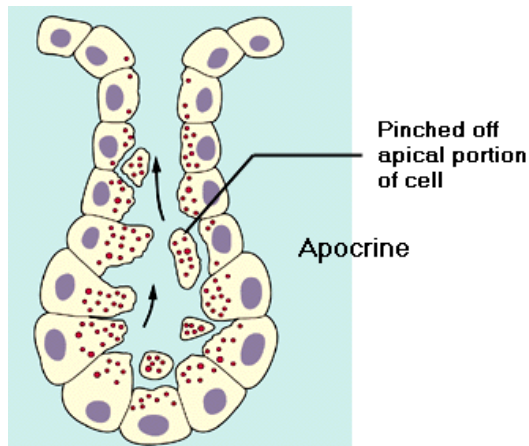


Fig.3.11b. Apocrine Glands

3] Holocrine Glands - the release of their products involves the destruction of the entire cell. The secretory product and the cell are released into the glandular lamina. The cell is, in effect, a portion of the secretory product. Accumulation of the product results in organelle disintegration and the ultimate death of the cell. Ex; sebaceous glands. Some refer to the testes and the ovaries as highly specialized holocrine glands due to the nature of their exocrine product, the gametes.

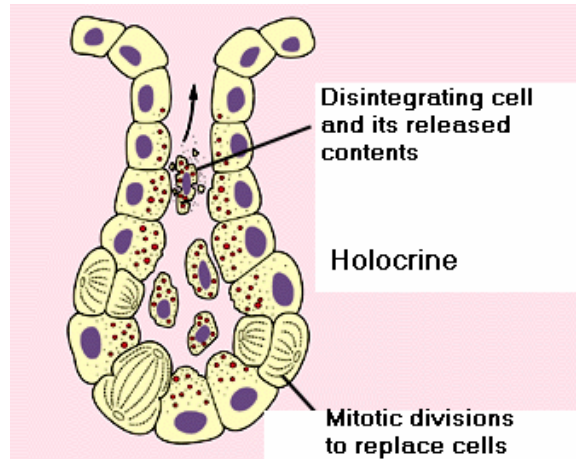


Fig.3.11c. Holocrine Glands

3.2. 3. Myoepithelial Cells

Myoepithelial cells are also known as basal cells or basket cells. Myoepithelial cells are specialized epithelial cells which are contractile in nature. They are located between the basal portions of secretory cells and the basement membrane of certain glands. Ex; sweat, salivary, mammary, lacrimal, and ceruminous glands. They help to squeeze the glandular product out of the secretory unit. Because they are contractile myoepithelial cells are described as being "muscle like", Myoid. Like muscle cells myoepithelial cells contain myofibrils. Unlike muscle cells, however, they are of ectodermal origin.

3.2. 4. Special Epithelia

In addition to the aforementioned epithelia a few epithelia possess unique structures, functions, and special properties. These are the "special epithelia". The most notable of these are concerned with sensory reception (neuroepithelia) and with reproduction (germinal epithelium lining the seminiferous tubules). The surface epithelia will be considered under the appropriate topics.

3.3. Epithelial Specializations

As a class epithelial tissues is the most diverse in function. This is partially due to its origin from all three germ layers. Related to this property is the multiformity of the various epithelial membranes as well as their internal cellular features.

Cytological specializations of the epithelial cell may occur at the various interfacial areas of:

1. apical cell surface - between the cell and the surface environment,
2. lateral cell surfaces - between the cell and adjacent cells,
3. basal cell surface - between the cell and the underlying basement membrane

In addition there may be specializations of the cytoskeleton.

3.3. 1. Specializations of the Apical Surface

a) Microvillae

Microvillae are delicate, finger-like extensions of the cell's apical surface formed by multiple evaginations of the plasmalemma and cytoplasm. Microvillae contain a core of fine (6 nm) microfilaments running along their longitudinal axis. This core of microfilaments is called the Actin Bundle. The actin bundle is attached to the apical tip of the microvillus in a dense structure called the Dense Tip.

The basal portion of the actin bundle is embedded in, and interconnected with, the cytoskeleton of the cell. The meeting point is called the Terminal Web. Microvillae increase a cell's surface area and are found in epithelial cells concerned with secretion and absorption. Ex; The "striated border" of intestinal absorptive cells, the "brush border" of the kidney's proximal tubules, and the stereocilia of the ductus deferens.

Note: stereocilia are much longer and more specialized than are the typical microvillae.

b) Cilia

Like microvillae, cilia are plasmalemma covered evaginations of the apical cell surface. Cilia are motile structures. Beating of the cilia consists of a rapid forward motion (called the Effective Stroke) and a slower backward motion (called the Recovery Stroke). This metachronal rhythm provides the means by which mucus and particulate matter is moved along the epithelial surface. This action is termed Mucociliary Clearance. Ex; respiratory epithelium

c) Glycocalyx

The glycocalyx is a surface coat consisting of complex carbohydrates in association with either structural proteins embedded in the cell membrane or with proteins located on the surface of the cell membrane. Although this glycoprotein encrustation occurs on all surfaces of epithelial cells, it is most prominent on the apical surface.

The Functions are: a] cellular recognition, b] adhesion and binding of various molecules, c] concentrate certain ions for absorption by the cell and d] chemical reactions. Ex; the enteric surface coat of intestinal absorptive cells contain hydrolytic enzymes to aid in digestion.

3.3.2. Specializations of the Lateral Surface

As mentioned previously, epithelial cells have many, and well developed intercellular junctions. 1) tight junctions or zona occludens, 2) desmosomes or macula adherens, 3) zonula adherens - an intermediate junction also serving to hold epithelial cells together. Like the desmosome there is some space between the two cells however it is structurally more similar to the tight junction. 4) gap junctions or macula communicans

3.3.3. Specializations of the Basal Surface

The basal surface specializations include the basement membrane and the hemidesmosome, both of which serve to bind the epithelium to the underlying connective tissue.

a) Basement Membrane

The basement membrane is also sometimes referred to as the basal lamina. The basement membrane is an acellular structure composed of two layers:

i] Basal Lamina Proper - the layer closest to the epithelium. It is composed of glycoproteins and it is produced by the epithelium itself.

ii] Reticular Lamina - the layer closest to the underlying loose connective tissue. It is composed of reticular fibers embedded in a matrix of glycoproteins and polysaccharides and it is produced by the loose connective tissue.

The basement membrane serves as an underlying support and cushion for the epithelium and to attach the epithelium to the underlying connective tissue. In special cases it may also act as a filtration barrier (ex; in the kidney).

b) Hemidesmosome

As the name indicates, this is in essence half a desmosome. The hemidesmosome serves to attach the epithelial cells to the basement membrane.

3.3.4. Specialization of the Cytoskeleton

Epithelial cells, especially squamous type, possess many intermediate filaments. Terminal Web - a dense accumulation of filaments running parallel to, and immediately below, the apical surface of the cell. The terminal web is particularly prevalent in cells having apical appendages. It serves to provide support and anchorage for apical appendages.