Squamous Epithelium

The cytoplasm of cells in this kind of epithelium forms only a thin layer. The nuclei produce bulgings of the cell surface (Figs. 2.1, 2.2). In surface view the cells have polygonal outlines that interlock with those of adjoining cells. With the EM the junctions between cells are marked by occluding junctions: the junctions are thus tightly sealed and any substance passing through the epithelium has to pass through the cells, and not between them.

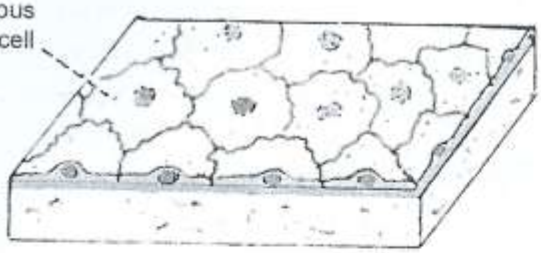


Fig. 2.1. Simple squamous epithelium (diagrammatic). BM= Basement membrane; LP= Lamina propria.

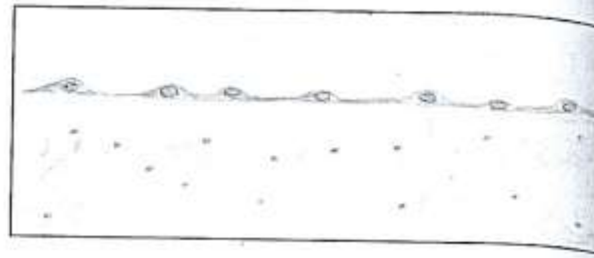


Fig. 2.2. Simple squamous epithelium as seen in a section (drawing). Also see figures A1.2 and A1.3 (page Atlas 3).

Squamous epithelium lines the alveoli of the lungs. It lines the free surface of the serous pericardium, of the pleura, and of the peritoneum: here it is called ***mesothelium***. It lines the inside of the heart, where it is called ***endocardium***; and of blood vessels and lymphatics, where it is called ***endothelium***. Squamous epithelium is also found lining some parts of the renal tubules, and in some parts of the internal ear.

Columnar Epithelium

We have seen that in vertical section the cells of this epithelium are rectangular. On surface view (or in transverse section) the cells are polygonal. In keeping with the elongated shape of the cells, the nuclei are also frequently elongated (Figs 2.3, 2.4).

Columnar epithelium can be further classified according to the nature of the free surfaces of the cells as follows.

(a) In some situations the cell surface has no particular specialization: this is ***simple columnar epithelium***.

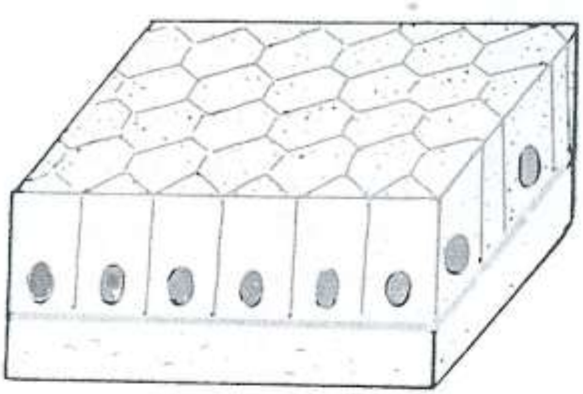


Fig. 2.3. Simple columnar epithelium (diagrammatic). Note the basally placed oval nuclei. The cells appear hexagonal in surface view.

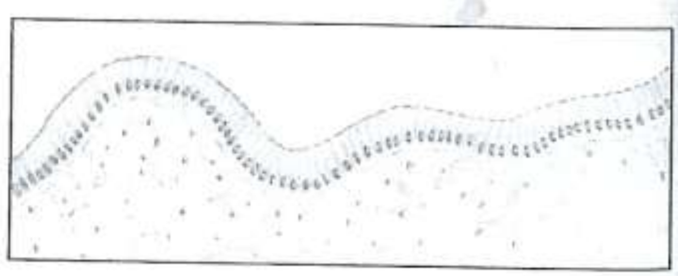


Fig. 2.4. Simple columnar epithelium as seen in a section (drawing). Also see Fig. A3.2 (page Atlas 4).

(b) In some situations the cell surface bears cilia. This is ***ciliated columnar epithelium*** (Fig. 2.5).

(c) In other situations the surface is covered with microvilli. Although the microvilli are visible only with the EM, with the light microscope the region of the microvilli is seen as a ***striated border*** (when the microvilli are arranged regularly) (Fig. 2.7) or as a ***brush border*** (when the microvilli are irregularly placed) (Fig. 1.32).

Some columnar cells have a secretory function. The apical parts of their cytoplasm contain secretory vacuoles.

Simple columnar epithelium (without cilia or microvilli) is present over the mucous membrane of the stomach and the large intestine.

Columnar epithelium with a striated border is seen most typically in the small intestine, and with a brush border in the gall bladder.

Ciliated columnar epithelium lines most of the respiratory tract, the uterus, and the uterine tubes. It is also seen in the efferent ductules of the testis, parts of the middle ear and auditory tube; and in the ependyma lining the central canal of the spinal cord and the ventricles of the brain. In the respiratory tract the cilia move mucous accumulating in the bronchi (and containing trapped dust particles) towards the larynx and pharynx. When excessive this mucous is brought out as sputum during coughing. In the uterine tubes the movements of the cilia help in the passage of ova towards the uterus.

Secretory columnar cells are scattered in the mucosa of the stomach and intestines. In the intestines many of them secrete mucous which accumulates in the apical part of the cell making it very light staining. These cells acquire a characteristic shape (Fig. 2.8) and are called ***goblet cells***. Some columnar cells secrete enzymes.

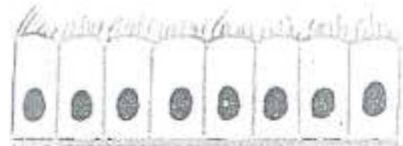


Fig. 2.5. Columnar epithelium showing cilia (diagrammatic).

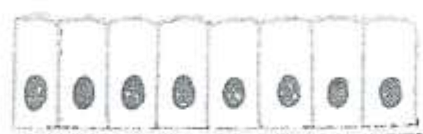


Fig. 2.7. Columnar epithelium showing a striated border made up of microvilli (diagrammatic).

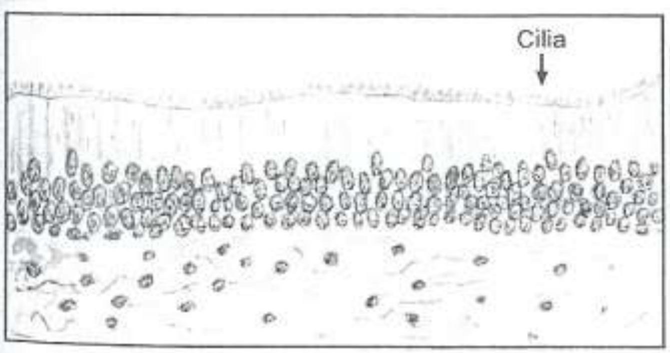


Fig. 2.6. Ciliated epithelium (pseudostratified columnar) as seen in a section. Also see Fig. A6.2 (page Atlas 5).

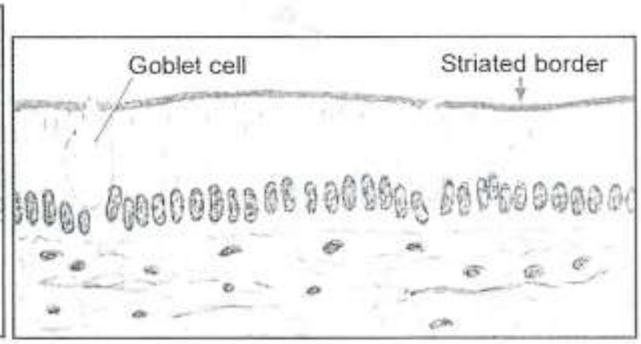


Fig. 2.8. Columnar epithelium with striated border as seen in a section (drawing). Also see Fig. A4.2 (page Atlas 4).

Cuboidal Epithelium

Cuboidal epithelium is similar to columnar epithelium, but for the fact that the height of the cells is about the same as their width. The nuclei are usually rounded (Fig. 2.9).

A typical cuboidal epithelium may be seen in the follicles of the thyroid gland, in the ducts of many glands, and on the surface of the ovary (where it is called ***germinal epithelium***). Other sites are the choroid plexuses, the inner surface of the lens, and the pigment cell layer of the retina.

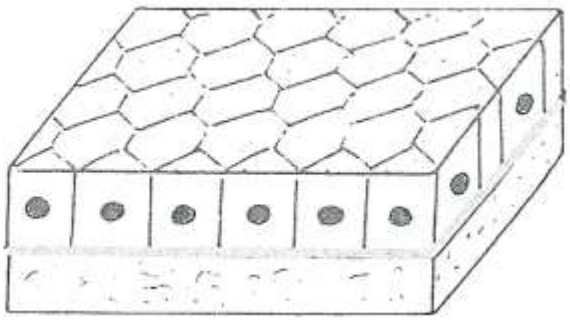


Fig. 2.9. Simple cuboidal epithelium (diagrammatic). Note that the cells appear cuboidal in section and hexagonal in surface view.

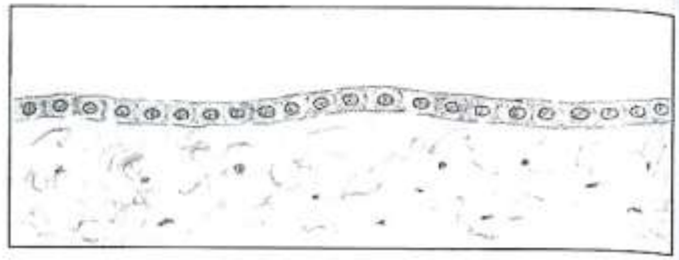


Fig. 2.10. Simple cuboidal epithelium as seen in a section (drawing). Also see Fig. A2.2 (page Atlas 3).

An epithelium that is basically cuboidal (or columnar) lines the secretory elements of many glands. In this situation, however, the parts of the cells nearest the lumen are more compressed (against neighbouring cells) than at their bases, giving them a triangular shape (Fig. 2.11).

A cuboidal epithelium with a prominent brush border is seen in the proximal convoluted tubules of the kidneys (Fig. 1.32).

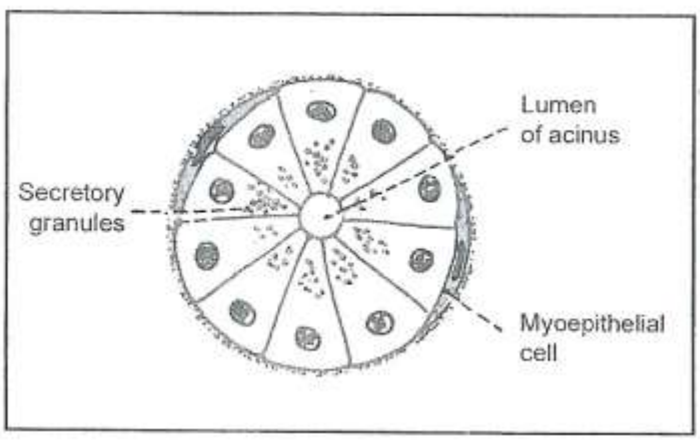


Fig. 2.11. Modified columnar cells in the wall of an acinus (of a gland) (diagrammatic). Note the triangular shape of the cells, the presence of secretory granules, and the myoepithelial cells lying between the gland cells and the basement membrane.

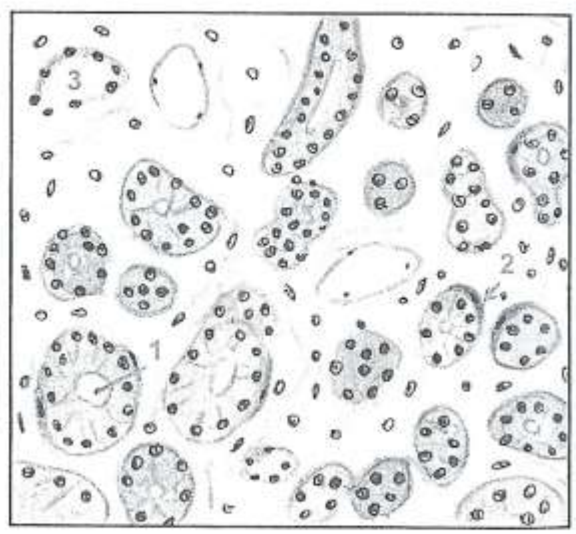


Fig. 2.12. Section through lacrimal gland (drawing) showing acini of the kind described in Fig. 2.11.

Pseudostratified Columnar Epithelium

In usual class-room slides the boundaries between epithelial cells are often not clearly seen. In spite of this we can make out what type of epithelium it is. This is because the shape and spacing of the nuclei gives a good idea of where the cell boundaries must lie.

Normally, in columnar epithelium the nuclei lie in a row, towards the bases of the cells. Sometimes, however, the nuclei appear to be arranged in two or more layers giving the impression that the epithelium is more than one cell thick (Fig. 2.14). The reason for this will be understood easily from Fig. 2.13. It is seen that there is actually only one layer of cells, but some cells are broader near the base, and others near the apex. The nuclei lie in the broader part of each cell and are, therefore, not in one layer. To distinguish this kind of epithelium from a true stratified epithelium, it is referred to as ***pseudostratified columnar epithelium***.

Fig. 2.13. Pseudostratified columnar epithelium (diagrammatic). This figure explains why the nuclei lie at various levels.

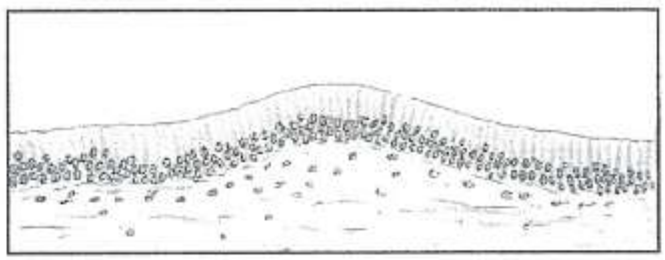


Fig. 2.14. Realistic appearance of pseudostratified columnar epithelium as seen in a section (drawing). Also see Fig. 2.6.

A pseudostratified columnar epithelium is found in some parts of the auditory tube, the ductus deferens, and the male urethra (membranous and penile parts). A ciliated pseudostratified columnar epithelium is seen in the trachea and in large bronchi (Fig. 2.6).

Stratified Squamous Epithelium

This type of epithelium is made up of several layers of cells. The cells of the deepest (or basal) layer rest on the basement membrane: they are usually columnar in shape. Lying over the columnar cells there are polyhedral or cuboidal cells. As we pass towards the surface of the epithelium these cells become progressively more flat, so that the most superficial cells consist of flattened squamous cells (Fig. 2.15).

Stratified squamous epithelium can be divided into two types: ***non-keratinised*** and ***keratinised***. In situations where the surface of the epithelium remains moist, the most superficial cells are living and nuclei can be seen in them. This kind of epithelium is described as non-keratinised. In contrast, at places where the epithelial surface is

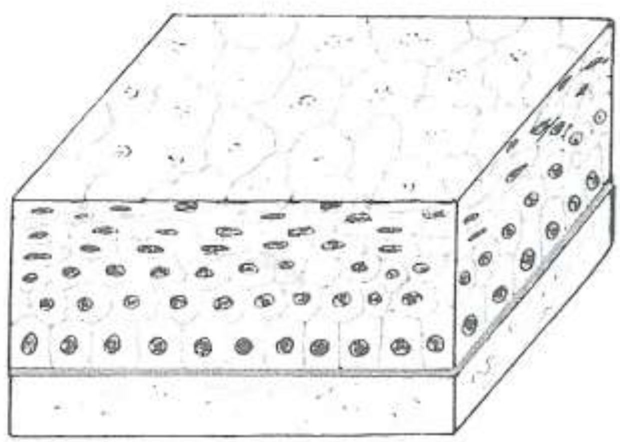


Fig. 2.15. Stratified squamous epithelium. There is a basal layer of columnar cells that rests on the basement membrane. Overlying the columnar cells of this layer there are a few layers of polygonal cells or rounded cells. Still more superficially, the cells undergo progressive flattening, becoming squamous.

dry (as in the skin) the most superficial cells die and lose their nuclei. These cells contain a substance called *keratin*, which forms a non-living covering over the epithelium. This kind of epithelium constitutes keratinised stratified squamous epithelium.

Stratified squamous epithelium (both keratinised and non-keratinised) is found over those surfaces of the body that are subject to friction. As a result of friction the most superficial layers are constantly being removed and are replaced by proliferation of cells from the basal (or germinal) layer. This layer, therefore, shows frequent mitoses.

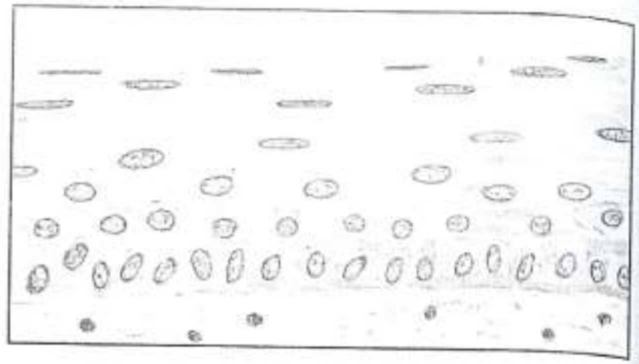


Fig. 2.16. Stratified squamous epithelium (non-keratinised) as seen in a section (drawing). Also see Fig. A8.2 (page Atlas 6).

Keratinised stratified squamous epithelium covers the skin of the whole of the body and forms the epidermis (Fig. A9.2, page Atlas 7). Non-keratinised stratified squamous epithelium is seen lining the mouth, the tongue, the pharynx, the oesophagus, the vagina and the cornea. Under pathological conditions the epithelium in any of these situations may become keratinised.

Transitional Epithelium

This is a multi-layered epithelium and is 4 to 6 cells thick. It differs from stratified squamous epithelium in that the cells at the surface are not squamous. The deepest cells are columnar or cuboidal. The middle layers are made up of polyhedral or pear-shaped cells. The cells of the surface layer are large and often shaped like an umbrella (Fig. 2.17).

Transitional epithelium is found in the renal pelvis and calyces, the ureter, the urinary bladder, and part of the urethra. Because of this distribution it is also called ***urothelium***. In the urinary bladder it is seen that transitional epithelium can be stretched considerably without being damaged. When stretched it appears to be thinner and the cells become flattened or rounded.

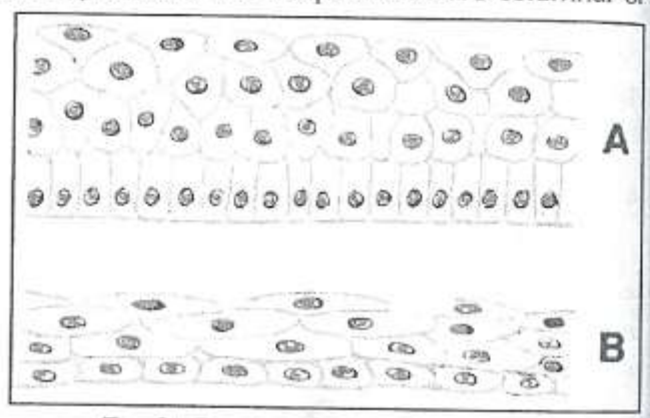


Fig. 2.17 A & B. Transitional epithelium (diagrammatic) in unstretched (A), and in stretched (B) conditions.

With the EM the cells of transitional epithelium are seen to be firmly united to one another by numerous desmosomes. Because of these connections the cells retain their relative position when the epithelium is stretched or relaxed. At the surface of the epithelium the plasma

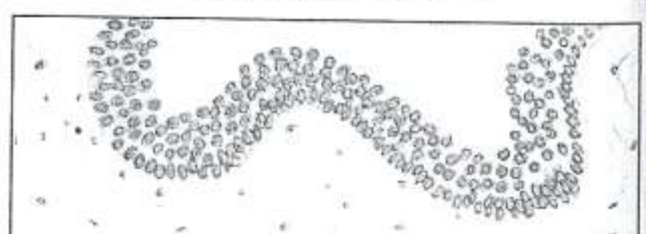


Fig. 2.18. Realistic appearance of transitional epithelium as seen in a section (drawing). Also see Fig. A7.2 (page Atlas 5).

membranes are unusual: embedded in the lipid layer of the membranes there are special glycoproteins. It is believed that these glycoproteins make the membrane impervious and resistant to the toxic effects of substances present in urine, and thus afford protection to adjacent tissues.

The cells in the basal layer of transitional epithelium show occasional mitoses, but these are much less frequent than those in stratified squamous epithelium, as there is normally little erosion of the surface. Many cells of the superficial (luminal) layers of the epithelium may contain two nuclei. In some cells the nucleus is single, but contains multiples of the normal number of chromosomes (i.e., it may be polyploid).

According to some workers, all cells of transitional epithelium reach the basal lamina through thin processes. If this observation is proved to be correct transitional epithelium would have to be classified as a pseudo-stratified epithelium (rather than as a stratified one).

Basement Membranes of Epithelia

We have seen that epithelial cells rest on a thin basement membrane. In multi-layered epithelia, the deepest cells lie on this membrane. Basement membranes are formed by thin layers of amorphous material and of reticular fibres.

A distinct basement membrane cannot be seen in H & E preparations, but can be well demonstrated using the PAS (periodic acid Schiff) method. The latter stains the glycoproteins present in the membrane.

Under the EM a basement membrane is seen to have a ***basal lamina*** (nearest the epithelial cells) and a ***reticular lamina*** or ***fibroreticular lamina*** (consisting of reticular tissue and merging into surrounding connective tissue). The basal lamina is divisible into the ***lamina densa*** containing fibrils; and the ***lamina lucida*** which appears to be transparent. The lamina lucida lies against the cell membranes of epithelial cells.

Membranes similar in structure and composition to basement membranes are also seen in relation to smooth muscle cells, Schwann cells, the glomerular membrane of the kidney, and in membranes covering the cornea and lens of the eye.

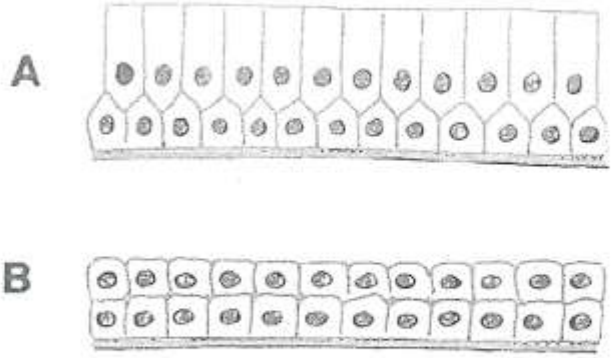
Several important functions have been ascribed to basement membranes as follows.

(a) They provide adhesion on one side to epithelial cells (or parenchyma); and on the other side to connective tissue (mainly collagen fibres).

(b) They act as barriers to the diffusion of molecules. The barrier function varies with location (because of variations in pore size). Large proteins are prevented from passing out of blood vessels, but (in the lung) diffusion of gases is allowed.

(c) Recent work suggests that basement membranes may play a role in cell organization, as molecules within the membrane interact with receptors on cell surfaces. Substances present in the membrane may influence morphogenesis of cells to which they are attached.

(d) The membranes may influence the regeneration of peripheral nerves after injury, and may play a role in re-establishment of neuromuscular junctions.



Some rare types of epithelia are shown in Fig. 2.19.

Fig. 2.19 A. Stratified columnar epithelium.
B. Stratified cuboidal epithelium.
These are rare epithelia seen in the ducts of some glands.

Further Comments on Epithelia

(1) The shape of epithelial cells is related to the amount of contained cytoplasm and organelles. These are in turn related to metabolic activity. Squamous cells are least active. Columnar cells contain abundant mitochondria and endoplasmic reticulum and are highly active.

(2) Laterally, epithelial cells are in contact with other epithelial cells. The contact between adjoining cells is generally an intimate one because of the presence of desmosomes, zonulae adherens, and zonulae occludens. The intimate contact ensures that materials passing through the epithelium have to pass through the cells, rather than between them.

(3) We have seen that cilia are present on the free surfaces of some epithelial cells. The surface area of an epithelial cell may be greatly increased by the presence of microvilli, or of basolateral folds.

(4) Some epithelial cells contain pigment. Such cells are present in the skin, the retina and the iris.

(5) Epithelia are generally devoid of blood vessels. Their cells obtain nutrition by diffusion from blood vessels in underlying tissues. In contrast, delicate nerve fibres frequently penetrate into the intervals between epithelial cells.

(6) Epithelia have considerable capacity for repair after damage. They grow rapidly after injury, to repair the defect.

(7) It should be remembered that epithelial cells that look alike (on superficial examination) could have very different functions. For example, cuboidal cells lining follicles of the thyroid gland have very little in common with cuboidal cells covering the surface of the ovary.

(8) Epithelia in secretory portions of glands show specialisations of structure that depend on the nature of the secretion produced by them.

(9) Epithelial cells in which transport of ions is an important function (e.g., renal tubules) are marked by the presence of basolateral folds, and the presence of large numbers of mitochondria. The mitochondria provide ATP which is the source of energy for ion transport. Tight junctions between the cells prevent passive diffusion of ions.

(10) Epithelial cells contain some proteins not present in non-epithelial cells. These include cytokeratin (present in intermediate filaments). Such proteins can be localised using immunohistochemical techniques (See below).

Mucous Membranes

We have seen that epithelia line many tubular structures within the body. In such structures the epithelium rests (with its basement membrane) on a layer of connective tissue called the *lamina propria* (or ***corium***). The layer of epithelium along with its lamina propria is referred to as the *mucous* ***membrane*** or ***mucosa*** (as its surface is kept moist by secretions of mucous glands).

In the intestines the mucous membrane has a third layer formed by a thin stratum of smooth muscle. This smooth muscle is called the ***muscularis mucosae*** (= muscle of the mucous membrane).

Tumours arising from epithelia

A tumour (or neoplasm) can arise from any tissue if there is uncontrolled growth of cells. Such a tumour may be benign, when it remains localised; or may be malignant. A malignant growth invades surrounding tissues. Cells of the tumour can spread to distant sites (through lymphatics or through the bloodstream) and can start growing there producing what are called ***secondaries*** or ***metastases***.

A malignant tumour arising from an epithelium is called a ***carcinoma***. If it arises from a squamous epithelium it is a ***squamous cell carcinoma***; and if it arises from glandular epithelium it is called an ***adenoma***.

Quite commonly cells in tumours resemble those of the tissue from which they are derived, and this is useful in pathological diagnosis. However, in metastases of fast growing tumours the cells may not show the characteristics of the tissue of origin (undifferentiated tumour), and it may be difficult to find out the location of the primary growth. In such cases diagnosis can be aided by localization of proteins that are present only in epithelia. As mentioned above this can be done by using immuno-histochemical techniques.

3: Glands

We have seen that some epithelial cells may be specialised to perform a secretory function. Such cells, present singly or in groups, constitute glands.

From this it is obvious that some glands are ***unicellular***. Unicellular glands are interspersed amongst other (non-secretory) epithelial cells. They can be found, for example, in the epithelium lining the intestines.

Most glands are, however, ***multicellular***. Such glands develop as diverticulae from epithelial surfaces. The 'distal' parts of the diverticulae develop into secretory elements, while the 'proximal' parts form ducts through which secretions reach the epithelial surface.

Those glands that pour their secretions on to an epithelial surface, directly or through ducts are called ***exocrine glands*** (or ***externally secreting glands***). Some glands lose all contact with the epithelial surface from which they develop: they pour their secretions into blood. Such glands are called ***endocrine glands***, ***internally secreting glands***, or ***duct-less glands***.

When all the secretory cells of an exocrine gland discharge into one duct the gland is said to be a ***simple gland***. Sometimes there are a number of groups of secretory cells, each group discharging into its own duct. These ducts unite to form larger ducts that ultimately drain on to an epithelial surface. Such a gland is said to be a ***compound gland***.

Both in simple and in compound glands the secretory cells may be arranged in various ways.

(a) The secretory element may be ***tubular***. The tube may be straight, coiled, or branched.

(b) The cells may form rounded sacs or ***acini***.

(c) They may form flask shaped structures called ***alveoli***. However, it may be noted that the terms acini and alveoli are often used as if they were synonymous. Glands in which the secretory elements are greatly distended are called ***saccular glands***.

(d) Combinations of the above may be present in a single gland. From what has been said above it will be seen that an exocrine gland may be:

1. Unicellular.
2. Simple tubular.
3. Simple alveolar (or acinar).
4. Compound tubular.
5. Compound alveolar.
6. Compound tubulo-alveolar (or racemose).

Some further subdivisions of these are shown in Fig. 3.1.

Exocrine glands may also be classified on the basis of the nature of their secretions into ***mucous glands*** and ***serous glands***. In mucous glands the secretion contains mucopolysaccharides. The secretion collects in the apical parts of the cells. As a result nuclei are pushed to the base of the cell, and may be flattened.

In classroom slides stained with haematoxylin and eosin the secretion within mucous cells remains unstained so that they have an 'empty' look (Fig. A57.2).

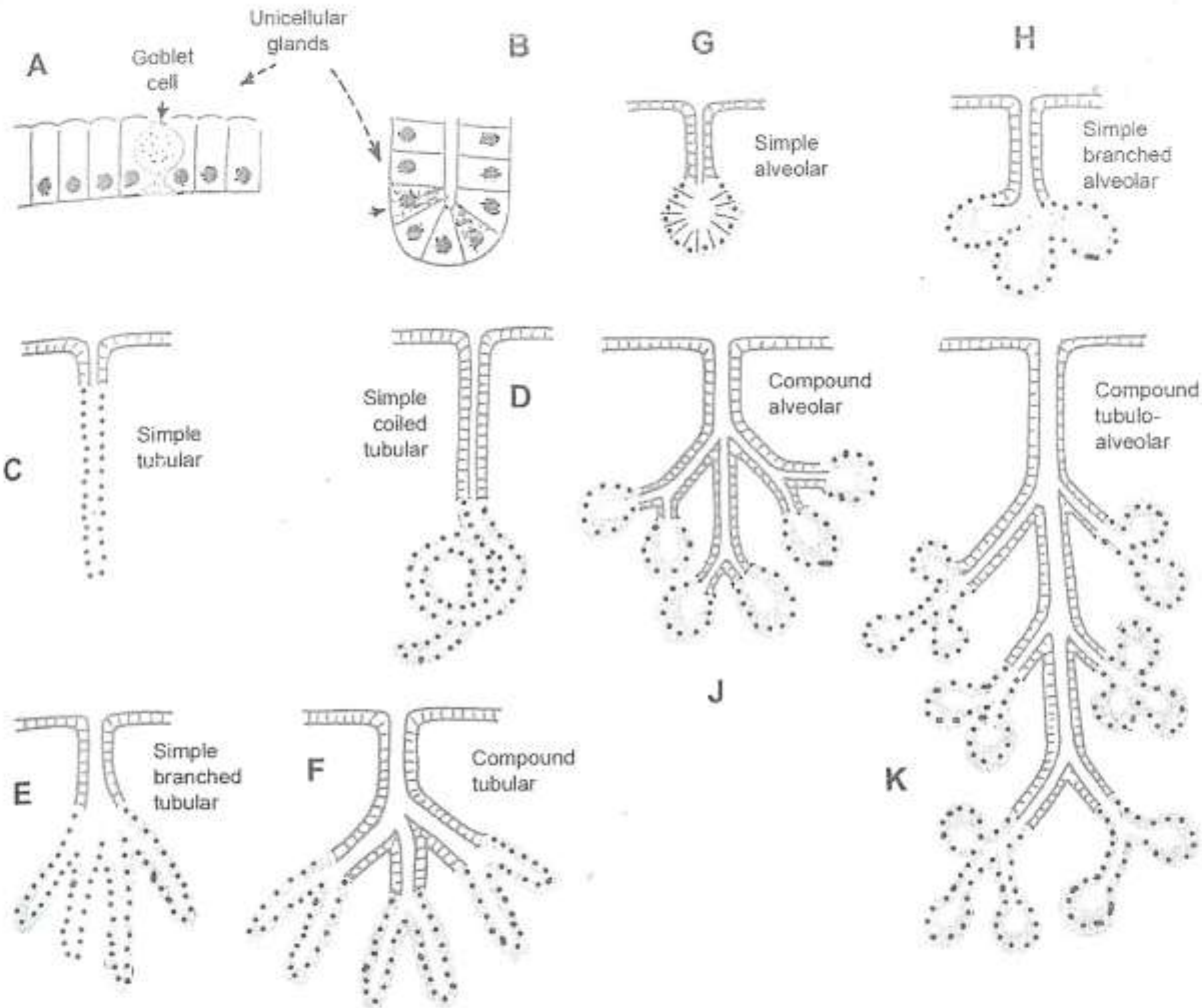


Fig. 3.1. Scheme to show various ways in which the secretory elements of a gland may be organised. A and B are examples of unicellular glands. All others are multicellular. Glands with a single duct are simple glands, while those with a branching duct system are compound glands.

However, the stored secretion can be brightly stained using a special procedure called the periodic acid Schiff (PAS) method. Unicellular cells secreting mucous are numerous in the intestines: they are called ***goblet cells*** because of their peculiar shape. (See Fig. 3.1A and Fig. 2.8).

The secretions of serous glands are protein in nature. The cytoplasm of these cells is granular and often stains bluish with haematoxylin and eosin (Fig. A54.1). Their nuclei are centrally placed. Some glands contain both serous and mucous elements (Fig. A56.3).

Epithelia in secretory portions of glands show specialisations of structure depending upon the nature of secretion as follows.

(1) Cells that are protein secreting (e.g., hormone producing cells) have a well developed rough ER, and a supranuclear Golgi complex. Secretory granules often fill the apical portions of the cells. The staining characters of the granules differ in cells producing different secretions (the cells being described as acidophile, basophile etc).

(2) Mucin secreting cells have a well developed rough ER (where the protein component of mucin is synthesised), and a very well developed Golgi complex (where proteins are glycosylated).

(3) Steroid producing cells are characterised by the presence of extensive smooth endoplasmic reticulum, and prominent mitochondria.

In addition to their classification on the basis of structure, and on the basis of the nature of their secretion, exocrine glands can also be classified on the basis of the manner in which their secretions are poured out of the cells. In most exocrine glands secretions are thrown out of the cells by a process of exocytosis the cell remaining intact: this manner of secretion is described as ***merocrine*** (sometimes also called ***eccrine*** or ***epicrine***). In some glands the apical parts of the cells are shed off to discharge the secretion: this manner of secretion is described as ***apocrine***. An example of apocrine secretion is seen in some atypical sweat glands, and in mammary glands. Finally, in some glands the entire cell disintegrates while discharging its secretion. This manner of discharging secretion is described as ***holocrine***, and is seen typically in sebaceous glands. Depending on the mode of secretion glands may, therefore, be described as merocrine, apocrine or holocrine.

The secretory elements of exocrine glands are held together by connective tissue (mainly reticular fibres). The glandular tissue is often divisible into lobules separated by connective tissue septa. Aggregations of lobules may form distinct lobes. The connective tissue covering the entire gland forms a ***capsule*** for it.

When a gland is divided into lobes the ducts draining it may be ***intralobular*** (lying within a lobule), ***interlobular*** (lying in the intervals between lobules), or ***interlobar*** (lying between adjacent lobes), in increasing order of size.

Blood vessels and nerves pass along connective tissue septa to reach the secretory elements. As a rule exocrine glands have a rich blood supply. Their activity is under nervous or hormonal control.

The secretory cells of a gland constitute its ***parenchyma***, while the connective tissue in which the former lie is called the ***stroma***.

Endocrine glands are usually arranged in cords or in clumps that are intimately related to a rich network of blood capillaries or of sinusoids. In some cases (for example the thyroid gland) the cells may form rounded follicles.

Endocrine cells and their blood vessels are supported by delicate connective tissue, and are usually surrounded by a capsule.

> Neoplasms can arise from the epithelium lining a gland. A benign growth arising in a gland is an ***adenoma***; and a malignant growth is an ***adenocarcinoma***.

In this chapter we have considered the general features of glands. Further details of the structure of exocrine and endocrine glands will be considered while studying individual glands.