Epithelial tissues are composed of closely aggregated polyhedral cells adhering strongly to one another and to a thin layer of extracellular matrix (ECM), forming cellular sheets that line the cavities of organs and cover the body surface. Epithelia line all external and internal surfaces of the body and all substances that enter or leave an organ must cross this type of tissue.

The principal functions of epithelial tissues include the following:

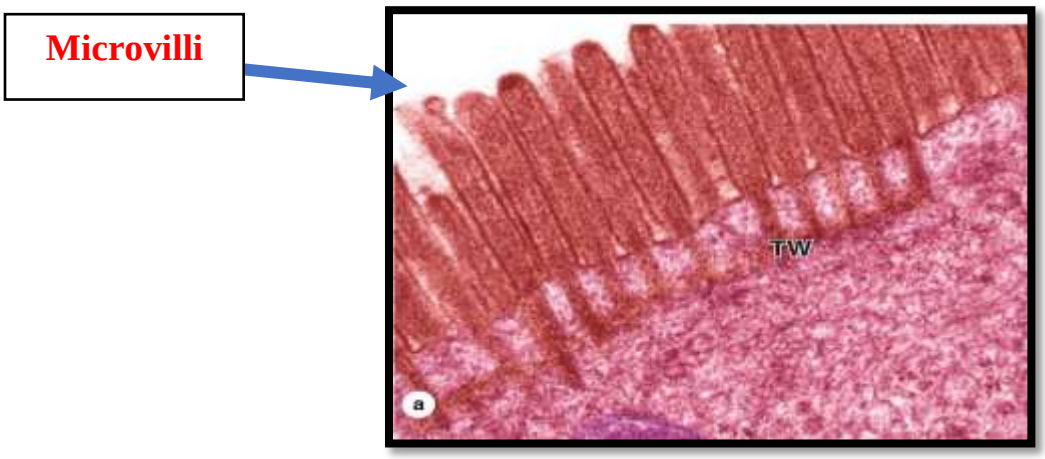
1. Covering, lining, and protecting surfaces (eg, epidermis)
2. Absorption (eg, the intestinal lining)
3. Secretion (eg, parenchymal cells of glands)

Specific cells of certain epithelia may be contractile (myoepithelial cells) or specialized sensory cells, such as those of taste buds or the olfactory epithelium.

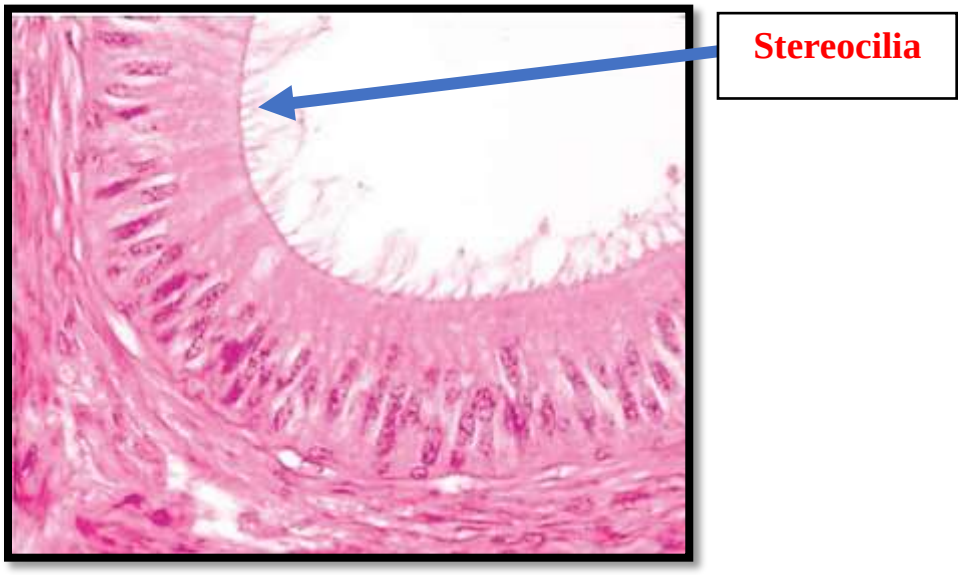
SPECIALIZATIONS OF THE APICAL CELL SURFACE

The apical ends of many columnar and cuboidal epithelial cells have specialized structures projecting from the cells. These function either to increase the apical surface area for better absorption or to move substances along the epithelial surface.

1. **Microvilli** many cells have cytoplasmic projections best seen with the electron microscope. Such extensions usually reflect the movements and activity of actin filaments and are both temporary and variable in their length, shape, and number. However, in epithelia specialized for absorption the apical cell surfaces are often filled with an array of projecting microvilli, usually of uniform length. In cells such as those lining the small intestine, densely packed microvilli are visible as a brush or striated border projecting into the lumen. The average microvillus is about 1 μm long and 0.1 μm wide, but with hundreds or thousands present on the end of each absorptive cell.



2. **Stereocilia** are a much less common type of apical process, best seen on the absorptive epithelial cells lining the male reproductive system. Like microvilli, stereocilia increase the cells' surface area, facilitating absorption. More specialized stereocilia with a motion-detecting function are important components of inner ear sensory cells. Stereocilia resemble microvilli in containing arrays of microfilaments and actin-binding proteins, with similar diameters, and with similar connections to the cell's terminal web. However, stereocilia are typically much longer and less motile than microvilli, and may show branching distally.



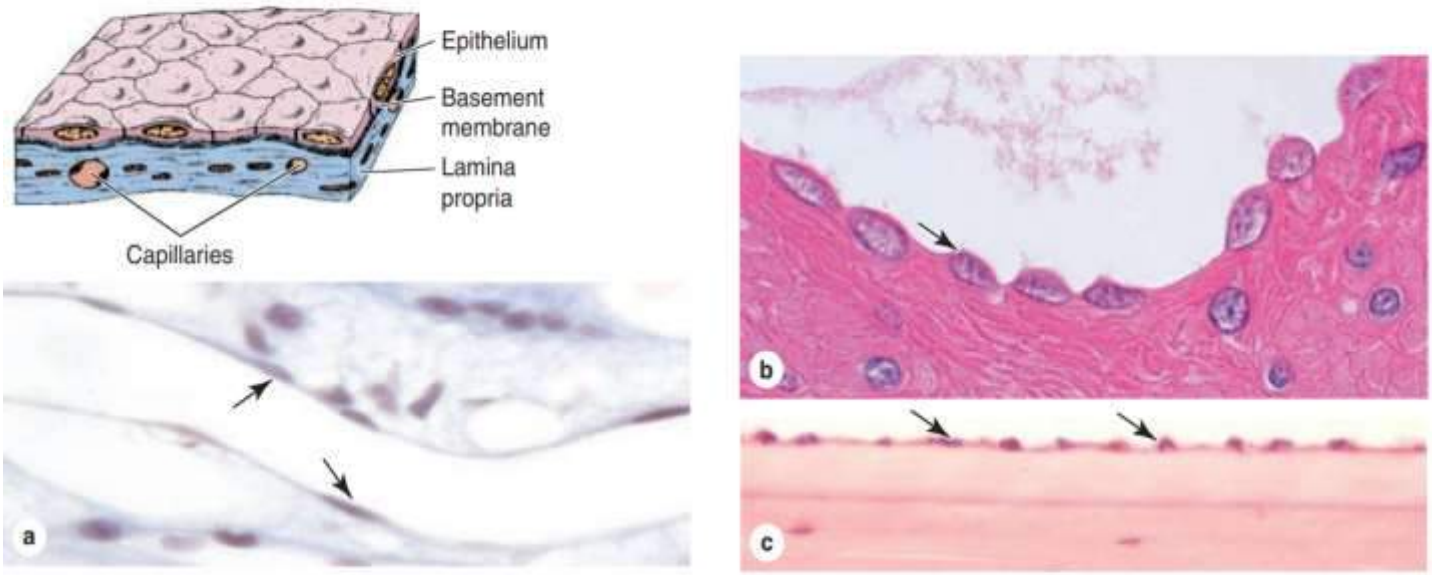
3. **Cilia** are long, highly motile apical structures, larger than microvilli, and containing internal arrays of microtubules not microfilaments. In addition to cilia on epithelial cells, most other cell types have at least one short projection called a primary cilium, which is not motile but is enriched with receptors and signal transduction complexes for detection of light, odors, motion, and flow of liquid past the cells. Motile cilia are abundant on cuboidal or columnar cells of many epithelia. Typical cilia are 5-10 μm long and 0.2 μm in diameter, which is much longer and two times wider than a typical microvillus.

TYPES OF EPITHELIA

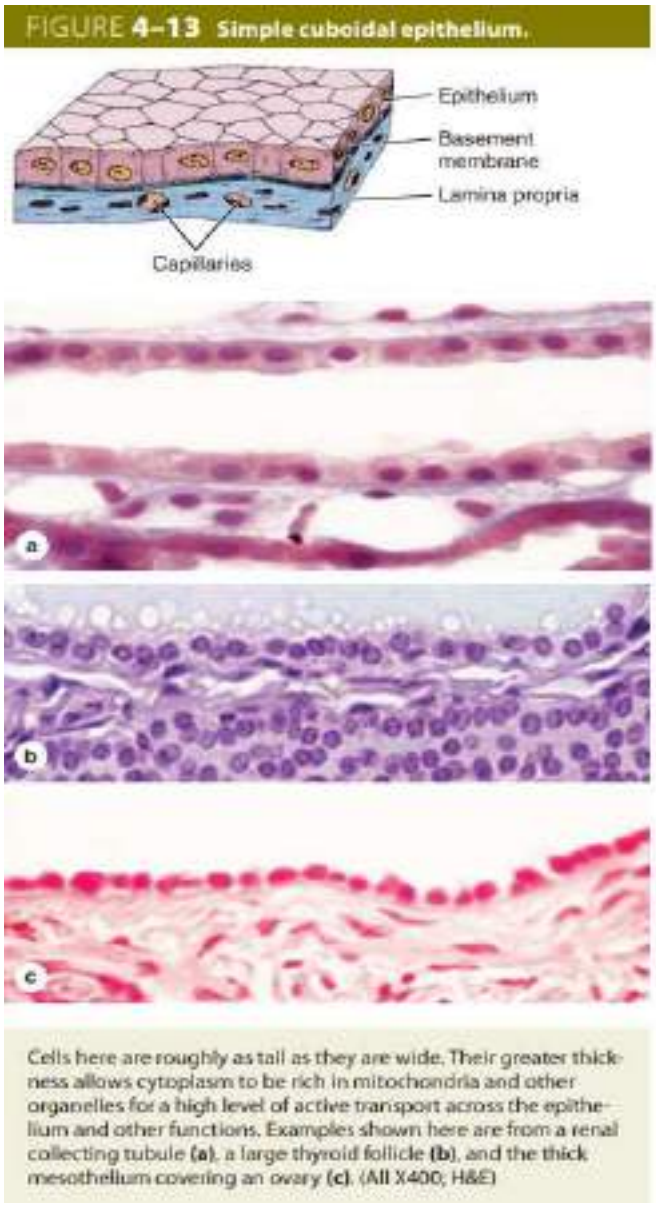
Epithelia can be divided into two main groups: **covering** (or **lining**) epithelia and **secretory** (**glandular**) epithelia. This is an arbitrary functional division for there are lining epithelia in which all the cells also **secrete** (eg, the lining of the stomach) or in which glandular cells are distributed among the lining cells (eg, mucous cells in the small intestine or trachea).

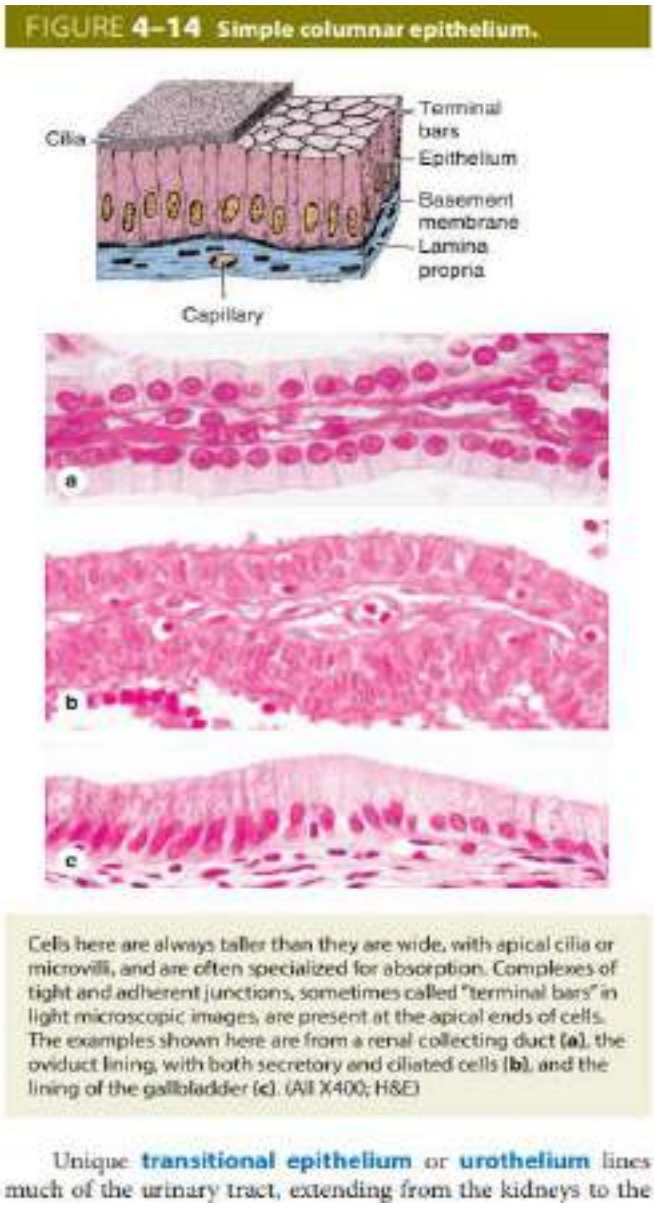
1. **Covering or Lining Epithelia** Cells of covering epithelia are organized into one or more layers that cover the surface or line the cavities of an organ. As summarized in Table 4–3, such epithelia are classified according to the number of cell layers and the cell morphology in the outer layer. **Simple epithelia** contain one cell layer and **stratified epithelia** contain two or more layers. Based on cell shape, simple epithelia are further classified as **squamous** (thin cells), **cuboidal** (cell width and thickness roughly similar), or **columnar** (cells taller than they are wide). Examples of these epithelial types are shown in Figures 4–12 through 4–14.

FIGURE **4–12** **Simple squamous epithelium.**



This is a single layer of thin cells, in which the **cell nuclei** (arrows) are the thickest and most visible structures. Simple epithelia are typically specialized as lining of vessels and cavities, where they regulate passage of substances into the underlying tissue. The thin cells often exhibit transcytosis. Examples shown here are those lining the thin renal loops of Henle **(a)**, covering the outer wall of the intestine **(b)**, and lining the inner surface of the cornea **(c)**. (a, c X400; b X600; H&E)





Unique **transitional epithelium** or **urothelium** lines much of the urinary tract, extending from the kidneys to the

Most stratified epithelia (Figure 4–15) are classified according to the cell shape of the superficial outer layer(s): **squamous**, **cuboidal**, or **columnar**. The very thin surface cells of stratified squamous epithelia can be "keratinized" (packed with keratin filaments) or "nonkeratinized" (with relatively sparse keratin). **Stratified squamous keratinized epithelium** is found mainly in the **epidermis of skin**, where it **helps prevent dehydration from the tissue** (Figure 4–15a). Its cells form many layers, with the less differentiated cuboidal cells near the basement membrane. These cells have many desmosomes and become more irregular in shape and then flatten as they accumulate keratin in the process of **keratinization** and are moved progressively toward the skin surface, where they become thin, metabolically inactive packets (squames) of keratin lacking nuclei with **skin**, this surface layer of cells helps protect against water loss across this epithelium.

TABLE 4–3 Common types of covering epithelia.

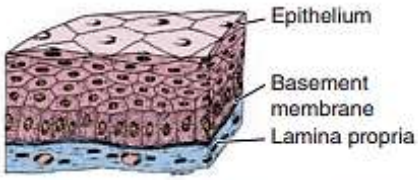
Major Feature	Cell Form	Examples of Distribution	Main Function
Simple (one layer of cells)	Squamous	Lining of vessels (endothelium); Serous lining of cavities: pericardium, pleura, peritoneum (mesothelium)	Facilitates the movement of the viscera (mesothelium), active transport by pinocytosis (mesothelium and endothelium), secretion of biologically active molecules (mesothelium)
	Cuboidal	Covering the ovary, thyroid	Covering, secretion
	Columnar	Lining of intestine, gallbladder	Protection, lubrication, absorption, secretion
Stratified (two or more layers of cells)	Squamous keratinized (dry)	Epidermis	Protection; prevents water loss
	Squamous nonkeratinized (moist)	Mouth, esophagus, larynx, vagina, anal canal	Protection, secretion; prevents water loss
	Cuboidal	Sweat glands, developing ovarian follicles	Protection, secretion
	Transitional	Bladder, ureters, renal calyces	Protection, distensibility
	Columnar	Conjunctiva	Protection
Pseudostratified (layers of cells with nuclei at different levels; not all cells reach surface but all adhere to basal lamina)		Lining of trachea, bronchi, nasal cavity	Protection, secretion; cilia-mediated transport of particles trapped in mucus out of the air passages

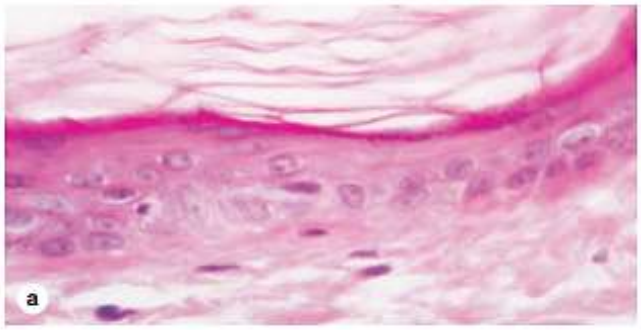
Stratified squamous nonkeratinized epithelium (Figures 4–15b and c) lines moist internal cavities (eg, **mouth, esophagus, and vagina**) where water loss is not a problem. Here the flattened cells of the surface layer retain their nuclei and most metabolic functions.

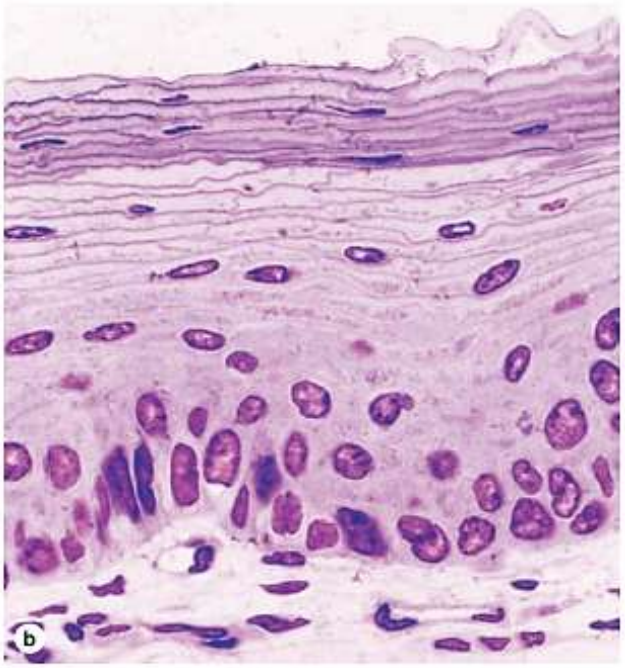
Stratified cuboidal and stratified columnar epithelia are both relatively rare. Stratified cuboidal epithelium occurs in the **excretory ducts of salivary** and **sweat glands** (Figure 4–15d). Stratified columnar epithelium is seen in the **conjunctiva lining the eyelids**, where it is both protective and mucus secreting.

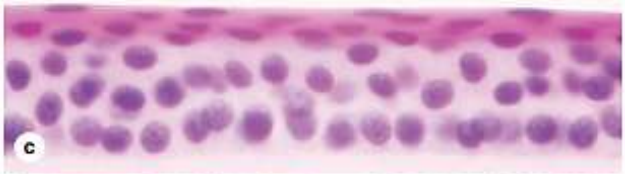
Unique **transitional epithelium** or **urothelium** lines much of the **urinary tract**, extending from the **kidneys** to the proximal part of the **urethra**, and is characterized by a superficial layer of large, dome-like cells sometimes called umbrella cells (Figure 4–16). These cells are **specialized to protect underlying tissues from the hypertonic and potentially cytotoxic effects of urine**. Importantly, unique morphological features of the cells **allow distension of transitional epithelium as the urinary bladder fills**.

FIGURE 4–15 Stratified epithelium.







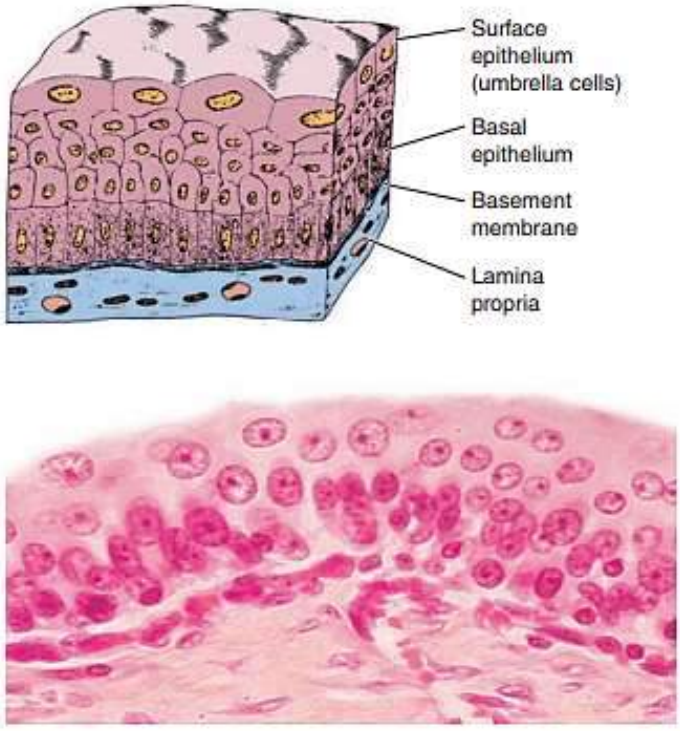


Stratified squamous epithelia usually have protective functions: protection against easy invasion of underlying tissue by microorganisms and protection against water loss. These functions are particularly important in the epidermis **(a)** in which differentiating cells become **keratinized**, that is, filled with keratin and other substances, eventually lose their nuclei and organelles, and form superficial layers flattened squames that impede water loss. Keratinized cells are sloughed off and replaced by new cells from more basal layers, which are discussed fully with the skin in Chapter 18.

Nonkeratinized stratified squamous epithelia occur in many organs, such as the esophageal lining **(b)** or outer covering of the cornea **(c)**. Here cells accumulate much less keratin and retain their nuclei but still provide protection against microorganisms.

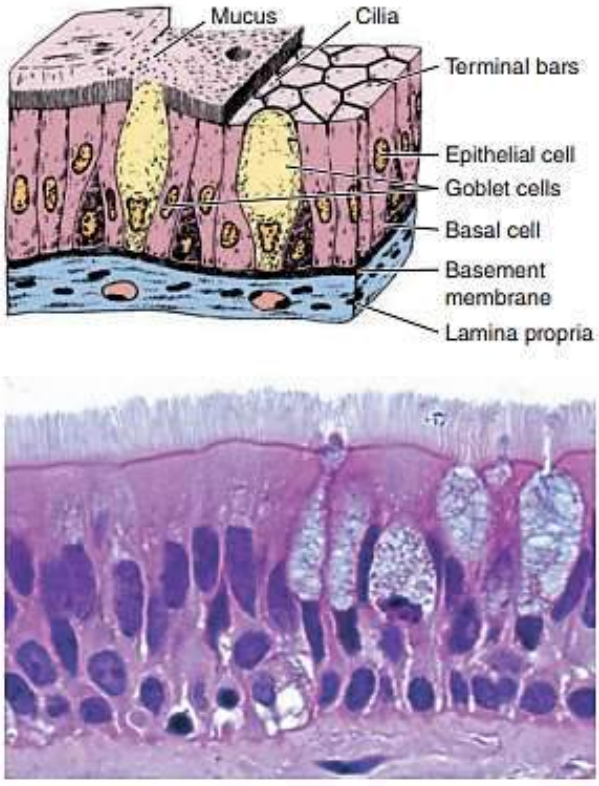
Stratified cuboidal or columnar epithelia are fairly rare but occur in excretory ducts of certain glands, such as sweat glands **(d)** where the double layer of cells allows additional functions. All X400; (b) PT, (a, c, and d) H&E.

FIGURE **4–16** **Transitional epithelium or urothelium.**



Urothelium is stratified and lines much of the urinary tract. The superficial cells are rounded or dome-shaped, and have specialized membrane features enabling them to withstand the hypertonic effects of urine and protect underlying cells from this toxic solution. Cells of this epithelium are also able to adjust their relationships with one another and undergo a transition in their appearance as the urinary bladder fills and the wall is distended. These unique features of transitional epithelium are discussed more extensively in Chapter 19. (X400; H&E)

FIGURE **4–17** **Pseudostratified epithelium.**



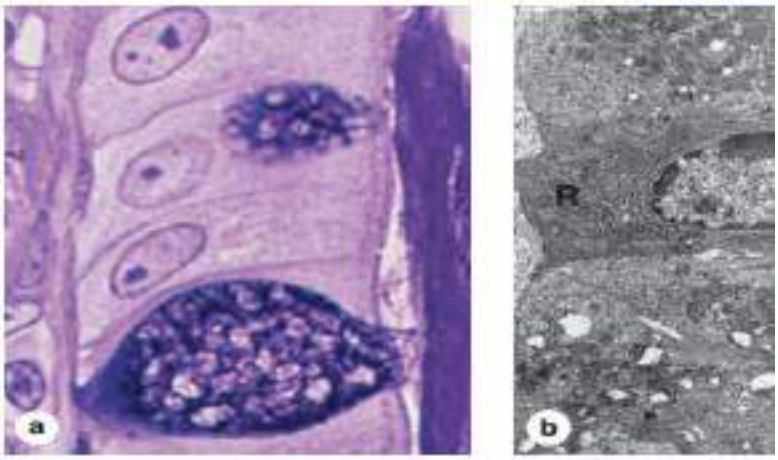
Cells of pseudostratified epithelia appear to be in several layers, but their basal ends all rest on the basement membrane. The pseudostratified columnar epithelium of the upper respiratory tract shown here contains many ciliated cells, as well as other cells with their nuclei at different levels. (X400; H&E)

2. Secretory Epithelia & Glands

Epithelial cells that function mainly to produce and secrete various macromolecules may occur in epithelia with other major functions or comprise specialized organs called **glands**. Secretory cells may **synthesize**, **store**, and **release proteins** (eg, in the **pancreas**), **lipids** (eg, **adrenal**, **sebaceous glands**), or complexes of **carbohydrates** and **proteins** (eg, **salivary glands**). Epithelia of **mammary glands** secrete all three substances.

Scattered secretory cells, sometimes called **unicellular glands**, are common in simple cuboidal, simple columnar, and pseudostratified epithelia. An important, easily seen example is the **goblet cell** abundant in the lining of the **small intestine** (Figure 4–18) and **respiratory tract** (Figure 4–17), which secretes lubricating mucus that aids the function of these organs. Glands develop from covering epithelia in the fetus by cell proliferation and growth into the underlying connective tissue, followed by further differentiation.

FIGURE 4–18 Goblet cells: unicellular glands.

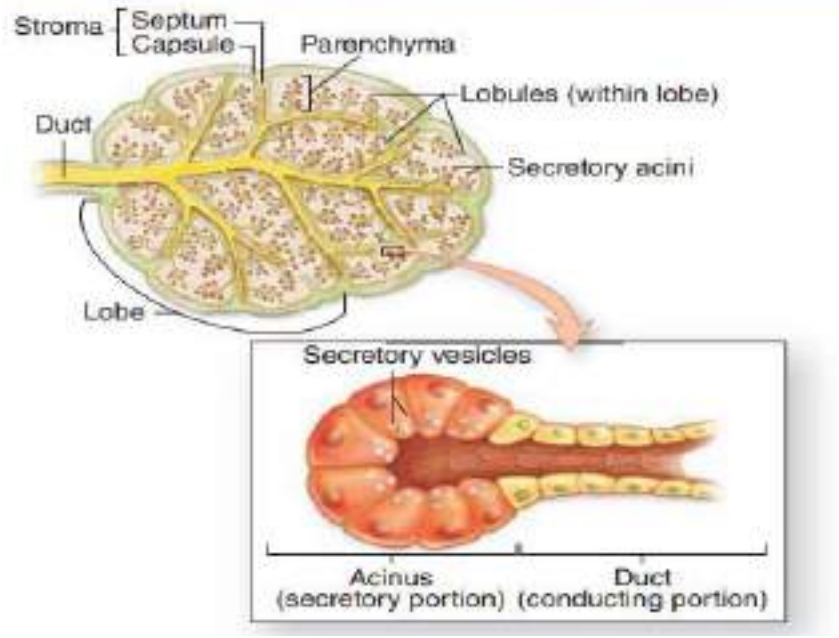


The simple columnar epithelium lining the small intestine shows many isolated goblet cells secreting mucus into the lumen.
(a) With a stain for the oligosaccharide components of mucin glycoproteins, the cytoplasmic secretory granules of two goblet cells and secreted mucus are stained purple. (X600; PAS-PT)

Exocrine glands remain connected with the surface epithelium, the connection forming the tubular ducts lined with epithelium that deliver the secreted material where it is used. **Endocrine glands** lose the connection to their original epithelium and therefore lack ducts. Thin-walled blood vessels (capillaries) adjacent to endocrine cells absorb their secreted hormone products for transport in blood to target cells throughout the body.

As shown in Figure 4–20, epithelia of exocrine glands are organized as a continuous system of many small secretory portions and ducts that transport the secretion out of the gland.

FIGURE 4–20 General structure of exocrine glands.



Three basic mechanisms for releasing the product are commonly used by cells specialized for secretion (Figure 4–21), and cells engaged in each type of secretion can be distinguished histologically:

1. **Merocrine secretion**: This is the most common method of protein or glycoprotein secretion and involves typical exocytosis from membrane-bound vesicles or secretory granules, **Salivary glands.**

2. **Holocrine secretion**: Here cells accumulate product continuously as they enlarge and undergo terminal differentiation, culminating in complete cell disruption that releases the product and cell debris into the gland's lumen. This is best seen in the **sebaceous glands** producing lipid rich material in **skin** (Figure 4–22).

3. **Apocrine secretion**: Here product accumulates at the cells' apical ends, portions of which are then extruded to release the product together with small amounts of cytoplasm and cell membrane. Lipid droplets are secreted in the **mammary gland** in this manner (Figure 4–23).

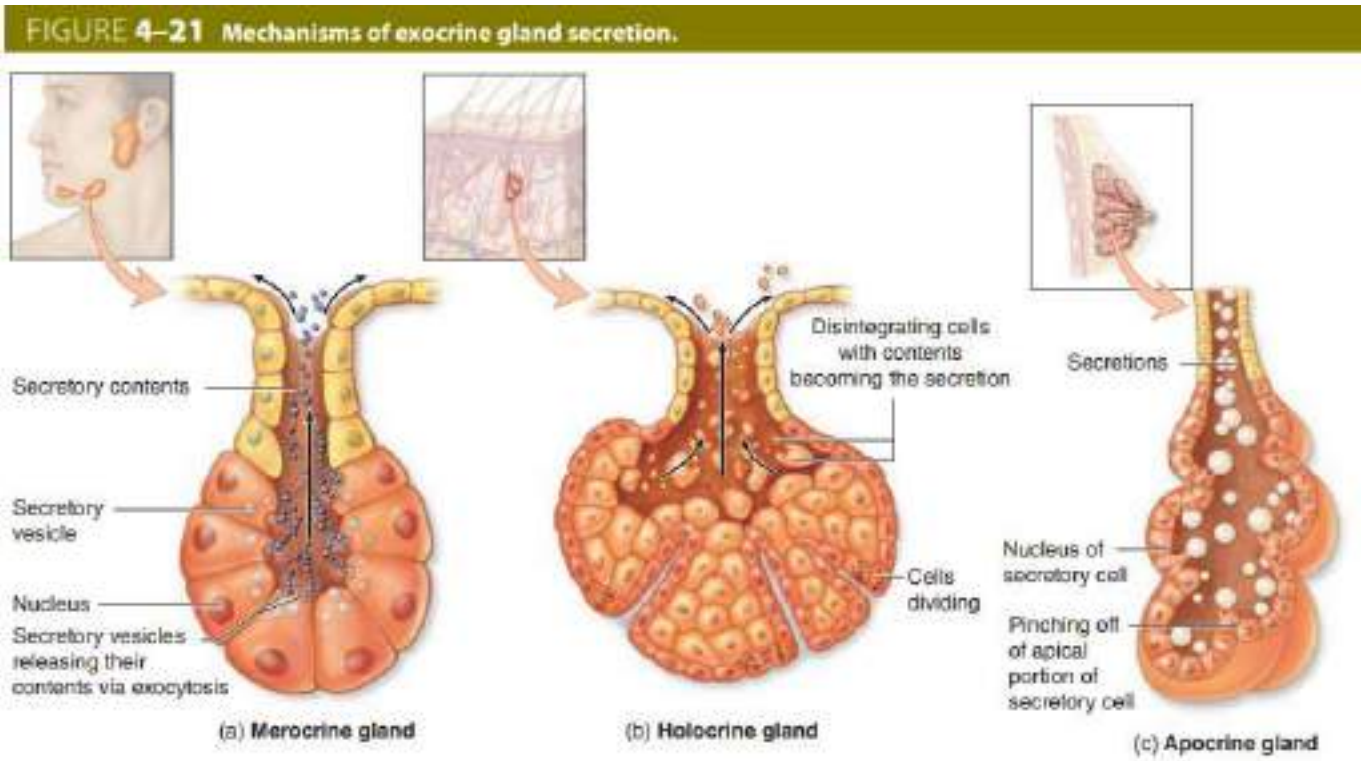


FIGURE 4–21 Mechanisms of exocrine gland secretion.

Three basic types of secretion are used by cells of exocrine glands, depending on what substance is being secreted.

(a) Merocrine secretion releases products, usually containing proteins, by means of exocytosis at the apical end of the secretory cells. Most exocrine glands are merocrine.

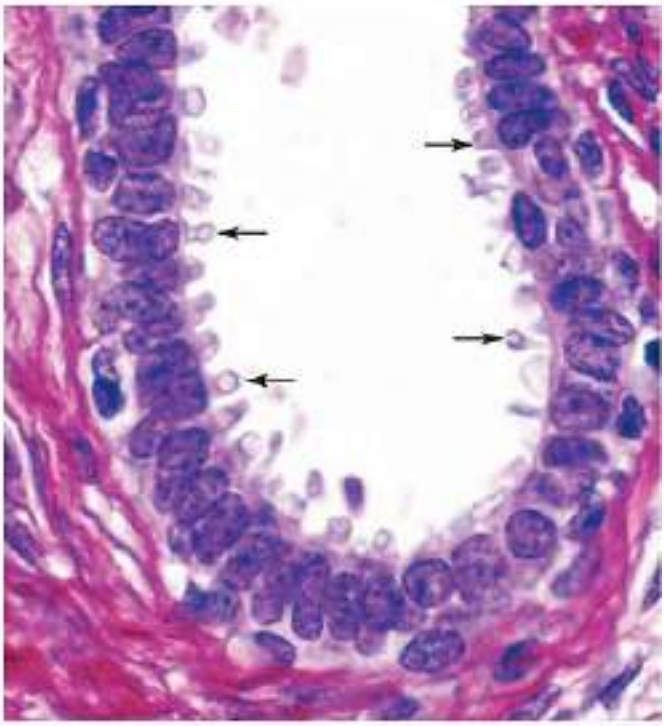
(b) Holocrine secretion is produced by the disintegration of the secretory cells themselves as they complete their terminal differentiation, which involves becoming filled with product. Sebaceous glands of hair follicles are the best examples of holocrine glands.

(c) Apocrine secretion involves loss of membrane-enclosed apical cytoplasm, usually containing one or more lipid droplets. Apocrine secretion, along with merocrine secretion, is seen in mammary glands.

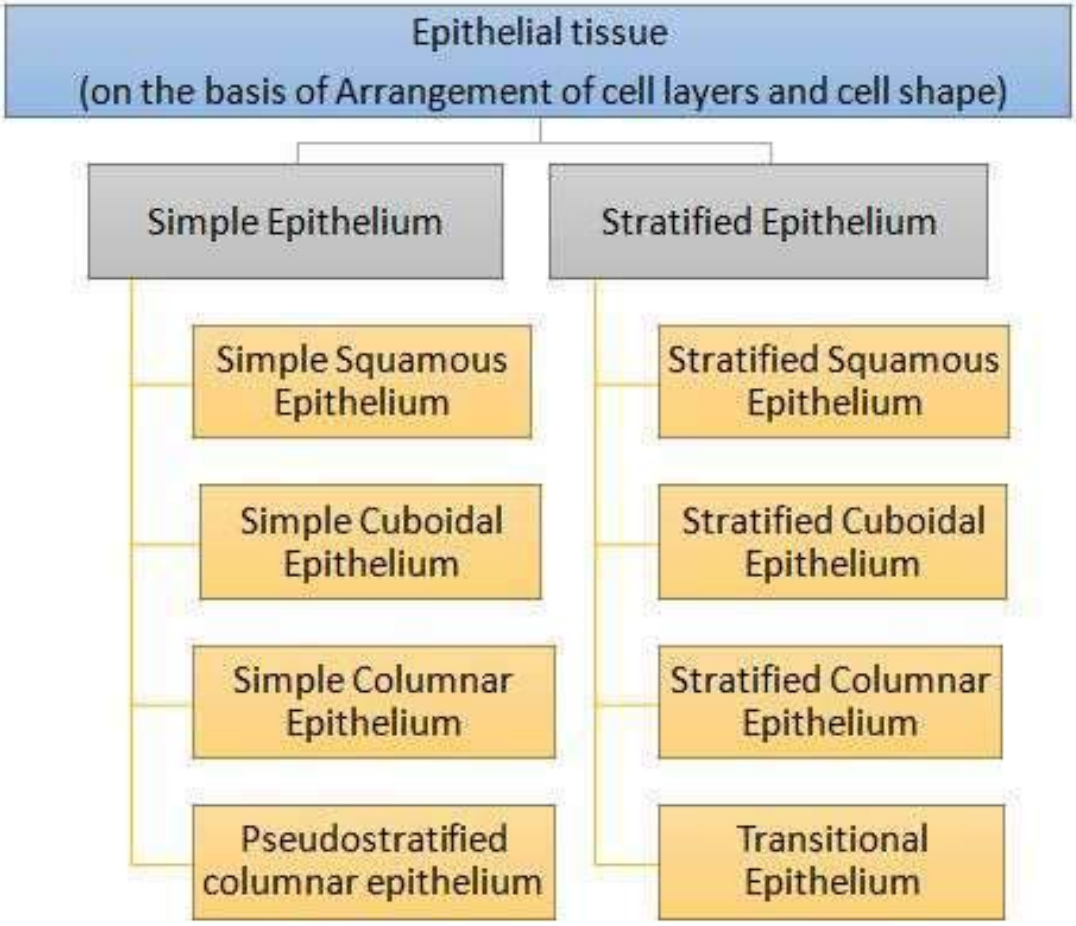
FIGURE **4–22** **Holocrine secretion in a sebaceous gland.**

In holocrine secretion, best seen in the sebaceous gland adjacent to hair follicles, entire cells fill with a lipid-rich product as they differentiate. Mature (terminally differentiated) cells separate and completely disintegrate, releasing the lipid that serves to protect and lubricate adjacent skin and hair. Sebaceous glands lack myoepithelial cells; cell proliferation inside a dense, inelastic connective tissue capsule continuously forces product into the duct. (X200; H&E)

FIGURE **4–23** **Apocrine secretion in the mammary gland.**



The secretory portions of a mammary gland demonstrate apocrine secretion, characterized by extrusion of the secretion product along with a bit of apical cytoplasm enclosed within a small amount of plasma membrane, which is quickly lost after separation from the secretory cell (**arrows**). The released portion of cell contains lipid droplet(s), the major product of apocrine secretion. Merocrine secretion also occurs from the same and other cells of the mammary gland. (X400; PSH)


Epithelial tissue
(on the basis of Arrangement of cell layers and cell shape)
Simple Epithelium
Stratified Epithelium
Simple Squamous Epithelium
Simple Cuboidal Epithelium
Simple Columnar Epithelium
Pseudostratified columnar epithelium
Stratified Squamous Epithelium
Stratified Cuboidal Epithelium
Stratified Columnar Epithelium
Transitional Epithelium