Epithelial Tissue
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1. Basic types of tissue
2. Principal functions of epithelial tissue
3. Forms & Characteristics of Epithelial Cells
4. Specializations of the Cell Surface
5. Types of Epithelia
6. General Biology of Epithelial Tissues
Basic types of tissue

- Epithelial tissue
- Connective tissue
- Muscular tissue
- Nervous tissue
## Basic types of tissue

### Table 4-1. Main Characteristics of the Four Basic Types of Tissues.

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Cells</th>
<th>Extracellular Matrix</th>
<th>Main Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nervous</td>
<td>Intertwining elongated processes</td>
<td>None</td>
<td>Transmission of nervous impulses</td>
</tr>
<tr>
<td>Epithelial</td>
<td>Aggregated polyhedral cells</td>
<td>Very small amount</td>
<td>Lining of surface or body cavities, glandular secretion</td>
</tr>
<tr>
<td>Muscle</td>
<td>Elongated contractile cells</td>
<td>Moderate amount</td>
<td>Movement</td>
</tr>
<tr>
<td>Connective</td>
<td>Several types of fixed and wandering cells</td>
<td>Abundant amount</td>
<td>Support and protection</td>
</tr>
</tbody>
</table>
Basic types of tissue

• Most organs can be divided into two components:
  
1. Parenchyma, which is composed of the cells responsible for the main functions typical of the organ.

2. Stroma, which is the supporting tissue.

• Except in the brain and spinal cord, the stroma is made of connective tissue.
The principal functions of epithelial tissue

1. Covering and lining of surfaces (skin, intestines)
2. Absorption (intestines)
3. Secretion (glands)
4. Sensation (gustative and olfactory neuroepithelium),
5. Contractility (myoepithelial cells).
The Forms & Characteristics of Epithelial Cells

- High columnar cells
- Cuboidal cells
- Low squamous cells

- Epithelial cell nuclei have distinctive shapes: varying from spherical to elongated or elliptic.
- The long axis of the nucleus is always parallel to the main axis of the cell.
- The form of the cell nucleus is an important clue to the shape and number of cells.
- Nuclear form is also of value in determining whether the cells are arranged in layers.
The Forms & Characteristics of Epithelial Cells

• Almost all epithelial cells, whether lining a surface or forming gland units, rest on a connective tissue.

• In the case of epithelia that line the cavity of internal organs (especially the digestive, respiratory, and urinary systems) this layer of connective tissue is often called lamina propria.
  
  – Serves to support the epithelium
  – Provides nutrition
  – Binds it to neighboring structures
The Forms & Characteristics of Epithelial Cells

• The area of contact between epithelium and lamina propria is increased by irregularities in the connective tissue surface in the form of small evaginations called **papillae**.

• Papillae occur most frequently in epithelial tissues subject to stress, such as the skin and the tongue.
The Forms & Characteristics of Epithelial Cells

- The portion of the epithelial cells that faces the connective tissue is called the **basal pole**.
- The opposite side, usually facing a space, is called the **apical pole**.
- The surface of the apical pole is also called the **free surface**.
- The surfaces that are apposed to neighbor cells are called **lateral surfaces**.
Basal Lamina

• Most epithelial cells are separated from the connective tissue by a sheet of extracellular material called the **basal lamina**.

• Two basal laminas can fuse in places where no intervening connective tissue is present.

• The main components of basal laminae are:
  – **Type IV collagen**
  – **The glycoproteins** laminin and entactin
  – **Proteoglycans** (e.g., the heparan sulfate proteoglycan called perlecan).

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Basal Lamina

• It appears as a dense layer, 20–100 nm thick, consisting of a delicate network of very fine fibrils (lamina densa)

• In addition, basal laminae may have an electron-lucent layer on one or both sides of the lamina densa, called lamina rara or lamina lucida.
Basal Lamina

- Basal laminae are attached to the underlying connective tissues by anchoring fibrils formed by type VII collagen.
- In some instances, reticular fibers are closely associated with the basal lamina, forming the reticular lamina.
Functions of Basal Lamina

- Supporting the cells.
- Provide a barrier that limits or regulates the exchange of macromolecules between connective tissue and cells of other tissues.
- Influence cell polarity.
- Regulate cell proliferation and differentiation by binding with growth factors.
- Influence cell metabolism.
Functions of Basal Lamina

- Serve as pathways for cell migration.
- Seems to contain the information necessary for certain cell-to-cell interactions, such as the reinnervation of denervated muscle cells.
- The presence of the basal lamina around a muscle cell is necessary for the establishment of new neuromuscular junctions.
Basement Membrane

• A periodic acid–Schiff (PAS)-positive layer.
• Visible with the light microscope,
• Present beneath some epithelia.

➢ The basement membrane is usually formed by the association of either two basal laminae
➢ or a basal lamina and a reticular lamina and is therefore thicker.
Intercellular Adhesion & Intercellular Junctions

- Junctions between cells can be classified as:
- **Impermeable junctions**
  - Zonula occludentes
- **Adhering junctions**
  - Zonula adherentes
  - Desmosomes
  - Hemidesmosomes
- **Communicating junctions**
  - Gab junctions
Tight junctions, or zonulae occludens

- The most apical of the junctions.
- The number of ridges and grooves, or fusion sites, has a high correlation with the leakiness of the epithelium.
- Epithelia with one or few fusion sites (e.g., proximal renal tubules) are more permeable to water and solutes than are epithelia with numerous fusion sites (e.g., urinary bladder).
Tight junctions, or zonulae occludens

- The principal function of the tight junction is to form a seal that prevents the flow of material between epithelial cells (called the paracellular pathway) in either direction (from apex to base or from base to apex.)
Zonula adherens

- In many epithelia, the next type of junction encountered is the **zonula adherens**
- This junction encircles the cell and provides for the adhesion of one cell to its neighbor.
Zonula adherens

• The feature of this junction is the insertion of numerous actin filaments into electron-dense plaques of material on the cytoplasmic surfaces of the junctional membranes.

• The filaments belong to the **terminal web**, a web of actin filaments, intermediate filaments, and spectrin found close to the free surface.
Desmosome or macula adherens

- The desmosome is a complex disk-shaped structure at the surface of one cell that is matched with an identical structure at the surface of the adjacent cell.
- On the cytosolic side of the membrane of each cell and separated from it by a short distance is a circular plaque of material called an attachment plaque.
Desmosome or macula adherens

- In epithelial cells, groups of intermediate cytokeratin filaments are inserted into the attachment plaque or make hairpin turns and return to the cytoplasm.
- Because intermediate filaments of the cytoskeleton are very strong, desmosomes provide a firm adhesion among the cells.
**Desmosome or macula adherens**

- In nonepithelial cells, the intermediate filaments attached to desmosomes are made not of cytokeratin but of other proteins, such as desmin or vimentin.
- Proteins of the **cadherin** family participate in the adhesion provided by desmosomes.
- *In vitro* this adhesiveness is abolished by the removal of Ca$^{+2}$.
Hemidesmosomes

- These structures take the form of half a desmosome and bind the epithelial cell to the subjacent basal lamina.
- The plaques are made of **integrins**, a family of transmembrane proteins that is a receptor site for the extracellular macromolecules laminin and type IV collagen.
Gap or communicating junctions

- Gap or communicating junctions can occur almost anywhere along the lateral membranes of epithelial cells.
- These junctions are seen as aggregates of intramembrane particles arranged in circular patches in the plasma membrane.
- Gap junctions permit the exchange between cells of molecules with molecular mass $<1500$ Da.
- Signaling molecules such as some hormones, cyclic AMP and GMP, and ions can move through gap junctions.
Gap or communicating junctions

- The individual unit of the gap junction is called a **connexon**.
- Each connexon is formed by six gap junction proteins called **connexins**, which join together leaving a hydrophilic pore about 1.5 nm in diameter in the center.
- Connexons of adjacent cells are aligned to form a hydrophilic channel between the two cells.
**Zonulae occludentes**
Extend along entire circumference of the cell. Prevent material from taking paracellular route in passing from the lumen into the connective tissues.

**Zonulae adherentes**
Basal to zonulae occludentes. E-cadherins bind to each other in the intercellular space and to actin filaments, intracellularly.

**Maculae adherentes**
E-cadherins are associated with the plaque; intermediate filaments form hairpin loops.

**Gap junctions**
Communicating junctions for small molecules and ions to pass between cells. Couple adjacent cells metabolically and electrically.

**Hemidesmosomes**
Attach epithelial cells to underlying basal lamina.
Specializations of the Cell Surface

• The free or apical surface of many types of epithelial cells contain specialized structures that:
  – Increase the cell surface area
  – or move substances or particles stuck to the epithelium.
Specializations of the Cell Surface

- Microvilli
- Stereocilia
- Cilia & Flagella
Microvilli

- Fingerlike extensions measuring about 1 µm high and 0.08 µm wide.
- Found mainly on the free cell surface.
- Hundreds of microvilli are found in absorptive cells, such as the lining epithelium of the small intestine and the cells of the proximal renal tubule.
Microvilli

• In these absorptive cells the glycocalyx is thicker than it is in most other cells.

• The complex of microvilli and glycocalyx may be seen with the light microscope and is called the brush, or striated, border.
Microvilli

- Within the microvilli are clusters of actin filaments that are cross-linked to each other and to the surrounding plasma membrane by several other proteins.
Stereocilia

- Long, nonmotile extensions of cells of the epididymis and ductus deferens that are actually long and branched microvilli and should not be confused with true cilia.
- Stereocilia increase the cell surface area, facilitating the movement of molecules into and out of the cell.
Cilia

- Cylindrical, motile structures on the surface of some epithelial cells, 5–10 μm long and 0.2 μm in diameter.
- They are surrounded by the cell membrane and contain a central pair of isolated microtubules surrounded by nine pairs of microtubules.
- Cilia are inserted into **basal bodies**, which are small cylindrical structures at the apical pole just below the cell membrane.
Cilia

- In living organisms, cilia have a rapid back-and-forth movement.
- Ciliary movement is frequently coordinated to permit a current of fluid or particulate matter to be propelled in one direction over the epithelial surface.
- Adenosine triphosphate (ATP) is the source of energy for ciliary motion.
Flagella

- Flagella, present in the human body only in spermatozoa, are similar in structure to cilia but are much longer and are limited to one flagellum per cell.
Types of Epithelia

Structure & Function

- Covering epithelia
- Glandular epithelia
<table>
<thead>
<tr>
<th>Type</th>
<th>Cell Form</th>
<th>Examples of Distribution</th>
<th>Main Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple</td>
<td>Squamous</td>
<td>Lining of vessels (endothelium). Serous lining of cavities; pericardium, pleura, peritoneum (mesothelium).</td>
<td>Facilitates the movement of the viscera (mesothelium), active transport by pinocytosis (mesothelium and endothelium), secretion of biologically active molecules (mesothelium).</td>
</tr>
<tr>
<td>Cuboidal</td>
<td></td>
<td>Covering the ovary, thyroid.</td>
<td>Covering, secretion.</td>
</tr>
<tr>
<td>Columnar</td>
<td></td>
<td>Lining of intestine, gallbladder.</td>
<td>Protection, lubrication, absorption, secretion.</td>
</tr>
<tr>
<td>Pseudostratified</td>
<td>Some columnar and some cuboidal</td>
<td>Lining of trachea, bronchi, nasal cavity.</td>
<td>Protection, secretion; cilia-mediated transport of particles trapped in mucus.</td>
</tr>
<tr>
<td>Stratified</td>
<td>Surface layer squamous keratinized (dry)</td>
<td>Epidermis.</td>
<td>Protection; prevents water loss.</td>
</tr>
<tr>
<td></td>
<td>Surface layer squamous nonkeratinized (moist)</td>
<td>Mouth, esophagus, larynx, vagina, anal canal.</td>
<td>Protection, secretion; prevents water loss.</td>
</tr>
<tr>
<td></td>
<td>Cuboidal</td>
<td>Sweat glands, developing ovarian follicles.</td>
<td>Protection, secretion.</td>
</tr>
<tr>
<td></td>
<td>Transitional: domelike to flattened, depending on the functional state of the organ</td>
<td>Bladder, ureters, renal calyces.</td>
<td>Protection, distensibility.</td>
</tr>
<tr>
<td></td>
<td>Columnar</td>
<td>Conjunctiva.</td>
<td>Protection.</td>
</tr>
</tbody>
</table>
Simple Epithelia

A Simple squamous epithelium

B Simple cuboidal epithelium

C Simple ciliated columnar epithelium

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Simple Epithelia

- **Simple squamous epithelium:**
  - **Endothelium** that lines blood and lymph vessels.
  - **Mesothelium** that lines certain body cavities, such as the pleural and peritoneal cavities, and covers the viscera.
Simple Epithelia

- **Simple cuboidal epithelium:**
  - Surface epithelium of the ovary
  - Cells that form certain tubules in glands and in the kidney
Simple Epithelia

- **Simple columnar epithelium:**
  - Lining of the intestines
  - Lining of the uterus
Stratified Epithelia

- **Stratified**
  - Squamous nonkeratinized
  - Cuboidal
  - Keratinized
  - Columnar

- **Transitional**
  - Transitional (relaxed)
  - Transitional (distended)

- **Pseudostratified**
  - Pseudostratified columnar
Stratified Epithelia

- **Stratified squamous keratinized epithelium:**
  - Covers dry surfaces such as the skin.

- **Stratified squamous nonkeratinized epithelium:**
  - Covers wet surfaces such as the esophagus.
Stratified Epithelia

- Stratified columnar epithelium
  - Ocular conjunctiva
  - Large ducts of salivary glands.
Stratified Epithelia

- Stratified cuboidal epithelium:
  - Sweat glands
  - Developing ovarian follicles.
Stratified Epithelia

- **Stratified Transitional epithelium**
  - Lines the urinary bladder
  - Lines the ureter
  - Lines the upper part of the urethra

- The form of these cells changes according to the degree of distention of the bladder.
Pseudostratified epithelium

- Nuclei appear to lie in various layers, all cells are attached to the basal lamina, although some do not reach the surface.

- The best-known example of this tissue is the ciliated pseudostratified columnar epithelium in the respiratory passages.
Neuroepithelial cells

• Are cells of epithelial origin with specialized sensory functions
  ✓ Cells of taste buds
  ✓ Cells of the olfactory mucosa
Myoepithelial cells

- Are branched cells that contain myosin and a large number of actin filaments.

- They are specialized for contraction, mainly of the secretory units of the mammary, sweat, and salivary glands.
Glandular Epithelia

• Glandular epithelia are formed by cells specialized to produce secretion.

• The molecules to be secreted are generally stored in the cells in small membrane-bound vesicles called secretory granules.
Glandular Epithelia

- Glandular epithelial cells may synthesize, store, and secrete:
  - Proteins (e.g., pancreas)
  - Lipids (e.g., adrenal, sebaceous glands)
  - Complexes of carbohydrates and proteins (e.g., salivary glands).
- The mammary glands secrete all three substances.
Classification of Glandular Epithelia

Unicellular glands

Multicellular glands
Glandular Epithelia

• An example of a unicellular gland is the **goblet cell** of the lining of the small intestine or of the respiratory tract.

• The term "**gland**," usually used to designate large, complex aggregates of glandular epithelial cells, such as in the salivary glands and the pancreas.
Classification of Glands

Glands

Exocrine glands

Endocrine glands
Glands arise during fetal life from covering epithelia by means of proliferation and invasion of the epithelial cells into the subjacent connective tissue, followed by further differentiation.
Exocrine glands

• Retain their connection with the surface epithelium from which they originated.

• This connection is transformed into tubular ducts lined with epithelial cells through which the glandular secretions pass to reach the surface.
Exocrine glands

- Exocrine glands have:
  - **Secretory portion**: Which contains the cells responsible for the secretory process.
  - **Ducts**: Which transport the secretions.

- **Simple glands** have only one unbranched duct.
  - Tubule
  - Coiled tubule
  - Branched tubule
  - Acinus
Exocrine glands

- **Compound glands** have ducts that branch repeatedly.
  - Tubular
  - Acinar
  - Tubuloacinar
Endocrine glands

• Glands whose connection with the surface is **lost** during development.

• These glands are therefore **ductless**, and their secretions are picked up and transported to their site of action by the bloodstream rather than by a duct system.
Endocrine glands

• The endocrine cells may form **anastomosing cords** interspersed between dilated blood capillaries:
  – Adrenal gland
  – Parathyroid
  – Anterior lobe of the pituitary
Endocrine glands

• The endocrine cells may arrange themselves as vesicles or follicles filled with noncellular material.
  – The thyroid gland.
**Secretion Modes of Glandular Epithelia**

- **A-Holocrine**: the product of secretion is shed with the whole cell—a process that involves destruction of the secretion-filled cells.
  - Sebaceous glands

- **B-Merocrine**: the secretory granules leave the cell by exocytosis with no loss of other cellular material.
  - Pancreas

- **C-Apocrine**: the secretory product is discharged together with parts of the apical cytoplasm.
  - Mammary gland
General Biology of Epithelial Tissues

- Innervation
- Renewal of Epithelial Cells
- Control of Glandular Activity
- Cells That Transport Ions
- Cells That Transport by Pinocytosis
- Serous Cells & Mucus-Secreting Cells
- The Diffuse Neuroendocrine System (DNES)
- Myoepithelial Cells

Epithelial Tissues

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Polarity

• In many types of epithelial cells the distribution of organelles and membrane proteins is different when comparing the basal and apical poles of the cell.

• Receptors for chemical messengers (eg, hormones, neurotransmitters) that influence the activity of epithelial cells are localized in the basolateral membranes.

• In absorptive epithelial cells, the apical cell membrane may contain enzymes such as disaccharidases and peptidases, which complete the digestion of molecules to be absorbed.
Innervation

• Most epithelial tissues receive a rich supply of sensory nerve endings from nerve plexuses in the lamina propria.

• The exquisite sensitivity of the cornea, the epithelium covering the anterior surface of the eye, is due to the great number of sensory nerve fibers that ramify between corneal epithelial cells.
Renewal of Epithelial Cells

- Epithelial tissues are labile and their cells are renewed continuously by means of mitotic activity.
  - It can be **fast** in tissues such as the intestinal epithelium.
  - It can be **slow**, as in the liver and the pancreas.
- In stratified and pseudostratified epithelial tissues, mitosis takes place within the **germinal layer**, closest to the basal lamina, which contains the stem cell.
Metaplasia

• Under certain abnormal conditions, one type of epithelial tissue may undergo transformation into another type.
• This reversible process is called **metaplasia**.
• In heavy cigarette smokers, the ciliated pseudostratified epithelium lining the bronchi can be transformed into stratified squamous epithelium.
Control of Glandular Activity

- Glands are usually sensitive to both neural and endocrine control.
  - Exocrine secretion in the pancreas depends mainly on stimulation by the hormones secretin and cholecystokinin.
  - Salivary glands are principally under neural control.
- The neural and endocrine control of glands occurs through the action of chemical substances called chemical messengers.
Some epithelial cells transfer ions and fluid across the epithelium, this is known as **transcellular transport**.

A: The direction of transport is from the lumen to the blood vessel, as in the gallbladder and intestine. This process is called **absorption**.

B: Transport is in the opposite direction, as in the choroid plexus, ciliary body, and sweat gland. This process is called **secretion**.
Cells That Transport by Pinocytosis

• In most cells, extracellular molecules are internalized in the cytoplasm by pinocytic vesicles that form abundantly on the plasmalemma.

• This activity is clearly observed in the simple squamous epithelia that line the blood and lymphatic capillaries (endothelia) or the body cavities (mesothelia).
Serous Cells

- The acinar cells of the pancreas and parotid salivary glands are examples of serous cells.
- In the basal region, serous cells exhibit an intense basophilia, which results from local accumulation of RNA.
- The apex contains light-stained secretory vesicles.
Serous Cells

- Between the nucleus and the free surface lies a well-developed Golgi complex, several **immature secretory granules** derived from the Golgi complex, and **mature secretory granules** formed after water is removed from the immature granules.
- The mature secretory granules accumulate in the apical cytoplasm.
- In cells that produce digestive enzymes (e.g., pancreatic acinar cells), these granules are called **zymogen granules**.
- The granules stay in the apex until the cell is stimulated to secrete.
- The release of the secretory products happens by a process called **exocytosis**.
Mucus-Secreting Cells

• An example of mucus-secreting cell is the **goblet cell** of the intestines.

• This cell has numerous large, lightly staining granules containing strongly hydrophilic glycoproteins called **mucins**.
Mucus-Secreting Cells

- **Secretory granules** fill the extensive **apical pole** of the cell, and the **nucleus** is located in the **cell base**, which is rich in rough endoplasmic reticulum.
- The **Golgi complex**, located just **above the nucleus**, is exceptionally well developed, indicative of its important function in this cell.
- When mucins are released from the cell, they become highly hydrated and form mucus, a viscous, elastic, protective lubricating gel.
Mucus-Secreting Cells

- Other cells that synthesize mucin glycoproteins are found in several parts of the digestive tube, salivary glands, respiratory tract, and genital tract.
- Many of these mucous cells are organized as tubules showing a pale cytoplasm and a darkly stained nucleus positioned at the cell base.
Serous + Mucus-Secreting Cells

• In salivary glands, mucous secretory cells frequently share the same acinus with serous secretory cells.

• The sublingual and submandibular glands are examples of mixed glands.
The Diffuse Neuroendocrine System (DNES)

- The cytoplasm of the endocrine cells contains either polypeptide hormones or the biogenic amines epinephrine, norepinephrine, or 5-hydroxytryptamine (serotonin).
- Many of these cells are able to take up amine precursors and exhibit amino acid decarboxylase activity.
- These characteristics explain the acronym APUD (amine precursor uptake and decarboxylation).
- Because some of these cells stain with silver salts, they are also called argentaffin and argyrophil cells.
The Diffuse Neuroendocrine System (DNES)

• These cells are widespread throughout the organism and include about 35 types of cells in the respiratory, urinary, and gastrointestinal systems, the thyroid, and the hypophysis.

• Some DNES cells are known as paracrine cells because they produce chemical signals that diffuse into the surrounding extracellular fluid to regulate the function of neighboring cells, without passing through the vascular system.

• Many of the polypeptide hormones and amines produced by DNES cells also act as chemical mediators in the nervous system.

• Apudomas are tumors derived from polypeptide-secreting cells of the DNES.
The Diffuse Neuroendocrine System (DNES)

- Electron micrograph of a cell of the diffuse neuroendocrine system.
- Note the accumulation of secretory granules (arrows) in the basal region of the cell.
- The Golgi complex seen in the upper part of the micrograph shows some secretory granules.
Myoepithelial Cells

- Several exocrine glands (e.g., sweat, lachrymal, salivary, mammary) contain stellate or spindle-shaped **myoepithelial cells**.
- Myoepithelial cells are located between the basal lamina and the basal surface of secretory or ductal cells.
- They are connected to each other and to the epithelial cells by gap junctions and desmosomes.
Myoepithelial Cells

• The cytoplasm contains numerous actin filaments, as well as myosin.
• Myoepithelial cells also contain intermediate filaments that belong to the cytokeratin family, which confirms their epithelial origin.
• The function of myoepithelial cells is to contract around the secretory or conducting portion of the gland and thus to help propel secretory products toward the exterior.
Steroid-Secreting Cells

- They are endocrine cells specialized for synthesizing and secreting steroids with hormonal activity.
- They are polyhedral or rounded acidophilic cells with a central nucleus and a cytoplasm that is usually rich in lipid droplets.
- The cytoplasm of steroid-secreting cells contains an exceptionally rich smooth endoplasmic reticulum.
- Smooth endoplasmic reticulum contains the enzymes necessary to synthesize cholesterol.
Steroid-Secreting Cells

- Their spherical or elongated mitochondria usually contain **tubular cristae** rather than the shelflike cristae that are common in mitochondria of other epithelial cells.

- The process of steroid synthesis results, therefore, from close collaboration between smooth endoplasmic reticulum and mitochondria.
Epithelial Cell-Derived Tumors

• Both benign and malignant tumors can arise from most types of epithelial cells.
  - A **carcinoma** is a malignant tumor of epithelial cell origin.
  - An **adenocarcinoma** is a malignant tumor derived from glandular epithelial tissue.
• These are by far the most common tumors in **adults**.

- **Differentiated** Carcinomas composed of cells reflect cell-specific morphological features and behaviors (e.g., the production of cytokeratins, mucins, and hormones).
- **Undifferentiated** carcinomas are often difficult to diagnose by morphological analysis alone.
• Because these carcinomas usually contain **cytokeratins**, the detection of these molecules by immunocytochemistry often helps to determine the diagnosis and treatment of these tumors.