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A. Epithelia
   1. Simple
      a. Simple squamous
      b. Simple cuboidal
      c. Simple columnar
      d. Pseudostratified columnar
   2. Stratified
      a. Stratified squamous
      b. Stratified cuboidal
      c. Stratified columnar
      d. Transitional

B. Exocrine Glands
   1. Simple (unbranched duct)
      a. Tubular
      b. Branched tubular
      c. Coiled tubular
      d. Branched acinar
   2. Compound (branched ducts)
      a. Tubular
      b. Acinar
      c. Tubulo-acinar

V. Summary

SEM of ciliated columnar epithelium of the uterine tube
Epithelium

1. Greek: *epi* – “upon”, *thele* – “teat, nipple”
2. Avascular tissue that covers body surfaces, lines body cavities, and forms glands (endocrine and exocrine).
3. Composed of sheets of closely aggregated cells, of one or more layers thick, sitting upon a basement membrane.
4. Creates a barrier between “external” environment and underlying connective tissue.
5. Polarized with a free surface (*apical surface*), generally facing the external environment or lumen, and a bound surface (*basal surface*), facing the basement membrane.
6. Epithelial tissues are categorized by the number of cell-layers and the shape of their cells.
7. Exocrine glands are categorized by the arrangement of their duct portion (branched or not) and the shape of their secretory portions.
Learning Objectives

1. Understand how epithelia are classified into simple, stratified, and pseudostratified types and the usual functional significance of each type.

2. Recognize the (extracellular) basement membrane of epithelia, apical specializations such as the terminal web, and ultrastructural features of the various types of intercellular junctions.

3. Understand that epithelium forms barriers and compartments by covering and lining the body’s outer and inner surfaces.

4. Understand that epithelium is specialized for protection (or as a barrier), transport, absorption, and secretion.

5. Understand that glands are composed mostly of epithelial cell aggregates clustered together to perform specific secretory and/or excretory functions and that there are two main types of glands: exocrine and endocrine.
Learning Objectives (cont.)

6. Distinguish the basic differences between the **parenchyma** and **stroma** of a gland.

7. Understand that exocrine glands can be classified according to four features: the secretory portion's shape (alveolar/acinar vs. tubular), the duct system (simple vs. compound), the nature of the secretion (serous vs. mucous), and the mode of cell secretion (merocrine, apocrine, holocrine).

8. Continue to appreciate how structure relates to function.
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A. Epithelia
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      c. Simple columnar
      d. Pseudostratified columnar
   2. Stratified
      a. Stratified squamous
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B. Exocrine Glands
   1. Simple (unbranched duct)
      a. Tubular
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      c. Coiled tubular
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   2. Compound (branched ducts)
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      b. Acinar
      c. Tubulo-acinar

V. Summary

Keywords

- Acinar
- Apocrine
- Branched tubular
- Brush border
- Cilia
- Coiled tubular
- Compound gland
- Epithelia
- Glands
- Glycocalyx
- Goblet cells
- Holocrine
- Intercellular junctions
- Keratin
- Keratinized
- Merocrine
- Microvilli
- Mucous
- Myoepithelial cell
- Non-keratinized
- PCCE
- Pseudostratified columnar
- Serous
- Simple columnar
- Simple cuboidal
- Simple epithelia
- Simple squamous
- Stratified cuboidal
- Stratified epithelia
- Striated border
- Terminal web
- Transitional
- Tubular
Classifying Epithelium

1. The initial classification of epithelial tissue is based upon the number of cell layers between the basement membrane and the apical surface:
   
   a. **Simple epithelia** are only one cell layer thick; despite how it may appear, all the cells of simple epithelia are *directly attached to the basement membrane*.
   
   b. **Stratified epithelia** are more than one cell layer thick so that not all the cells are directly attached to the basement membrane; the apical layers of cells are attached to the cells below them, not the basement membrane.

2. Next, epithelia are classified by the shape of the cells composing the tissue:

   a. The shapes may be classified as **squamous**, **cuboidal**, or **columnar**.
   
   b. Since it is often difficult to see the actual shape of individual cells, generally the *shape of the nucleus* is used to determine the shape of the cell.

   c. For stratified epithelia, the shape of the cells may appear different between the basal layer of the cells and the more apical layers of cells; therefore, the *most apical cell shape is used to classify the tissue*.

3. Finally, specific epithelia are distinguished by the presence of apical modifications such as **microvilli**, **cilia**, and **stereocilia**.
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V. Summary

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**Slide 78: Eye, H&E**

**Slide Overview**

- cornea
- iris
- lens
- retina
- optic nerve

Look at the interior surface of the cornea to see an example of **simple squamous epithelium**.
simple squamous epithelium consists of a single layer of flattened (squamous) cells; specialized types include endothelium (lines the interior of vessels and heart chambers) and mesothelium (lines the exterior of certain organs and body cavities)
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         c. Tubulo-acinar
V. Summary
look in the cortex (outer region of an organ) to find renal corpuscles with Bowman's capsule lined by simple squamous epithelium.
the center of the slide shows a glomerulus (capillary network) of a nephron, which compose the parenchyma (functional tissue) of the kidney (~ 1 million nephrons / kidney)

using a trichrome stain, blue shows collagen of the basement membrane of the simple squamous epithelium tissue that forms the outer layer of Bowman’s capsule

the basement membrane is composed of two layers: the basal lamina (with type IV collagen) and the reticular lamina (with type III collagen)
simple squamous epithelium (endothelium) lines blood vessels

blood vessels, especially venous, can often be distinguished by looking for red blood cells within the lumen

notice that the shape of the nucleus of the squamous epithelial cell is “squashed” (flat and elongated) as is the overall shape of the cell
Slide 14: Kidney, Masson Trichrome

distinguishing the type of epithelium (and apical modifications) will be important later on when discussing the kidney in order to distinguish the different tubules (e.g., collecting duct vs. proximal convoluted tubule)

simple squamous epithelium

simple cuboidal epithelium

lines small ducts as seen here

the nuclei of the cuboidal epithelial cells are round and generally located in the center of the cell

this is still a simple epithelium because all of the cells are directly attached to the basement membrane (thin blue line)

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V. Summary
look at the tissue surrounding the lumen to find simple columnar epithelium
the gallbladder has very tall simple columnar epithelium

notice the column-shaped nuclei located toward the basal aspect of the cells

a mucosa (or mucous membrane), as seen here, is a layer of an organ composed of an epithelium and the underlying loose connective tissue
the purple/pink border is **glycocalyx** (glycolipids/glycoproteins) coating the **microvilli** on the apical surface of the epithelium, giving a **brush** or **striated border** appearance; notice that in light microscopy individual microvilli cannot be seen – they are only seen as a collective border – while individual cilia or stereocilia can be seen (none are seen here but will be seen later)
Slide 21: Ileum, Masson Trichrome

The terminal web (seen as a thin dark line) is composed of actin filaments running perpendicular and below the microvilli; it serves to connect and anchor the actin filaments of the cytoskeleton with those extending into the microvilli.
cilia vs. microvilli: cilia are larger, cytoplasmic processes containing microtubules, while microvilli are short, cytoplasmic projections containing actin filaments; while it may be possible to distinguish individual cilia in light microscopy, this is not possible with microvilli
the thyroid gland is found adjacent to the trachea; it is easily identified by the presence of numerous colloid-filled follicles (at arrow tip)

tracheal rings of hyaline cartilage

lumen of the trachea is lined by pseudostratified ciliated columnar epithelium (PCCE), sometimes referred to simply as respiratory epithelium
how does this slide look different from the slide of the gallbladder (slide 105) seen earlier? what differences can be used to distinguish the slide of the gallbladder vs. the trachea?

look at the tissue surrounding the lumen to find **pseudostratified ciliated columnar epithelium (PCCE)**
even though the PCCE appears to be stratified, it is a simple epithelium because all the cells are directly attached to the basement membrane (thin pink line); also note that the red blood cells seen in the tracheal lumen are an artifact – they are the result of the slide preparation when they leaked out of the blood vessels seen in the tissue below.

cilia are the small hair-like projections into the lumen off the apical surface of the epithelium.

pseudostratified ciliated columnar epithelium (PCCE) also known as respiratory epithelium.
stereocilia vs. cilia: stereocilia are not actually cilia but a rare, unusually long, immotile type of microvilli (contain actin filaments) found only in the male reproductive tract (epididymis and ductus deferens) and the hair cells of the inner ear.
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V. Summary

Slide 120: Eye, H&E

non-keratinized stratified squamous epithelium on the anterior (exterior) surface of the cornea

simple squamous epithelium
clearly this epithelium is stratified, but should it be classified as stratified cuboidal or stratified squamous? the convention is to classify epithelium based upon the appearance of the apical layers of cells, not the basal – so while the basal cells of this epithelium are cuboidal in shape, it is classified as squamous because of the very flat ("squashed") apical layers; also note that true stratified cuboidal epithelium is very rarely ever more than two layers thick and this epithelium is at least four cell layers thick

non-keratinized stratified squamous epithelium
notice that nuclei can be seen in all the strata of the epithelium from the basement membrane all the way to the apical surface at the lumen; as nuclei are still present in the apical cells, they cannot be keratinized, therefore this is a non-keratinized stratified squamous epithelium
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V. Summary

Slide 7: Larynx, Trichrome
look within the larynx to find the vocal cords/folds which are composed of non-keratinized stratified squamous epithelium

Slide 133: Uterine Cervix, H&E
look at the cervix (opening to uterus) and vaginal wall to see additional examples of non-keratinized stratified squamous epithelium
Slide 36: Thin Skin, H&E

Notice that nuclei cannot be seen in the apical layers of the tissue; the organelles of these cells have been replaced by large amounts of keratin proteins, thus this is a **keratinized** stratified squamous epithelium.

The epidermis of the skin is composed of keratinized stratified squamous epithelium.

Keratin

The separation of the layers is an artifact of the slide preparation.
stratified cuboidal epithelia are generally only found in the ducts of sweat glands and in large ducts of exocrine glands, such as the submandibular salivary gland seen here; stratified cuboidal (and stratified columnar, which is even more rare) are usually never more than two cell layers thick and usually lack any apical modifications.
stratified columnar epithelia are very rare and generally only found in very large ducts of exocrine glands or within the reproductive tract; additionally, it can be found composing the conjunctiva which is a mucous membrane that lines that inside of the eyelid and the anterior portion of the sclera (white part) of the eye; because stratified columnar epithelium is so rare, if trying to identify an epithelium, it is much more likely to be pseudostratified columnar than true stratified columnar (especially if apical modifications are present)
transitional epithelium lines the lumen of all urinary organs, so it is sometimes referred to simply as urinary epithelium
transitional epithelium (or urinary epithelium) is found only within the organs of the urinary system, and its appearance changes as it stretches and flattens out; the apical cells are sometimes referred to as umbrella cells and may be multinucleated, and when not stretched, have a characteristic “bulging” or “pear-shaped” protrusion into the lumen; individual strata are difficult to clearly define, but there are generally 6-8 cell layers (much more than seen in stratified cuboidal or columnar)
notice the change in the appearance of the epithelium as the bladder goes from being empty to being full; why is the ability of this epithelium to stretch and rebound so important?
Classifying Exocrine Glands

1. There are three principal ways of classifying exocrine glands: (1) based upon the nature of their secretory product (e.g., mucous and serous); (2) based upon their mode of secretion (e.g., merocrine, apocrine, and holocrine); or (3) based upon their morphology.

2. When categorizing glands based upon morphology, glands are described both by the shapes of their duct portions (parts of the gland which are non-secretory) and their secretory portions:

   a. Ducts, which are non-secretory epithelial cells that conduct the secretory product onto the epithelial surface, may be unbranched (simple) or branched (compound).

   b. Secretory portions, which are the epithelial cells responsible for the production of the glandular product (e.g., saliva, digestive enzymes, etc.), can be arranged in either tubular or rounded (acinar) configurations.

   c. Additionally, the secretory portions can be themselves be branched or coiled in shape.

3. Several configurations of glands are rarely seen; for instance, simple, acinar glands are seen during development of urethral glands but are otherwise generally not seen.
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A. Epithelia
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   2. Stratified
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B. Exocrine Glands
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V. Summary
goblet cells are the simplest type of exocrine gland; they are unicellular glands consisting of only a single, specialized epithelial cell (epithelial cells are the major component of all the glands of the body) and are found interspersed amongst other epithelial cells, such as the simple columnar cells seen above in the ileum; they secrete mucins (glycosylated proteins), the main components of mucus.

the apical portion of the cell fills with the secretory product, displacing the cytoplasmic organelles to the basal region of the cell, giving the cell the general appearance of a goblet/chalice.

what accounts for the difference in staining between the goblet cells seen above in PAS staining and in H&E?
the secretory cells of **simple, tubular glands** discharge their product into the straight, tubular lumen which they line; the lumen then empties via a short duct portion onto the apical surface of the epithelium (the lumen of the ileum); the glands are seen in longitudinal section but may also be seen in cross-section
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A. Epithelia
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V. Summary

due to sectioning, it is common to not be able to see the entire gland extending to the apical surface (lumen)
gastric pits are the duct portions of the glands, emptying into the lumen of the stomach.

Pyloric (gastric) glands are lined almost entirely by mucus-secreting cells and are generally classified as branched tubular.

Simple, branched tubular glands are found almost exclusively in the stomach; several tubular secretory portions drain together into a single, unbranched duct which then empties onto the surface of the gland (the stomach lumen).
sweat glands are almost the only example of **simple, coiled tubular glands**; their secretory portions are highly-coiled simple cuboidal epithelium which drain into the unbranched, non-secretory duct portion (darker staining) which is lined by stratified cuboidal epithelium and empties onto the surface of the skin.
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A. Epithelia
   1. Simple
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      c. Tubulo-acinar
V. Summary

Slide 51: Thin Skin, H&E

Sebaceous glands are simple, branched acinar glands consisting of several secretory acini surrounding a hair follicle, which serves as the single, unbranched duct; the acini empty their product (sebum) into their excretory duct (the hair follicle) via holocrine secretion.
Brunner's glands of the duodenum (the first segment of the small intestine) are compound, tubular glands (more specifically, they are compound, branched coiled tubular glands); there are extensive secretory portions that secrete a mucus-rich alkaline product to neutralize the acidic contents emptying into the duodenum from the stomach.
Slide 154: Pancreas, H&E

the exocrine portion of the pancreas is a **compound, acinar gland** composed of secretory epithelial cells arranged in an acinar (Lt. “grape”) configuration; at the center of the acini are small ducts which are not usually able to be seen; these small ducts drain into larger ducts, lined by simple cuboidal epithelium, which form the branched duct system; eventually all the ducts converge into the main pancreatic duct which empties into the duodenum.
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A. Epithelia
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V. Summary

the serous acini (plural of acinus) have 5-10 secretory cells surrounding a small central duct (lumen is not readily visible); the apical ends are eosinophilic due to the presences of secretory granules, while the basal ends are basophilic due to the nucleus and rER
the submandibular gland is an example of a **compound, tubulo-acinar gland**; it is composed of secretory units arranged as branched tubular, branched acinar, and combined tubular units capped by acinar ends; there are both **serous** (eosinophilic-staining) and **mucous** (pale-staining) secretory cells; the mucous cells tend to form the tubular components and the serous cells form the acinar components; all the secretory portions converge into branched ducts which converge and empty into the oral cavity
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   A. Epithelia
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         c. Tubulo-acinar
   V. Summary

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Common Confusion:
Pseudostratified vs. Stratified Cuboidal/Columnar Epithelium

**Pseudostratified:** simple epithelium with all cells attached to basement membrane; found in upper respiratory tract and reproductive system (rare)

Look for: (1) nuclei give appearance of multiple layers (more than two) but are not in-line forming strata; (2) nuclei are generally confined to basal 2/3 of epithelium; (3) cilia (Ci) are usually present (PCCE), while never present on true stratified epithelia; (4) goblet cells (Gb) are often interspersed

**Stratified cuboidal/columnar:** stratified cuboidal and columnar epithelia are rare and mainly restricted to large ducts and parts of the reproductive system; sectioning may skew appearance, so look at thinnest portion of epithelium to visualize true organization

Look for: (1) generally no more than two cell layers thick; (2) clearly defined strata; (3) apical nuclei are in-line and have characteristic shape; (4) lack apical modifications
Common Confusion:
Pseudostratified vs. Transitional Epithelium

**Pseudostratified**: simple epithelium with all cells attached to basement membrane; found in upper respiratory tract and reproductive system (rare)

Look for: (1) all cells are directly attached to basement membrane so nuclei normally do not appear directly stacked above one another; (2) nuclei are generally confined to basal 2/3 of epithelium; (3) more apical nuclei have columnar appearance instead of rounded; (4) cilia are usually present (PCCE); (5) goblet cells are often interspersed

**Transitional**: stratified epithelium found only within organs of the urinary system

Look for: (1) multiple layers of nuclei generally with rounded appearance (but more layers and less in-line nuclei than stratified cuboidal epithelium); (2) multinucleated cell may be present at apical surface; (3) when tissue is relaxed: "bulging" of apical surface into lumen; (4) when tissue is stretched: may give appearance of stratified squamous epithelium, but nuclei are more round and there are fewer overall layers of cells; also stratified squamous "undulates" with the underlying connective tissue but stretched transitional is more flat as is the underlying connective tissue

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2. Compound (branched ducts)
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V. Summary
Summary

1. Epithelium is polarized (different apical and basal surfaces), avascular tissue composed of sheets of closely aggregated cells (one or more layers) upon a basement membrane (basal lamina + reticular lamina); it covers body surfaces, lines body cavities, and forms glands.

2. For simple epithelia, all the epithelial cells are directly attached to the basement membrane (i.e., only one cell layer thick); for stratified epithelia, not all the cells are directly attached to the basement membrane (i.e., more than one cell layer thick).

3. Epithelia are classified according to the shape of the cells (the most apical cells for stratified epithelia): squamous (flattened), cuboidal, columnar, and pseudostratified (simple but may appear stratified).

4. Epithelial apical modifications include: microvilli (short, finger-like cytoplasmic processes containing actin which may be visible as a brush/striated border), stereocilia (rare, long microvilli containing actin), and cilia (hair-like extensions of plasma membrane containing an axoneme – core of 9+2 microtubule doublets).

5. The type of epithelium (thickness, shape, and apical modifications) can be used in inferring the function of a tissue or organ.

6. Intercellular junctions are seen in EM and include: tight/occluding junctions (apical; prevent substances passing down and between cells), anchoring junctions (zona adherens; hold cells together and to basement membrane), and communicating junctions (channels allowing small molecules to pass between adjacent cells).
7. Glandular epithelium is specialized for secretion and classified according to how products are released: the secretory portions of exocrine glands maintain contact via ducts/tube onto the apical surface of the epithelium where the products are released; endocrine glands lack ducts so secrete their products (hormones) into the surrounding connective tissue from which they enter the bloodstream.

8. Exocrine glands are either unicellular (goblet cells) or multicellular, which are further classified morphologically according to the branching of their ducts (simple – have unbranched ducts; compound – have branched ducts) and the configuration of their secretory portions (e.g., tubular or acinar in shape).

9. Exocrine glands may also be classified according to: (1) the nature of their secretory product (serous glands produce watery, poorly-glycosylated or nonglycosylated proteins which generally stain eosinophilic; mucous glands produce viscous, glycosylated proteins and oligosaccharides and stain with PAS but poorly in H&E), or (2) the mode of secretion (merocrine – via exocytosis of vesicular contents; apocrine – via membrane-coated vesicles, or holocrine – via rupture and expulsion of entire cellular contents).
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         d. Transitional
   B. Exocrine Glands
      1. Simple (unbranched duct)
         a. Tubular
         b. Branched tubular
         c. Coiled tubular
         d. Branched acinar
      2. Compound (branched ducts)
         a. Tubular
         b. Acinar
         c. Tubulo-acinar

V. Summary

### Appearance, Function, and Locations of Epithelial Tissues

<table>
<thead>
<tr>
<th>Epithelium</th>
<th>Draw and Label (&amp; possible apical modifications)</th>
<th>Functions</th>
<th>Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Squamous</td>
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<tr>
<td>Cuboidal</td>
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<td>Columnar</td>
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<tr>
<td>Pseudostratified</td>
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<tr>
<td>Simple</td>
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<tr>
<td>Stratified Squamous</td>
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<tr>
<td>Stratified Cuboidal</td>
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<td>Stratified Columnar</td>
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<tr>
<td>Stratified Transitional</td>
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<tr>
<td>Stratified Transitional</td>
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</tbody>
</table>
### IUSM – 2016

#### Lab 4 – Epithelia and Glands

### I. Introduction

### II. Learning Objectives

### III. Keywords

### IV. Slides

#### A. Epithelia

1. Simple
   - a. Simple squamous
   - b. Simple cuboidal
   - c. Simple columnar
   - d. Pseudostratified columnar

2. Stratified
   - a. Stratified squamous
   - b. Stratified cuboidal
   - c. Stratified columnar
   - d. Transitional

#### B. Exocrine Glands

1. Simple (unbranched duct)
   - a. Tubular
   - b. Branched tubular
   - c. Coiled tubular
   - d. Branched acinar

2. Compound (branched ducts)
   - a. Tubular
   - b. Acinar
   - c. Tubulo-acinar

### V. Summary

#### Epithelial Terminology Compare and Contrast

<table>
<thead>
<tr>
<th>Terms</th>
<th>Compare and Contrast (Similarities? Distinctive differences?)</th>
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<tbody>
<tr>
<td>Simple vs. Stratified epithelia</td>
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<tr>
<td>Microvilli vs. Stereocilia vs. Cilia</td>
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<tr>
<td>Merocrine vs. Apocrine vs. Holocrine secretion</td>
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<tr>
<td>Mucous vs. Serous acini</td>
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<tr>
<td>Occluding vs. Anchoring vs. Communicating junctions</td>
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<tr>
<td>Parenchyma vs. Stroma</td>
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<tr>
<td>Brush border vs. Terminal web</td>
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V. Summary

---

### Exocrine Gland Morphology and Characteristics

<table>
<thead>
<tr>
<th>Gland</th>
<th>Draw and Label (Duct and Secretory portions)</th>
<th>Locations</th>
<th>Function / Features</th>
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<tbody>
<tr>
<td>Tubular</td>
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<td>Coiled tubular</td>
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<tr>
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