This lecture will present the histology of epithelial tissues that cover body surfaces, line the gastrointestinal tract, blood vessels and body cavities. There are two basic types of epithelial tissue – a tissue that forms sheets of cells that compartmentalize the body and a tissue that forms glands to synthesize and secrete important products. Epithelial tissue that forms glands will be presented in a different lecture to introduce the histology of glandular organs.

These are the resources that relate to the content of this lecture. The lecture PDF downloadable from the Blackboard Course Website contains all of the slides and the narrative of this lecture. The laboratory exercise is found in the WebMic Study Guide and is used along with the online program, WebMic.

These are the learning outcomes for this lecture. At the end of the lecture, you will be presented with a few questions to aid in assessing your understanding and retention of the important concepts in this lecture. Summarizing the learning outcomes, you should be able to define tissue in general, and epithelial tissue in particular, know how epithelial cells are related to one another to form an epithelial tissue, explain how epithelial tissues are classified, list the types of epithelial tissue, relate the structure of different types of epithelial tissue to the function performed by that specific kind of epithelium and describe the process whereby epithelial tissues are renewed.
Histology of Epithelial Tissue

Vocabulary

- **Epithelial Types**
  - Simple
  - Stratified
  - Squamous
  - Cuboidal
  - Columnar
  - Pseudostratified
  - Transitional
- **Junctions**
  - Zonula Occludens
  - Zonula Adherens
  - Macula Adherens
  - Hemidesmosome
  - Nexus (Gap)
- **Special Features**
  - Lumen
  - Basement membrane
  - Keratinized
  - Non-keratinized
  - Apical Modifications
  - Cilia
  - Microvilli
  - Stereocilia

Lecture Topics

- Tissue Definition & Epithelium Building Materials
- Polarity and Domains of Epithelial Cells
- How epithelial cells are connected
- Classification of the different types of epithelia
- Structure-Function Correlations
- Epithelium Renewal
- Quiz

What is a tissue?

- A tissue is an aggregate of cells & extracellular matrix organized to function in a collective manner.
- There are four basic tissues that comprise the structure of the organs of our bodies, they are:
  - Epithelial Tissue
    - Covers body surface, lines body cavities and blood vessels & forms the main component of glands
  - Connective Tissue
    - Fills, packs and connects bone to bone and muscle to bone
  - Muscle Tissue
    - Contracts to move bones and regulate blood pressure
  - Nerve Tissue
    - Provides sensory perception to environment and ability to respond to perceptions.
Histology of Epithelial Tissue

Slide 7

What is Epithelial Tissue?

- A tissue made up of cells attached to each other by special junctions and a means of communication
- The cells are so close together that there is very little substance between the cells.
- The cells may be arranged in a single monolayer or multiple layers.
- Epithelial tissue covers the surface of the body and lines body cavities, the digestive tract and blood vessels. Epithelial tissue cells also make up glands of the body. Epithelial cells also form special nerve end structures that are sensory.

Slide 8

Epithelium Building Materials

- Three Cell Types are the building blocks of epithelial tissues
  - Columnar cell
    - Rectangular in tissue sections
  - Cuboidal cell
    - Square in tissue sections
  - Squamous
    - Flat in tissue sections

The basic cell types that are used to construct epithelial tissues are 1) the columnar cell, 2) the cuboidal cell, and 3) the squamous cell. Some epithelia are composed of purely columnar, or cuboidal, or squamous cells. Some epithelia are composed of a mixture of these cell types. Some epithelia are composed of only a single layer of one of these cell types and they are called simple epithelia. Some epithelia are composed of multiple layers of one or more of these cell types and they are called stratified epithelia. It is very important also to note that epithelial tissues are also fastened to a membrane made up of extracellular material called the basement membrane.

Slide 9

Polarity andDomains of epithelial cells

The cells of a simple epithelium have polarity. Each cell has 3 surfaces (poles or domains)- the apical, lateral and basal. The surface bordering the lumen is known as the apical surface or end of the cell. The surface bordering and attached via a basement membrane to underlying connective tissue is the basal surface. The other surface is the lateral surface that faces the surrounding cells. The cells making up cuboidal and columnar epithelia may have certain specializations such as cilia, microvilli or stereocilia projecting from their apical surfaces. In the next several slides, these projections are presented after which how cells are fastened together to form the sheets that make up the various types of epithelial tissues will be presented and explained. The lateral and basal surfaces are where these junctions will be located.
Microvilli are short up to 6 micron long and 0.1 micron wide projections. They are so numerous on the apical surface of intestinal cells that they form a special border that looks like a brush (also referred to as a striated border). Note that there is a web of actin filaments called a terminal web that occupies a layer within the cytoplasm just beneath the apical end of intestinal columnar cells. The actin filaments in the core of the microvilli interact with the actin filaments of the terminal web through myosin molecules that interposed between the two populations of actin filaments. Because actin filaments are anchored at the tip of the microvillus into the cell membrane and those of the terminal web are anchored into the zonula adherens when contraction occurs, the microvillus becomes shorter.

Cilia are very important in the function of the respiratory and reproductive tracts. Compared to microvilli, cilia are longer, ranging from 6 – 10 microns and wider, about 0.2 microns. Cilia are motile. They can move when supplied with energy via ATP. The drawing shows that the core of a single cilium is composed of a specific arrangement of microtubules. Nine pairs of microtubules are circumferentially arranged around one pair in the middle the so-called 9 + 2 arrangement). Observe the two Transmission Electron Micrographs (TEMs). Note the electron dense basal bodies of the cilia shown in the longitudinal section profiles in the TEM. These modified centrioles constitute the body from which the cilia were formed. It is through communication between these bodies that the cilia of one cell are coordinated to beat in synchrony. Observe the fine hair-like projections from the epithelial cells in the color light micrograph. Also, below that micrograph is an view of cilia looking at the surface as seen in a Scanning Electron Microscope. Each cell lining the respiratory tract can have up to 250 cilia projecting from its surface into the lumen. The cilia of an entire population of cells move or beat in a coordinated way due in part to the intercellular communication provided by gap junctions. They function to move a coat of mucus where dust and bacteria are entrapped up the airways to the mouth. Cell junctions play a very important role in epithelial tissue. The next few slides will present these junctions.
There are four uniquely different structures that serve as connections between epithelial cells. Three are adhering connections (junctions) and one provides a means of communication between cells. The four junctions are 1) zonula occludens (tight junctions) that seal the space between epithelial cells so that no ion or water can flow between them, 2) zonula adherens that physically bind the cells together in a zone near the apical pole, 3) Macula Adherens (desmosome) that physically bind cells together in smaller areas resembling spots, and 4) Gap junctions (nexus) that connect the cells together via protein lined channels that provide a means for communication by permitting ions to flow from one cell to another.

Zonula Occludens, also known as a Tight Junction (TJ) is a specialized cell to cell junction that actually seals the cells together so that no molecules, ions, or water can move parallel to two adjacent cells from, for example, the lumen of the intestine to the underlying connective tissue. This forces any exchange of substances to be carried out by going through the cells which is very important for controlling what is absorbed and preventing bacteria in the intestine from gaining entrance into the body. Note the drawing illustrating the network of fuse lines between adjacent cell membranes of a zonula occludens and the structure of a zonula adherens forming a ‘glue’ zone between cells without fusion of the cell membranes. This transmission electron micrograph illustrates the location of these junctions just below where microvilli project from the apical end of two adjacent cells. Enlargement of the two junctions is shown in this electron micrograph where you can see the beaded nature of the zonula occludens and the space between the cells in the region of the zonula adherens where adheren molecules ‘stick’ the cells together.
Desmosomes (Macular Adherens) are areas of plaques or spots of adhesion between cells. Observe the drawing of a macula adherens showing filamentous proteins called tonofilaments insert into dense plaques. Between the cells, proteins called desmocolin and desmoglein form a ‘glue’ that adheres the cell together. The electron micrograph illustrates one macula adherens showing tonofilaments inserting into the intracellular dense plaques. The color light micrograph is a sample of stratified squamous epithelium stained with Hematoxylin and Eosin that shows between each cell many projections that look like little spines, one of which is indicated by the arrow. At the site of each spiny projection is the location of one desmosome. In the skin, for example, desmosomes play an incredibly important role in maintaining the strength and integrity of the epidermis. The cells are connected one to another not only with desmosomes, but the tonofilaments crisscross the cytoplasm of every cell anchoring into the cytoplasmic side of the desmosome so that the entire epithelium behaves as a strong multilayered sheet.

The hemidesmosome is a modified macula adherens, in fact, exactly one half of the structure of a macular adherens. Hemidesmosomes serve to anchor epithelial cells at their basal surfaces to either a basal lamina or a basement membrane. Observe that tonofilaments insert into the cytoplasmic plaque at the hemidesmosome. The next slide will illustrate and explain the relationship between hemidesmosomes and the underlying basal lamina and basement membranes.
Here you see the continuum of connections from the cell through the basal lamina to the connective tissue fibers beneath via the reticular connecting fibers. The basal lamina consists of a lamina lucida and densa. The basement membrane consists of the basal lamina and another layered element, the reticular lamina. The basal lamina is more delicate but is ubiquitously distributed throughout the body. The basement membrane is more robust serving anchoring functions where more strength of connection is needed. Hemidesomes (literally one half of a macula adherens) serve as anchoring attachments to the basement membrane. These hemidesmosomes insert into a layer of the basement membrane called the lamina lucida that is about 40 nm wide. The lamina lucida contains receptors for binding to fibronectin and laminin that are contained within the lamina densa. The lamina densa then is connected by anchoring fibrils composed of a type of collagen to reticular fibers within the connective tissue. These fibers then interweave with the collagen fibers of the connective tissue, thereby anchoring the epithelial cell into the underlying connective tissue.

Gap Junctions (nexuses) are very important for communication between cardiac muscle cells, smooth muscle cells, between cells of simple cuboidal and simple columnar epithelium. It provides a way for a sheet of epithelial cells that form essentially a membrane of cells to coordinate function. The line drawing shows that gap junctions consist structures close together arranged in clusters. The repeating structure in these clusters is a channel lined with proteins that form a structure called connexons. The connexons are arranged in hexagonal arrays that form communicating channels between the cells as seen in this color drawing. When examined with an electron microscope, it can be seen that the cells membranes appear fused as seen in this electron micrograph where you can see an enlarged view of a gap junction in the inset as indicated. If you look very closely in the inset where the arrows are located, you can just barely make out densities with intervening lighter areas. The densities are the location of the communicating channels. Looking backward now, the gap junction is within the area enclosed by the red arrow.
### Classification of Epithelial Tissues

- **Covering/lining epithelium**
  - Simple squamous, cuboidal and columnar
  - Stratified squamous, cuboidal and columnar
  - Pseudostratified
  - Transitional
- **Glandular epithelium** (not in this lecture)
  - Unicellular glands
  - Multicellular glands

#### Simple Epithelial Tissues

- **Simple Squamous Epithelium**
  - One layer of flat shaped cells
  - Lines body cavities and blood vessels

- **Simple Cuboidal Epithelium**
  - One layer of cube shaped cells
  - Lines ducts and tubules, e.g. in salivary glands and kidney, functional cells in thyroid gland

- **Simple Columnar Epithelium**
  - One layer of cylindrical shaped cells
  - Lines ducts of glands, lines stomach and intestines, forms structure of tubules in the kidney

#### Stratified Epithelial Tissues

- **Stratified Squamous Non-keratinized**
  - Multiple layers of cells
  - Named for shape of surface cells
  - Lines oral cavity, esophagus & vagina
  - Surface layer of keratin
  - The epidermis of skin

- **Stratified Cuboidal**
  - Multiple layers of cells
  - Named for shape of surface cells
  - Lines large ducts

- **Stratified Columnar**
  - Multiple layers of cells
  - Named for shape of surface cells
  - Lines larger ducts

The terms for classifying / categorizing covering and lining epithelium describe whether the epithelium consists of a monolayer or multiple layers of cells, whether all cells touch the basement membrane, but nuclei are stratified giving a false (pseudo) impression of stratified, and whether the epithelial cell morphology changes with stretching and relaxing. Glandular epithelium will be presented in a lecture that will introduce the histology of glandular organs later in the semester.

Now that we have an understanding of how epithelial cells are fastened together, let's consider the different types of epithelial tissue and how they are classified. These drawings illustrate three kinds of simple epithelia. Note that in each case the epithelial cells are touching (they are fastened together) and each cell is fastened to an underlying basement membrane. In this way, the cells form monolayer sheets (also can be referred to as epithelial membranes). The term simple means a monolayer of cells and the varieties are named for the shape of the cells. Simple squamous epithelium lines body cavities and blood vessels. Simple cuboidal epithelium lines ducts and tubules and constitutes cells forming specific functions in organs. Simple columnar epithelium also lines ducts and tubules and also constitutes cells forming specific functions in organs.

Three basic types of stratified epithelium are stratified squamous, stratified cuboidal and stratified columnar. The term stratified denotes that there is more than one layer of cells forming the epithelium. The terms squamous, cuboidal and columnar denote the shape of the surface layers of cells. There are two variants of stratified squamous epithelium. Stratified squamous non-keratinized epithelium lines the oral cavity, esophagus, and vagina. The cells at the surface are intact retaining their nuclei although they are in the process of dying and being shed. Stratified squamous keratinized epithelium has a surface layer of cells in which keratin has replaced the nucleus and other organelles. This epithelium forms the epidermis of skin. Stratified cuboidal epithelium lines large ducts of organs like salivary glands and pancreas. Stratified columnar epithelium also lines even larger ducts in salivary glands and pancreas.
Histology of Epithelial Tissue

Special or Exceptional Epithelial Tissues

- Pseudostratified Columnar Epithelium
  - Appears having more than one layer but it does not because all cells anchor to the basement membrane
  - Always classified as columnar because cells that reach the surface are columnar
  - Lines nose, trachea and bronchi where cells have motile projections call cilia. Also lines certain ducts in reproductive organs

- Transitional Epithelium
  - Has specialized cells that can increase membrane area when stretched and contain extra membrane when relaxed
  - Lines ureter and urinary bladder

There are two types of special or exceptional epithelial tissue – pseudostratified epithelium and transitional epithelium. Observe carefully the drawing of pseudostratified epithelium noting that all of the cells touch and are fastened to a basement membrane, but the cells are of different lengths. Therefore, not all cells reach the free surface. This results in the nuclei arranged in two strata so on first glance the epithelium looks stratified but, in fact, consists of a monolayer of adjacent cells of varying lengths. Pseudostratified epithelium is always columnar and it may or may not be ciliated. This epithelium lines much of the respiratory tract and certain ducts in the reproductive organs. Transitional epithelium is unique because its cells are stretchable and therefore, the epithelium can adapt to different physical constraints. This epithelium lines the urinary bladder resulting in an intact lining of the bladder whether the bladder is full of urine or empty. Transitional epithelium also lines the ureter and special cavities in the kidney called calyces. Transitional epithelium will be presented in more detail in the lecture on the urinary tract and kidney.

In general, thinner epithelia are involved in ion transport between two compartments. The thicker epithelia, whether stratified squamous or columnar are involved in forming a protective lining for the conducting substances within a lumen. Simple squamous epithelium is designed to provide a smooth lining to all blood vessels where, in capillaries, it is so thin that it can act as a selective barrier allowing certain substances across by passive processes. The exchange of gases in the lung is facilitated by this kind of epithelium. Simple cuboidal cells are thick or fat enough to contain sufficient mitochondria and amplification of the basal-lateral cell membrane so that this epithelium can provide active transport of substances for absorption and secretion. Simple columnar epithelium can perform similar functions as cuboidal epithelium. Stratified squamous epithelium with its multiple layers of cells, functions to provide a lining that can accommodate friction by allowing for shedding of surface cells as, for example, when food is being transported from the oral cavity to the esophagus in the act of swallowing. Special glands in the esophagus, for example, secrete a lubricating substance, mucus, onto its surface which further facilitates the transport of bulky substances within the lumen. Large ducts of glands that are secreting products into the lumen of the gastrointestinal tract are lined by stratified cuboidal and columnar epithelium where it is important to isolate the product from the internal aspects of the gland, but no need for robust lining like stratified squamous epithelium because the products are not bulky or robust.
Epithelial tissues are renewed by mitosis. The drawing illustrates the layers of the epidermis, a stratified squamous keratinized epithelium. The life cycle of an epidermal cell begins deep in the epithelium near the basement membrane. Dividing cells migrate toward the surface as they differentiate to become cells that synthesize keratin. Observe the anaphase stage of mitosis deep in this light micrograph of an epidermis. The population of cells deep in the epidermis that is generated by mitosis push existing cells so that, at the surface, cells are being shed to maintain the thickness of the epidermis. Observe at the dotted line the cells lose their nucleus and from that point on, the cells stain pink due to the presence of keratin. These cells are no longer living......they are cellular bags of keratin...and they are continuously shed from the surface. Most all epithelia are renewed by mitosis. Here are two more examples in the lining cells of the stomach and colon. Here you can see examples of prophase and anaphase.

Summary

- Epithelial tissue was defined
- The polarity of epithelial cells was explained and illustrated.
- The 3 means of physical junctions and one means of chemical junction between cells was presented.
- The 8 different types of lining / covering epithelia were distinguished from one another and examples given where they are found.
- The structure – function relationships of epithelia were explained.
- Epithelial cell renewal was presented.

A quiz follows this slide to assess your understanding of this lecture.