ANAT2241

Histology: Basic and Systematic

Notes from Semester 1, 2014

Topics:

- Introduction to Histology
- Covering and Lining Epithelia
- Glandular Epithelia
- Connective Tissue
- Bone, Bone Formation and Joints
- Blood
- Muscle
- Nervous tissue (PNS and CNS)
- Cardiovascular System
- Respiratory System
- Integumentary System
- Liver, Gallbladder and Pancreas
- Gastrointestinal System
- Lymphatic Tissue and the Immune System
- Endocrine System
- Urinary System
- Female Reproductive System
- Male Reproductive System
- The Eye
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Introduction to Histology

Definitions and Terminology:
Anatomy: study of organ and tissue structure at **macroscopic level (gross)**
Histology: study of organ and tissue structure at **microscopic level**
  - XS-cross section
  - TS-transverse section
  - LS-longitudinal section
  - LM-light microscope/light micrograph
  - EM-electron microscope/electron micrograph

Dimensions:
- $1 \text{mm} = 10^3 \text{micrometers (µm)} = 10^6 \text{nanometers (nm)}$
- A micrometer is often called a “micron” (µm).
  - $1 \text{µm} = 10^{-6} \text{m}$

Resolving Powers:
- Unaided eye: approx. $0.1 \text{mm} = 100 \text{µm}$
- Light microscope: approx. $0.1 \text{µm} = 100 \text{nm}$
- Electron microscope: approx. $1 \text{nm}$

Stains:
Haematoxylin and Eosin (H&E): most commonly used histological stain, has two components:
  - Haematoxylin-basic stain, appears black, blue or purple. Stains acidic structures, especially nuclei. Structures stained are basophilic
  - Eosin-acidic dye, red in colour. Stains tissues pink to red.
Periodic Acid-Schiff Reaction (PAS): stains complex carbohydrates a deep red/magenta colour (e.g. mucin, glycogen, glycocalyx). Very useful for goblet cells and basement membranes.
Osmium tetroxide: stains lipids e.g. adipose tissue or myelinated nerve fibers. Unsaturated bonds in the lipids reduce the osmium tetroxide to black osmium.
Masson trichrome: contains three colours. Nuclei and other basophilic structures stained blue, collagen stained green/blue and cytoplasm, muscle, erythrocytes and keratin stain bright red.
Haematoxylin and Van Gieson: has 2 acidic dyes:
  - Picric Acid
  - Acid Fuschin: stains collagen red, other tissue

 Artefacts:
- Tissue is fixed and embedded in materials e.g. paraffin, gelatin, resin prior to sectioning
- Knives are used on various cutting machines, microtomes, to obtain sections
- Tissue damage can result, with tissue being pushed out of shape, and scratches, tears or folds appearing. Excessive drying can create spaces that don’t exist-these extra features are called artefacts.
Covering and Lining Epithelia

**Epithelial tissue is present in 2 forms:**

1. **Sheets of cells** that cover external surfaces (e.g. skin), line the digestive, respiratory, cardiovascular and urogenital tracts and membranes (pleura, peritoneal, pericardial)
2. **Glands (exocrine and endocrine)** that originate from epithelial cells

Epithelial cells are close to each other, with a space between membranes (about 20nm) and a small amount of intercellular material (cement substance e.g. glycosaminoglycan)

- Attachment points (junctional complexes) occur between epithelial cells to hold adjacent cell membranes together
- Epithelial cells sit on a basement membrane, which separates them from underlying connective tissue.
- Epithelium is avascular and depends on diffusion of substances (oxygen and metabolites) across the basement membrane

Epithelia are classified according to 3 morphological characteristics:

- The number of cell layers (1 layer=simple, >1 layer = stratified)
- The shape of the cells (squamous = flattened, cuboidal = about equal dimensions, columnar = tall)
- The presence of surface features (e.g. cilia, microvilli and keratin)

<table>
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<th>Type of Cell</th>
<th>Special Features</th>
<th>Example</th>
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<td>Simple Epithelium</td>
<td>Squamous</td>
<td>Also known as endothelium (lining blood vessels)</td>
<td>Vascular endothelium, peritoneum</td>
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<td>Cuboidal</td>
<td>Microvilli</td>
<td>Sweat gland ducts</td>
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<td></td>
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<td>Pseudostratification</td>
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<td>Goblet cells</td>
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<td>Small and large bowel</td>
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<td>Stereocilia</td>
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<td>Squamous</td>
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<td>Keratinisation</td>
<td>Epidermis of skin</td>
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<td></td>
<td>Transitional</td>
<td>Exocrine gland ducts</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Bladder, ureter</td>
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Epithelial Surface Modifications

Apical Surface (top of cell): the site where secretory products are delivered for release

**Microvilli**: finger-like projections of the cytoplasm (plasma membrane) from the top surface of cells. They represent the striated border of intestinal absorptive cells and the brush border of kidney proximal tubules. In intestinal epithelia, where absorption occurs, they increase (up to 30x) the SA of cells

**Stereocilia**: long microvilli (not cilia) found in epididymis, vas deferens and on sensory hair cells of the cochlea (inner ear). Non-motile structures in epididymis function to increase the SA, whereas in the hair cells of the ear they function in signal generation.

**Cilia**: motile projections (0.2µm diameter, 7-10µm long) from the surface of epithelial cells e.g. trachea, bronchi and in the oviduct. They are specialised to function in propelling mucous (trachea) and other substances (fertilized ovum) over the surface of the epithelium by rhythmic wavelike oscillations.

**Flagella**: resemble cilia but are longer and wider and occur singly as free cells e.g. spermatozoa. By a whip-like action, they aid in moving sperm

**Basolateral Area**: has 2 regions:

- **Lateral plasma membrane**
- **Basal plasma membrane**

Each region possesses its own junctional specialisations and receptors for hormones and neurotransmitters.

### Lateral Plasma Membrane Specialisations

**Terminal bars** are where epithelial cells contact each other, and are classified into 3 types:

- **Zonula occludens (tight junctions)**: prevent movement of membrane proteins from apical domain to basolateral domain, fuse plasma membranes of adjacent cells to disallow water-soluble molecules from passing between cells
- **Zonula adherens**: below the zonulae occludens, join cell membranes to each other and maintain cell-to-cell adherence
- **Desmosomes (macula adherens)**: ‘spot weld-like’ junctions along lateral cell membranes of simple epithelia and throughout cell membranes of stratified squamous epithelia e.g. epidermis

### Basal Surface Specialisations

Anchor the basal plasma membrane to the basal lamina.

**Basal Lamina (basement lamina)/basement membrane**

- Acellular supportive structure (20 to 100 nm thick) secreted by the epithelium resting on it. The basal lamina is located at the boundary between the epithelium and the underlying connective tissue (CT). Composed mainly of Type IV collagen, laminin, and proteoglycans. The basal lamina with a deeper layer, the reticular lamina of the CT (reticular fibers and ground substance) is the “basement membrane”.

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ANAT2241: Histology-Basis and Systematic
Glandular Epithelia

Epithelium that is primarily involved in secretion is often arranged into structures called glands. Glands are basically invaginations of epithelial surfaces into underlying connective tissue, forming secretory units.

**Function**
- Glandular epithelia make their products intracellularly by synthesis of macromolecules-stored in vesicles (secretory granules) e.g. mucin from goblet cells, sebum from sebaceous glands, enzymes from the exocrine pancreas
- Glandular epithelium can remove metabolic wastes e.g. sweat glands

**Classification of Glands**
- Classified on their organisation (exocrine/endocrine), the number of cells involved, having ducts, branching of ducts, type of material secreted and manner of secretion

**Exocrine Glands**
These glands maintain their connection with the epithelial surface via a duct. Exocrine glands put their products into ducts that open into the lumen of an organ or onto skin.

Exocrine glands are classified as:

- **Unicellular Exocrine Glands**: form as isolated secretory cells in an epithelium e.g. goblet cells, amongst the simple columnar epithelia lining the digestive tract (e.g. small intestine) and pseudostratified columnar epithelium of the respiratory tract (e.g. trachea). Mucous release is regulated and stimulated by chemical irritation and parasympathetic innervation. This mucous lubricates the passage of materials protecting the lining along parts of the GIT. In the respiratory system, it moistens the air and traps inhaled dust and other pollutants and antigens.

- **Multicellular Exocrine Glands**: composed of more than one cell and drained by a series of ducts. Classification into simple and compound multicellular is by the morphology of their ducts and the shape of the secretory portion e.g. tubular (straight or coiled), acinar (grapelike)/alveolar (flask like).
  - **Ducts (Non-Secretory Portion)**
    - Simple: a single duct which does not branch.
    - Compound: several ducts which branch.
  - **Secretory Portion (Acini)**
    - Simple: simple tubular (large intestine, stomach body, uterine endometrium), simple coiled tubular (sweat glands), simple branched tubular (pylorus of the stomach, oesophageal glands) or simple branched acinar (sebaceous glands).
    - Compound: compound tubular (Brunner’s glands of duodenum), compound acinar (pancreas) and compound tubulo-acinar types (salivary glands, mammary, prostate and seminal vesicles).
**Architecture:** Larger multicellular glands are surrounded by a connective tissue (CT) capsule sending septa (strands of CT) into the gland, subdividing it into **lobes and lobules.** Blood vessels, lymphatics, nerves, and ducts enter and leave the gland via the septa. The septa also give structural support for the gland.

- The location of ducts in a gland may be:
  - **interlobar** (between lobes)
  - **intralobar** (within lobes)
  - **interlobular** (between lobules)
  - **intralobular** (within lobules)

**Type of Secretion:** Glands can be classified according to material secreted

- **Mucous** e.g. goblet cells, secrete mucinogens, large glycosylated proteins which swell to become a gel-like protective lubricant (mucin).
- **Serous** e.g. in the pancreas and salivary glands. Serous secretions are watery and rich in enzymes (proteins, peptides).
- **Mixed** e.g. sublingual and submandibular salivary glands. Contain acini (secretory units) that produce mucous secretions and acini that produce serous secretions. In addition, some of the mucous acini have **serous demilunes** that secrete a serous fluid.

**Method (Mode) of Secretion**

- **Eccrine (merocrine)** secretion is the process of exocytosis and is the most common form of secretion (e.g. salivary glands).
- **Apocrine** secretion involves the top of the cell being pinched off with a portion of the cytoplasm, which becomes part of the secretory product (lipid droplet). The remainder of the cell repairs itself.
- **Holocrine** secretion involves the discharge of the whole cell with disintegration of whole secretory cells to release the secretion e.g. sebaceous glands. The basal cells multiply to replace those cells that are lost, and the gland continues to secrete sebum.

**Endocrine Glands**

- Endocrine glands arise from an epithelium sheet and lose their connections with the surface and thus **lack ducts** to leave isolated islands of epithelial secretory tissue within other tissues. These glands secrete hormones directly into the blood, which initially empty into tissue spaces, and then into the blood and the lymphatics for distribution to target organs/tissues. The major endocrine glands include the adrenal, pituitary, thyroid, parathyroids, pineal gland, the ovaries and testes.

**Mixed Endocrine/Exocrine Glands**

- These glands contain both exocrine and endocrine secretory units e.g. pancreas, where the **exocrine portion** secretes its product (digestive enzymes) into a duct, whereas the **endocrine portion** secretes its product (hormones) into the blood.

**Myoepithelial (basket) Cells:** The secretory units of some glands have myoepithelial cells **between glandular cells and basal lamina.** Long cytoplasmic processes extend from body of the cell around secretory units and **contract to express products** from the secretory units into the ducts. Myoepithelial cells are found in sweat, mammary and salivary glands. These cells are epithelial in origin, but **function like a muscle (myo-)** by contracting with actin filaments.
Adult Connective Tissue Types

- Connective tissue divided into **loose** and **dense**, depending on whether the fibers are loosely or closely packed.
- **Loose CT** can be classified further on the basis of some special properties of their constituents, such as adipose, reticular tissue.
- **Dense CT** can be subdivided into two groups according to whether the fibers are randomly arranged (irregular) or show an orderly arrangement (regular).

**Loose CT:**
**Fewer fibers but more cells and matrix** than dense CT. Characterised by much ground substance and tissue fluid housing the CT cells: fibroblasts, adipose cells, macrophages, and mast cells, as well as some undifferentiated cells. Scattered throughout the ground substance are loosely woven collagen, reticular and elastic fibers.

**Location:** widely distributed in the body filling spaces just deep to the skin, below the mesothelial lining of body cavities, in adventitia of blood vessels, respiratory tract

**Function:** binds organs and organ components. Because this tissue lies immediately beneath the epithelia of the digestive and respiratory tracts, it is where the body first attacks antigens and bacteria.

**Reticular CT:** forms delicate networks and support of various organs. Reticular fibers are thin 0.5-2.0 µm diameter, mostly type III collagen embedded in loose CT.

**Location:** in embryonic CT, around fat and smooth muscle cells and fine supporting mesh in liver, lymph nodes and spleen.

**Elastic CT:** are loose bundles of elastic fibers with some collagen and cartilage in between. The elastic fibers are coiled, branching fibers 0.2-1.0 µm in diameter, and may stretch up to 150% of their resting length.

**Location:** dermis, lungs, elastic cartilage and large blood vessels

**Dense CT:**
**Contains more fibers but less matrix and fewer cells** than loose CT

**Dense Irregular CT:** contains thick collagenous bundles that are irregularly woven into a compact meshwork resisting stress and producing tensile strength from different directions. Among the collagen fibers is a network of elastic fibers and cells such as fibroblasts, mast cells, macrophages.

**Location:** dermis of skin, nerve sheaths, capsules of spleen, testes, ovary, kidney and lymph nodes

**Dense Regular CT:** fibers are arranged in parallel bundles for tensile strength in 1 direction. Fibroblasts occur in rows parallel to the collagenous bundles and are the only cells present with little ground substance.

**Location:** tendons, ligaments and aponeuroses

**Dense Regular Elastic CT:** possesses branching elastic fibers arranged parallel to each other with only a few collagen fibers forming networks.

**Location:** large blood vessels, ligamenenum flava, of the spine, and suspensory ligaments of the penis