Chapter 5

Histology: The Tissue Level of Organization

4 Basic Types of Tissues

• *Epithelial tissue*
  – covers body surfaces, lines hollow organs, body cavities, and ducts; and forms glands.

• *Connective tissue*
  – protects and supports the body and its organs, binds organs together, stores energy reserves as fat, and provides immunity.

• *Muscle tissue*
  – is responsible for movement and generation of force.

• *Nervous tissue*
  – initiates and transmits action potentials (nerve impulses) that help coordinate body activities.

Introduction

• Tissues are collections of cells and cell products (extracellular matrix) that perform specific, limited functions
• Histology = the study of tissues
• 4 tissue types form all the structures of the human body:
  – epithelial, connective, muscle, and neural

Development

• Normally, most cells within a tissue remain in place, anchored to
  – other cells
  – a basement membranes
  – connective tissues
• Exceptions include blood cells, phagocytes and embryonic cells involved in differentiation and growth
**Biopsy**

- Removal of living tissue for microscopic examination
  - surgery
  - needle biopsy
- Useful for diagnosis, especially cancer
- Tissue preserved, sectioned and stained before microscopic viewing

**Cell Junctions**

- *Cell junctions* are points of contact between adjacent plasma membranes.
- Depending on their structure, cell junctions may serve one of three functions.
  - Some cell junctions form fluid-tight seals between cells.
  - Other cell junctions anchor cells together or to extracellular material.
  - Still others act as channels, which allow ions and molecules to pass from cell to cell within a tissue

**Tight Junctions**

- Watertight seal between cells
- Plasma membranes fused with a strip of proteins
- Common between cells that line GI and bladder
Gap Junctions

- Tiny space between plasma membranes of 2 cells
- Crossed by protein channels called connexons forming fluid filled tunnels
- Cell communication with ions & small molecules
- Muscle and nerve impulses spread from cell to cell
  - heart and smooth muscle of gut

Desmosomes

- Resists cellular separation and cell disruption

Hemidesmosomes

- Half a desmosome
- Connect cells to extracellular material
  - Basement membrane

Epithelial Tissue -- General Features

- Closely packed cells with little extracellular material
  - Many cell junctions often provide secure attachment
- Cells sit on basement membrane
  - Apical (upper) free surface
  - Basal surface against basement membrane
- Avascular--without blood vessels
  - nutrients and waste must move by diffusion
- Good nerve supply
- Rapid cell division (high mitotic rate)
- Functions
  - protection, filtration, lubrication, secretion, digestion, absorption, transportation, excretion, sensory reception, and reproduction
Basement Membrane

- Basal lamina
  - from epithelial cells
  - collagen fibers
- Reticular lamina
  - secreted by connective tissue cells
  - reticular fibers
- Functions:
  - attachment and support of epithelium
  - may become thickened due to increased collagen and laminin production
  - Example: In diabetes mellitus, the basement membrane of small blood vessels, especially those in the retina and kidney, thickens

Types of Epithelium

- Covering and lining epithelium
  - epidermis of skin
  - lining of blood vessels and ducts
  - lining respiratory, reproductive, urinary & GI tract
- Glandular epithelium
  - secreting portion of glands
  - thyroid, adrenal, and sweat glands

Classification of Epithelium

- Classified by arrangement of cells into layers
  - simple = one cell layer thick
  - stratified = two or more cell layers thick
  - pseudostratified = cells contact BM but all cells don’t reach apical surface
    - nuclei are located at multiple levels so it looks multilayered
- Classified by shape of surface cells
  - squamous = flat
  - cuboidal = cube-shaped
  - columnar = tall column
  - transitional = shape varies with tissue stretching
**Simple Squamous Epithelium**

- Single layer of flat cells
  - very thin --- controls diffusion, osmosis and filtration
  - found in lungs and kidneys
  - blood vessel lining (endothelium) and lining of body cavities (mesothelium)
  - nuclei are centrally located
  - cells are in direct contact with each other

**Example of Simple Squamous Epithelium**

**Simple Cuboidal Epithelium**

- Single layer of cube-shaped cells viewed from the side
  - nuclei are round and centrally located
  - lines tubes of kidney
  - adapted for absorption or secretion

**Example of Simple Cuboidal Epithelium**

- X-Sectional view of kidney tubules
Simple Columnar Epithelium

• Consists of a single layer of column-like cells and can exist in two forms
  – **Nonciliated simple columnar epithelium** contains microvilli
    • increase surface area and the rate of secretion and absorption
  – **Ciliated simple columnar epithelium** contains cells with hair-like processes called cilia
    • provides motility and helps to move fluids or particles along a surface

Pseudostratified Columnar Epithelium

• Appears to have several layers because the nuclei are at various levels.
• All cells are attached to the basement membrane but some do not reach the apical surface.
• Found in respiratory system, male urethra & epididymis

Simple Columnar

• Single layer rectangular cells, nuclei near base
• Unicellular glands (goblet cells) secrete mucus
• Microvilli (small, non-motile, fingerlike membrane projections)
  – adapted for absorption in GI tract (stomach to rectum)
• Cilia (motile membrane extensions) move mucus
  – found in respiratory system and in uterine tubes

Stratified Epithelium

• Epithelia have at least two layers of cells
  – more durable and protective
  – name depends on the shape of the surface (apical) cells
• **Stratified squamous epithelium** consists of several layers of
  – top layer of cells is flat
  – deeper layers of cells vary cuboidal to columnar
  – basal cells replicate by mitosis
• **Keratinized stratified squamous epithelium**
  – a tough layer of keratin (a protein resistant to friction and repels bacteria) is deposited in the surface cells.
• Nonkeratinized epithelium remains moist
Stratified Epithelium

- **Stratified cuboidal epithelium**
  - rare tissue consisting of two or more layers of cube-shaped cells whose function is mainly protective

- **Stratified columnar epithelium**
  - consists of layers of cells
  - top layer is columnar
  - somewhat rare
  - adapted for protection and secretion

- **Transitional epithelium**
  - consists of several layers of variable shape
  - capable of stretching / permits distention of an organ
  - lines the urinary bladder
  - lines portions of the ureters and the urethra

Stratified Squamous Epithelium

- Several cell layers thick
  - flat surface cells
  - Keratinized = surface cells dead and filled with keratin
    - skin (epidermis)
  - Nonkeratinized = no keratin in moist living cells at surface
    - mouth, vagina

Papanicolaou Smear (Pap smear)

- Collect sloughed off cells of uterus and vaginal walls
- Detect cellular changes (precancerous cells)
- Recommended annually for women over 18 or if sexually active

Transitional Epithelium

- Multilayered
  - surface cells varying in shape
    - round to flat (if stretched)
  - lines hollow organs that expand from within (urinary bladder)
Glandular Epithelium

**Gland:**
- a single cell or a mass of epithelial cells adapted for secretion

- **Exocrine glands**
  - cells that secrete—sweat, ear wax, saliva, digestive enzymes onto free surface of epithelial layer
  - connected to the surface by tubes (ducts)
  - unicellular glands (goblet cells) or multicellular glands

- **Endocrine glands**
  - secrete hormones into the bloodstream
  - ductless
  - hormones help maintain homeostasis

Structural Classification of Exocrine Glands

- **Unicellular (single-celled) glands**
  - goblet cells

- **Multicellular glands**
  - branched (compound) or unbranched (simple)
  - tubular or acinar (flask-like) shape

Examples of Simple Glands

Examples of Compound Glands

Duct of Multicellular Glands

- Sweat gland duct
- Stratified cuboidal epithelium
Exocrine Glands – Functional Classification

- **Merocrine glands**
  - form the secretory products and discharge it by exocytosis

- **Apocrine glands**
  - accumulate secretory products at the apical surface of the secreting cell; that portion then pinches off from the rest of the cell to form the secretion with the remaining part of the cell repairing itself and repeating the process

- **Holocrine glands**
  - accumulate the secretory product in the cytosol
  - cell dies and its products are discharged
  - the discharged cell being replaced by a new one

Methods of Glandular Secretion

- **Merocrine -- most glands**
  - saliva, digestive enzymes & watery (sudoriferous) sweat

- **Apocrine**
  - smelly sweat

- **Holocrine -- oil gland**
  - cells die & rupture to release products

Connective Tissue

- Abundant and widely distributed
- Consist of:
  - Cells
  - Extracellular matrix
    - Ground substance (fluid, gelatinous, calcified)
    - Fibers (collagen, elastic, reticular)

Connective Tissues

- Cells rarely touch due to “extracellular matrix.”
- Matrix (fibers & ground substance) is secreted by cells
- Consistency varies
  - liquid, gel or solid
- Good nerve & blood supply except in cartilage & tendons
Connective Tissue Cells

- Immature cells have names that end in -blast (e.g., fibroblast, chondroblast)
- Mature cells have names that end in -cyte (e.g., osteocyte).
- Fibroblasts (which secrete fibers and matrix)
- Adipocytes (or fat cells, which store energy in the form of fat)
- White blood cells (or leukocytes)
  - Macrophages develop from monocytes
    - engulf bacteria & debris by phagocytosis
  - Plasma cells develop from B lymphocytes
    - produce antibodies that fight against foreign substances
  - Mast cells produce histamine that dilate small BV

Extracellular Matrix: Ground Substance

- Ground Substance
  - glycosamino glycans (GAG’s) hyaluronic acid, chondroitin sulfate, dermalan sulfate, and keratan sulfate
    - hyaluronic acid is thick, viscous and slippery
    - chondroitin sulfate is jellylike substance providing support
    - adhesion proteins (fibronectin) binds collagen fibers to ground substance
  - Chondroitin sulfate and glucosamine are used as nutritional supplements to maintain joint cartilage

Extracellular Matrix: Fibers

- Collagen fibers
  - composed of the protein collagen
  - tough and resistant to stretching
  - allow some flexibility in tissue
  - bone, cartilage, tendons, and ligaments
- Elastic fibers
  - composed of the protein elastin surrounded by the glycoprotein fibrinlin
  - provide strength and stretching capacity
  - skin, blood vessels, and lungs
- Reticular fibers
  - composed of collagen and glycoprotein
  - support in the walls of blood vessels, in spleen, in lymph nodes
  - supporting network around fat cells, nerve fibers, and skeletal and smooth muscle fibers

Embryonic Connective Tissue

- Connective tissue that is present primarily in the embryo or fetus is called embryonic connective tissue
- Mesenchyme, found almost exclusively in the embryo, is the tissue form from which all other connective tissue eventually arises
- Mucous connective tissue (Wharton’s jelly) is found in the umbilical cord of the fetus
Types of Mature Connective Tissue

- **Connective tissue proper**
  - loose connective tissue
  - dense connective tissue
- **Cartilage**
  - hyaline, elastic, reticular
- **Bone tissue**
  - compact and trabecular (spongy)
- **Blood and Lymph**

Loose Connective Tissues

- Consists of all three types of fibers, several types of cells, and a semi-fluid ground substance
- Loosely woven fibers throughout tissues
- Sub-types of loose connective tissue
  - areolar connective tissue
  - adipose tissue
  - reticular tissue

Areolar Connective Tissue

- Cell types = fibroblasts, plasma cells, macrophages, mast cells and a few white blood cells
- All 3 types of fibers present
- Gelatinous ground substance
- It is found in the subcutaneous layer of the integument

Adipose

- Adipose tissue consists of adipocytes which are specialized for storage of fat (triglycerides)
  - deeper layer of skin, organ padding, yellow marrow
  - reduces heat loss through the skin, serves as an energy reserve, supports, protects organs
  - peripheral nuclei due to large fat storage droplet
  - brown fat (found in infants) has more blood vessels and mitochondria and is responsible for heat generation
  - liposuction involves sucking out small amounts of adipose tissue
Reticular Connective Tissue

- Network of reticular fibers & cells that produce framework of organ
- Holds organ together (liver, spleen, lymph nodes, bone marrow)

Dense Connective Tissue

- Dense connective tissue contains more numerous, thicker, and dense fibers but considerably fewer cells than loose connective tissue.
- Types of dense connective tissue
  - dense regular connective tissue
  - dense irregular connective tissue
  - elastic connective tissue

White Fibrous (Dense Regular) Connective Tissue

- Collagen fibers in parallel bundles with fibroblasts between bundles of collagen fibers
- White, tough and pliable when unstained (forms tendons & ligaments)

Dense Irregular Connective Tissue

- Dense irregular connective tissue contains collagen fibers that are irregularly arranged and is found in parts of the body where tensions are exerted in various directions
  - occurs in sheets, such as the dermis of the skin
  - found in heart valves, the perichondrium, the periosteum, white of eyeball, dermis of skin
Elastic Connective Tissue

- Branching elastic fibers and fibroblasts
- Can stretch & still return to original shape
- Lung tissue, vocal cords, ligament between vertebrae

Cartilage

- *Cartilage* consists of a dense network of collagen fibers and elastic fibers embedded in chondroitin sulfate
  - strength is due to its collagen fibers
  - resilience is due to the chondroitin sulfate
  - Chondrocytes occur with spaces called lacunae in the matrix.
- It is surrounded by a dense irregular connective tissue membrane called the *perichondrium*
- Unlike other connective tissues, cartilage has no blood vessels or nerves (except in the perichondrium)

Three Types of Cartilage

- **Hyaline cartilage**
  - most abundant, but weakest
  - has fine collagen fibers embedded in a gel-type matrix
  - affords flexibility and support and
  - at joints, reduces friction and absorbs shock
- **Fibrocartilage**
  - contains bundles of collagen fibers in its matrix
  - lacks perichondrium
  - strongest of the three types of cartilage
- **Elastic cartilage**
  - contains a threadlike network of elastic fibers
  - perichondrium is present
  - provides strength and elasticity
  - maintains the shape of certain organs

Hyaline Cartilage

- Bluish-shiny white rubbery substance
- Chondrocytes sit in spaces called lacunae
- No blood vessels or nerves so repair is very slow
- Reduces friction at joints as articular cartilage
Fibrocartilage

- Many more collagen fibers causes rigidity & stiffness
- Strongest type of cartilage (intervertebral discs)

Growth & Repair of Cartilage

- Grows and repairs slowly because it is avascular
- Interstitial growth
  - chondrocytes divide and form new matrix
  - occurs in childhood and adolescence
- Appositional growth
  - chondroblasts secrete matrix onto surface
  - produces increase in width

Elastic Cartilage

- Elastic fibers help maintain shape after deformations
- Ear, nose, vocal cartilages

Bone (Osseous) Tissue

- Protects, provides for movement, stores minerals, site of blood cell formation
- Bone (osseous tissue) consists of a matrix containing mineral salts and collagenous fibers and cells called osteocytes
  - Spongy bone
    - sponge-like with spaces and trabeculae
    - trabeculae = struts of bone surrounded by red bone marrow
    - no osteons (cellular organization)
  - Compact bone
    - solid, dense bone
    - basic unit of structure is osteon
Compact Bone: Osteon

- Lamellae (rings) of mineralized matrix
  - calcium & phosphate---give it its hardness
  - interwoven collagen fibers provide strength
- Lacunae are small spaces between lamellae that contain mature bone cells called osteocytes.
- Canaliculi are minute canals containing processes of osteocytes that provide routes for nutrient and waste transport.
- A central canal contains blood vessels and nerves.

Liquid connective tissue

- **Blood**
  - liquid matrix called plasma
  - formed elements
- **Lymph** is interstitial fluid flowing in lymph vessels
  - Contains less protein than plasma
  - Move cells and substances (e.g., lipids) from one part of the body to another

Membranes

Membranes are flat sheets of pliable tissue that cover or line a part of the body

- Epithelial membranes consist of an epithelial layer and an underlying connective tissue layer (lamina propria)
  - include mucous membranes, serous membranes, and the cutaneous membrane (skin)
- **Synovial membranes** line joints and contain mainly connective tissue

Blood

- Connective tissue with a liquid matrix (the plasma)
- Cell types include red blood cells (erythrocytes), white blood cells (leukocytes) and cell fragments called platelets
  - clotting, immune functions, transport of O\textsubscript{2} and CO\textsubscript{2}
Mucous Membranes

- *Mucous membranes* (mucosae) line cavities that open to the exterior
  - mouth, stomach, vagina, urethra, etc
- Epithelial cells form a barrier to microbes
- The connective tissue layer of a mucous membrane is called the *lamina propria*.
- Tight junctions between cells prevent simple diffusion of most substances.
- Mucous is secreted from underlying glands to keep surface moist

Serous Membranes

- Simple squamous cells overlying loose CT layer
  - consist of parietal and visceral layers
- Squamous cells secrete slippery fluid
- Lines a body cavity that does not open to the outside such as chest or abdominal cavity
- Examples:
  - pleura, peritoneum and pericardium
    - membrane on walls of cavity = parietal layer
    - membrane over organs in cavity = visceral layer
- Serous membranes may become inflamed with the buildup of serous fluid resulting in pleurisy, peritonitis, or pericarditis.
Cutaneous Membranes

- Cutaneous membranes cover body surfaces and consist of epidermis and dermis

Synovial Membranes

- Line joint cavities of all freely movable joints
- Line bursae, and tendon sheaths
- Just a few epithelial cells that secrete slippery synovial fluid

Muscle Tissue

- Consists of fibers (cells) that are modified for contraction (provide motion, maintenance of posture, and heat)
- 3 types:
  - **Skeletal muscle** tissue is attached to bones, is striated, and is voluntary
  - **Cardiac muscle** tissue forms most of the heart wall, is striated, and is usually involuntary
  - **Smooth (visceral) muscle** tissue is found in the walls of hollow internal structures (blood vessels and viscera), is nonstriated, and is usually involuntary. It provides motion (e.g., constriction of blood vessels and airways, propulsion of foods through the gastrointestinal tract, and contraction of the urinary bladder and gallbladder)

Skeletal Muscle

- Cells are long cylinders with many peripheral nuclei
- Visible light and dark banding (looks striated)
- Voluntary (conscious control)
Cardiac Muscle

- Cells are branched cylinders with one central nuclei
- Involuntary and striated
- Attached to and communicate with each other by intercalated discs and desmosomes

Smooth Muscle

- Spindle shaped cells with a single central nuclei
- Walls of hollow organs (blood vessels, GI tract, bladder)
- Involuntary and nonstriated

Nervous Tissue

- The nervous system is composed of only two principal kinds of cells:
  - *neurons* (nerve cells)
  - *neuroglia* (protective and supporting cells)
- Most neurons consist of a *cell body* and two types of processes called *dendrites* and *axons*
- Neurons are sensitive to stimuli, convert stimuli into nerve impulses, and conduct nerve impulses to other neurons, muscle fibers, or glands
- *Neuroglia* protect and support neurons and are often the sites of tumors of the nervous system

Nerve Tissue

- Cell types -- nerve cells and neuroglial (supporting) cells
- Nerve cell structure
  - nucleus & long cell processes conduct nerve signals
    - dendrite(s) --- signal travels toward the cell body
    - axon ---- signal travels away from cell body
Tissue Repair: Restore Homeostasis

- Tissue repair is the process that replaces worn out, damaged, or dead cells.
- Each tissue type has a different capacity to repair itself
  - Epithelial cells are replaced by the division of stem cells or by division of undifferentiated cells
  - Some connective tissues such as bone have a continuous capacity for renewal whereas cartilage replenishes cells less readily
  - Muscle cells have a poor capacity for renewal
  - Nervous tissue has the poorest capacity for renewal

Conditions Affecting Tissue Repair

- Nutrition
  - adequate protein for structural components
  - vitamin C for production of collagen and new blood vessels
- Proper blood circulation
  - delivers O₂ & nutrients & removes fluids & bacteria
- With aging
  - collagen fibers change in quality
  - elastin fibers fragment and abnormally bond to calcium
  - cell division and protein synthesis are slowed

Tissue Repair: Restoring Homeostasis

- Worn-out, damaged tissue must be replaced
- Fibrosis is the process of scar formation
  - If the injury is extensive, granulation tissue (actively growing connective tissue) is formed
- Adhesions, which sometimes result from scar tissue formation, cause abnormal joining of adjacent tissues, particularly in the abdomen and sites of previous surgery. These can cause problems such as intestinal obstruction.