Lecture Outline: Histology

I. **Introduction to Histology**

A. **Definition and Scope**

1. Histology is the study of tissues, focusing on human histology for health-related fields.
2. Unlike courses for other sciences, this course (156) emphasizes human biology over plant biology.

B. **Hierarchy of Biological Organization**

1. Cells of different types make up tissues.
2. Tissues of different types make up organs.

C. **Four Primary Tissue Types in the Human Body**

1. Epithelial tissue
2. Connective tissue
3. Muscle tissue
4. Nervous tissue
5. Any given organ contains at most these four tissue types.

D. **Excitable Tissues**

1. Definition: Tissues capable of producing and transmitting action potentials (electrochemical signals).
2. Types:
    a. Muscle tissue (for movement)
    b. Nervous tissue (for communication)
3. Epithelial and connective tissues are not excitable.

II. **Epithelial Tissue (Epithelium)**

A. **Major Functions**

1. Covers the surfaces of structures (e.g., epidermis of skin, internal organs).

2. Lines the internal spaces of hollow structures (e.g., digestive tract).
3. Forms glands, producing various substances (e.g., hormones).

B. **Important Properties**

1. **Cellularity**: Epithelium is composed almost entirely of cells packed tightly together, with very little extracellular material.
2. **Polarity**: Refers to having two different surfaces, an apical and a basal surface.
    a. **Apical surface**: The free surface, not attached to anything (e.g., the skin's surface, the inner lining of the gut where food touches).
    b. **Basal surface**: The attached surface, connected to a basement membrane (or basal lamina), which is a layer of connective tissue.
3. **Avascularity**: Epithelium does not have blood vessels running through it.
    a. It relies on diffusion from nearby blood vessels (often located beneath it in connective tissue) for oxygen, nutrients, and waste removal.
    b. Epithelia are typically thin, allowing for efficient diffusion.
4. **Regeneration**: Epithelial tissue has a strong ability to rebuild and heal itself if damaged, as long as some cells remain.

C. **Classification of Epithelia**

1. **Based on Number of Layers**
    a. **Simple Epithelium**: Consists of a single layer of cells.
    b. **Stratified Epithelium**: Consists of two or more layers of cells.
    c. **Pseudostratified Epithelium**: Appears to have multiple layers due to varying cell heights and nuclear positions, but all cells are in contact with the basement membrane, making it structurally a simple epithelium.
        (1) Example: Trachea, often ciliated to sweep debris.
    e. **Transitional Epithelium**: A specialized stratified epithelium capable of significant stretching.
        (1) Appearance changes from columnar (when relaxed) to

more squamous (when stretched).

(2) Location: Found in organs that need to expand greatly, such as the urinary bladder and ureters.

2. **Based on Cell Shape** (shape is determined by the cells in the apical layer)
    a. **Squamous**: Cells are thin and flat, wider than they are thick (like floor tiles).
    b. **Cuboidal**: Cells are cube-shaped, roughly as thick as they are wide.
    c. **Columnar**: Cells are column-shaped, thicker than they are wide.
3. **Combined Classification**: Epithelia are typically classified by combining terms for the number of layers and the shape of the apical cells (e.g., simple squamous, stratified columnar).

D. **Examples of Epithelia and Their Functions**

1. **Simple Squamous Epithelium**
    a. Properties: Extremely thin and delicate.
    b. Function: Ideal for rapid diffusion over short distances.
    c. Location: Lines the air sacs (alveoli) of the lungs, facilitating efficient oxygen and carbon dioxide exchange between air and blood.
2. **Simple Cuboidal Epithelium**
    a. Function: Involved in secretion and reabsorption.
    b. Cell Structure: Cells are thicker, allowing for more cytoplasm to house machinery for transport protein synthesis.
    c. Location: Found in the kidney, where it filters blood and reabsorbs necessary substances.
3. **Simple Columnar Epithelium**
    a. Function: Primarily responsible for absorption of digested food molecules.
    b. Cell Structure: Tall, column-shaped cells with extensive transport proteins; often possess microvilli to drastically increase surface

area for absorption.

c. Location: Lines the small intestine, efficiently absorbing nutrients.

4. **Stratified Squamous Epithelium**
    a. Function: Provides robust protection against abrasion and continuous cell loss.
    b. Location: Forms the epidermis of the skin, which is constantly exposed to environmental stresses.
    c. Renewal: Cells are continuously produced by mitosis at the basal layer, migrate upwards, mature, die, harden, and are shed from the apical surface.
    d. Avascularity: Blood vessels are located in the underlying dermis, not within the epithelium itself.
5. **Stratified Cuboidal Epithelium**
    a. Location: Found in the ducts of glands, such as salivary glands.
    b. Function: Primarily involved in secretion.
6. **Stratified Columnar Epithelium**
    a. Rarity: Less common in the body.
    b. Location: Found in places like mammary gland ducts and parts of the larynx.

III. **Connective Tissue**

A. **General Characteristics**

1. The most diverse of the four tissue types, ranging from liquid (blood) to hard (bone).
2. Often serves as a "catch-all" category for tissues not classified as epithelial, muscle, or nervous tissue.
3. Connects and supports other tissues, such as epithelia which are built on connective tissue.

B. **Two Major Components**

1. **Cells**: Different types of cells perform specific roles.
    a. **Blasts** (e.g., chondroblast, osteoblast): Cells responsible for producing the extracellular matrix.

b. **Cytes** (e.g., chondrocyte, osteocyte): Mature blast cells that primarily maintain the extracellular matrix.

c. **Clasts** (e.g., osteoclast): Cells that degrade or destroy the extracellular matrix, facilitating tissue remodeling.

2. **Extracellular Matrix (ECM)**: The material located outside and between the cells.

a. **Ground Substance**: The non-fibrous component of the ECM, varying in consistency (e.g., fluid, gel, solid).

b. **Fibers**: Protein fibers embedded within the ground substance.

(1) **Collagenous fibers** (Collagen): Tough, rope-like proteins that provide tensile strength and resist stretching.

(2) **Elastic fibers**: Delicate, able to stretch and recoil to their original shape (like a rubber band).

(3) **Reticular fibers**: Branched fibers that form delicate, net-like or web-like networks.

C. **Classification of Connective Tissue**

1. **Embryonic Connective Tissue**

a. **Mesenchyme**: An undifferentiated embryonic connective tissue that develops into all other adult connective tissues.

b. **Mucous connective tissue**: Embryonic tissue specialized in producing mucus.

2. **Adult Connective Tissue (Six Major Kinds)**

a. **Loose (Areolar) Connective Tissue**

(1) Properties: Characterized by a relatively low number of fibers and a high proportion of ground substance, making it less strong.

(2) Function: Serves as packing material and allows for movement and gliding of structures.

(3) Location: Found deep in the skin, enabling it to move over underlying structures without damage.

e. **Dense Connective Tissue**: Characterized by a high density of fibers, providing significant strength.

(1) **Dense Regular Collagenous Connective Tissue**

1. Fibers: Composed primarily of collagen fibers arranged in parallel.
2. Strength: Extremely strong in one direction of pull.
3. Location: Forms tendons (connecting muscles to bones) and ligaments (connecting bones to bones).

(2) **Dense Regular Elastic Connective Tissue**

1. Fibers: Contains elastic fibers arranged in parallel.
2. Function: Provides strength with the ability to stretch and vibrate.
3. Location: Found in structures like the vocal folds (vocal cords).

(3) **Dense Irregular Collagenous Connective Tissue**

1. Fibers: Contains collagen fibers arranged in all directions.
2. Strength: Withstands pulling forces from multiple directions.
3. Location: Constitutes the dermis, the deeper layer of the skin, which experiences multidirectional tugging.

(4) **Dense Irregular Elastic Connective Tissue**

1. Fibers: Contains elastic fibers arranged in all directions.
2. Function: Allows for stretching and recoiling in multiple directions.
3. Location: Found in the aorta, the largest artery, enabling it to bulge with each heartbeat and recoil to help propel blood.

j. **Connective Tissues with Special Properties**

(1) **Adipose Tissue**

1. Function: Specialized for storing fat, serving as padding, thermal insulation, and the most energy-dense nutrient storage.
2. Cells: Composed of adipocytes (fat cells), which appear

empty on prepared slides because the fat dissolves during processing.

3. Location: Distributed throughout the body for various protective and energy-storage roles.

(2) **Reticular Tissue**

1. Fibers: Rich in reticular fibers, forming a net-like structure.
2. Function: Acts as a filter.
3. Location: Found in lymph nodes, where it helps trap invaders like bacteria for the immune system to eliminate.

m. **Cartilage**: A hard, tough connective tissue, but not as hard as bone. It is avascular, relying on diffusion, which makes it slow to heal.

(1) Cells: Chondroblasts produce the matrix, chondrocytes maintain it, and chondroclasts break it down.

(2) **Hyaline Cartilage**

1. Appearance: Glassy.
2. Abundance: The most abundant type of cartilage in the body.
3. Location: Forms the articular surfaces of highly movable joints (providing a low-friction surface) and connects ribs to the sternum. Most bones initially develop as hyaline cartilage before ossifying into bone.

(3) **Fibrocartilage**

1. Fibers: Contains a heavy density of fibers in its extracellular matrix.
2. Location: Found in intervertebral discs between vertebrae, providing strong anchoring.

(4) **Elastic Cartilage**

1. Fibers: Primarily composed of elastic fibers.
2. Function: Provides elasticity, allowing structures to deform and then spring back into shape.

3. Location: Forms the external ear (pinna).

r. **Bone**: The hardest connective tissue. It is vascular, meaning it has blood vessels running through it, unlike cartilage.

(1) Cells: Osteoblasts build the extracellular matrix, osteoclasts break it down, and osteocytes maintain it.

(2) Extracellular Matrix: Very hard, primarily composed of a mineral called hydroxyapatite (calcium phosphate).

(3) Osteocytes: Are located in small chambers called lacunae within the solid matrix and communicate with each other and blood vessels via tiny canals called canaliculi to exchange nutrients and waste.

(4) **Cancellous Bone (Spongy Bone)**

1. Appearance: Appears spongy due to being full of holes, but remains hard.
2. Location: Found deep inside bones and in the interior of flat bones (like the "filling" of a sandwich).
3. Structure: Consists of a network of small rods or girders called trabeculae.
4. Marrow: The spaces within cancellous bone are filled with marrow.

(5) **Compact Bone**

1. Properties: Much denser and stronger than cancellous bone due to tightly packed bone material.
2. Location: Forms the exterior surfaces of bones, where forces are directly applied.
3. Structure: Arranged in microscopic units called osteons.
4. Osteon: Each osteon contains a central canal (Haversian canal) through which blood vessels and nerves run, surrounded by concentric layers of bone called lamellae.

x. **Blood and Hemopoietic Tissue**

(1) Components: Consists of cells suspended in an extracellular matrix.

(2) **Cells**

1. **Red Blood Cells (Erythrocytes)**: The most abundant blood cells.
    1. Function: Transport oxygen (via hemoglobin) and carbon dioxide.
    2. Properties: In mammals, they are anucleate (lack a nucleus) to maximize space for hemoglobin.
    3. Lifespan: Short-lived due to lack of repair mechanisms and wear-and-tear from squeezing through capillaries. Billions are lost and replaced daily.
2. **White Blood Cells (Leukocytes)**: Larger cells involved in immune responses.
3. **Platelets**: Cell fragments involved in blood clotting.

(3) **Extracellular Matrix (Plasma)**: The fluid component of blood, which is the extracellular matrix.

1. Components: Includes ground substance and various dissolved plasma proteins (fibers).
2. **Serum**: The ground substance of blood, remaining after cells and proteins (fibers) are removed from plasma.

(4) **Hemopoietic Tissue**: The tissue responsible for producing blood cells.

1. Cells: Contains stem cells (hemopoietic cells) capable of differentiating into various blood cell types.
2. Location: Found in red marrow, typically located at the tips of long bones. Yellow marrow, on the other hand, is primarily composed of fat cells.

IV. **Muscle Tissue**

A. **General Properties**: Muscle tissue, along with nervous tissue, is excitable.

1. **Excitability**: Ability to produce and transmit action potentials.
2. **Contractility**: Ability to shorten or contract (muscles only pull, they do not push on their own).

3. **Extensibility**: Ability to be stretched by external forces (e.g., gravity or other muscles).
4. **Elasticity**: Ability to recoil or rebound to original length after being stretched.

B. **Three Major Classes of Muscle Tissue**

1. **Skeletal Muscle**
    a. Location: Primarily attached to bones, enabling movement of the skeleton.
    b. Control: **Voluntary**, meaning it is under conscious control of the brain.
    c. Cell Shape (Myofiber/Muscle Fiber): Long, cylindrical, and unbranched; does not taper at the ends.
    d. Nuclei: **Multi-nucleate** (contains many nuclei per cell), which are typically pushed to the periphery of the cell.
    e. Striations: Highly and orderly **striated** (exhibits a distinct banding pattern under a microscope).
    f. Function: Requires nervous system input (action potentials from neurons) to contract.
2. **Smooth Muscle**
    a. Location: Lines the walls of internal organs and hollow structures, such as the digestive tract.
    b. Control: **Involuntary** (controlled by the autonomic nervous system) and exhibits **autorhythmicity**, meaning it can contract spontaneously, though typically slower and less strongly than cardiac muscle.
    c. Cell Shape: Spindle-shaped, tapering at both ends.
    d. Nuclei: Contains a single, centrally located nucleus.
    e. Striations: **Not striated**.
    f. Function: Propels substances through hollow organs (e.g., food through the digestive tract).
3. **Cardiac Muscle**

a. Location: Found exclusively in the heart.

b. Control: **Involuntary** (controlled by the autonomic nervous system) and possesses **autorhythmicity**, allowing it to beat spontaneously even without nervous input, though the nervous system can adjust the rate.

c. Cell Shape: Long, cylindrical, and often branched; does not taper at the ends.

d. Nuclei: Contains a single, centrally located nucleus.

e. Striations: **Striated**, though the banding pattern may appear less orderly than skeletal muscle due to branching.

f. Special Feature: Contains **intercalated discs** at the end-to-end attachments between adjacent cardiac myofibers. These discs facilitate the direct transmission of action potentials, ensuring synchronized contraction of heart chambers for efficient pumping.

V. **Nervous Tissue**

A. **General Characteristics**: The other excitable tissue type, along with muscle tissue.

1. Composed of two main cell classes: neurons and neuroglia.

B. **Neurons (Nerve Cells)**

1. Excitability: Neurons are the excitable cells within nervous tissue, responsible for creating and transmitting action potentials.
2. Function: Receive and send impulses (information) to other parts of the body, including other neurons.
3. Structure: Neurons are often very long, thin, and narrow cells, allowing them to maintain a high surface area to volume ratio despite their length.

a. **Cell Body**: The largest part of the neuron, containing the nucleus.

b. **Dendrites**: Branched extensions that serve as inputs, receiving stimuli and sending impulses towards the cell body.

c. **Axon**: A single, long extension originating from the cell body that serves as the output. It transmits action potentials away from the cell body.

(1) An axon may branch to deliver information to multiple target cells (e.g., a single motor neuron can connect to many muscle fibers in a motor unit).

C. **Neuroglia (Glial Cells)**

1. Excitability: Neuroglia are **not excitable** and do not produce or transmit action potentials.
2. Function: Their primary role is to support and protect neurons in various ways.
3. **Myelination**: Some neuroglial cells form a myelin sheath around axons.
    a. Myelin sheath: A fatty, insulating layer formed by wrapping a neuroglial cell's plasma membrane around an axon.
    b. Function: Electrically insulates the axon, significantly increasing the speed at which electrical impulses (action potentials) travel along it by allowing them to "jump" between myelinated segments.
4. Location: Found throughout the nervous system, including the Central Nervous System (brain and spinal cord) and the Peripheral Nervous System.

```
```