Lecture Outline: Histology

I. **Cells**

A. Introduction to Cells

1. Focus on **human (animal) cells**
2. First unit contains introductory information, followed by organ system study

B. Cell Types

1. **Eukaryotic cells**: Have a **true nucleus** and **other membrane-bounded organelles**
    a. Humans are eukaryotes
2. **Prokaryotic cells**: **Do not have a true nucleus** or other membrane-bounded organelles
    a. Only membrane is the plasma membrane
    b. Consist of a single compartment

C. Organelles (Little Organs within a Cell)

1. **Nucleus**
    a. Contains **DNA**
    b. Example of a **doubly membrane-bounded organelle**
    c. Double membrane called the **nuclear envelope**
    d. Nuclear envelope is perforated by **nuclear pores** for transport
    e. Outer membrane of nuclear envelope is continuous with endoplasmic reticulum
2. **Endoplasmic Reticulum (ER)**
    a. Membrane is continuous with the nuclear envelope

b. Two parts with different functions:

(1) **Rough Endoplasmic Reticulum (Rough ER)**

1. Appearance: Studded with ribosomes, giving it a "rough" look
2. Function: **Modifies newly made proteins** (e.g., sticking things on, cutting things off)

(2) **Smooth Endoplasmic Reticulum (Smooth ER)**

1. Appearance: Lacks ribosomes, looks like tubes
2. Functions: **Produces lipids** and is a **storage place** for substances like calcium ions (important for muscle function)

3. **Golgi Complex (Golgi Apparatus/Golgi)**

a. Structural similarity to rough ER but distinct function

b. Function: Acts as a **receiving and shipping center**

c. Receives proteins in **vesicles** (membrane-bound bags) from the rough ER

d. Figures out destination of proteins (secretion, plasma membrane incorporation, or other organelles)

e. Repackages proteins into new vesicles that bud off its membrane

4. **Mitochondria (Mitochondrion singular)**

a. Bean-shaped organelles

b. Example of a **multiply membrane-bounded organelle** (has two membranes)

c. Function: **"Powerhouse of the cell"** â€“ where most **ATP** (energy storage from food) is made through **cellular respiration**

d. Dismantles fuel molecules completely, producing carbon

dioxide as a byproduct

5. Lysosomes and Peroxisomes
    a. **Lysosomes**
        (1) Meaning: "Splitting body" (lyse = split, some = body)
        (2) Function: Site of **digestion or breakdown of molecules** using digestive enzymes
        (3) Enzymes are contained to prevent damage to the rest of the cell
    e. **Peroxisomes**
        (1) Function: Deal with **harmful peroxides** that naturally build up, converting them into safer substances
6. **Cytoskeleton**
    a. Meaning: "Cell skeleton" (cyto = cell, skeleton = support structure)
    b. Function: Provides **support and maintains order** within the cell
    c. Made of three major kinds of fibrous proteins:
        (1) **Microtubules**: Widest diameter
        (2) **Microfilaments**: Narrowest diameter (thinnest)
        (3) **Intermediate filaments**: Intermediate diameter
7. **Ribosomes**
    a. Tiny organelles (brown dots in pictures)
    b. **Not membrane-bounded organelles** (present in prokaryotic cells as well)
    c. Function: **Assemble proteins** by stringing together amino acids in a specific order based on genetic code

8. **Cytosol**
    a. The **liquid part of the cytoplasm**
    b. Cytoplasm is all the stuff inside the cell but outside of other organelles
    c. Site where much of the chemistry of life occurs

D. Plasma Membrane
1. Structure
    a. Main substructure: **Two layers of phospholipids (phospholipid bilayer)**
        (1) Phospholipids have a polar head (likes water) and two non-polar tails (avoid water)
        (2) Self-assemble in water to form the bilayer, with tails facing each other and heads facing outward
        (3) Crucial for the formation of proto-cells
    e. **Membrane-bound proteins**: Embedded within the membrane, performing various jobs
        (1) Allow substances that cannot directly pass through the phospholipid bilayer to enter or exit the cell
        (2) Different from "membrane bounded" organelles, as they are part of the membrane itself
2. Intercellular Junctions (Between Cells)
    a. **Desmosomes**
        (1) Complexes of proteins connecting plasma membranes of adjacent cells
        (2) Function: Act as "spot welds" to **keep cells together and maintain tissue integrity**
    d. **Tight Junctions**
        (1) More complex protein complexes that go all the

way around cells

(2) Function: Form **blockades between cells**, preventing particles from passing through the spaces between cells in a multi-cellular membrane (e.g., epithelium)

(3) Ensure substances must enter cells to pass through the tissue

h. **Gap Junctions**

(1) Protein complexes forming **little tunnels** between cells

(2) Function: Allow for **intercellular communication** by permitting certain particles to pass directly between cells

(3) Important for synchronous actions (e.g., heart contraction through ion flow)

E. Transport Across the Membrane

1. **Passive Processes** (Energy already contained within the system; no additional energy needed)

a. **Diffusion**

(1) The spreading out of particles from an area of **higher concentration to lower concentration** (down their gradient)

(2) Occurs due to random motion of particles

d. **Simple Diffusion**

(1) Directly through the **phospholipid bilayer**

(2) Requires particles to be **small enough** and **non-polar** (or sufficiently non-polar)

g. **Osmosis**

(1) A **special case of diffusion** where the diffusing particle is the **solvent (water)**

(2) Water moves through a membrane from where it's **more watery to where it's less watery** (down its water gradient)

(3) Examples with red blood cells and external solutions:

1. **Isotonic solution**: Same wateriness as cell interior; water moves in and out at same rate, cell volume unchanged (normal red blood cell)
2. **Hypertonic solution**: Higher solute concentration / less watery than cell; water leaves cell, causing **crenation (shrinkage)**
3. **Hypotonic solution**: Lower solute concentration / more watery than cell; water enters cell, causing **swelling or lysis (bursting)**

k. **Facilitated Diffusion**

(1) Still diffusion (passive, down gradient) but requires **transport proteins** embedded in the membrane

(2) For particles too big, polar, or charged to pass directly through the phospholipid bilayer

2. **Active Processes** (Requires additional energy, often ATP, to force movement)

a. **Active Transport**

(1) Moves substances **against their concentration gradient** (from lower to higher concentration)

(2) Performed by **pumps** (transport proteins that force movement)

(3) Creates and maintains gradients, stockpiling

substances

(4) Example: **Sodium-potassium exchange pump**

1. Pumps sodium ions out of the cell and potassium ions into the cell simultaneously
2. Crucial for nervous and muscle cell function; accounts for a significant portion of body's energy budget

f. **Vesicular Transport** (Transport using vesicles)

(1) **Exocytosis** (Exo = out, Cyto = cell)

1. Movement of substances **out of the cell** via a vesicle
2. Vesicle fuses with the plasma membrane, spilling its contents outside
3. Often called **secretion** (e.g., how glands work)

(2) **Endocytosis** (Endo = in, Cyto = cell)

1. Movement of substances **into the cell** via a vesicle
2. Different kinds based on what is brought in:
    1. **Pinocytosis**: "Cell drinking," taking a sip of liquid from the exterior
    2. **Phagocytosis**: "Cell eating," bringing in a solid chunk from the exterior
    3. **Receptor-mediated endocytosis**: Cell forms a vesicle only when specific substances bind to cell-surface receptors

F. DNA Functions

1. **Replication**

a. The **exact copying of DNA**

b. Necessary for **cell division** (new cells come from pre-existing cells)

c. Before a cell splits, it doubles its DNA to provide a full copy to each daughter cell

d. Based on DNA's **double-stranded nature** and **complementarity** (A with T, C with G)

(1) Each strand serves as a template for building the complementary new strand

f. The original cell does not survive after division; it splits into two new cells

g. Cell division involves two components:

(1) **Mitosis**: Division of the nucleus

(2) **Cytokinesis**: Division of everything else in the cell

2. **Gene Expression**

a. Process by which information from a **gene** (instructions for a protein within DNA) is used to make a protein

b. Consists of two main parts:

(1) **Transcription**

1. Occurs in the **nucleus** (where DNA is located)
2. DNA's code (gene sequence) is used to make an **RNA molecule** (a copy of the instructions)
3. RNA carries the code out of the nucleus via **nuclear pores**

(2) **Translation**

1. Occurs at a **ribosome** (in the cytoplasm)
2. The ribosome reads the RNA code to assemble the specific **protein** (stringing amino acids together)

G. Major Cell Functions/Types

1. Cells that **Connect Body Parts** (e.g., fibroblasts, red blood cells â€“ functionally connecting by transporting oxygen)
2. Cells that **Cover and Line Body Organs** (e.g., epithelial tissues like epidermis for protection)
3. Cells that **Move Organs and Body Parts** (e.g., muscle cells, which shorten or contract)
4. Cells that **Store Nutrients** (e.g., **adipocytes/fat cells**, specialized for fat storage due to high energy density and for padding/insulation)
5. Cells that **Fight Disease** (e.g., **white blood cells/ leukocytes**, involved in immunity, produce antibodies, basis for vaccinations)
6. Cells that **Gather Information and Control Body Functions**
    a. **Nervous system** (e.g., **neurons**: send electrochemical signals via axons and dendrites)
    b. **Endocrine system** (e.g., cells that release **hormones** â€“ chemical signals into bloodstream)
7. Cells of **Reproduction** (e.g., **gametes**: sperm (male) and egg (female); fusion forms a **zygote**, the beginning of a new life)

II. **Tissues**

A. Introduction to Tissues

1. **Histology**: The study of tissues
2. Tissues are **collections of cells** that come together to perform a specific job
3. Humans have **four major tissue types**:
    a. **Epithelial tissue**
    b. **Connective tissue**

c. **Nervous tissue**

d. **Muscle tissue**

B. Epithelial Tissue (Epithelia plural)

1. Function: **Line surfaces** of organs or the body (exteriorly or interiorly)
2. Characteristics:
    a. **Polarity**: One side is attached, the other is free
        (1) **Basal surface**: Attached to an underlying **basement membrane**
        (2) **Apical surface**: Free or unattached surface (e.g., surface of skin)
3. Classification by Layers (Specifies how many layers of cells)
    a. **Simple epithelium**: **One layer** of cells thick
    b. **Stratified epithelium**: **More than one layer** of cells (layered)
    c. **Pseudostratified epithelium**: "Falsely stratified"; appears layered but is actually a **simple epithelium** where all cells touch the basement membrane (cells vary in height)
    d. **Transitional epithelium**: Special category found in organs like the urinary bladder; can change from multiple layers to fewer layers as it stretches, and cell shape changes (e.g., columnar to squamous)
4. Classification by Cell Shape (Determined by the shape of cells in the **apical layer**)
    a. **Squamous**: Cells are much **thinner/shorter than they are wide** (scale-like, like floor tiles)
    b. **Cuboidal**: Cells are roughly as **thick/tall as they are wide** (cube-shaped)

c. **Columnar**: Cells are **thicker/taller than they are wide** (column-shaped)

5. Examples of Epithelia:

a. **Simple Squamous Epithelium**

(1) Characteristics: Thinnest possible epithelium (one layer, squamous cells)

(2) Ideal for: Rapid **diffusion** over tiny distances

(3) Example: Lining of the interior of the **lungs** (for gas exchange)

e. **Simple Cuboidal Epithelium**

(1) Characteristics: One layer of cuboidal cells

(2) Ideal for: Functions requiring internal machinery for **secretion** or absorption

(3) Example: Tubules in the **kidneys**

i. **Simple Columnar Epithelium**

(1) Characteristics: One layer of columnar cells (thickest simple type)

(2) Ideal for: Functions requiring extensive internal machinery for **absorption** and transport proteins

(3) Example: Lining of the **gut**

m. **Pseudostratified Epithelium**

(1) Characteristics: Appears stratified due to varied cell heights, but all cells contact basement membrane (simple)

o. **Stratified Squamous Epithelium**

(1) Characteristics: Multiple layers, with apical cells being squamous

(2) Ideal for: Areas undergoing a lot of **abrasion**,

providing protection by having many layers to lose

(3) Examples: Lining of the **throat**, **epidermis** of the skin, vagina

s. **Transitional Epithelium**

(1) Example: **Urinary bladder** (stretches, layers slip past each other and cells change shape)

C. Connective Tissue

1. General Characteristics:

a. **Catch-all category** for tissues not classified as epithelial, nervous, or muscle tissue

b. Has two major components:

(1) **Cellular component**: Various types of cells specific to the tissue

(2) **Extracellular matrix**: Stuff outside the cells, varying greatly among connective tissues

2. Examples/Types of Connective Tissue:

a. **Bone**

(1) Cellular component: **Osteocytes** (bone cells) living in spaces called **lacunae**

(2) Extracellular matrix: Hard, mineralized material

(3) Structural unit: **Osteon** (concentric layers around a central canal containing blood vessels)

e. **Cartilage**

(1) Tough but not as hard as bone

(2) Cellular component: **Chondrocytes** (cartilage cells) living in lacunae

(3) Types:

1. **Hyaline Cartilage**: "Glassy" appearance, e.g.,

between sternum and ribs

2. **Fibrocartilage**: Contains many **protein fibers** in extracellular matrix, making it strong
3. Example: **Intervertebral discs** (pads between vertebrae of the spine), made of tough protein fibers like collagen, to hold vertebrae together

i. **Dense Fibrous Connective Tissue**

(1) Characteristics: Extracellular matrix contains many protein fibers packed closely together ("dense")

(2) Example: **Tendons**

1. Connect skeletal muscle to bone
2. Fibers are arranged in parallel ("regular") because they are pulled in one direction
3. Do not stretch; provide strong, direct pull

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

(1) Characteristics: Few fibers packed loosely, with much space between them

(2) Function: Allows for free movement, acts as "packing material"

(3) Example: In the **hypodermis** beneath the dermis of the skin, allowing skin to move freely

p. **Adipose Tissue**

(1) Composed of **adipocytes** (fat cells), specialized to contain fat

(2) Function: Efficient **energy storage** (higher energy density than carbohydrates/proteins), **padding** delicate organs, **thermal insulation**

(3) Fat is dissolved during slide preparation, making

cells appear empty

t. **Reticular Tissue**

(1) Characteristics: Fibers arranged in a **weblike network** ("reticulum")

(2) Function: Acts as a **filter**

(3) Examples: In **lymph nodes** (filtering harmful substances) and the **spleen** (filtering out old, worn-out red blood cells)

(4) Red blood cells lose nucleus and mitochondria during development, limiting their lifespan and ability to repair; wear out squeezing through capillaries

y. **Blood**

(1) A **mobile tissue** and a **connective tissue**

(2) Cellular component: **Red blood cells (erythrocytes)** (most numerous) and **five types of white blood cells (leukocytes)**

(3) Extracellular matrix: **Plasma** (liquid component, remaining after cells are centrifuged out)

D. Muscle Tissue

1. General Characteristics:

a. **Excitable tissue**: Able to create and transmit electrochemical signals (like nervous tissue)

b. All types **contract** (get shorter) actively; cannot push or actively get longer

2. Three Major Kinds:

a. **Skeletal Muscle**

(1) Component of the **muscular system**

(2) Cells (**myofibers/muscle fibers**) are long, non-

branching cylinders that run the entire length of the muscle

(3) Characterized by very regular **striations** (banding patterns) that are all oriented in parallel

(4) Contraction is initiated by signals from the **nervous system** (voluntary movement)

f. **Cardiac Muscle**

(1) Makes up the **heart**; part of the circulatory system

(2) Cells are also **striated** but individual cells are **branched**, leading to less regular striations

(3) **Autorythmic**: Contracts on its own, over and over (involuntary)

j. **Smooth Muscle**

(1) Found in many organ systems, usually lining **hollow organs** (e.g., intestines)

(2) Cells are **spindle-shaped** (thicker in the middle, tapering at ends)

(3) **Non-striated**: Lacks the regular striations seen in skeletal and cardiac muscle

(4) **Autorythmic**: Contracts on its own (involuntary), forcing contents through organs

E. Nervous Tissue

1. Components:

a. **Neurons**

(1) The **excitable cells** that create and transmit **electrochemical signals**

(2) Have a large **cell body**, input structures called **dendrites**, and a long output structure called an **axon**

(3) Form the basis of thought and personality in the brain

e. **Neuroglia (Glial Cells)**

(1) A category of cells within nervous tissue that are **not excitable**

(2) Function: **Support the neurons** so they can live and perform their job

2. Functions: **Gather information** and **control body functions** (nervous system controls other systems)