UNIT I: Introduction to Human Body

1. Definition of Anatomy and Physiology

Anatomy:
Anatomy is the branch of biology concerned with the **study of the structure** of body parts and their relationships to one another.

- The word "Anatomy" is derived from the Greek word *"ana"* (up) and *"tome"* (cutting).
- It involves dissection and observation of organs and systems.

Types of Anatomy:

1. **Gross Anatomy** – Study of large body structures visible to the naked eye (e.g., heart, lungs).
    - Systemic Anatomy
    - Regional Anatomy
    - Surface Anatomy
2. **Microscopic Anatomy** – Study of structures seen only under a microscope.
    - Cytology (study of cells)
    - Histology (study of tissues)
3. **Developmental Anatomy** – Study of structural changes over a lifespan.
    - Embryology: study of prenatal development.

Physiology:
Physiology is the science dealing with the **functions of various body parts**, i.e., how the body works.

- From the Greek *"physis"* (nature) and *"logos"* (study).

Subdivisions of Physiology:

- Cell Physiology
- Systemic Physiology (e.g., renal physiology, cardiovascular physiology)
- Pathophysiology (disease-related changes in function)
- Exercise Physiology
- Endocrine Physiology

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2. Scope of Anatomy and Physiology

Understanding anatomy and physiology is **essential for healthcare professionals** to:

- Understand **normal structure and function** of the body.
- Recognize **abnormalities**, i.e., disease states.
- Apply knowledge in **clinical practices**, diagnostics, and pharmacological interventions.

Applications in Pharmacy:

- Targeted **drug delivery** (e.g., knowing BBB, GIT lining, etc.)
- Understanding **drug action** at tissue and cellular level.
- Assessing **pharmacokinetics** and **pharmacodynamics** based on organ function.
- Understanding **adverse effects** of drugs on organs/systems.

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3. Levels of Structural Organization in the Human Body

The human body exhibits a hierarchy of structural levels:

Level	Description
Chemical level	Atoms combine to form molecules (e.g., H_2O, glucose).
Cellular level	Molecules combine to form cells—the basic units of life.
Tissue level	Groups of similar cells perform specific functions (e.g., muscle tissue).
Organ level	Tissues combine to form organs (e.g., heart, lungs).
System level	Organs work together in systems (e.g., digestive system).
Organism level	All systems combine to make a living human being.

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4. Characteristics of Life

All living organisms exhibit:

- **Metabolism** (catabolism + anabolism)
- **Responsiveness** (detect and respond to stimuli)
- **Movement** (internal & external)
- **Growth** (increase in size and number of cells)
- **Differentiation** (unspecialized to specialized cells)
- **Reproduction** (formation of new cells/organisms)

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5. Homeostasis

Homeostasis: Maintenance of a **stable internal environment** despite external changes.

- **Controlled by**: Nervous system & endocrine system.
- Involves **feedback systems**:
    - **Negative feedback** (e.g., regulation of blood pressure, glucose)
    - **Positive feedback** (e.g., childbirth, blood clotting)

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6. Basic Terminology in Anatomy

Term	Meaning
Anterior (ventral)	Front of the body
Posterior (dorsal)	Back of the body
Superior	Towards the head
Inferior	Towards the feet
Medial	Towards the midline
Lateral	Away from the midline
Proximal	Closer to point of origin
Distal	Farther from point of origin

📌 **7. Body Planes and Sections**

Plane	Description
Sagittal plane	Divides body into left and right
Frontal (coronal) plane	Divides body into front and back
Transverse plane	Divides body into top and bottom

📌 **8. Body Cavities**

- **Dorsal cavity**: Contains cranial and spinal cavities.
- **Ventral cavity**: Contains thoracic, abdominal, and pelvic cavities.
    - **Thoracic**: lungs, heart
    - **Abdominopelvic**: digestive, urinary, reproductive organs

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📌 **9. Organ Systems of the Human Body**

There are **11 organ systems**, each with specific functions:

1. **Integumentary**
2. **Skeletal**
3. **Muscular**
4. **Nervous**
5. **Endocrine**
6. **Cardiovascular**
7. **Lymphatic**
8. **Respiratory**
9. **Digestive**
10. **Urinary**
11. **Reproductive**

Levels of Structural Organization

The human body exhibits a hierarchy of structural organization that ranges from the simplest chemical level to the most complex organism level.

1. **Chemical Level**
   This is the most basic level. It includes atoms and molecules. Atoms such as carbon, hydrogen, oxygen, nitrogen are essential for life. Molecules such as water, proteins, carbohydrates, lipids, and nucleic acids form the structural basis of cells.
2. **Cellular Level**
   Cells are the basic structural and functional units of life. Each cell has specialized components called organelles such as the nucleus, mitochondria, endoplasmic reticulum, and others, which perform specific functions necessary for cell survival and activity.
3. **Tissue Level**
   Tissues are groups of similar cells that perform a specific function. The human body has four basic types of tissues:
   - Epithelial tissue: covers body surfaces and lines cavities
   - Connective tissue: supports and binds other tissues
   - Muscular tissue: enables movement
   - Nervous tissue: transmits nerve impulses

4. **Organ Level**
   Organs are structures composed of two or more types of tissues that perform specific functions. Examples include the stomach, heart, lungs, brain, and liver. Each organ has a unique structure and role in the body.

5. **System Level**
   A system consists of related organs that have a common function. For example, the digestive system includes the mouth, esophagus, stomach, intestines, liver, and pancreas, all working together to process food and absorb nutrients.

6. **Organism Level**
   The human body as a whole is the organism level. All systems function together to maintain the life and health of the individual.

Body Systems

There are eleven major systems in the human body. Each system contributes to the overall function and homeostasis of the body.

1. **Integumentary System**
   Includes the skin, hair, nails, sweat glands, and sebaceous glands. Functions include protection, regulation of body temperature, sensation, and synthesis of vitamin D.

2. **Skeletal System**
   Consists of bones, cartilage, and joints. Provides support, protection of internal organs, movement (in conjunction with muscles), blood cell production (hematopoiesis), and mineral storage.

3. **Muscular System**
   Includes skeletal muscles and tendons. Responsible for body movement, posture, and heat production.

4. **Nervous System**
   Includes the brain, spinal cord, nerves, and sensory organs. Controls and coordinates body activities by transmitting electrical signals (nerve impulses) rapidly.

5. **Endocrine System**
   Consists of glands such as the pituitary, thyroid, adrenal, pancreas, and gonads. Regulates body activities by releasing hormones into the blood.

6. **Cardiovascular System**
   Includes the heart, blood, and blood vessels. Transports oxygen, nutrients, hormones, and waste products throughout the body. Plays a role in immune response and temperature regulation.

7. **Lymphatic System**
   Includes lymph, lymph nodes, lymphatic vessels, spleen, thymus, and tonsils. Maintains fluid balance, aids in fat absorption, and provides immune responses.

8. **Respiratory System**
   Consists of the nose, pharynx, larynx, trachea, bronchi, and lungs. Responsible for gas exchange – intake of oxygen and removal of carbon dioxide.

9. **Digestive System**
   Includes the mouth, pharynx, esophagus, stomach, small intestine, large intestine, liver, pancreas, and gallbladder. Breaks down food, absorbs nutrients, and eliminates waste.

10. **Urinary System**
    Composed of kidneys, ureters, urinary bladder, and urethra. Removes waste products from the blood, regulates fluid and electrolyte balance, and maintains pH.

11. **Reproductive System**
    In males: testes, penis, vas deferens, seminal vesicles, prostate.
    In females: ovaries, uterus, fallopian tubes, vagina.
    Functions to produce gametes and facilitate reproduction.

Basic Life Processes

Basic life processes are essential activities carried out by all living organisms to sustain life. In humans, these processes help maintain homeostasis and proper body functioning. The major life processes include the following:

1. **Metabolism**
   Metabolism is the sum of all chemical reactions occurring in the body. It includes:
   - **Catabolism**: Breakdown of complex molecules into simpler ones with the release of energy (e.g., breakdown of glucose during respiration).
   - **Anabolism**: Synthesis of complex molecules from simpler ones, requiring energy (e.g., protein synthesis from amino acids).

2. **Responsiveness**
   This is the ability of the body to detect and respond to changes in its internal or external environment. Examples include:
   - Withdrawal of hand when touching something hot.
   - Regulation of blood pressure when it becomes too high or low.

3. **Movement**
   Movement includes motion of the whole body, individual organs, cells, or even organelles within cells. Examples:
   - Movement of muscles
   - Movement of food through the digestive tract
   - Migration of white blood cells to infection sites

4. **Growth**
   Growth refers to an increase in body size due to an increase in:
   - The number of cells (hyperplasia)
   - The size of existing cells (hypertrophy)
   - The amount of extracellular material

5. **Differentiation**
   Differentiation is the process through which unspecialized cells become specialized in structure and function. For example, stem cells differentiate into red blood cells, muscle cells, or nerve cells. This process is essential for development and tissue repair.

6. **Reproduction**
   Reproduction involves the formation of new cells or new organisms. It can occur in two ways:

   - Cellular reproduction: Mitosis for growth, repair, or replacement of cells.
   - Organismal reproduction: Formation of a new individual through sexual reproduction involving sperm and egg cells.

These life processes are interrelated. For example, metabolism provides energy for responsiveness and movement; growth and reproduction require energy and structural components formed through metabolic processes.

Homeostasis

Homeostasis refers to the maintenance of a stable internal environment within the body despite changes in the external environment. It is essential for the proper functioning of body cells, tissues, and organs.

The term is derived from the Greek words “homeo” (similar) and “stasis” (standing still).

Importance of Homeostasis
The body’s internal environment includes factors like temperature, pH, pressure, volume, glucose levels, etc. These must be maintained within a narrow range to ensure normal cellular functions.

Components of Homeostatic Control Systems

1. **Receptor**
   A sensor that detects a change (stimulus) in the environment. It sends input to the control center.

2. **Control Center**
   Receives the information from the receptor, processes it, and sends out commands. The control center is often the brain or spinal cord.

3. **Effector**
   Carries out the response to restore homeostasis. Effectors are usually muscles or glands.

Types of Feedback Systems

1. **Negative Feedback**
   This reverses the change in a controlled condition. It is the most common feedback mechanism in the body.
   Examples:

   - Regulation of body temperature
   - Blood glucose level control by insulin and glucagon
   - Blood pressure regulation

2. **Positive Feedback**
   This reinforces the initial change rather than reversing it. These are less common but important in certain situations.
   Examples:
   - Blood clotting
   - Childbirth (uterine contractions)

Disruption of Homeostasis
A prolonged disruption of homeostasis may lead to disease, disorder, or even death. Aging also affects the efficiency of homeostatic mechanisms.

Basic Anatomical Terminology

To describe the human body and its parts clearly, standardized terms are used in anatomy.

Anatomical Position
This is the standard reference position used in anatomical terminology. In this position:

- The body stands erect
- Facing forward
- Arms at the sides
- Palms facing forward
- Feet slightly apart and flat on the floor

Directional Terms
These terms describe the position of one body part in relation to another.

Superior – Toward the head or upper part of the body

Inferior – Away from the head or lower part of the body

Anterior (ventral) – Toward the front of the body

Posterior (dorsal) – Toward the back of the body

Medial – Toward the midline of the body

Lateral – Away from the midline of the body

Proximal – Closer to the point of attachment or origin

Distal – Farther from the point of attachment or origin

Superficial – Toward or at the surface of the body

Deep – Away from the body surface or more internal

Body Planes

These are imaginary lines that divide the body into sections.

Sagittal plane – Divides the body into right and left portions

Midsagittal (median) plane – Divides the body into equal right and left halves

Parasagittal plane – Divides the body into unequal right and left portions

Frontal (coronal) plane – Divides the body into anterior and posterior portions

Transverse (horizontal) plane – Divides the body into superior and inferior parts

Oblique plane – A slanted plane between the horizontal and vertical

Body Cavities

These are spaces within the body that contain internal organs.

Dorsal body cavity

- Cranial cavity (contains brain)
- Vertebral cavity (contains spinal cord)

Ventral body cavity

- Thoracic cavity (contains lungs and heart)
- Abdominal cavity (contains stomach, liver, intestines, etc.)
- Pelvic cavity (contains bladder, reproductive organs)

Cellular Level of Organization

The cell is the basic structural, functional, and biological unit of all living organisms. It is the smallest unit of life that can perform all life processes. Human beings are multicellular organisms made up of trillions of cells.

Types of Cells

1. Prokaryotic cells – Lack a true nucleus (e.g., bacteria)
2. Eukaryotic cells – Have a true nucleus and membrane-bound organelles (e.g., human cells)

Structure of a Typical Human Cell

A typical human (eukaryotic) cell consists of three main parts:

1. **Plasma Membrane (Cell Membrane)**
   It is a flexible, semi-permeable membrane that surrounds the cell and separates the internal contents from the external environment.

Structure:

- Composed of a phospholipid bilayer with embedded proteins.
- Also contains cholesterol and glycoproteins.

Functions:

- Provides structural support
- Controls entry and exit of substances
- Facilitates cell communication and recognition

2. **Cytoplasm**
   The cytoplasm is the jelly-like substance that fills the cell and holds all the cell organelles.

It has two components:

- **Cytosol**: The fluid part that contains water, enzymes, ions, and nutrients
- **Organelles**: Specialized structures performing specific functions

3. **Nucleus**
   The nucleus is the control center of the cell and contains the genetic material (DNA).

Structure:

- Surrounded by the nuclear envelope (double membrane with pores)
- Contains nucleoplasm, chromatin (DNA + proteins), and nucleolus

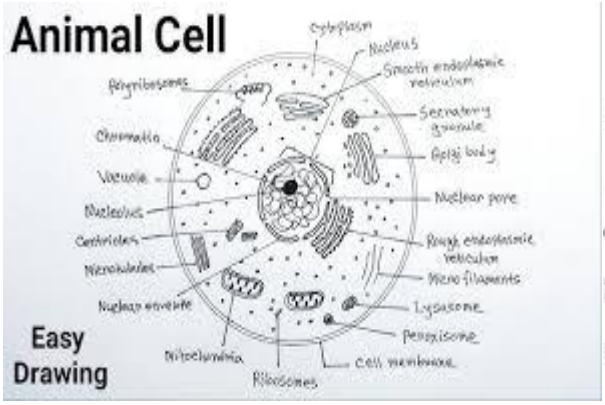
Functions:

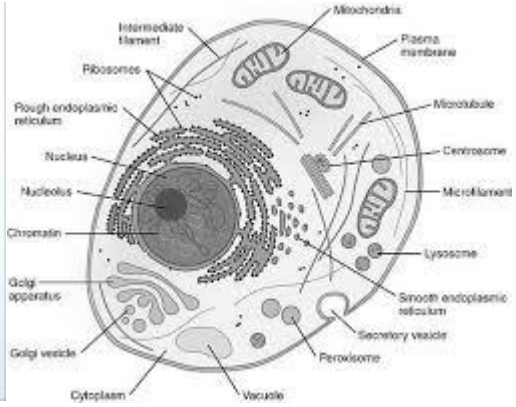
- Controls cellular activities
- Stores genetic information
- Directs protein synthesis through messenger RNA

Functions of Cell Organelles

1. **Mitochondria**
   - Site of ATP (energy) production
   - Referred to as the powerhouse of the cell
2. **Endoplasmic Reticulum (ER)**
   - Rough ER: Contains ribosomes, synthesizes proteins
   - Smooth ER: Lacks ribosomes, synthesizes lipids and detoxifies drugs
3. **Ribosomes**
   - Composed of RNA and protein
   - Sites of protein synthesis
   - Found freely in cytosol or attached to rough ER

4. **Golgi Apparatus**
    - Modifies, sorts, and packages proteins and lipids
    - Forms vesicles for secretion or delivery to other parts of the cell
5. **Lysosomes**
    - Contain digestive enzymes
    - Break down waste materials and cellular debris
    - Involved in autolysis and apoptosis
6. **Peroxisomes**
    - Contain enzymes that detoxify harmful substances
    - Involved in the breakdown of fatty acids
7. **Centrosome and Centrioles**
    - Important in cell division
    - Help in organizing the mitotic spindle
8. **Cytoskeleton**
    - Network of protein filaments (microtubules, microfilaments, intermediate filaments)
    - Provides shape, support, and aids in movement
9. **Cilia and Flagella**
    - Cilia: Short, hair-like structures for movement of substances over the cell surface
    - Flagella: Longer structures for movement of the cell (e.g., sperm tail)





Transport Across the Cell Membrane

The **plasma membrane** is a **selectively permeable barrier** that controls the movement of substances into and out of the cell. This property is critical for maintaining the **internal environment (homeostasis)** of the cell and for various functions such as nutrient uptake, excretion, signal transduction, and maintaining ionic balance.

Transport across the membrane is classified into:

I. Passive Transport (No ATP required)

Movement occurs **along the concentration gradient** (from **high** concentration to **low** concentration). It depends on the **kinetic energy** of molecules.

1. Simple Diffusion

- Movement of small, non-polar molecules across the lipid bilayer without the help of any protein or energy.
- It continues until equilibrium is reached.

Examples:

- Exchange of gases in lungs: **O_2 diffuses into blood**, **CO_2 diffuses out**
- Diffusion of **fat-soluble vitamins** (A, D, E, K)

Factors affecting simple diffusion:

- Concentration gradient
- Temperature
- Surface area
- Molecular size
- Lipid solubility

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2. Facilitated Diffusion

- Involves **transport proteins** (channels or carriers)
- Movement of **large, polar, or charged molecules**
- Still passive, but requires a carrier or channel to pass through the membrane

Types:
a. **Channel-mediated**: Ions pass through water-filled channels
b. **Carrier-mediated**: Molecules bind to specific protein carriers

Examples:

- **Glucose transport** into cells by **GLUT** transporters
- **Na^+, K^+, Cl^-** movement through ion channels in neurons

Characteristics:

- **Specificity**: Each transporter is specific for a molecule
- **Saturation**: Once all carriers are occupied, rate plateaus
- **Competition**: Similar molecules may compete for the same transporter

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3. Osmosis

- Diffusion of **water** across a semipermeable membrane
- Water moves from an area of **low solute concentration** to **high solute concentration**

Example:

- Absorption of water in the intestines
- Kidney tubules reabsorbing water

Tonicity terms:

- **Isotonic**: Same solute concentration (e.g., 0.9% NaCl IV fluids)
- **Hypotonic**: Lower solute concentration → water moves into cell (cell swells or bursts)
- **Hypertonic**: Higher solute concentration → water moves out (cell shrinks)

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4. Filtration

- Process where **hydrostatic pressure** forces water and solutes across the membrane

Example:

- Filtration of plasma in the **glomerulus of kidney nephrons**
- Capillary filtration in tissues

II. Active Transport (ATP required)

In this process, substances are moved **against the concentration gradient** (from **low to high**) and hence require **energy in the form of ATP**.

1. Primary Active Transport

- Uses ATP directly to transport substances via **pumps**

Example: Sodium-Potassium Pump (Na^+/K^+-ATPase):

- Pumps **3 Na^+ ions out** and **2 K^+ ions in** per ATP
- Maintains **resting membrane potential**, essential for **nerve and muscle function**

Other examples:

- **Calcium pump (Ca^{2+}-ATPase)** in muscle cells
- **Hydrogen ion pump (H^+-ATPase)** in gastric glands

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2. Secondary Active Transport

- Does **not use ATP directly**
- Utilizes the energy from the **electrochemical gradient** created by primary active transport

Types:
a. **Symport (Cotransport)** – Both molecules move in the **same direction**

- **Example**: Sodium-glucose cotransporter (SGLT) in intestinal cells transports **glucose and Na^+**

b. **Antiport (Countertransport)** – Molecules move in **opposite directions**

- **Example**: Na^+/Ca^{2+} exchanger in heart cells removes **Ca^{2+}** from cytoplasm as **Na^+ enters**

III. Vesicular Transport (Bulk Transport)

This type involves **membrane-bound vesicles** to move **large particles, macromolecules, or fluids** across membranes. It is an **active process** and requires ATP.

1. Endocytosis (Into the cell)

a. **Phagocytosis (Cell eating)**

- Engulfment of **solid particles** by specialized cells like **macrophages or neutrophils**
- Forms a vesicle called a **phagosome**, which fuses with lysosomes

Example: WBCs engulf bacteria

b. **Pinocytosis (Cell drinking)**

- Ingestion of **fluid droplets** containing dissolved solutes
- Common in **cells lining intestines and kidneys**

c. **Receptor-Mediated Endocytosis**

- Specific receptors on the membrane bind target molecules (ligands)
- The complex is internalized via clathrin-coated vesicles

Example: Uptake of **LDL cholesterol**, **vitamin B12**

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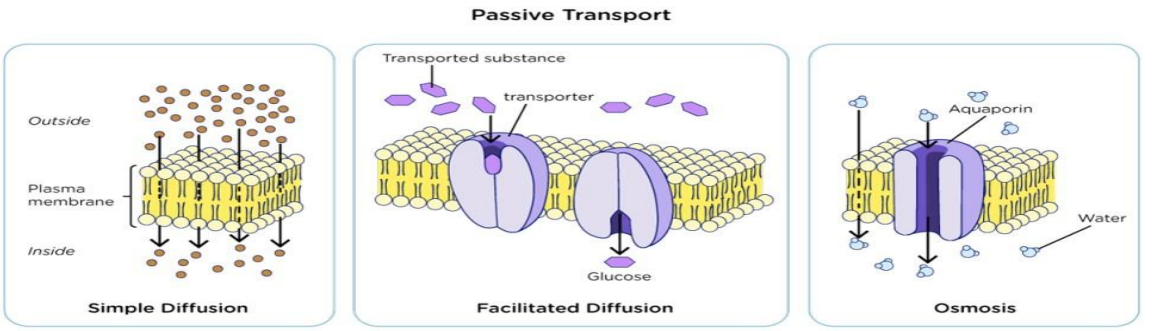
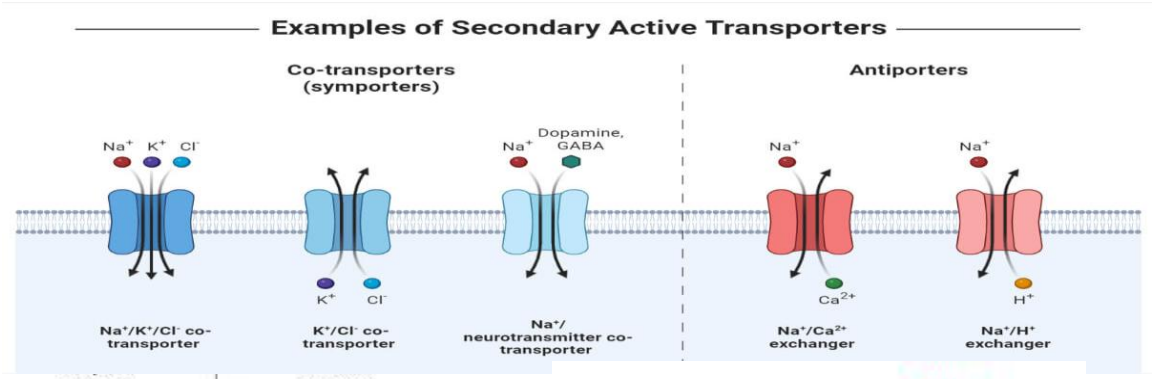
2. Exocytosis (Out of the cell)

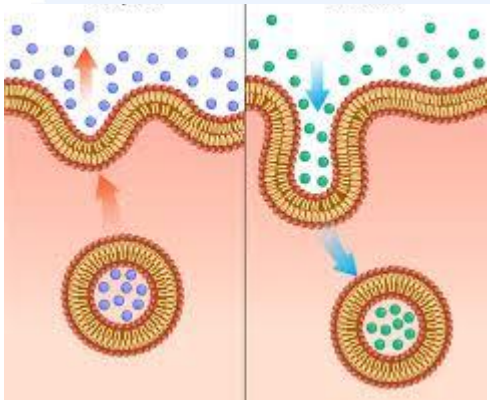
- Vesicles formed within the cell fuse with the plasma membrane to release contents outside
- Used to secrete **hormones, enzymes, neurotransmitters**

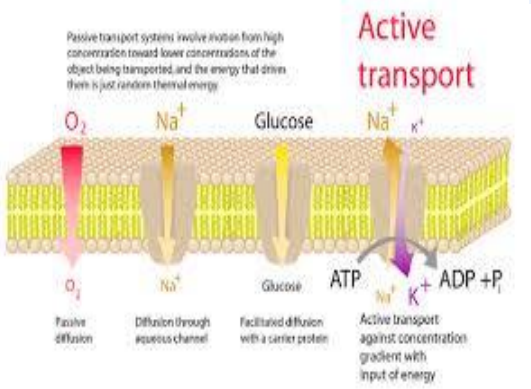
Examples:

- Release of **insulin** from pancreatic β-cells
- Release of **acetylcholine** at the neuromuscular junction









Cell Division

Definition
Cell division is the biological process by which a parent cell divides into two or more daughter cells. It is essential for growth, repair, maintenance, and reproduction in living organisms.

There are two main types of cell division in humans:

1. **Mitosis** – occurs in somatic (body) cells
2. **Meiosis** – occurs in reproductive (germ) cells

I. Cell Cycle

Before a cell divides, it passes through a sequence of events known as the **cell cycle**. This cycle ensures that the genetic material is accurately duplicated and distributed.

The cell cycle consists of two main phases:

A. Interphase – Period of cell growth and DNA replication
B. Mitotic (M) phase – Actual cell division

A. Interphase

This is the longest phase of the cell cycle where the cell prepares for division. It includes three sub-phases:

1. **G1 phase (Gap 1)**
    - Cell grows in size
    - Organelles are duplicated
    - Metabolic activity is high
    - RNA and protein synthesis occur
2. **S phase (Synthesis)**
    - **DNA replication** takes place
    - Each chromosome becomes two sister chromatids
3. **G2 phase (Gap 2)**
    - Final preparation for mitosis
    - Proteins necessary for mitosis are synthesized
    - Centrosome replication completes

Some cells enter a resting stage called **G0 phase** (e.g., nerve and cardiac muscle cells) and do not divide unless stimulated.

B. Mitotic (M) Phase

Mitosis is the process by which **a single cell divides to produce two genetically identical daughter cells**. It is used for **growth, repair, and maintenance**.

It consists of two main processes:

- **Karyokinesis**: Division of the nucleus
- **Cytokinesis**: Division of the cytoplasm

Phases of Mitosis

1. **Prophase**
    - Chromatin condenses into visible chromosomes
    - Each chromosome consists of two sister chromatids joined at the centromere
    - Nucleolus disappears
    - Mitotic spindle forms from centrioles
    - Nuclear envelope begins to break down
2. **Metaphase**
    - Chromosomes align at the cell's equatorial plate (metaphase plate)
    - Spindle fibers attach to centromeres via kinetochores
3. **Anaphase**
    - Centromeres split, separating sister chromatids
    - Chromatids are pulled toward opposite poles
    - Each pole ends up with an identical set of chromosomes
4. **Telophase**
    - Chromosomes decondense into chromatin
    - Nuclear envelope and nucleolus reappear
    - Spindle fibers disappear
    - Cell now contains two nuclei

Cytokinesis

- Division of cytoplasm
- Begins during late anaphase or telophase
- In animal cells, a **cleavage furrow** forms and pinches the cell into two daughter cells
- Each daughter cell has the same number of chromosomes as the parent

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Significance of Mitosis

- Maintains genetic stability
- Essential for **growth**, **tissue repair**, and **asexual reproduction**
- Helps in **replacement of dead or damaged cells**

II. Meiosis

Definition
Meiosis is a type of cell division that occurs in the **gonads (testes and ovaries)** to produce **gametes (sperm and egg cells)**. It results in **four daughter cells**, each with **half the number of chromosomes** as the parent.

Human body cells have 46 chromosomes (diploid, 2n), but gametes have 23 (haploid, n).

Stages of Meiosis

Meiosis consists of **two successive divisions**:

- **Meiosis I (Reductional division)**
- **Meiosis II (Equational division)**

Meiosis I

1. **Prophase I** (Longest and most complex)
    - Chromosomes condense
    - Homologous chromosomes pair up (synapsis) to form tetrads
    - **Crossing over** occurs – exchange of genetic material between chromatids → increases genetic variation
    - Nuclear membrane disappears
2. **Metaphase I**
    - Homologous pairs align at the metaphase plate
    - Spindle fibers attach to centromeres
3. **Anaphase I**
    - Homologous chromosomes are pulled to opposite poles
    - Sister chromatids remain attached
4. **Telophase I and Cytokinesis**
    - Two haploid cells are formed
    - Each has half the chromosome number (but with duplicated chromatids)

Meiosis II

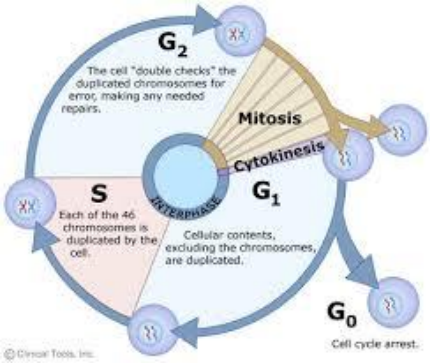
This resembles mitosis but occurs in haploid cells.

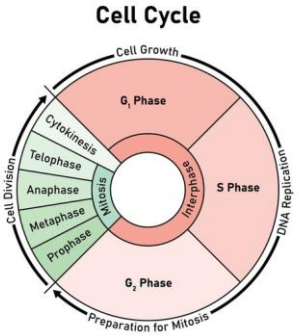
1. **Prophase II**
    - New spindle forms in each haploid cell

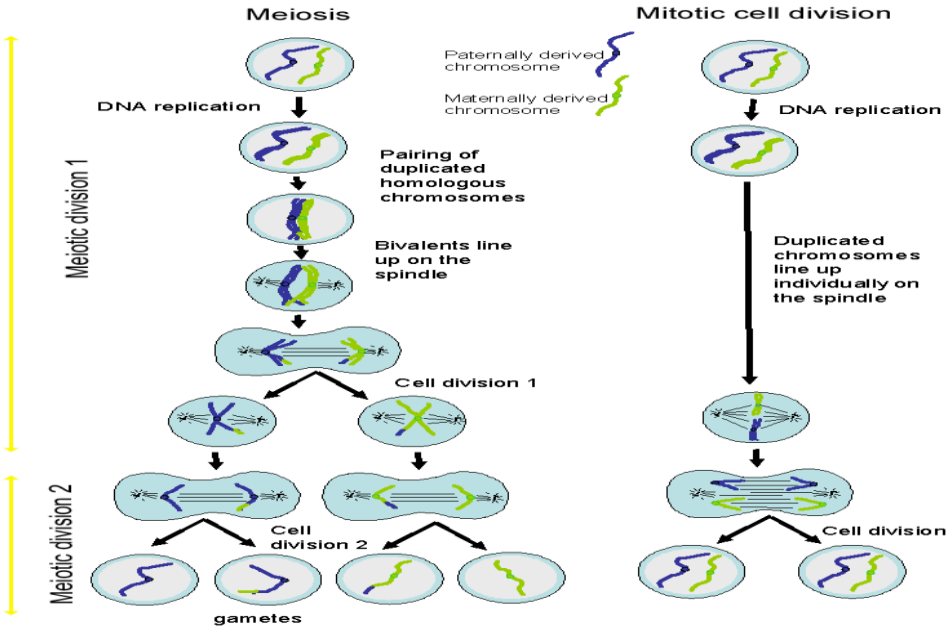
2. **Metaphase II**
    - Chromosomes align at the center
3. **Anaphase II**
    - Centromeres split and sister chromatids move to opposite poles
4. **Telophase II and Cytokinesis**
    - Four **non-identical haploid cells** are formed
    - Each contains **23 chromosomes**

Significance of Meiosis

- Maintains chromosome number across generations
- Introduces **genetic variation** (due to crossing over and independent assortment)
- Essential for **sexual reproduction**







Cell Junctions

Definition
Cell junctions are specialized structures that connect adjacent cells or a cell to the extracellular matrix. They help maintain tissue integrity, allow communication between cells, and control the movement of substances across cellular barriers.

Cell junctions are most prominent in **epithelial tissues**, where cells are closely packed together, forming continuous sheets.

Types of Cell Junctions

Cell junctions are classified into **three main types** based on their functions:

1. **Tight Junctions (Occluding junctions)**
2. **Adherens Junctions and Desmosomes (Anchoring junctions)**
3. **Gap Junctions (Communicating junctions)**

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1. Tight Junctions

Also known as: Zonula occludens

Structure

- Formed by transmembrane proteins such as **claudins and occludins**
- These proteins fuse adjacent cell membranes at multiple points, forming a tight seal

Function

- Prevents leakage of substances between cells (paracellular pathway)
- Maintains the polarity of cells by separating apical and basolateral membranes
- Acts as a barrier to diffusion

Examples

- Found in **epithelial cells lining the intestines**, **blood-brain barrier**, and **urinary bladder epithelium**

Importance

- In the intestines, tight junctions prevent digestive enzymes and pathogens from leaking into the blood
- In the brain, they restrict entry of harmful substances

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2. Anchoring Junctions

These junctions **mechanically attach cells to one another** or to the extracellular matrix. They provide **strength and stability**, especially in tissues subject to mechanical stress like skin and heart.

A. Adherens Junctions

Also known as: Zonula adherens

Structure

- Composed of **cadherin proteins** that link to **actin filaments** inside the cell
- Actin cytoskeleton forms a contractile belt around the cell

Function

- Maintains mechanical integrity by holding adjacent cells together
- Involved in embryonic development and cell shape maintenance

Examples

- Present in **intestinal epithelial cells**, **cardiac muscle cells**

B. Desmosomes

Also known as: Macula adherens

Structure

- Composed of **desmogleins and desmocollins** (cadherins)
- These proteins are linked to **intermediate filaments** (like keratin) inside the cell
- Create spot-like adhesions between cells

Function

- Provide **strong adhesion** and resist **shear stress**
- Prevent cells from being pulled apart

Examples

- Found in **skin (epidermis)**, **uterine cervix**, and **cardiac muscle** (intercalated discs)

Clinical relevance

- **Pemphigus vulgaris** is an autoimmune disorder where desmosomes are targeted, leading to blistering of skin

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C. Hemidesmosomes

Structure

- Connect epithelial cells to the **basement membrane**, not to adjacent cells
- Use **integrin proteins** to attach to **extracellular matrix components** like laminin

Function

- Provide **firm anchorage** of cells to the underlying connective tissue

Examples

- Seen in **basal layer of skin epithelium**

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3. Gap Junctions

Also known as: Nexus

Structure

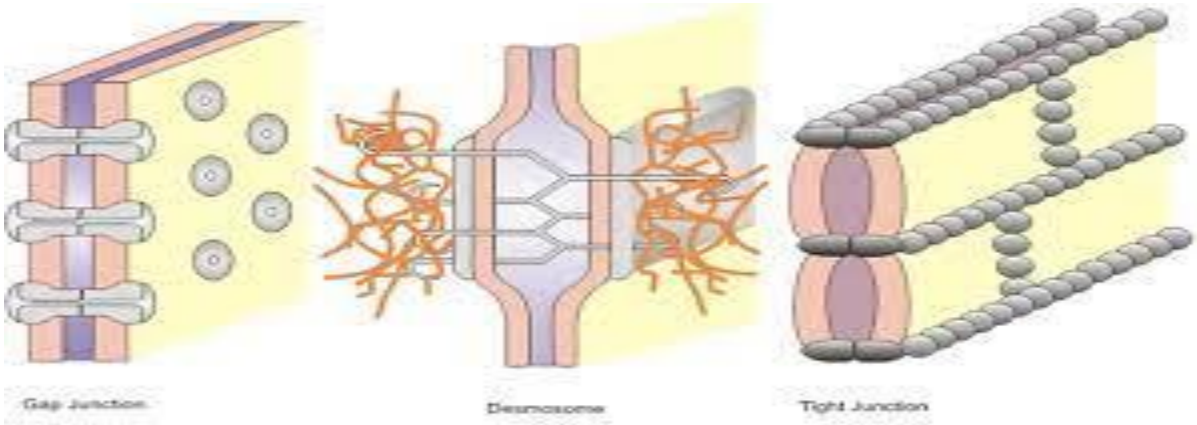
- Formed by **connexons**, which are protein channels made of **connexin subunits**
- These channels connect the cytoplasm of two adjacent cells

Function

- Allow **direct passage of ions, nutrients, and small molecules** between cells
- Facilitate **electrical and metabolic communication**
- Enable synchronized contraction of tissues

Examples

- **Cardiac muscle cells**: Allow rapid spread of action potentials
- **Smooth muscles**: Coordinate contraction
- **Neurons and glial cells**: For intercellular signaling



General Principles of Cell Communication

Definition:
Cell communication refers to the process by which cells detect, interpret, and respond to signals in their environment. This is crucial for maintaining **homeostasis**, **growth**, **differentiation**, **immunity**, and **coordinated function** in multicellular organisms.

Why is Cell Communication Important?

- To coordinate functions between different cells and tissues
- To respond to changes in the environment
- To trigger specific cellular responses such as division, secretion, apoptosis, etc.
- To allow tissues and organs to work as a system (e.g., nervous and endocrine systems)

Basic Components of Cell Communication

1. **Signal molecule (ligand):**
   A chemical messenger (e.g., hormone, neurotransmitter, cytokine) that starts the communication process.
2. **Target cell:**
   The cell that receives the signal. It must have specific **receptors** for the signal molecule.
3. **Receptor protein:**
   Found on the cell surface or inside the cell; it binds the ligand and initiates a response.
4. **Intracellular signaling pathway:**
   A series of molecules inside the cell that pass the signal and amplify it.
5. **Effector proteins:**
   These perform the final action—such as altering gene expression, metabolism, or cytoskeleton.

Intracellular Signaling Pathway Activation by Extracellular Signal Molecule

When a **signal molecule** binds to its **receptor**, a **signal transduction pathway** is triggered inside the cell. This involves multiple steps that **amplify**, **integrate**, and **distribute** the signal to appropriate cellular targets.

Steps in Intracellular Signaling Pathway

1. **Reception**
   - The ligand binds to a receptor (e.g., G-protein coupled receptor, enzyme-linked receptor, ion channel).

- This induces a conformational change in the receptor.

2. **Transduction**
    - Signal is converted into an internal signal via second messengers like **cAMP**, **IP3**, **DAG**, or **Ca^{2+}**.
    - Involves activation of **kinases** (e.g., protein kinase A, MAP kinase) or **G-proteins**.
3. **Amplification**
    - A single ligand-receptor interaction may activate many signaling molecules, resulting in a large cellular response.
4. **Integration and Modulation**
    - Signals from multiple pathways may converge, interact, or inhibit each other, refining the response.
5. **Response**
    - Cellular activity is changed: for example, gene transcription, enzyme activity, ion channel opening, or cytoskeletal rearrangement.
6. **Termination**
    - Signal is turned off by degrading the ligand, dephosphorylating proteins, or internalizing the receptor.

Types of Cell Surface Receptors

1. **G-protein coupled receptors (GPCRs)**
    - Largest family
    - Involved in sensory perception, neurotransmission
    - Example: β-adrenergic receptor (epinephrine)
2. **Enzyme-linked receptors**
    - Often **tyrosine kinases**
    - Example: insulin receptor
3. **Ion channel-linked receptors**
    - Open or close in response to ligand binding
    - Example: acetylcholine receptor in muscle
4. **Intracellular receptors**
    - Located in cytoplasm or nucleus
    - Bind **lipid-soluble signals** like steroid hormones
    - Example: estrogen receptor

Forms of Intercellular Signaling

Cells can communicate using **different modes** depending on **distance**, **signal type**, and **specificity**.

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a) Contact-Dependent Signaling

Definition:
In this type, the signal molecule is not secreted but remains **bound to the membrane** of the signaling cell. The target cell must come into **direct physical contact**.

Features:

- Involves **membrane-bound ligands and receptors**
- Common during **immune response** and **development**

Example:

- T-cell activation by antigen-presenting cells via MHC-TCR interaction
- Notch-Delta signaling in embryogenesis

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b) Paracrine Signaling

Definition:
Here, the signaling cell secretes molecules that **act locally** on nearby target cells.

Features:

- The signal diffuses through extracellular fluid
- Acts within a **short range**
- Often **inflammatory cytokines** or **growth factors**

Example:

- Histamine released from mast cells causes nearby blood vessels to dilate
- Nitric oxide (NO) in vasodilation

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c) Synaptic Signaling

Definition:
Specialized form of paracrine signaling where **neurons** transmit signals to **specific target cells** across **synapses**.

Features:

- Uses **neurotransmitters** (e.g., acetylcholine, dopamine)
- Very **fast** and **precise**

- Targeted to **only one postsynaptic cell**

Example:

- Motor neuron stimulating skeletal muscle using acetylcholine
- Dopaminergic neurons in the brain

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d) Endocrine Signaling

Definition:
In endocrine signaling, **hormones** are secreted into the **bloodstream** and carried to **distant target cells** throughout the body.

Features:

- Involves **long-distance** signaling
- Signal is **slow but long-lasting**
- Low concentrations are sufficient due to high sensitivity

Example:

- Insulin secreted by pancreas affects glucose uptake by muscles and liver
- Thyroxine affects metabolism in multiple organs

Tissue Level of Organization

Definition:
Tissue is a group of **structurally and functionally similar cells** that work together to perform a specific activity.

The human body is composed of **four basic tissue types**:

1. Epithelial tissue
2. Connective tissue
3. Muscular tissue
4. Nervous tissue

Each of these tissues has subtypes with distinct **structure, location, and functions**.

---

1. Epithelial Tissue

Definition:
Epithelial tissue forms the **covering or lining of body surfaces, cavities, and organs**. It also forms **glands**.

Characteristics:

- Cells are **closely packed** with minimal intercellular matrix
- Have **apical (free)** and **basal (attached)** surfaces
- **Avascular** (no blood supply) but **innervated**
- Supported by **basement membrane**

Functions:

- Protection
- Absorption
- Secretion
- Excretion
- Sensory reception

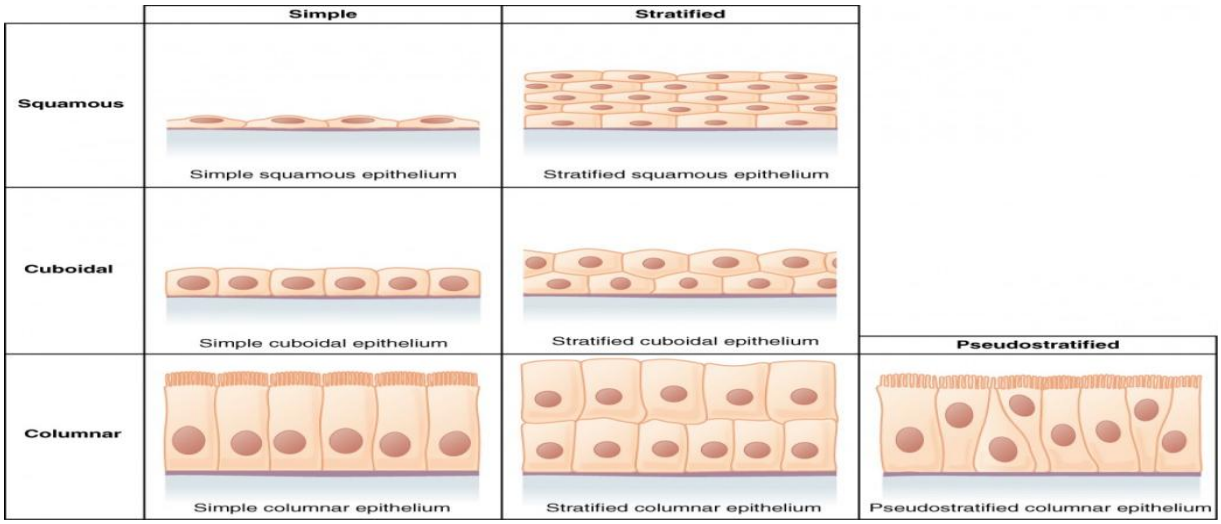
Classification of Epithelial Tissue

A. **Based on Layers**

1. **Simple epithelium** – single layer of cells
2. **Stratified epithelium** – multiple layers of cells
3. **Pseudostratified epithelium** – appears layered but is not
4. **Transitional epithelium** – multiple layers that stretch

B. **Based on Cell Shape**

1. **Squamous** – flat cells
2. **Cuboidal** – cube-like cells
3. **Columnar** – tall, column-like cells



Types with Structure, Location, Function

Type	Structure	Location	Function
Simple squamous	Single layer, flat cells	Alveoli, lining of heart, blood vessels	Diffusion, filtration
Simple cuboidal	Single layer, cube-shaped	Kidney tubules, glands	Secretion, absorption
Simple columnar	Tall cells with nuclei at base	GI tract, uterus	Absorption, secretion
Pseudostratified columnar	Appears layered, cilia present	Respiratory tract	Mucus secretion, movement
Stratified squamous	Multiple layers, flat surface cells	Skin, esophagus, vagina	Protection from abrasion
Transitional epithelium	Dome-shaped surface cells	Urinary bladder, ureters	Allows stretching

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2. Connective Tissue

Definition:
Connective tissue is the most **abundant and widely distributed** tissue. It connects, supports, and binds other tissues and organs.

Characteristics:

- Cells are **scattered** in an abundant **extracellular matrix (ECM)**
- Matrix contains **fibers (collagen, elastic, reticular)** and **ground substance**
- **Highly vascular** (except cartilage)
- Contains **fibroblasts**, **macrophages**, **mast cells**, **plasma cells**, **adipocytes**

Classification of Connective Tissue

A. **Connective Tissue Proper**

1. **Loose connective tissue**
    - Areolar
    - Adipose
    - Reticular

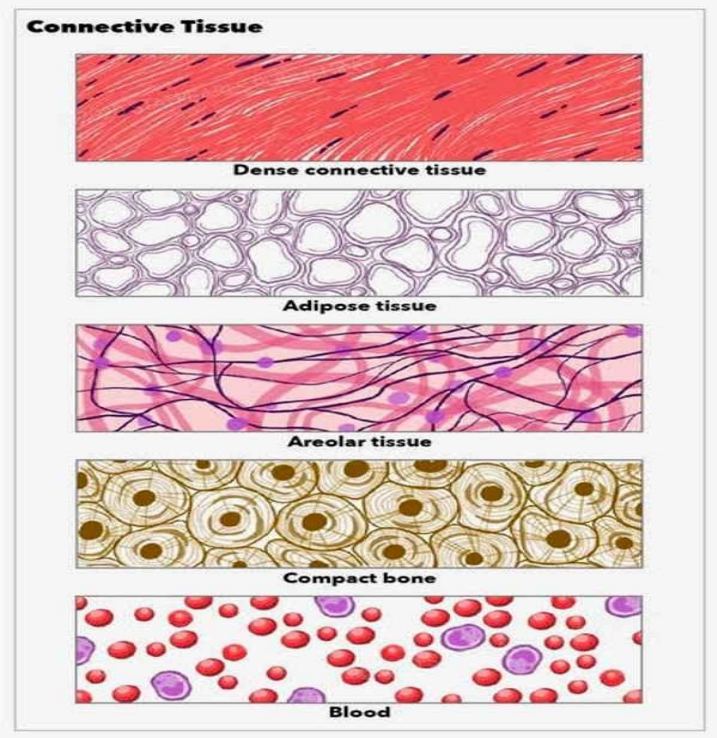
2. **Dense connective tissue**
    - Dense regular
    - Dense irregular
    - Elastic

B. **Supporting Connective Tissue**

- Cartilage (hyaline, elastic, fibrocartilage)
- Bone (compact, spongy)

C. **Fluid Connective Tissue**

- Blood
- Lymph



Types with Structure, Location, Function

Type	Structure	Location	Function
Areolar	Loose fibers, many cells	Under skin, around vessels	Support, strength, elasticity
Adipose	Fat cells (adipocytes)	Subcutaneous layer, around kidneys	Insulation, energy storage
Reticular	Reticular fibers, reticular cells	Spleen, lymph nodes	Framework for soft organs
Dense regular	Collagen in parallel bundles	Tendons, ligaments	Strong attachment
Dense irregular	Irregular collagen bundles	Dermis of skin, capsules	Strength in multiple directions
Elastic	Elastic fibers	Lungs, arteries	Stretch and recoil
Hyaline cartilage	Chondrocytes in lacunae	Nose, trachea, joints	Flexibility, support
Fibrocartilage	Thick collagen, few cells	Intervertebral discs	Shock absorption
Elastic cartilage	Elastic fibers	Ear pinna, epiglottis	Flexibility
Bone	Osteocytes in matrix	Skeleton	Support, protection
Blood	RBCs, WBCs, plasma	Circulatory system	Transport gases, nutrients
Lymph	WBCs in lymph fluid	Lymphatic vessels	Immunity, drainage

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3. Muscular Tissue

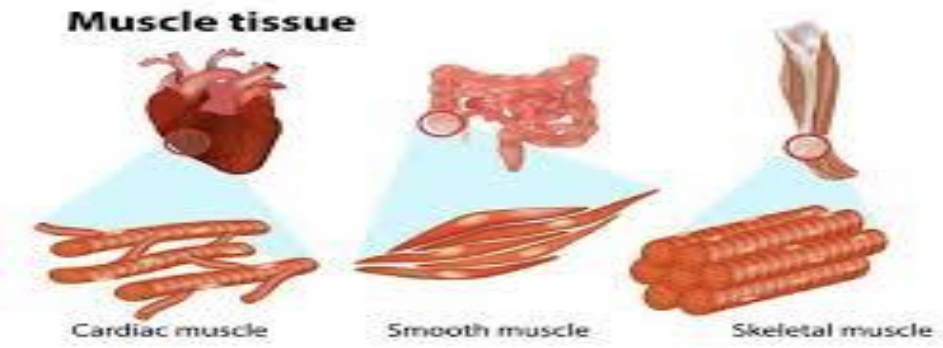
Definition:
Muscular tissue is responsible for producing **movement**, **maintaining posture**, and **generating heat** through contraction.

Characteristics:

- Composed of **elongated muscle fibers (cells)**
- Contain **actin and myosin** filaments for contraction
- Highly vascularized and innervated

Types with Structure, Location, Function

Type	Structure	Location	Function
Skeletal muscle	Long, cylindrical, striated, multinucleated	Attached to bones	Voluntary movement
Cardiac muscle	Branched, striated, single nucleus, intercalated discs	Heart wall (myocardium)	Involuntary contraction of heart
Smooth muscle	Spindle-shaped, non-striated, single nucleus	Walls of hollow organs (intestine, blood vessels)	Involuntary movement, peristalsis



4. Nervous Tissue

Definition:
Nervous tissue is specialized to detect stimuli, generate and transmit **nerve impulses** and coordinate body activities.

Main Cells:

- **Neurons**: Excitable cells that transmit impulses
- **Neuroglia (glial cells)**: Supportive, non-excitable cells that nourish and protect neurons

Structure and Function

Component	Structure	Location	Function
Neurons	Large cell body (soma), axon, dendrites	Brain, spinal cord, nerves	Receive, process, and transmit information
Neuroglia	Smaller cells, many types (astrocytes, microglia, oligodendrocytes)	CNS, PNS	Support, repair, and protect neurons