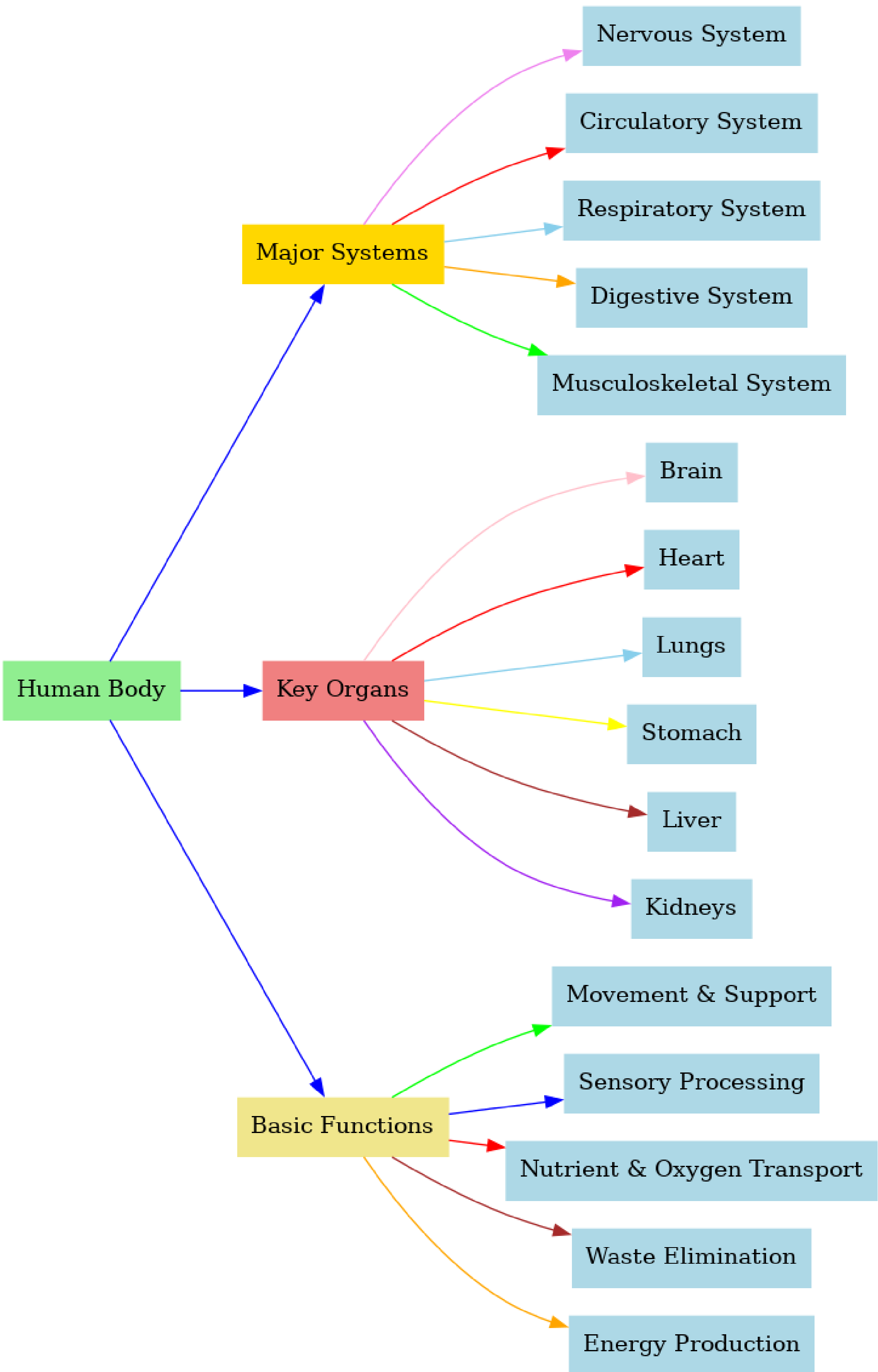
FirstHope Notes | B.Pharm Semester 1

Introduction to Human Body



Definition and Scope of Anatomy and Physiology

Anatomy: Definition and Scope

- Anatomy is the study of the structure and organization of living organisms, particularly focusing on the physical makeup of the human body.
- It involves examining the body's various parts, including bones, muscles, organs, blood vessels, nerves, and tissues.

Anatomy is further divided into several branches:

1. **Gross anatomy (macroscopic anatomy):**
   - Studies the structures visible to the naked eye, such as organs and organ systems.
2. **Microscopic anatomy:**
   - Examines structures that can only be observed under a microscope, including cells and tissues.
   - Histology and cytology are sub-disciplines within microscopic anatomy.
3. **Developmental anatomy:**
   - Investigates the changes in an organism's structure from conception to adulthood, including embryology, which focuses on the development of an organism from fertilization to birth.
4. **Comparative anatomy:**
   - Analyses and compares the anatomical structures of different species, providing insight into evolutionary relationships and adaptations.

Physiology: Definition and Scope

- Physiology is the study of the functions and processes of living organisms, with a particular focus on how the human body's various systems work together to maintain homeostasis.
- Physiology examines the mechanisms behind the body's functions at the molecular, cellular, tissue, organ, and system levels.

The field is divided into several branches, including:

1. **Cell physiology:**
   - Investigates the processes and functions of cells and their components.
2. **Systems physiology:**
   - Explores the function and interaction of specific organ systems, such as the cardiovascular, respiratory, and nervous systems.
3. **Neurophysiology:**
   - Examines the functions and mechanisms of the nervous system, including the brain, spinal cord, and peripheral nerves.

4. Endocrinology:

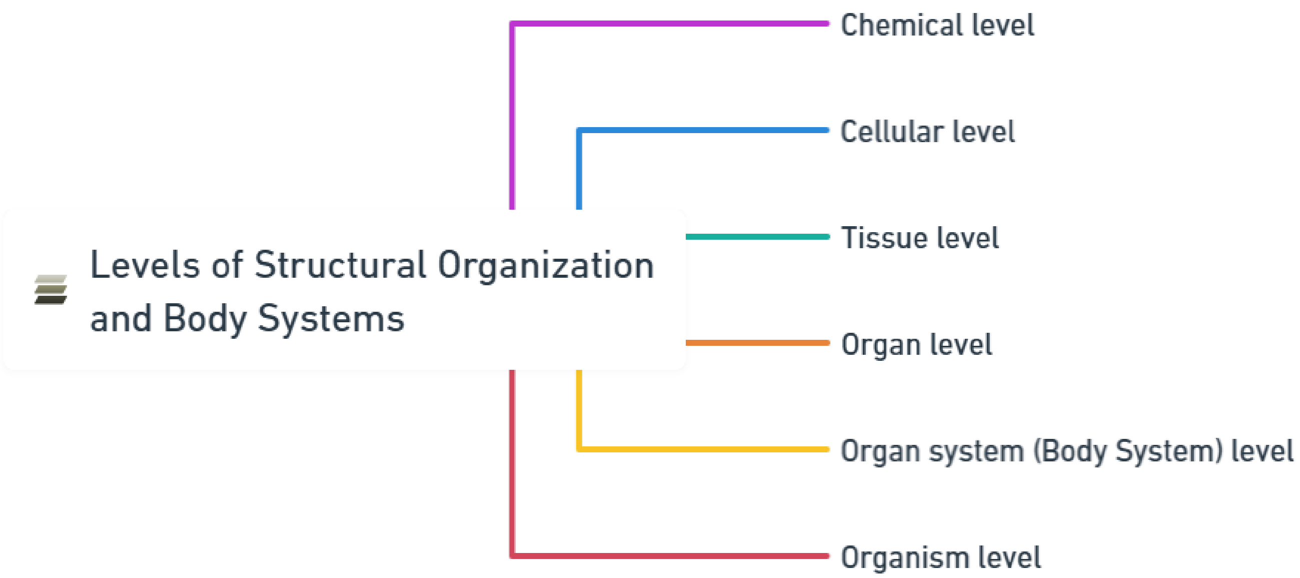
➢ Studies the production, secretion, and action of hormones and their role in regulating the body's functions.

5. Exercise physiology:

➢ Focuses on the effects of physical activity on the body and its systems, including adaptations and performance optimization.

Levels of structural organization and body systems

- The human body is a complex, organized structure consisting of various levels, from the smallest unit of life to the most complex systems.



The levels of structural organization can be categorized as follows:

1. Chemical Level

➢ This is the most basic level, encompassing atoms and molecules.

➢ Atoms, the smallest units of matter, combine to form molecules, which are the building blocks for cells and their components.

➢ Examples include water, proteins, lipids, and carbohydrates.

2. Cellular Level

➢ Cells are the smallest functional units of life, each with a specific role in the body.

➢ They contain various organelles, such as the nucleus, mitochondria, and endoplasmic reticulum, which perform specialized tasks to ensure proper functioning.

3. Tissue Level

➢ Tissues are groups of similar cells working together to perform specific functions.

➢ There are four primary types of tissues in the human body:

- Epithelial tissue

- Connective tissue
- Muscle tissue
- Nervous tissue

4. Organ Level

- Organs are structures composed of two or more tissue types that work together to perform specific functions.
- Examples of organs include the heart, lungs, liver, and kidneys.

5. Organ System (Body System) Level

- The body consists of 11 major organ systems, each responsible for specific physiological functions:

A. Integumentary System

- **Components:** Skin, hair, nails, and glands.
- **Function:** Protects the body, regulates temperature, and provides sensory information.

B. Skeletal System

- **Components:** Bones, cartilage, ligaments, and joints.
- **Function:** Provides structure, protects organs, anchors muscles, and stores minerals.

C. Muscular System

- **Components:** Skeletal muscles, tendons.
- **Function:** Facilitates movement, maintains posture, and produces heat.

D. Nervous System

- **Components:** Brain, spinal cord, peripheral nerves, sensory organs.
- **Function:** Controls body activities with electrical signals, processes sensory information, and coordinates responses.

E. Endocrine System

- **Components:** Glands such as the thyroid, adrenal glands, pancreas, and pituitary gland.
- **Function:** Secretes hormones that regulate growth, metabolism, and reproduction.

F. Cardiovascular System

- **Components:** Heart, blood vessels (arteries, veins, capillaries).
- **Function:** Transports nutrients, gases, hormones, and waste products throughout the body.

G. Lymphatic/Immune System

- **Components:** Lymph nodes, lymphatic vessels, thymus, spleen, tonsils.
- **Function:** Defends against infection, returns leaked fluids to the blood, and absorbs dietary fats.

H. Respiratory System

- **Components:** Lungs, trachea, bronchi, nasal cavity, larynx.
- **Function:** Provides oxygen to the blood and removes carbon dioxide.

I. Digestive System

- **Components:** Mouth, esophagus, stomach, intestines, liver, pancreas, gallbladder.
- **Function:** Breaks down food, absorbs nutrients, and eliminates waste.

J. Urinary System

- **Components:** Kidneys, ureters, bladder, urethra.
- **Function:** Removes waste products from the blood, regulates blood volume, and maintains electrolyte balance.

K. Reproductive System

- **Components:**
  - **Male:** Testes, vas deferens, prostate gland, penis
  - **Female:** Ovaries, fallopian tubes, uterus, vagina
- **Function:** Produces gametes (sperm in males, eggs in females) and supports fetal development in females.

L. Organism Level

- The organism level represents the highest level of organization, encompassing all organ systems working together to maintain the life and well-being of the individual.

Basic Life Processes

- Basic life processes are the essential functions that all living organisms, including humans, must perform to maintain life and ensure survival.
- These processes are **interdependent** and play a vital role in maintaining **homeostasis** – the stable internal environment of the organism.

The fundamental life processes include:

A. Metabolism

- Metabolism refers to the sum of all chemical reactions that occur within an organism to maintain life.
- It is divided into two main processes:
  - **Catabolism:** Breaking down complex molecules into simpler ones to release energy.
  - **Anabolism:** Building complex molecules from simpler ones, utilizing energy.

B. Responsiveness

- Responsiveness, or **irritability**, is the ability of an organism to detect and respond to changes in its internal or external environment.
- In humans, the **nervous** and **endocrine systems** play crucial roles in sensing and reacting to stimuli.

C. Movement

- Movement encompasses both the motion of the whole organism and the movement of substances within the organism.
- It is essential for activities such as:
  - Locomotion
  - Transporting nutrients and waste products
  - Circulating blood

D. Growth

- Growth is an increase in size and mass of an organism due to the synthesis of new cellular materials.
- Growth typically occurs through **cell division** and the addition of **extracellular material**, such as bone or connective tissue.

E. Differentiation

- Differentiation is the process by which **unspecialized cells** develop into **specialized cells** with distinct structures and functions.
- This process is crucial during **embryonic development** and also occurs in some adult tissues, such as the **bone marrow**, where new blood cells are formed.

F. Reproduction

- Reproduction is the process by which an organism produces offspring, ensuring the continuation of its species.
- In humans, reproduction is **sexual** and involves the fusion of male and female gametes to form a **zygote**, which eventually develops into a new individual.

G. Respiration

- Respiration is the process of exchanging gases, primarily **oxygen** and **carbon dioxide**, between an organism and its environment.

- Oxygen is necessary for **cellular respiration**, a process that generates energy (ATP) by breaking down glucose and other nutrients.

H. Excretion

- Excretion is the elimination of waste products generated by metabolic processes.
- These waste products, such as **carbon dioxide, urea, and ammonia**, must be removed to prevent toxic accumulation and maintain homeostasis.

I. Circulation

- Circulation is the transport of **nutrients, gases, hormones, and waste products** throughout the organism.
- In humans, the **cardiovascular system** and **lymphatic system** play key roles in maintaining efficient circulation.

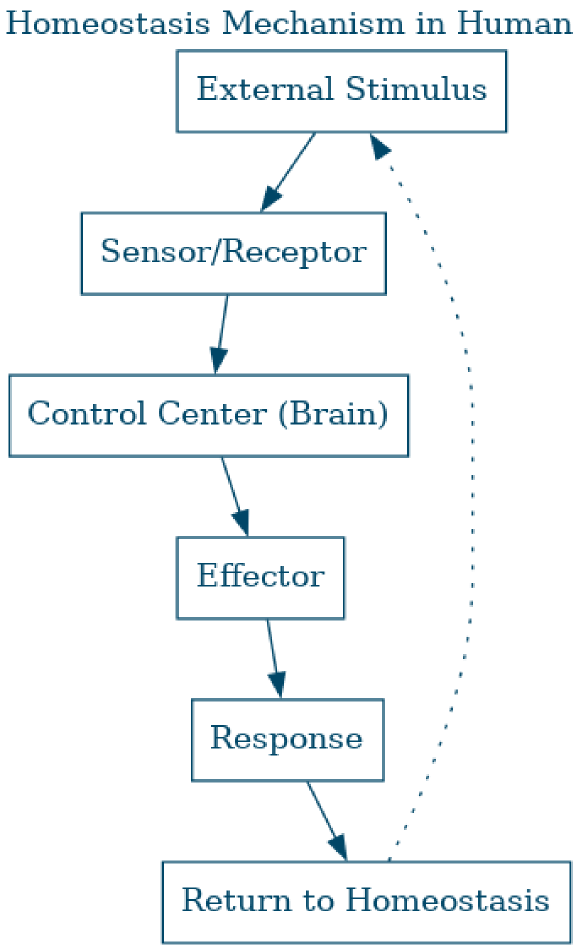
J. Nutrition

- Nutrition involves the **consumption, digestion, and absorption** of essential nutrients, such as carbohydrates, lipids, proteins, vitamins, and minerals.
- Proper nutrition is crucial for:
  - Maintaining energy levels
  - Supporting growth and repair
  - Ensuring overall health

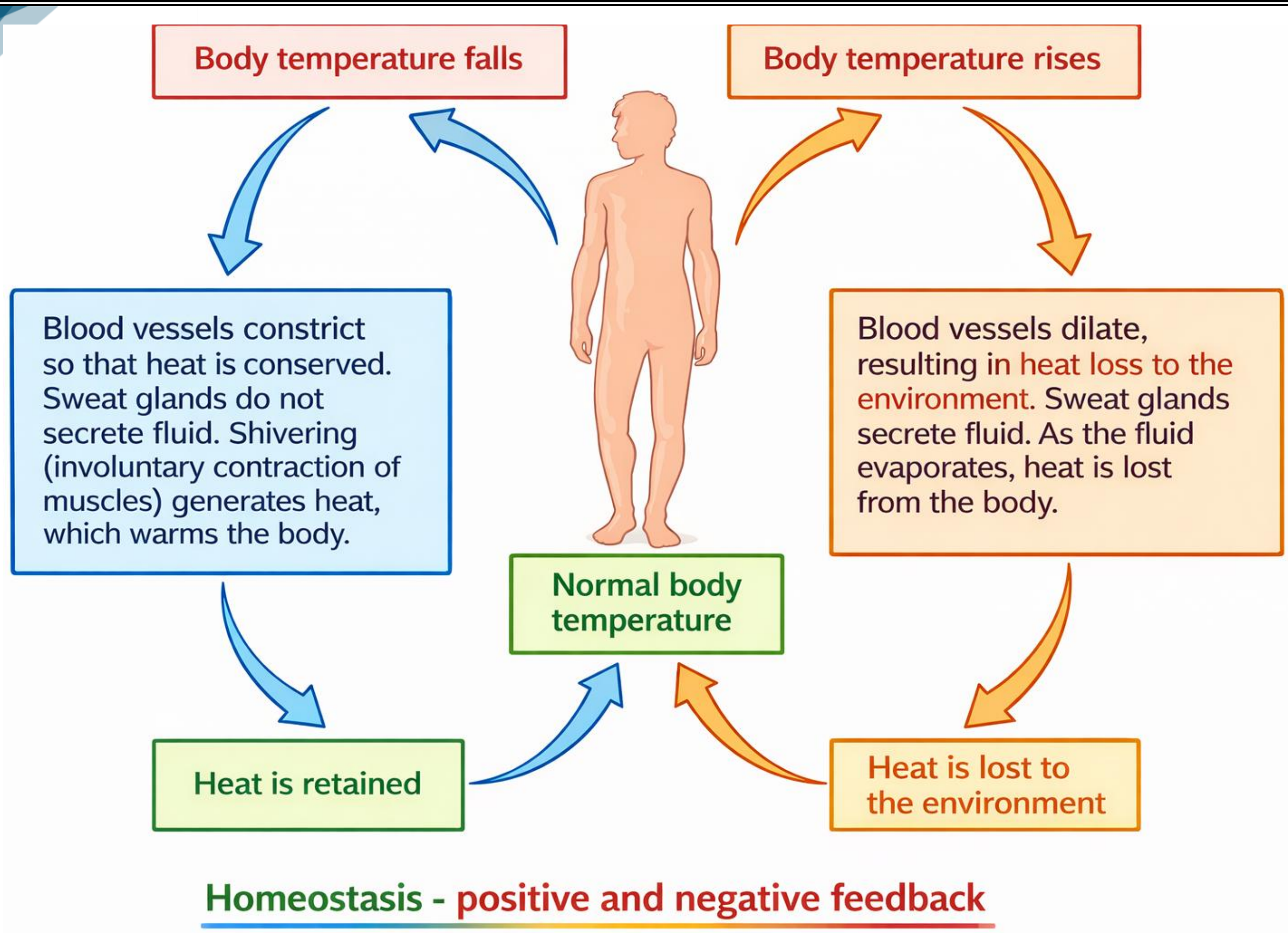
Homeostasis

- Homeostasis is the process by which living organisms maintain a stable internal environment despite fluctuations in external conditions.

- The term *"homeostasis"* comes from the Greek words *"homeo,"* meaning **similar**, and *"stasis,"* meaning **stable**.
- It is a fundamental concept in biology and physiology, as the proper functioning and survival of an organism depend on its ability to maintain homeostasis.
- Homeostasis involves the regulation of various physiological parameters within specific ranges, such as:
    - Body temperature
    - pH
    - Blood sugar levels
    - Fluid balance
- These parameters are monitored and controlled by **complex feedback mechanisms** that involve multiple organs and systems.



The feedback mechanisms can be classified into two categories:



1. Negative Feedback

- Negative feedback mechanisms work to counteract deviations from the normal range.
- When a parameter moves away from its set point, negative feedback mechanisms initiate a response to bring it back to the desired level.
- This type of feedback is the **most common** in the body and helps maintain stability.
- **Example:** When body temperature rises, sweat glands are activated to release sweat. The evaporation of sweat cools the body, bringing the temperature back to the normal range.

2. Positive Feedback

- Positive feedback mechanisms amplify a change, driving it further away from the normal range.
- While this may seem counterintuitive, positive feedback is essential in certain situations that require a **rapid or decisive response**, such as blood clotting or childbirth.
- **Example:** During childbirth, the release of oxytocin stimulates uterine contractions. These contractions cause more oxytocin to be released, resulting in increasingly stronger contractions until the baby is born.

Several organ systems play crucial roles in maintaining homeostasis, including:

1. **Nervous system:**
   - The nervous system detects changes in the internal and external environment and coordinates the body's response through the transmission of nerve impulses.
2. **Endocrine system:**
   - The endocrine system regulates bodily functions through the production and secretion of hormones, which act as chemical messengers targeting specific cells or tissues.
3. **Respiratory system:**
   - The respiratory system helps regulate blood pH and maintain proper oxygen and carbon dioxide levels through gas exchange in the lungs.
4. **Cardiovascular system:**
   - The cardiovascular system transports nutrients, gases, waste products, and hormones throughout the body, maintaining a stable internal environment.
5. **Urinary system:**
   - The urinary system filters waste products from the blood and maintains electrolyte balance and fluid volume by regulating urine production.

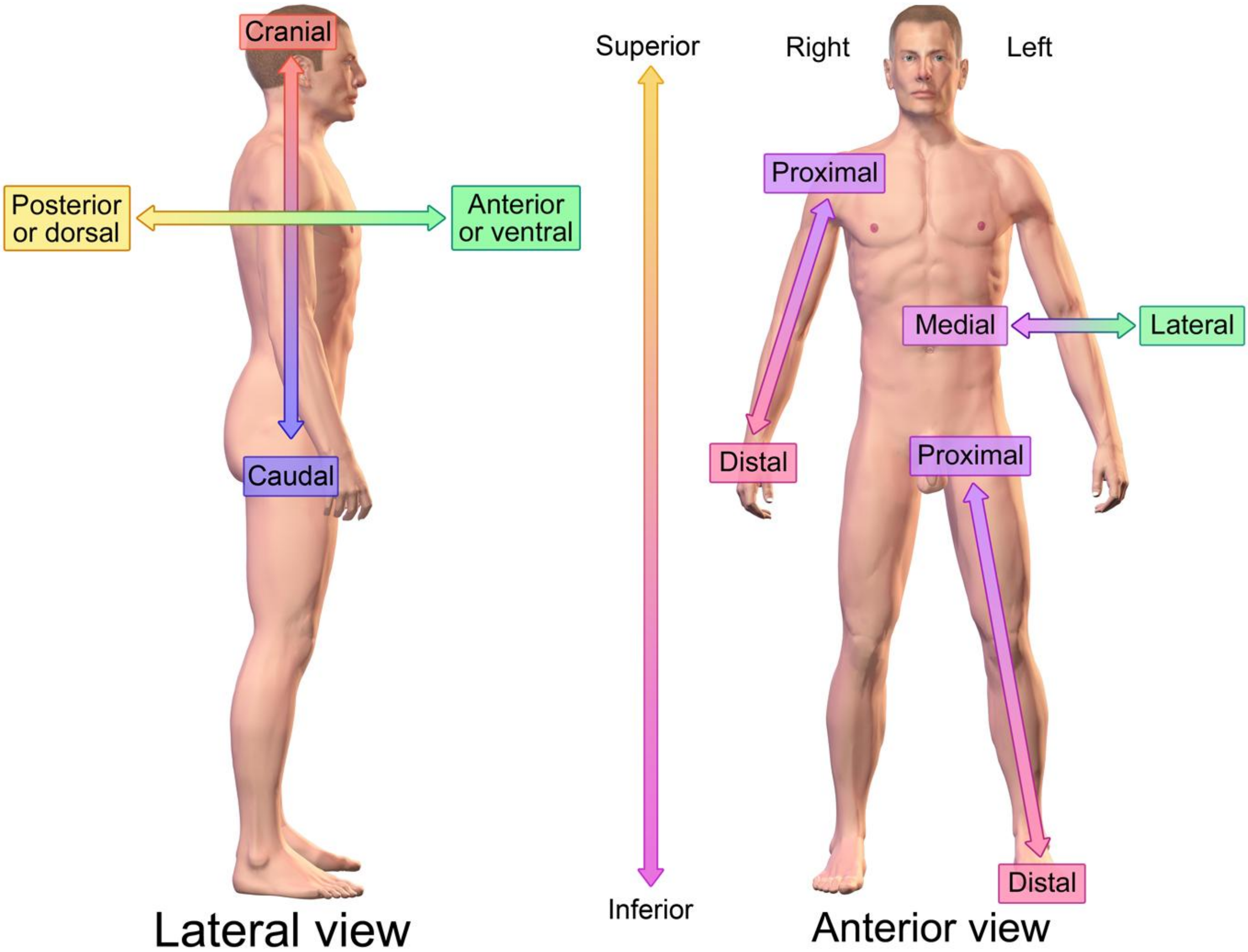
Basic Anatomical Terminology

- Basic anatomical terminology is essential for accurate and effective communication in the fields of anatomy, physiology, and medicine.
- These terms provide a **standardized way** to describe the **location, orientation, and relationships** of body structures.

Some fundamental anatomical terms include:

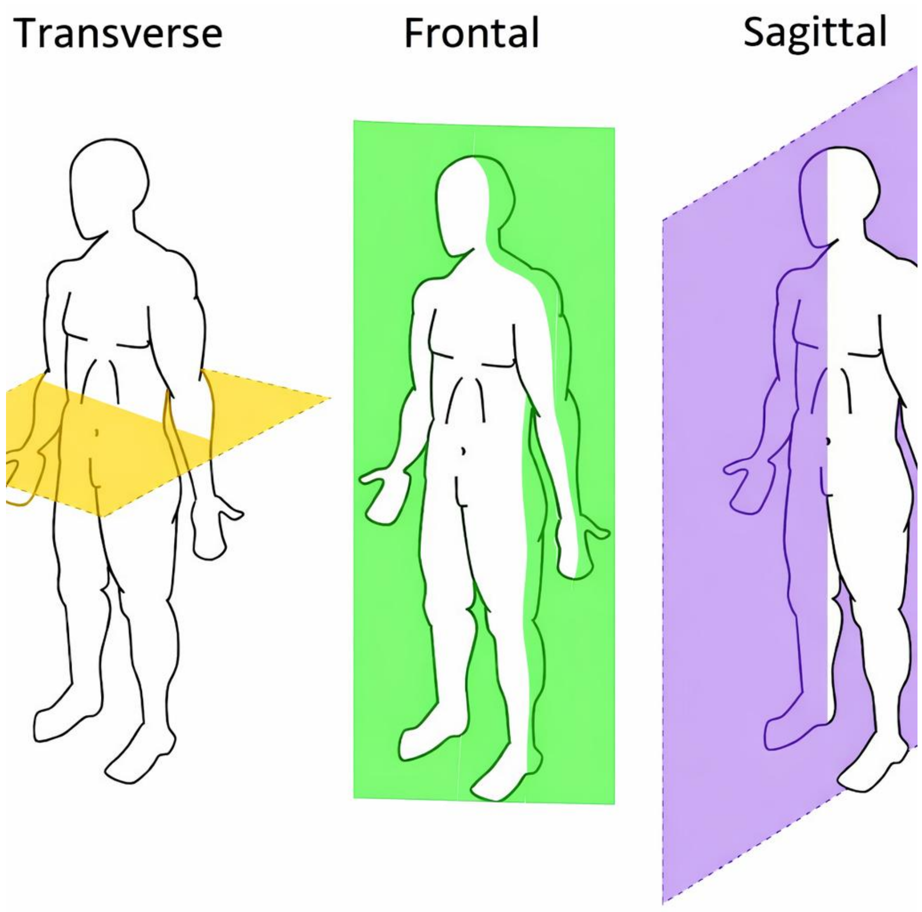
1. **Anatomical Position:**
   - A reference point for describing the location and orientation of body structures.
   - The anatomical position involves the individual standing upright, facing forward, with arms at the sides, palms facing forward, and feet parallel.
2. **Directional Terms:**
   - These terms describe the relative position of body structures in relation to each other:
     - **Anterior (Ventral)**: Toward the front of the body.
     - **Posterior (Dorsal)**: Toward the back of the body.
     - **Superior (Cranial)**: Closer to the head or higher than another structure.
     - **Inferior (Caudal)**: Closer to the feet or lower than another structure.
     - **Medial**: Nearer to the midline of the body.

- **Lateral**: Farther from the midline of the body.
- **Proximal**: Closer to the point of attachment or origin, typically used for limbs.
- **Distal**: Farther from the point of attachment or origin, typically used for limbs.
- **Superficial**: Closer to the surface of the body.
- **Deep**: Farther from the surface of the body.

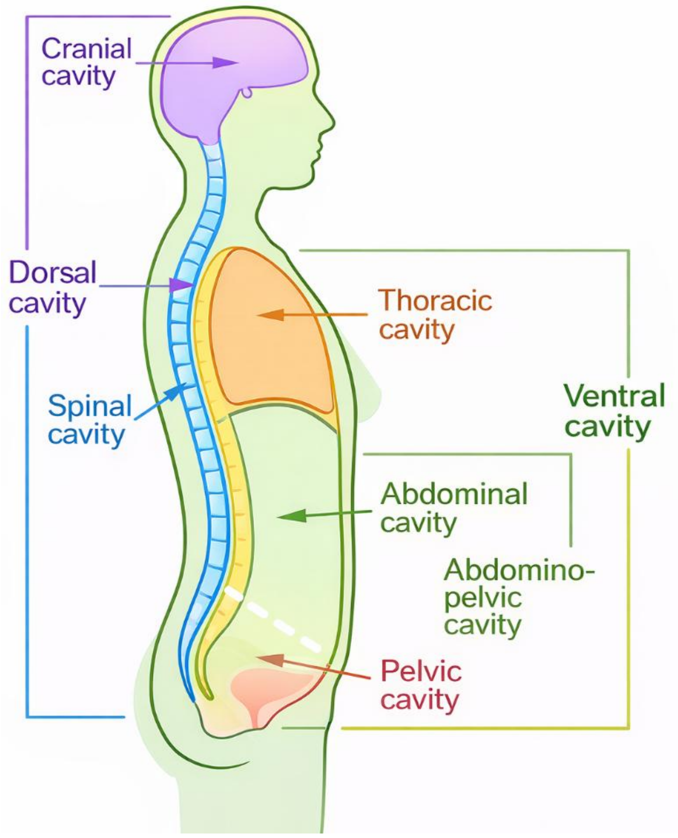


3. Body Planes:

- Imaginary flat surfaces that divide the body or organs into sections:
  - **Sagittal Plane**: A vertical plane that divides the body into left and right sections.
    - **Midsagittal (Median) Plane**: Specifically divides the body into equal left and right halves.
  - **Coronal (Frontal) Plane**: A vertical plane that divides the body into anterior and posterior (front and back) sections.
  - **Transverse (Horizontal) Plane**: A horizontal plane that divides the body into superior and inferior (top and bottom) sections.



4. Body Cavities:



- Spaces within the body that house and protect internal organs:
    - **Dorsal Cavity**: Contains the cranial cavity (housing the brain) and the spinal cavity (housing the spinal cord).
    - **Ventral Cavity**: Divided into the thoracic cavity (containing the heart and lungs) and the abdominopelvic cavity (containing the digestive, urinary, and reproductive organs). The thoracic and abdominopelvic cavities are separated by the diaphragm.

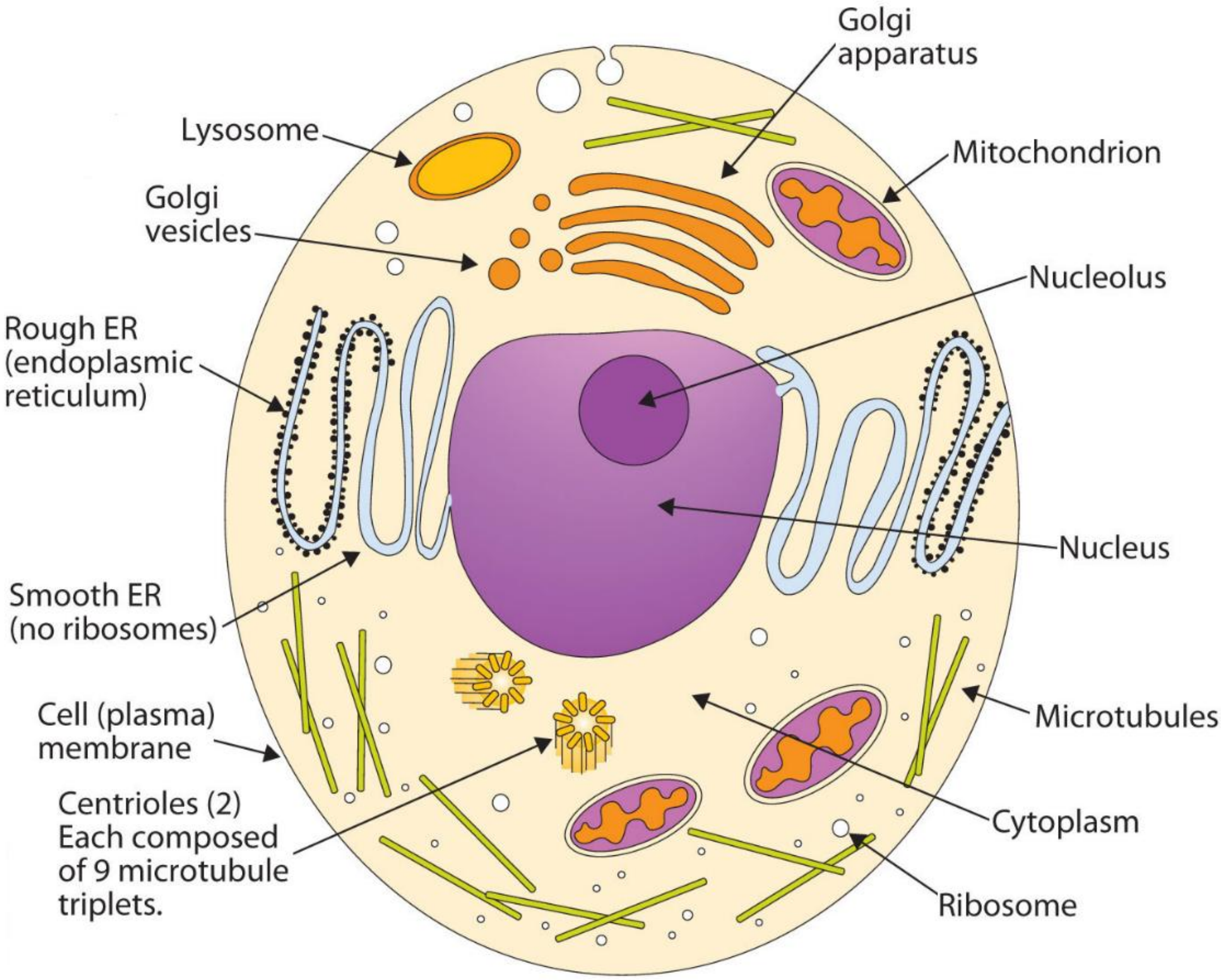
5. Body Regions:

- Specific areas of the body used for descriptive purposes:
    - **Axial Region**: Includes the head, neck, and trunk.
    - **Appendicular Region**: Includes the limbs or extremities (arms and legs).

Cellular level of organization

Structure and functions of cell

- Cells are the basic structural and functional units of life.
- They can be classified into two main types:
  - **Prokaryotic cells:** Found in bacteria and archaea.
  - **Eukaryotic cells:** Found in plants, animals, fungi, and protists.
- Both cell types share some basic structures and functions, but eukaryotic cells are generally larger and more complex than prokaryotic cells.



Here are the main structures (organelles) and functions of a typical eukaryotic cell:

A. Cell membrane (plasma membrane):

- A selectively permeable barrier that surrounds the cell, controlling the passage of substances in and out of the cell.
- It is composed of a phospholipid bilayer with embedded proteins.

Function:

- Controls the movement of substances in and out of the cell, maintaining a balance of ions, nutrients, and waste products.
- It also mediates cell-to-cell communication and recognition.

B. Cytoplasm:

- The gel-like substance within the cell membrane that contains organelles, enzymes, and other molecules required for the cell's functions.
- It is the site of many cellular processes.

Function:

- Provides a medium for cellular processes to occur, suspending organelles and facilitating the transport of molecules throughout the cell.

C. Nucleus:

- The control center of the cell, which contains the cell's DNA, organized into chromosomes.
- The nucleus is surrounded by a double-layered nuclear membrane and contains a nucleolus, which is involved in ribosome synthesis.

Function:

- Contains genetic information (DNA) and regulates gene expression, controlling the synthesis of proteins required for cellular function, growth, and reproduction.
- It also houses the nucleolus, which produces ribosomes.

D. Endoplasmic reticulum (ER):

- A network of membranous tubules and sacs that play a crucial role in protein and lipid synthesis.
- The ER can be classified into two types:
  - I. Smooth ER (involved in lipid synthesis and detoxification)
  - II. Rough ER (studded with ribosomes and involved in protein synthesis).

Function:

- Involved in protein synthesis (rough ER) and lipid synthesis (smooth ER).
- The rough ER is studded with ribosomes and produces proteins destined for secretion or incorporation into the cell membrane.
- The smooth ER produces lipids and detoxifies harmful substances.

E. Ribosomes:

- Small structures made of protein and RNA that are responsible for protein synthesis.
- They can be found free-floating in the cytoplasm or attached to the rough ER.

Function:

- Small structures made of protein and RNA responsible for protein synthesis.
- They can be found free-floating in the cytoplasm or attached to the rough ER.

F. Golgi apparatus:

- A series of flattened, membrane-bound sacs that modify, package, and sort proteins and lipids for transport to their final destinations within or outside the cell.

Function:

- Modifies, packages, and sorts of proteins and lipids for transport to their final destinations within or outside the cell.

G. Mitochondria:

- The powerhouse of the cell, responsible for producing ATP (adenosine triphosphate), the cell's primary energy source, through cellular respiration.
- Mitochondria have their own DNA and are believed to have originated from an endosymbiotic relationship with bacteria.

Function:

- Produce ATP (adenosine triphosphate), the cell's primary energy source, through cellular respiration.

H. Lysosomes:

- Small, membrane-bound organelles containing hydrolytic enzymes that break down waste materials, cellular debris, and foreign substances.

Function:

- Contain hydrolytic enzymes that break down waste materials, cellular debris, and foreign substances.

I. Peroxisomes:

- Organelles that contain enzymes involved in various metabolic reactions, including the breakdown of fatty acids and the detoxification of harmful substances.

Function:

- Contain enzymes involved in various metabolic reactions, including the breakdown of fatty acids and the detoxification of harmful substances.

J. Cytoskeleton:

- A network of protein filaments that provides structural support, maintains cell shape, and aids in cell movement and division.
- The cytoskeleton consists of microtubules, microfilaments, and intermediate filaments.

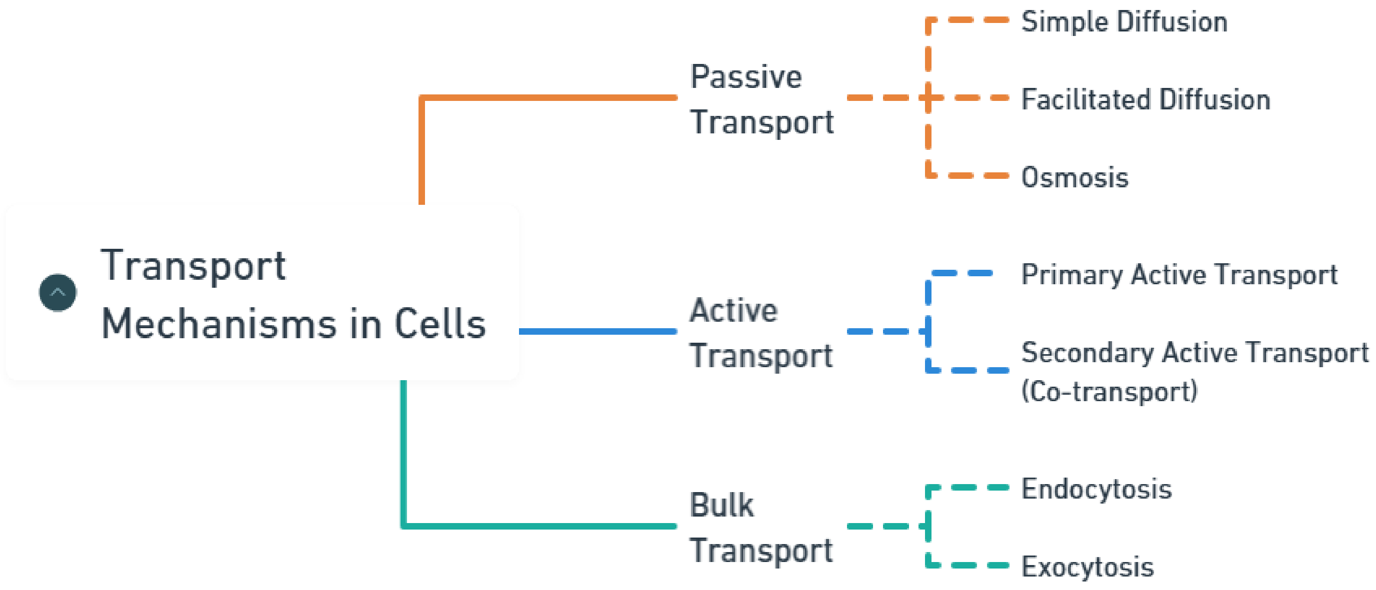
Function:

- A network of protein filaments that provide structural support, maintain cell shape, and aid in cell movement and division.
- The cytoskeleton consists of microtubules, microfilaments, and intermediate filaments.

Transport across cell membrane

- Transport across the cell membrane is essential for cells to exchange materials with their environment and maintain homeostasis.

Types of transport mechanisms



1. Passive Transport

- Passive transport does not require energy input from the cell, as it relies on the natural movement of molecules from an area of **higher concentration** to an area of **lower concentration** (down the concentration gradient).
- There are **three** types of passive transport:

A. Simple Diffusion

- Small, nonpolar molecules (such as oxygen and carbon dioxide) and lipid-soluble substances can pass directly through the phospholipid bilayer of the cell membrane.
- This process is driven by the concentration gradient until equilibrium is reached.

B. Facilitated Diffusion

- Some larger or polar molecules (such as glucose and amino acids) cannot pass through the cell membrane directly.

- Instead, they move down their concentration gradient with the help of **transport proteins** (channel proteins and carrier proteins) embedded in the cell membrane.

C. Osmosis

- Movement of **water molecules** across a selectively permeable membrane from an area of **higher water concentration (lower solute concentration)** to an area of **lower water concentration (higher solute concentration)**.
- Osmosis is crucial for maintaining the correct balance of water and solutes within cells.

2. Active Transport

- Active transport requires energy input from the cell, usually in the form of ATP (adenosine triphosphate), to move substances against their concentration gradient (from lower concentration to higher concentration).
- **There are two types of active transport:**

A. Primary Active Transport

- Uses energy directly from the **hydrolysis of ATP** to pump molecules against their concentration gradient.
- Example: The **sodium-potassium pump**, which moves sodium ions out of the cell and potassium ions into the cell, maintaining the cell's electrochemical gradient.

B. Secondary Active Transport (Co-transport)

- Uses the energy stored in the **electrochemical gradient** created by primary active transport to move other molecules against their concentration gradient.
- Two types of co-transport:
  - **Symport:** Both molecules move in the same direction.
  - **Antiport:** Molecules move in opposite directions.
- Example: The **glucose-sodium symporter**, which transports glucose into the cell along with sodium ions.

3. Bulk Transport

- In addition to the above mechanisms, cells can move large particles or large quantities of substances across the cell membrane through **bulk transport**, which involves the formation of vesicles.
- There are **two** types of bulk transport:

A. Endocytosis

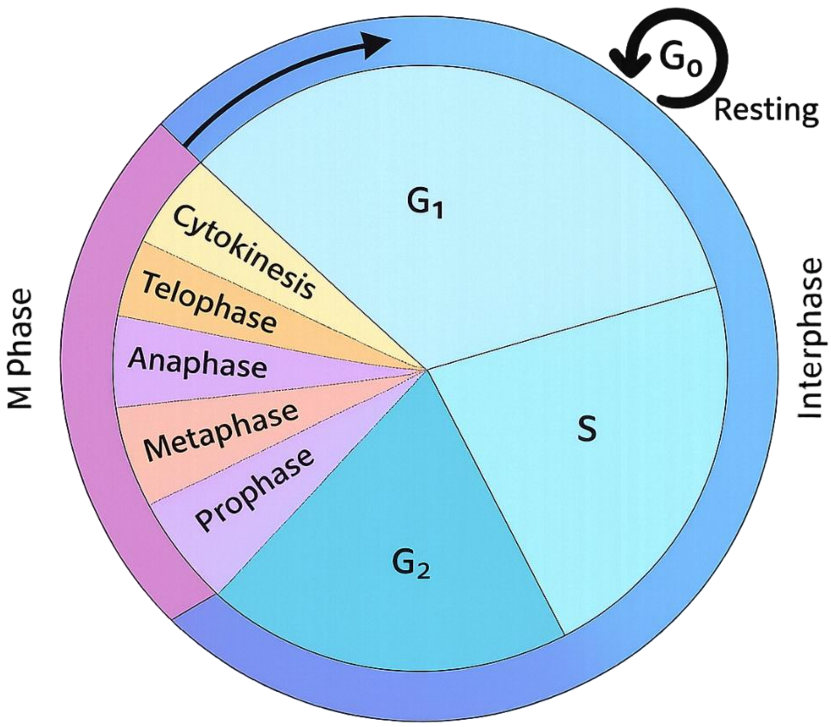
- The process of engulfing large particles or large volumes of extracellular fluid into the cell by folding the cell membrane inward and forming a vesicle.
- Three types of endocytosis:
    1. **Phagocytosis:** Cell eating, engulfing large particles.
    2. **Pinocytosis:** Cell drinking, engulfing small particles or liquid.
    3. **Receptor-mediated endocytosis:** Specific molecules bind to receptors on the cell membrane, triggering vesicle formation.

B. Exocytosis

- The process of expelling large particles or large volumes of substances from the cell by fusing a vesicle with the cell membrane and releasing its contents into the extracellular environment.
- Exocytosis is essential for the secretion of **hormones, neurotransmitters, and waste products**.

Cell division

- **Cell division is a fundamental process** in which a parent cell divides into two or more daughter cells.
- It allows for **growth, repair, and reproduction** in living organisms.
- There are **two** main types of cell division:
    - **Mitosis** (in eukaryotic cells)
    - **Binary fission** (in prokaryotic cells)



- Additionally, eukaryotic organisms undergo a specialized form of cell division called **meiosis** to produce **gametes (sperm and egg cells)** for sexual reproduction.

Interphase

- Interphase is the preparation phase, divided into **three** stages:

G1 Phase (Gap 1):

➢ The cell grows, produces proteins, and checks conditions for DNA replication.

S Phase (Synthesis):

- DNA is replicated, resulting in two identical sets of chromosomes.

G2 Phase (Gap 2):

- The cell continues to grow, produces proteins needed for mitosis, and checks for DNA errors.

M Phase (Mitotic Phase)

- The M phase involves:

Mitosis:

- Division of the nucleus and chromosomes into two identical nuclei.

Cytokinesis:

- Division of the cytoplasm, resulting in two separate daughter cells.

- This cycle ensures proper cell growth, DNA replication, and division, maintaining healthy cell function.

M Phase (Mitotic Phase)

- **Cell division** is a fundamental process by which a single cell divides into two or more daughter cells.
- This process is essential for **growth, development, and repair** in living organisms.
- There are **two** main types of cell division: **mitosis** and **meiosis**.

1. Mitosis

- Mitosis is responsible for the **growth and maintenance of tissues**.
- It is how organisms grow and replace old or damaged cells.

Process of Mitosis

A. Interphase

- The cell prepares for division by replicating its DNA, so each daughter cell will have a complete set of chromosomes.

B. Prophase

- The chromatin condenses into visible chromosomes, and the nuclear membrane begins to disintegrate.
- Spindle fibers start to form.

C. Metaphase

- The chromosomes align in the middle of the cell, attached to spindle fibers.

D. Anaphase

- The chromosomes are pulled apart, with each half moving to opposite sides of the cell.

E. Telophase

- The chromosomes reach the poles, and a new nuclear membrane forms around each set, creating two nuclei.

F. Cytokinesis

- The cell's cytoplasm divides, forming two separate daughter cells, each with an identical set of chromosomes.

2. Meiosis

- Meiosis is crucial for **sexual reproduction** and occurs in **germ cells (sperm and eggs)**.
- It reduces the chromosome number by half, resulting in four genetically diverse daughter cells, each with half the number of chromosomes as the original cell.

Process of Meiosis

A. Meiosis I:

- **Prophase I:** Chromosomes condense, and homologous chromosomes pair up, exchanging segments in a process called crossing over.
- **Metaphase I:** Paired homologous chromosomes line up at the cell's equator.
- **Anaphase I:** The homologous chromosomes are pulled apart to opposite sides.
- **Telophase I and Cytokinesis:** The cell divides into two non-identical daughter cells, each with half the original number of chromosomes.

B. Meiosis II:

- **Prophase II:** The two cells prepare for another division.
- **Metaphase II:** Chromosomes line up at the equator of each cell.
- **Anaphase II:** Sister chromatids are pulled apart to opposite poles.
- **Telophase II and Cytokinesis:** Both cells divide, resulting in **four non-identical daughter cells**, each with half the original chromosome number.

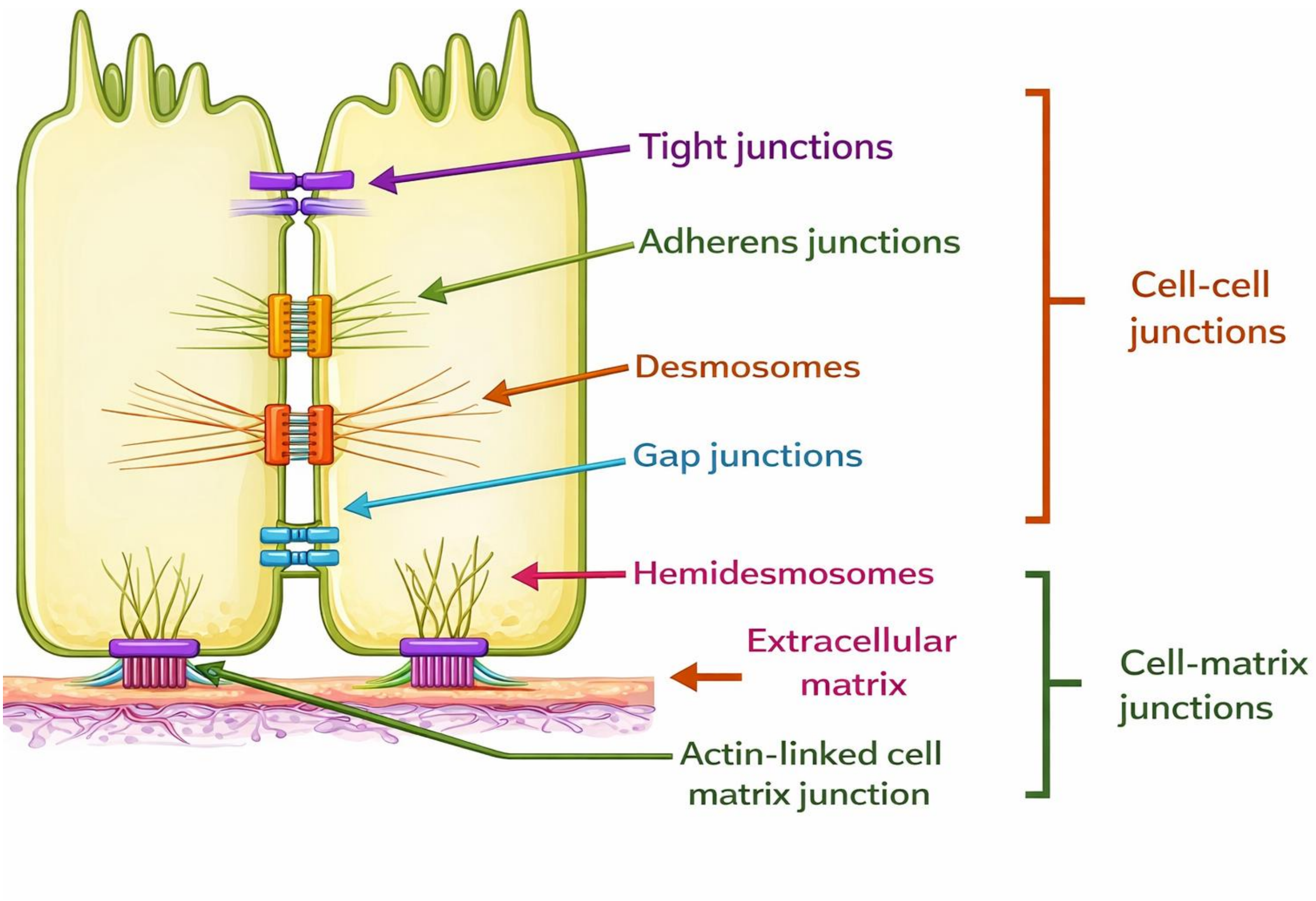
Key Differences Between Mitosis and Meiosis

- **Mitosis:** Produces two genetically identical daughter cells with the same number of chromosomes as the parent cell.
- **Meiosis:** Produces four genetically diverse daughter cells with half the chromosome number of the parent cell.

Cell junctions

- **Cell junctions** are specialized structures that connect cells to each other or to the extracellular matrix.
- These junctions play crucial roles in maintaining the **integrity** and **function** of tissues by:
  - Allowing communication between cells
  - Holding cells together
  - Regulating the passage of molecules between them

There are three main types of cell junctions:



1. Tight Junctions (Occluding Junctions)

- **Function**: Tight junctions create a seal between adjacent cells, preventing the passage of substances between them. They are essential for maintaining the selective permeability of epithelial layers.
- **Location**: Commonly found in epithelial tissues, such as the lining of the intestines and blood vessels.
- **Structure**: Composed of proteins like claudins and occludins that form a continuous barrier.

2. Adherens Junctions and Desmosomes (Anchoring Junctions)

- **Function:** These junctions provide mechanical stability by anchoring cells to each other or to the extracellular matrix.

- They help tissues resist stretching and tearing.

A. **Adherens Junctions:**

  - Connect the actin cytoskeleton of one cell to another, important in maintaining the shape and tension of tissues.

B. **Desmosomes:**

  - Connect the intermediate filaments of one cell to another, providing strong adhesion between cells.

- **Location:** Found in tissues subject to mechanical stress, like the skin and heart muscle.
- **Structure:** Involve proteins such as cadherins (in adherens junctions and desmosomes) that link to the cytoskeleton.

3. **Gap Junctions (Communicating Junctions)**

- **Function**: Gap junctions allow direct communication between adjacent cells by permitting the passage of ions, nutrients, and signaling molecules. This enables cells to coordinate their activities.
- **Location**: Found in many tissues, including cardiac muscle, where they facilitate the synchronized contraction of the heart.
- **Structure**: Composed of connexin proteins that form channels (connexons) between neighbouring cells.

Key Roles of Cell Junctions

- **Barrier Function**: Tight junctions prevent leakage between cells.
- **Mechanical Support**: Adherens junctions and desmosomes help tissues withstand mechanical stress.
- **Cell Communication**: Gap junctions enable the transfer of signals and molecules between cells.

These junctions are essential for the structure and function of tissues in multicellular organisms, contributing to everything from tissue integrity to coordinated cell behavior.

General principles of cell communication

- Cell communication is a vital process in multicellular organisms that allows cells to coordinate their activities, respond to changes in their environment, and maintain homeostasis.

The general principles of cell communication in the following steps:

1. **Signal Generation**

- In response to a stimulus, a signalling molecule or ligand is produced and released by a signalling cell.
- The stimulus can be:

- **External:** Environmental changes
- **Internal:** Presence of specific molecules or cellular conditions

2. Signal Transmission

- The signalling molecule travels:
  - Through the **extracellular space** (local signalling)
  - Through the **circulatory system** (long-range signalling) to reach target cells
  - Some common modes of signal transmission include:

A. Autocrine signalling

- The signalling cell releases a ligand that binds to receptors on its own surface, affecting its own activity.

B. Paracrine signalling

- The signalling cell releases a ligand that affects neighbouring cells in close proximity.

C. Endocrine signalling

- The signalling cell releases a hormone into the bloodstream, which travels long distances to reach target cells throughout the body.

D. Juxtacrine signalling

- Direct cell-to-cell contact, where signalling molecules remain attached to the surface of the signalling cell and interact with receptors on the target cell.

3. Signal Reception

- The target cell detects the signalling molecule via **specific receptor proteins**, located on the cell membrane or within the cell.
- Receptor proteins are highly **specific** for their ligands, ensuring that only the appropriate target cells respond.

4. Signal Transduction

- Once the receptor binds to the ligand, it undergoes a conformational change, activating a cascade of intracellular signalling events.
- This often involves:
  - Protein modifications (e.g., phosphorylation)
  - Activation/deactivation of proteins, enzymes, and secondary messengers
- The pathway ultimately leads to a **specific cellular response**.

5. Cellular Response

- The signal transduction pathway produces changes in the target cell's activity, such as:
  - Alterations in **gene expression**

  - Protein synthesis
  - Enzyme activity
  - Cytoskeletal organization
- Outcomes may include:
  - Cell division
  - Differentiation
  - Migration
  - Secretion
  - Apoptosis (programmed cell death)

6. Signal Termination

- To prevent continuous activation and maintain sensitivity to new signals, the cellular response must be terminated.
- This occurs through:
  - Removal or degradation of the signalling molecule
  - Internalization or inactivation of the receptor
  - Deactivation of intracellular signalling proteins

Intracellular signalling pathway activation by extracellular signal molecule

- Intracellular signalling pathways are activated by extracellular signal molecules, which allow cells to respond and adapt to changes in their environment.

The process of activating an intracellular signalling pathway typically involves the following steps:

1. Signal Generation

- A signalling molecule (**ligand**) is produced and released by a signalling cell in response to a specific stimulus.

2. Signal Transmission

- The ligand travels through the extracellular space to reach target cells via:
  - Autocrine signalling
  - Paracrine signalling
  - Endocrine signalling
  - Juxtacrine signalling

3. Signal Reception

- The target cell detects the ligand through specific receptors, usually located on the cell membrane or within the cell:

A. G-protein-coupled receptors (GPCRs):

- Interact with intracellular G proteins upon ligand binding.

B. Receptor tyrosine kinases (RTKs):

- Undergo autophosphorylation upon ligand binding, creating docking sites for downstream proteins.

C. Ligand-gated ion channels:

- Regulate ion flow across the membrane in response to ligand binding.

D. Nuclear receptors:

- Located within the cell and directly regulate gene expression upon ligand binding.

4. Signal Transduction

- The receptor undergoes a **conformational change** upon ligand binding, initiating a cascade of intracellular events.
- This often involves:
  - Activation or deactivation of proteins and enzymes
  - Secondary messengers such as **cAMP, IP3, DAG, Ca^{2+}**
- Allows for **signal amplification and integration**.

5. Cellular Response

- The signal transduction pathway leads to changes in the target cell's activity, such as:
  - Gene expression
  - Protein synthesis
  - Enzyme activity
  - Cytoskeletal organization
- Outcomes may include: **cell division, differentiation, migration, secretion, or apoptosis**.

6. Signal Termination

- The cellular response is terminated to maintain sensitivity to new signals.
- Achieved through mechanisms such as:
  - Removal or degradation of the signalling molecule
  - Receptor inactivation

- Deactivation of intracellular signalling proteins

Forms of intracellular signalling

- **Intracellular signalling** refers to the communication between cells using signalling molecules and cellular pathways.
- These signals allow cells to respond to their environment and coordinate their functions.

There are several forms of intracellular signalling, which can be classified based on the mode of signal transmission:

1. Contact-dependent signalling

- In this form of signalling, the signalling molecule remains attached to the surface of the signalling cell and directly interacts with receptors on the surface of the target cell.
- This requires physical contact between the two cells, and the signal typically affects only the adjacent cells.
- Examples of contact-dependent signalling include **Notch-Delta signalling**, which plays a crucial role in cell differentiation and development, and **interactions between immune cells and their target cells**.

2. Paracrine signalling

- In paracrine signalling, the signalling cell releases signalling molecules, such as growth factors or cytokines, which diffuse over a short distance through the extracellular space to affect neighbouring cells in close proximity.
- The signalling molecules are often rapidly degraded or taken up by nearby cells, limiting their range of action.
- Paracrine signalling plays essential roles in processes like **wound healing, inflammation, and tissue repair**.

3. Synaptic signalling

- Synaptic signalling is a specialized form of paracrine signalling that occurs at **synapses between neurons** in the nervous system.
- When an electrical signal (**action potential**) reaches the synapse, neurotransmitter molecules are released from the presynaptic neuron and diffuse across the **synaptic cleft**.
- These neurotransmitters bind to specific receptors on the postsynaptic neuron, either triggering or inhibiting an action potential in the target cell.
- This precise, rapid form of signalling allows for the efficient transmission of information within the nervous system.

4. Endocrine signalling

- Endocrine signalling involves the release of **hormones** by specialized endocrine cells or glands into the bloodstream.

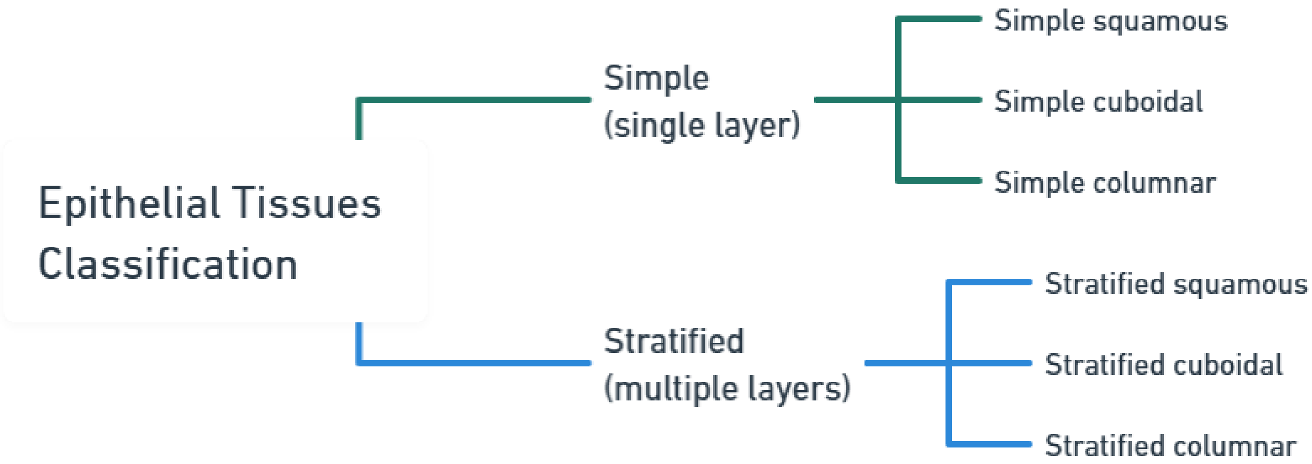
- These hormones travel long distances through the circulatory system to reach their target cells, which may be located in distant parts of the body.
- Hormone receptors are highly specific, ensuring that only the appropriate target cells respond to a particular hormone.
- Endocrine signalling plays a crucial role in regulating various physiological processes, such as **metabolism, growth, development, and reproduction**.

Tissue level of organization

Epithelial Tissue

- Epithelial tissues cover body surfaces, line cavities and form glands.
- They function in protection, secretion, absorption, and transportation.

Epithelial tissues are classified based on the number of cell layers and cell shape:



1. Simple Epithelium:

- Single layers of cells primarily functions in absorption, secretion, and filtration.

Types:

A. Simple Squamous Epithelium:

- **Structure:** Single layer of flat cells.
- **Location:** Alveoli of lungs, glomeruli of kidneys, lining of blood vessels (endothelium), and lining of body cavities (mesothelium).
- **Function:** Allows for rapid diffusion and filtration.

B. Simple Cuboidal Epithelium:

- **Structure:** Single layer of cube-shaped cells.
- **Location:** Kidney tubules, ducts of small glands, ovary surface.
- **Function:** Secretion and absorption.

C. Simple Columnar Epithelium:

- **Structure:** Single layer of tall, column-shaped cells.
- **Location:** Lining of the gastrointestinal tract, gallbladder, and some ducts of glands.
- **Function:** Absorption and secretion; may have microvilli for increased surface area or cilia for movement of substances.

2. Stratified Epithelium:

- Multiple layers of cells, primarily functions in protection against abrasion.

Types:

A. Stratified Squamous Epithelium:

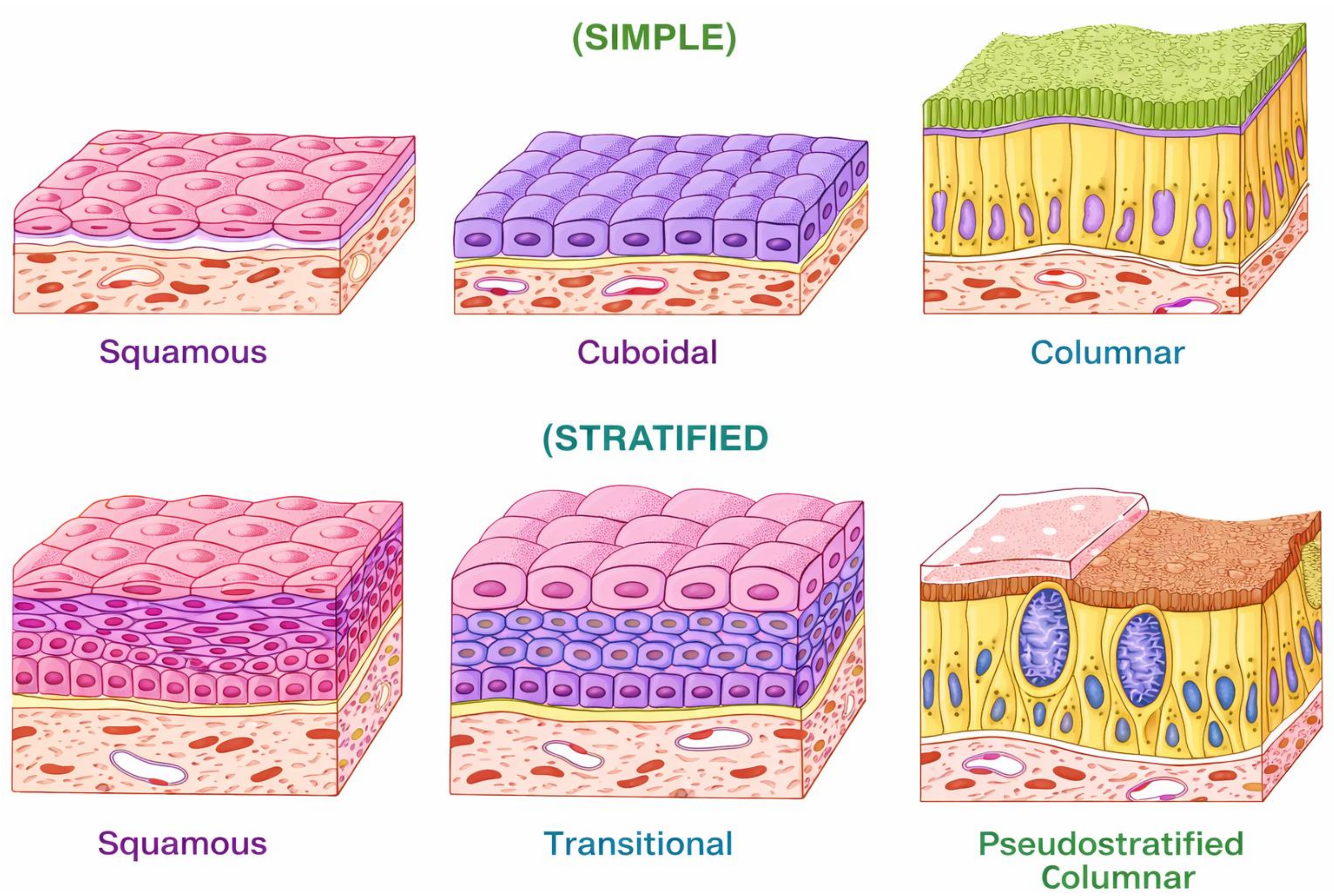
- **Structure:** Multiple layers with flat apical cells.
- **Location:**
  - **Keratinized:** Epidermis of the skin.
  - **Non-keratinized:** Lining of the mouth, esophagus, and vagina.
- **Function:** Protects underlying tissues from abrasion and pathogens.

B. Stratified Cuboidal Epithelium:

- **Structure:** Typically, two layers of cube-shaped cells.
- **Location:** Ducts of sweat glands, mammary glands, and salivary glands.
- **Function:** Protection and limited secretion/absorption.

C. Stratified Columnar Epithelium:

- **Structure:** Multiple layers with columnar apical cells.
- **Location:** Rare; found in the male urethra and large ducts of some glands.
- **Function:** Protection and secretion.



Structure:

- Epithelial cells are closely packed together with little extracellular matrix, and they form a continuous sheet held together by cell junctions such as tight junctions, gap junctions, and desmosomes.
- They have an apical surface facing the body cavity or external environment and a basal surface attached to the underlying connective tissue via a basement membrane.

Location:

1. **Surface epithelium:** External body surfaces (skin), internal cavities (mouth, respiratory tract, and gastrointestinal tract)
2. **Glandular epithelium:** Forms glands (e.g., sweat glands, salivary glands, thyroid gland)

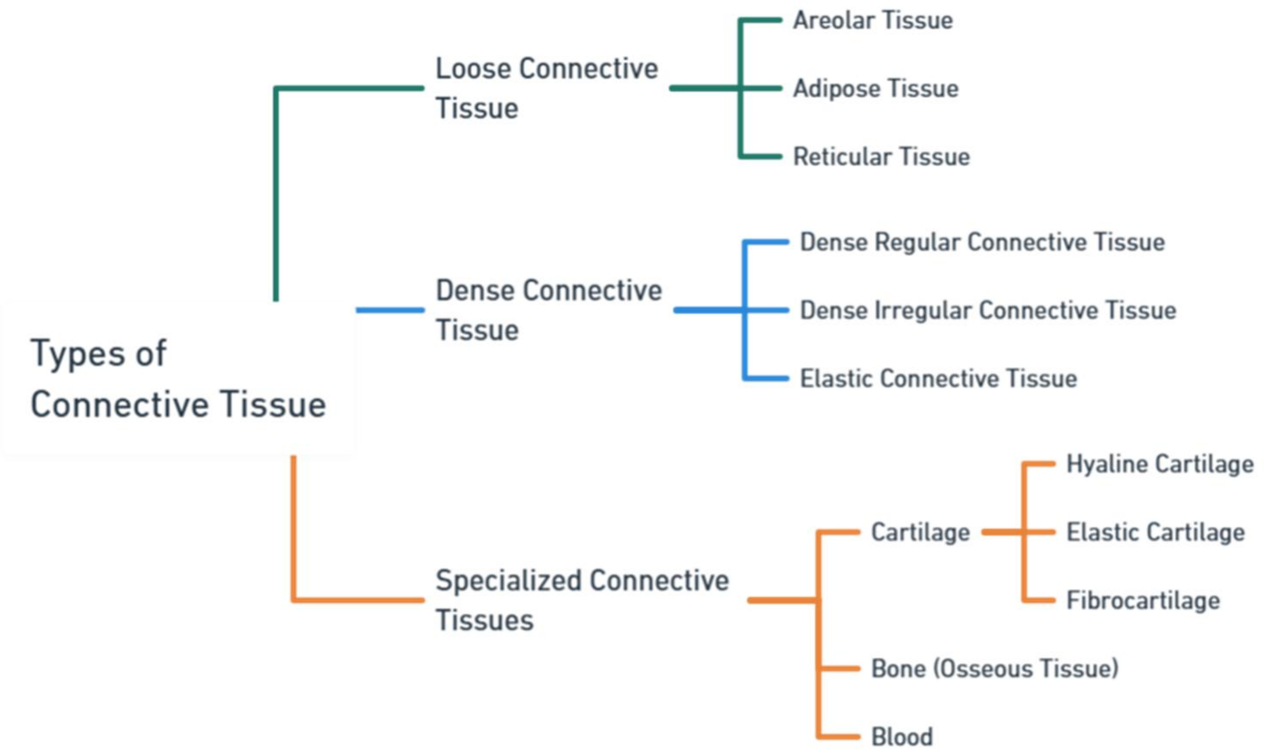
Functions:

1. **Protection:** Epithelial tissues protect the body from mechanical injury, harmful substances, and pathogens.
2. **Secretion:** Glandular epithelium secretes substances like hormones, enzymes, and mucus.
3. **Absorption:** Simple columnar and simple cuboidal epithelia help absorb nutrients in the gastrointestinal tract and kidney tubules.
4. **Transportation:** Ciliated epithelial cells help transport particles and mucus across their surfaces.

Connective tissue

- Connective tissues provide support, protection, and structure to the body.

Types of Connective Tissue



1. Loose Connective Tissue:

I. Areolar Tissue:

- **Structure:** Contains a loose arrangement of fibers and various cell types.
- **Location:** Widely distributed under epithelia, surrounds capillaries.
- **Function:** Provides cushioning, binds tissues, and allows for nutrient diffusion.

II. Adipose Tissue:

- **Structure:** Comprised mainly of adipocytes filled with fat droplets.
- **Location:** Under the skin (subcutaneous layer), around kidneys and eyeballs, within the abdomen, and in breasts.
- **Function:** Stores energy insulates against heat loss, and cushions organs.

III. Reticular Tissue:

- **Structure:** Network of reticular fibers with supportive cells.
- **Location:** Lymphoid organs (lymph nodes, bone marrow, and spleen).
- **Function:** Provides a supportive framework for soft organs.

2. Dense Connective Tissue:

I. Dense Regular Connective Tissue:

- **Structure:** Parallel collagen fibers with a few elastic fibers; major cell type is fibroblasts.
- **Location:** Tendons, ligaments, and aponeuroses.
- **Function:** Attaches muscles to bones or to muscles and bones to bones; withstands great tensile stress in one direction.

II. Dense Irregular Connective Tissue:

- **Structure:** Irregularly arranged collagen fibers with some elastic fibers; major cell type is fibroblasts.
- **Location:** Dermis of the skin, submucosa of digestive tract, fibrous capsules of organs and joints.
- **Function:** Withstands tension exerted in many directions; provides structural strength.

III. Elastic Connective Tissue:

- **Structure:** Dense regular connective tissue containing a high proportion of elastic fibers.
- **Location:** Walls of large arteries, within certain ligaments associated with the vertebral column, within the walls of the bronchial tubes.

- **Function:** Allows tissue to recoil after stretching; maintains pulsatile flow of blood through arteries; aids passive recoil of lungs following inspiration.

3. Specialized Connective Tissues

I. Cartilage:

A. Hyaline Cartilage:

- **Structure:** Amorphous but firm matrix with collagen fibers; chondrocytes lie in lacunae.
- **Location:** Embryonic skeleton ends of long bones in joint cavities, costal cartilages of the ribs, nose, trachea, and larynx.
- **Function:** Supports and reinforces; serves as a resilient cushion; resists compressive stress.

B. Elastic Cartilage:

- **Structure:** Similar to hyaline cartilage, but more elastic fibers in matrix.
- **Location:** External ear (pinna), epiglottis.
- **Function:** Maintains the shape of a structure while allowing great flexibility.

C. Fibrocartilage:

- **Structure:** Matrix similar to but less firm than that in hyaline cartilage; thick collagen fibers predominate.
- **Location:** Intervertebral discs, pubic symphysis, discs of knee joint.
- **Function:** Tensile strength allows it to absorb compressive shock.

II. Bone (Osseous Tissue):

- **Structure:** Hard, calcified matrix containing many collagen fibers; osteocytes lie in lacunae. Very well vascularized.
- **Location:** Bones.
- **Function:** Supports and protects (by enclosing); provides levers for the muscles to act on; stores calcium and other minerals and fat; marrow inside bones is the site for blood cell formation (hematopoiesis).

III. Blood:

- **Structure:** Red and white blood cells in a fluid matrix (plasma).
- **Location:** Contained within blood vessels.
- **Function:** Transports respiratory gases, nutrients, wastes, and other substances.

Structure:

- Connective tissues have fewer cells and more extracellular matrix than other tissues.

- The extracellular matrix consists of protein fibers (collagen, elastin, reticular) and ground substance.

Location:

- **Connective tissue proper:** Beneath the skin, around organs, tendons, ligaments, and bone marrow.
- **Specialized connective tissue:** Joints, rib cage, ear, and skeletal system.
- **Fluid connective tissue:** Blood vessels and lymphatic vessels.

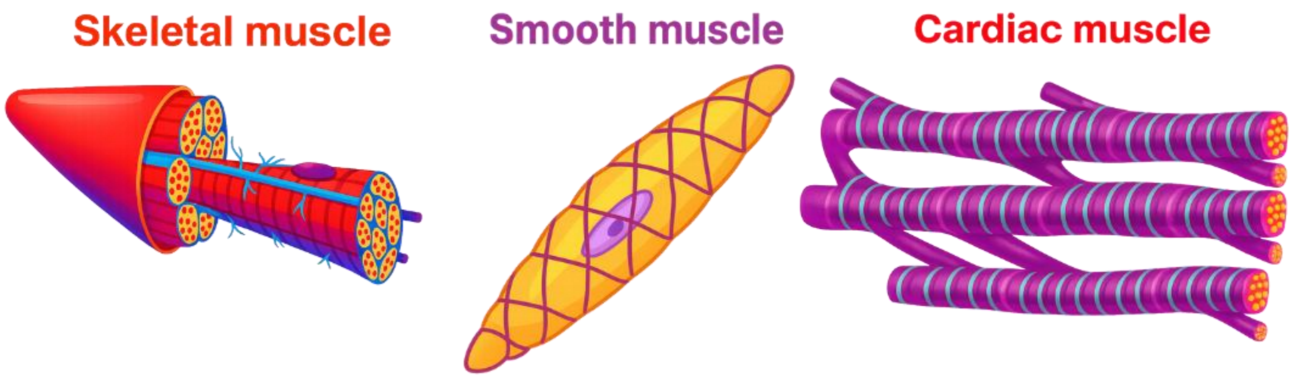
Functions:

- **Support:** Connective tissues bind and support other tissues and organs.
- **Protection:** They protect and cushion organs.
- **Insulation:** Adipose tissue stores energy and insulates the body.

Muscle tissue

- Muscle tissue is a specialized tissue found in animals which functions by contracting and thereby causing movement.
- This contraction is achieved through the interaction of actin and myosin filaments within muscle cells, known as muscle fibers.
- Muscle tissue is categorized into three types: skeletal muscle, cardiac muscle, and smooth muscle, each with distinct structures and functions.

Types of Muscle Tissue



1. Skeletal Muscle

- **Structure:** Long, cylindrical, multinucleated fibers with striations from actin and myosin filaments arranged in sarcomeres.
- **Location:** Attached to bones by tendons.
- **Function:** Responsible for voluntary movements, posture maintenance, and heat generation.
- **Control:** Voluntary, via the somatic nervous system.

2. Cardiac Muscle

- **Structure:** Branched cells (cardiomyocytes) connected by intercalated discs with gap junctions and desmosomes; striated like skeletal muscle.
- **Location:** Walls of the heart.
- **Function:** Pumps blood rhythmically and continuously.
- **Control:** Involuntary, regulated by the autonomic nervous system and intrinsic conduction systems.

3. Smooth Muscle

- **Structure:** Spindle-shaped cells with a single central nucleus; lacks striations due to less organized actin and myosin.
- **Location:** Walls of hollow organs (e.g., intestines, blood vessels, bladder, uterus).
- **Function:** Involuntary movements such as peristalsis, vasoconstriction, and contractions during childbirth.
- **Control:** Involuntary, via the autonomic nervous system.

Structure:

- **Skeletal muscle:** Multinucleated, long, cylindrical cells with a striated appearance.
- **Smooth muscle:** Spindle-shaped, uninucleated cells without striations.
- **Cardiac muscle:** Uninucleated, branched cells with striations and intercalated discs.

Microscopic Structure

1. Myofibrils:

- Each muscle fiber contains numerous myofibrils, which are the contractile elements made up of repeating units called sarcomeres.

2. Sarcomeres:

- The basic functional unit of a myofibril, consisting of actin (thin) and myosin (thick) filaments.
- The arrangement of these filaments gives skeletal and cardiac muscle their striated appearance.

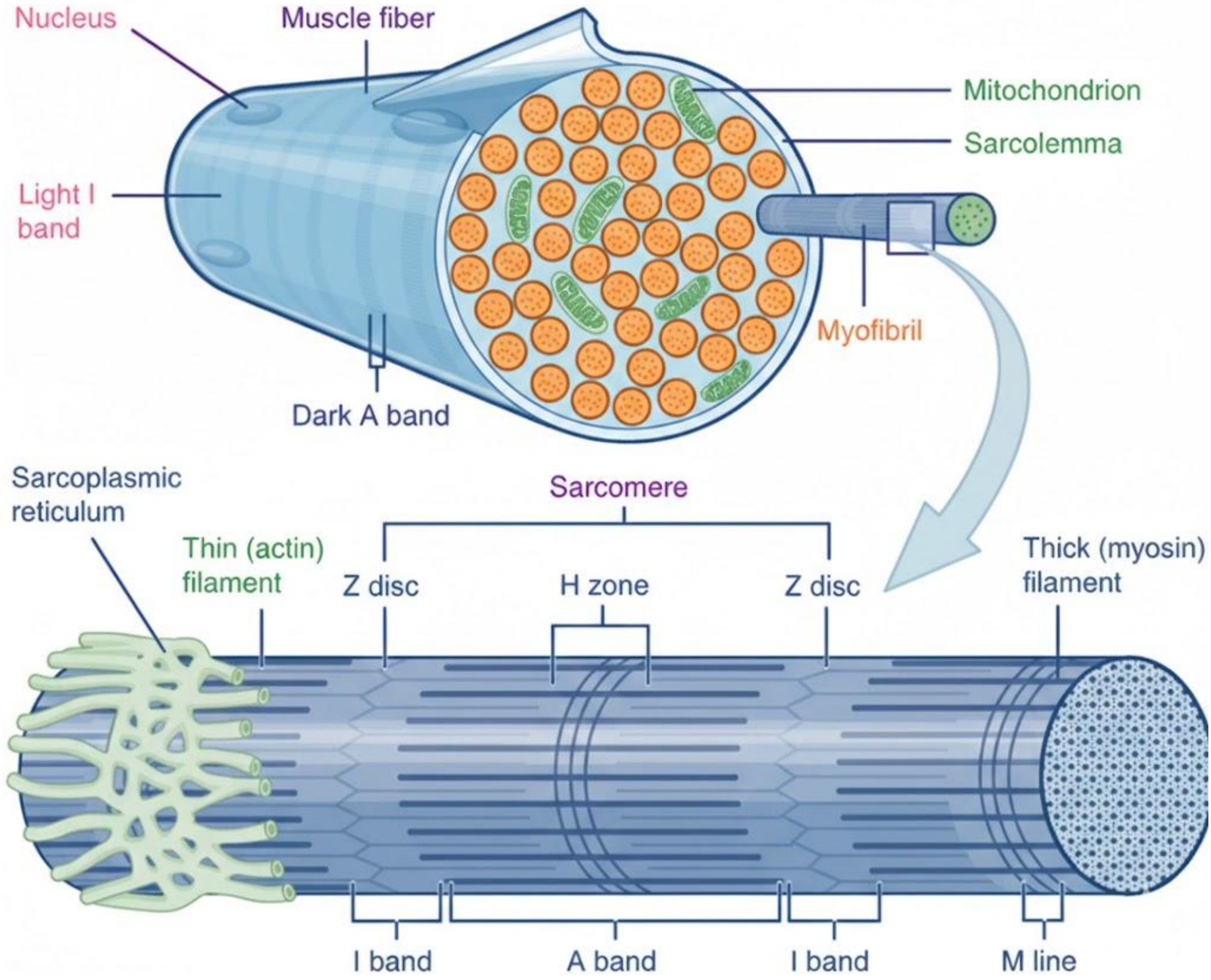
3. Sarcoplasmic Reticulum:

- A specialized form of the endoplasmic reticulum that stores and releases calcium ions, which are essential for muscle contraction.

4. Mitochondria:

- Muscle cells contain numerous mitochondria to meet the high energy demands required for contraction.

Muscle Fibre



Location:

- **Skeletal muscle:** Attached to bones by tendons.
- **Smooth muscle:** Walls of internal organs like the stomach, intestines, and blood vessels.
- **Cardiac muscle:** Heart.

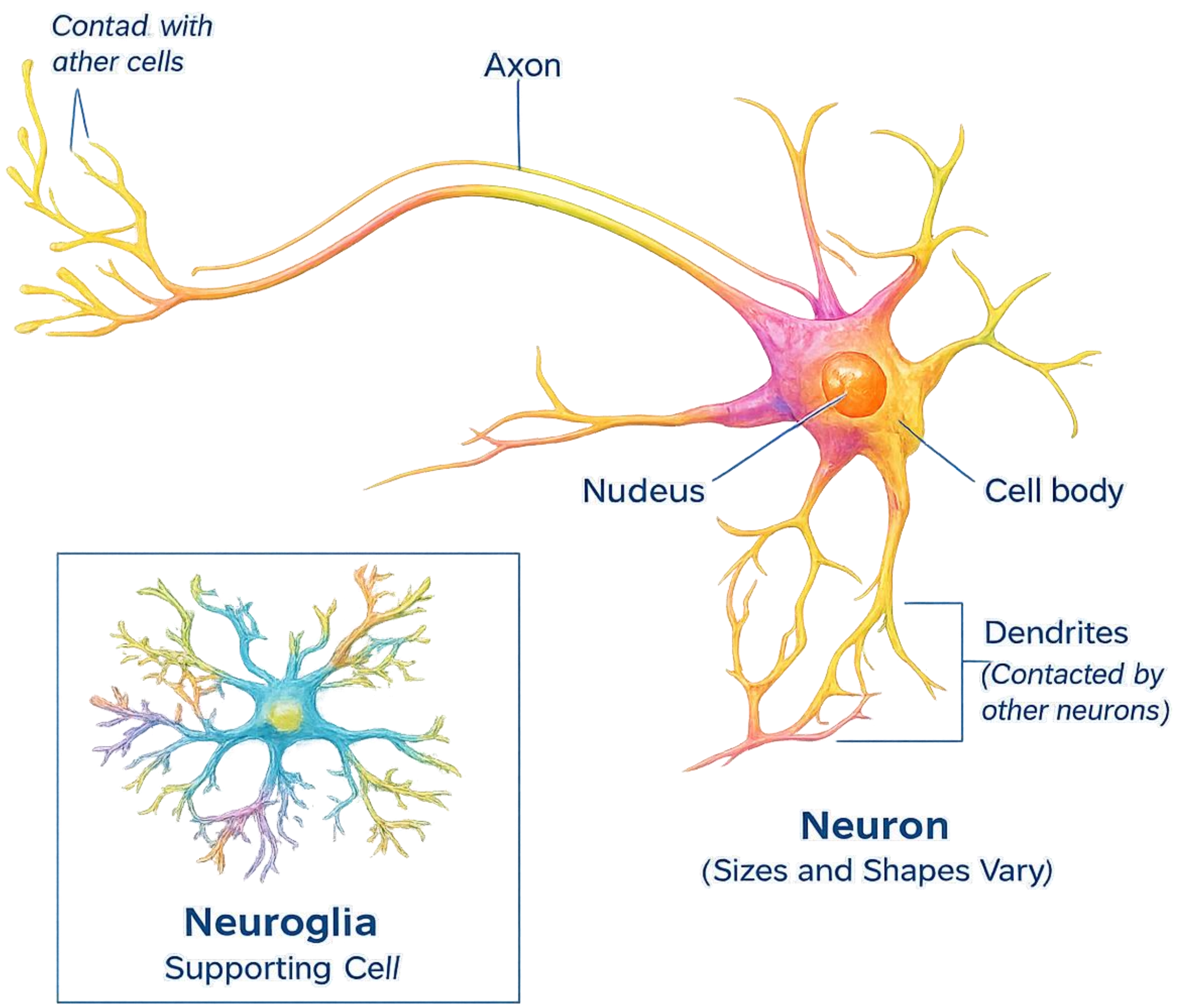
Functions:

- **Movement:** Muscle contractions enable body movement, facial expressions, and posture.
- **Regulation:** Smooth muscle contractions regulate blood flow and control the passage of food through the digestive system.
- **Pumping:** Cardiac muscle contractions pump blood throughout the body.

Nervous tissue

- Nervous tissue is a highly specialized tissue that forms the nervous system, responsible for coordinating and controlling many body activities.
- It consists of neurons and supporting cells known as neuroglia or glial cells.
- Nervous tissue is essential for sensing stimuli, transmitting signals, and regulating bodily functions.

Structure of Nervous Tissue



1. Neurons

I. **Cell Body (Soma)**: Contains the nucleus and other organelles. It is the metabolic center of the neuron.

II. **Dendrites**: Branched extensions from the cell body that receive signals from other neurons and conduct impulses toward the cell body.

III. **Axon**: A long, singular projection that transmits impulses away from the cell body to other neurons, muscles, or glands. The axon can be covered with a myelin sheath, which increases the speed of signal transmission.

IV. **Axon Terminals**: The endings of the axon that release neurotransmitters to communicate with other cells across synapses.

2. Neuroglia (Glial Cells)

I. **Astrocytes**: Star-shaped cells that provide structural support, regulate blood flow, maintain the blood-brain barrier, and influence synaptic activity.

II. **Microglia**: Act as the immune cells of the central nervous system, providing defense against pathogens and cleaning up cellular debris.

III. **Oligodendrocytes**: Produce the myelin sheath in the central nervous system.

IV. **Schwann Cells**: Produce the myelin sheath in the peripheral nervous system.

V. **Ependymal Cells**: Line the ventricles of the brain and the central canal of the spinal cord, involved in the production and circulation of cerebrospinal fluid.

VI. **Satellite Cells**: Surround neuron cell bodies in the peripheral nervous system, providing support and nutrients.

Types of Nervous Tissue

1. Gray Matter

- **Location**: Found in the brain (cerebral cortex and basal nuclei) and spinal cord (central region).
- **Components**: Consists mainly of neuron cell bodies, dendrites, and unmyelinated axons.
- **Function**: Involved in muscle control, sensory perception, decision making, and emotions.

2. White Matter

- **Location**: Found in deeper tissues of the brain and the outer portion of the spinal cord.
- **Components**: Consists primarily of myelinated axons.
- **Function**: Responsible for the transmission of signals between different parts of the brain and between the brain and spinal cord.

Functions of Nervous Tissue

1. Sensory Input:

- Detects internal and external stimuli through sensory receptors and transmits this information to the central nervous system.

2. Integration:

- Processes and interprets sensory input, deciding what action, if any, should be taken.

3. Motor Output:

- Sends signals to muscles and glands to elicit a response, such as muscle contraction or hormone release.

4. Homeostasis:

- Regulates and maintains stable internal conditions, such as temperature and pH balance, through feedback mechanisms.

5. Mental Activity:

- Facilitates cognitive functions such as thinking, memory, learning, and emotions.

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