Cellular Level of Organisation

At the foundation of life, the **cell** stands as the smallest unit exhibiting all characteristics of life, serving as the structural and functional unit of a living body. To sustain itself and contribute to the organism, each cell requires **nutrition and oxygen**, produces energy for growth and repair, eliminates metabolic wastes like **carbon dioxide**, maintains its immediate environment, and responds swiftly to threats such as bacteria. Most cells reproduce through division, though some, like neurons, are exceptions.

Key Organelles and Their Functions:

- **Rough endoplasmic reticulum:** Primarily responsible for the **synthesis of proteins** and the degradation of worn-out organelles.
- **Smooth endoplasmic reticulum:** Involved in the **synthesis of lipids and steroids**, plays a role in cellular metabolism, stores and metabolises calcium, and aids in the catabolism and detoxification of toxic substances.
- **Golgi apparatus:** Processes, packages, labels, and delivers proteins and lipids.
- **Lysosomes:** Degrade macromolecules and worn-out organelles, remove excess secretory products, and secrete perforin, granzymes, melanin, and serotonin.
- **Peroxisomes:** Break down excess fatty acids, detoxify hydrogen peroxide and other metabolic products, utilise oxygen, accelerate gluconeogenesis, degrade purine to uric acid, and contribute to the formation of myelin and bile acids.
- **Centrosome:** Facilitates the **movement of chromosomes during cell division**.
- **Mitochondria:** The powerhouses of the cell, responsible for **energy production**, ATP synthesis, and initiating apoptosis.
- **Ribosomes:** Sites of **protein synthesis**.
- **Cytoskeleton:** Determines cell shape, provides stability, and is involved in cellular movements.

- **Nucleus:** The control centre, regulating all cell activities, synthesising RNA, sending genetic instructions for protein synthesis, forming ribosome subunits, controlling cell division, and **storing hereditary information in genes**.

Transport Across Cell Membrane

Cells require a continuous supply of essential substances like nutrients, water, and electrolytes, while also needing to eliminate unwanted substances such as waste materials and carbon dioxide. This exchange is managed by transport mechanisms across the cell membrane. There are two primary types:

- **Passive Transport Mechanism:** This process does **not require energy**. Substances move along a **concentration or electrical gradient** (electrochemical gradient), from a region of higher concentration to a region of lower concentration, often called "downhill movement" or diffusion.

    - **Simple Diffusion:** Occurs directly through the lipid layer or protein layer of the membrane.
    - **Facilitated Diffusion:** Requires the help of carrier proteins in the cell membrane.
    - **Special Types of Passive Transport:**
        - **Bulk flow:** Diffusion of large quantities of substances from high to low pressure, driven by a pressure gradient.
        - **Filtration:** Movement of water and solutes from high to low hydrostatic pressure.
        - **Osmosis:** A specialised type of diffusion involving the movement of water or another solvent across a **semipermeable membrane** from an area of lower solute concentration to an area of higher solute concentration.
- **Active Transport Mechanism:** This mechanism requires **energy**, primarily obtained from the breakdown of **adenosine triphosphate (ATP)**, to move substances *against*

a chemical or electrochemical gradient.

    - When a substance approaches the cell membrane, it binds with a carrier protein to form a substance-protein complex, which then moves towards the inner surface of the membrane to release the substance. The carrier protein then moves back to transport another molecule.
    - **Primary Active Transport:** Energy is liberated directly from ATP breakdown to transport substances like sodium, potassium, calcium, hydrogen, and chloride across the cell membrane.
    - **Secondary Active Transport:** Involves the transport of a substance using a **sodium ion** and a common carrier protein. When sodium is transported, another substance is simultaneously transported by the same protein, either in the same direction or the opposite direction.

Cell Division

Cell division is a sequence of events where a cell duplicates its genome and other contents, eventually dividing into two daughter cells, a process termed the **cell cycle**. This is a highly coordinated, genetically controlled process.

- A typical eukaryotic somatic cell cycle includes two main stages: a long non-dividing **interphase** (I-phase) and a shorter nuclear dividing stage, **mitotic phase** (M-phase), followed by **cytokinesis** (C-phase), which is cytoplasmic division.

    - **Interphase** is a metabolically active period of intense synthesis and growth, divided into three periods: G1 phase (first gap phase), S-phase (synthesis phase), and G2-phase (second gap/growth phase).
    - The M-phase can be either **mitosis** or **meiosis**.
- **Mitosis (Somatic Cell Division / Duplication Division):** Occurs during the formation of body cells. It produces **diploid daughter cells with identical genetic**

complement to the mother cell, helps restore the nucleo-cytoplasmic ratio, and replaces old cells while increasing cell numbers within an organism.

- **Phases of Mitosis:**
  - **Interphase:** The first stage of the cell cycle before division, where the cell matures, copies its DNA, and prepares to divide.
  - **Prophase:** Chromatin condenses, spindle fibres form, and the nuclear membrane breaks apart.
  - **Metaphase:** Chromosomes line up along the **centre of the cell**, and spindle fibres attach to each chromosome at the centromere. This is considered the best phase to study chromosome morphology.
  - **Anaphase:** Spindle fibres split the centromere, and **chromatids move to opposite sides** of the cell.
  - **Telophase:** Chromosomes loosen, and the nuclear membrane begins to form around the chromatin.
  - **Cytokinesis:** The cell membrane pinches in (animal cells) or a cell plate forms (plant cells) at the middle, dividing the cell into two separate daughter cells. Each daughter cell receives half of the organelles and an **identical set of chromosomes**.

- **Meiosis (Specialised Cell Division / Reductional Division):** Reduces the **chromosome number by half**, producing **haploid daughter cells**. It ensures the haploid phase in sexually reproducing organisms, with fertilisation restoring the diploid phase. Meiosis involves two sequential cycles of nuclear and cell division (Meiosis I and Meiosis II) but only a single cycle of DNA replication.

  - **Meiosis I (Reductional Division / Heterotypic Division):** Changes the cell from diploid to haploid state.
    - **Prophase I:** Long and complex, divided into five stages:
      - **Leptotene:** Beaded, long chromosomes.

        - **Zygotene:** Chromosomes become shorter and thicker; bivalents or tetrads (paired homologous chromosomes) are seen; **synapsis occurs**.
        - **Pachytene:** Longest stage; tetrads clearly appear as spirally arranged homologous chromosomes; **crossing over occurs**, characterised by recombination nodules.
        - **Diplotene:** Bivalents repel each other; **chiasmata points** strongly appear.
        - **Diakinesis:** Terminalisation occurs; nuclear membrane disappears, centrioles migrate to poles, and spindle fibres begin to form.
    - **Metaphase I:** Chromosomes arrange at the **equator**, showing maximum condensation.
    - **Anaphase I: Homologous chromosomes move to opposite poles** without centromere breakage; nuclei form.
    - **Telophase I:** Chromosomes elongate, and **two haploid cells** are formed.
- **Meiosis II (Equational Division / Homotypic Division):** Maintains the haploid number.
    - **Prophase II:** Initiated after cytokinesis, resembles normal mitosis. Chromosomes become compact.
    - **Metaphase II:** Chromosomes align at the **equator**; microtubules attach to kinetochores of sister chromatids.
    - **Anaphase II: Centromeres of each chromosome split simultaneously**, and chromatids move to opposite poles by shortening microtubules.
    - **Telophase II:** The last stage, where two groups of chromosomes are enclosed by a nuclear envelope. Cytokinesis follows, resulting in the formation of a tetrad of cells, i.e., **four haploid daughter cells**.

Cell Junctions

Cell junctions are connections between neighbouring cells or between a cell and the extracellular matrix, also known as membrane junctions. They are classified into three types:

- **Occluding Junctions (Tight Junctions):** Prevent the **intercellular exchange of substances**, stopping the movement of ions and molecules from one cell to another. They provide **strength and stability** to tissues, ensure selective permeability, act as a fencing function, maintain cell polarity, and form the blood-brain barrier. Examples include epithelial lining of intestinal mucosa and renal tubule, and endothelium in capillary walls.
- **Communicating Junctions (Gap Junctions / Chemical Synapse):** Permit the **intercellular exchange of substances**, allowing the movement of ions and molecules between cells. They facilitate the passage of small molecules, ions, and chemical messengers, and enable the propagation of action potential. Found in epithelial lining, heart, and intestine.
- **Anchoring Junctions (Adherens Junctions, Focal Adhesions, Desmosomes, Hemidesmosomes):** Provide **strength and structural attachments** between cells or between a cell and the extracellular matrix. They are crucial for the **structural integrity of tissues**, found in heart muscle and the epidermis of skin.
    - **Adherens junctions:** Involve cadherins for cell-to-cell attachment, found in epithelial lining and heart intestine.
    - **Focal adhesions:** Involve integrins for cell attachment to the basal lamina and extracellular matrix, found in epithelial lining.
    - **Desmosomes:** Involve cadherins for cell-to-cell attachment, found in epithelial lining and skin.
    - **Hemidesmosomes:** Involve integrins for cell attachment to the basal lamina and extracellular matrix, found in epithelial lining.

General Principles of Cell Communication (Cell Signalling)

Cell signalling, or signal transduction, is the ability of cells to respond to stimuli from their environment. This communication, whether between cells (**intercellular signalling**) or within a cell (**intracellular signalling**), is vital for various processes such as wound healing, immune system activation, and developmental changes.

- **Signalling molecules (Ligands)** initiate the cell signalling process. These can be proteins, lipids, amino acid metabolites, gases, and many other molecules.
- **Receptors** are proteins that respond to ligands. When a ligand binds to a specific receptor, the receptor undergoes a conformational change, transmitting a signal into the cell. This specificity arises because signalling molecules have unique characteristics that permit them to bind to complementary regions on receptors.

Types of Cell Signalling:

- **Endocrine Signalling (Long-range):** Signals, called **endocrine signals**, originate from **endocrine cells** (often located in endocrine glands) and travel through the bloodstream to distant target cells. These signals typically produce a **slower but longer-lasting effect**. Ligands in endocrine signalling are called **hormones**.
- **Paracrine Signalling (Short-range):** Signalling cells secrete signal molecules into the **extracellular fluid**. These molecules act as **local mediators**, affecting only cells in the immediate local environment of the signalling cell.
- **Synaptic Signalling:** An example of paracrine signalling where nerve cells transmit signals. An electrical impulse travels down a neuron's **axon** to a **synapse** (the junction between nerve cells). This triggers the release of **neurotransmitters** (ligands) into the small gap between nerve cells, which then bind to receptors on the receiving cell, causing a chemical change.
- **Contact-dependent Signalling (Juxtacrine Signalling):** Cells **physically interact** to initiate signalling. This can occur via **gap junctions** or through direct interactions of **transmembrane proteins**. The signalling molecule/ligand is bound to the membrane

of one cell, requiring direct contact with the receptor on the target cell to deliver the signal.

Intracellular signalling pathways are activated by extracellular signal molecules that bind to **cell-surface receptor proteins**. This leads to a cascade involving intracellular signalling proteins like **kinases, phosphatases, and GTP-binding proteins**, which ultimately alter **target proteins**. These target proteins, which can be gene regulatory proteins, ion channels, metabolic pathway components, or parts of the cytoskeleton, change the cell's behaviour depending on the signal's effect.

Levels of Structural Organisation and Body Systems

The human body's vital processes are controlled and maintained by different levels of structural organisation, which show an increase in structural complexity and function. There are six fundamental levels:

1. **Chemical Level:** The most basic level, involving **atoms** (e.g., carbon, hydrogen, oxygen, nitrogen, phosphorus, calcium, sulphur) that participate in chemical reactions to form **molecules**.
2. **Cellular Level:** The **most basic structural and functional unit of the human body**. Different molecules combine to form cells, which vary greatly in structure and function, with each type performing a specific task (e.g., muscle cells, nerve cells, epithelial cells).
3. **Tissue Level:** A **group of cells that work together** to perform a particular function. The human body has four basic types: epithelial, connective, muscular, and nervous tissue.
4. **Organ Level:** Different types of **tissue combine to form an organ**, which has specific functions and a recognisable shape (e.g., stomach, skin, heart, lungs, brain).
5. **System Level:** A group of **organs that combine to form a system** to perform a major physiological function. The human body comprises eleven organ systems (e.g.,

integumentary, skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, reproductive, special sensory organs).

6. **Organism Level:** The **highest level of structural organisation**, where all parts of the human body function together to constitute the **total organism**, capable of independently performing vital functions necessary for life.

Body Systems

The human body is composed of eleven organ systems, each with specific organs and functions:

- **Digestive System:**
  - **Organs:** Mouth, pharynx, oesophagus, stomach, small and large intestine, anus, and accessory organs (salivary glands, liver, gallbladder, pancreas).
  - **Functions:** Mechanical and chemical breakdown of food, absorption of nutrients, and elimination of solid wastes.
- **Urinary System:**
  - **Organs:** Kidneys, ureters, urinary bladder, and urethra.
  - **Functions:** Produces, stores, and eliminates urine, eliminates wastes, regulates blood volume and chemical composition, maintains acid-base balance of body fluids, and maintains mineral balance.
- **Respiratory System:**
  - **Organs:** Nose, lungs, pharynx, larynx, trachea, and bronchial tubes.
  - **Functions:** Transfers oxygen from inhaled air to blood and carbon dioxide from blood to exhaled air, helps regulate acid-base balance of body fluids, and produces sound by the vocal cord.
- **Lymphatic System:**
  - **Organs:** Lymph, lymph vessels, spleen, thymus, lymph nodes, and tonsils.

    - **Functions:** Returns proteins and fluid to blood, carries lipids from the gastrointestinal tract to blood, and lymphatic cells protect against disease-causing microbes.
- **Endocrine System:**
    - **Organs:** Pineal gland, hypothalamus, pituitary gland, thymus, thyroid gland, parathyroid glands, adrenal glands, pancreas, ovaries, and testes.
    - **Functions:** Regulates body activities by releasing **hormones**, which affect specific target cells and alter their metabolism, typically with a relatively longer effect.
- **Male Reproductive System:**
    - **Organs:** Testes, epididymis, ductus deferens, and penis.
    - **Functions:** Produces and releases sex hormones, produces, stores, and transports sperm, and discharges sperm in the female reproductive tract.
- **Female Reproductive System:**
    - **Organs:** Ovaries, uterine tubes, uterus, and vagina.
    - **Functions:** Produces ova necessary for fertilisation, transports ova to the site of fertilisation, enables sperm to enter the body, and provides a favourable environment for the developing embryo.
- **Muscular System:**
    - **Organs:** Skeletal muscle and tendons.
    - **Functions:** Produces body movements (e.g., walking, running), stabilises body posture, and generates heat.
- **Integumentary System:**
    - **Organs:** Skin, hair, nails, sebaceous glands, and sweat glands.
    - **Functions:** Protects underlying tissues, prevents loss of body fluids, maintains normal body temperature, and secretes substances such as salt, water, and organic wastes.
- **Special Sense System:**
    - **Organs:** Eyes, ears, skin, tongue, and nose.

- **Functions:** Detects changes in the body's internal and external environments, including vision, hearing, smell, taste, touch, and general sensations.

Basic Life Processes

Nine fundamental life processes characterise living organisms:

1. **Responsiveness:** The body's ability to **detect and respond to changes** in the environment. Different cells respond in various ways.
2. **Metabolism:** The **sum of all chemical processes** occurring in the body. It includes **catabolism** (breakdown of complex substances into simpler components) and **anabolism** (building up of chemical substances from smaller components).
3. **Movement:** Includes the motion of the whole body, individual organs, and even tiny structures inside cells.
4. **Growth:** An increase in body size due to an **increase in the size of existing cells** or an **increase in the number of cells**.
5. **Differentiation:** The **development of a cell from an unspecialised to a specialised state**. This process leads to the formation of an embryo, foetus, infant, child, and ultimately an adult from a fertilised egg.
6. **Reproduction:** Refers to the formation of **new cells for tissue growth, repair, or replacement**, or to the **production of a new individual**. In humans, fertilisation of an ovum by a sperm results in embryo development.
7. **Respiration:** Involves the **exchange of oxygen and carbon dioxide** between cells and the external environment, including their diffusion and transport in the blood.
8. **Digestion:** The process of **breaking down complex ingested foods** into simple molecules that can be absorbed and utilised for energy. It involves both mechanical and chemical processes.
9. **Excretion:** The process that **removes waste products of digestion and metabolism** from the body. The kidneys play a crucial role in eliminating nitrogenous waste materials.

Homeostasis

Homeostasis is the body's or a cell's ability to **maintain a condition of equilibrium within its internal environment** despite external changes. It is a dynamic condition, ensuring constant body temperature, blood sugar levels, and blood pH are maintained for physiological processes.

- The body constantly adapts to changes in equilibrium. Disruptions can arise from external factors (e.g., intense heat, lack of oxygen) or psychological stress. Usually, the body quickly restores balance.

- **Feedback Systems** are cycles of events where a body condition is monitored, evaluated, altered, and re-evaluated. A monitored variable (e.g., body temperature, blood pressure) is a **controlled condition**. Any disruption to this is a **stimulus**.

    - A feedback system has three components:
        - **Receptor:** A body structure that **monitors changes** in a controlled condition and sends input (nerve impulses or chemical signals) to the **control centre**.
        - **Control Centre:** Often the **brain**, which evaluates the input from receptors and generates output commands (nerve impulses, hormones, or other chemical signals).
        - **Effector:** A body structure that **receives output** from the control centre and produces a response that alters the controlled condition (e.g., shivering to raise body temperature).
- There are two types of feedback:

    - **Negative Feedback:** The system reacts to **reverse the direction of change** or arrest the change, thus stabilising its function and attempting to maintain homeostasis. For example, if thyroxine levels increase, the pituitary gland is

inhibited from secreting TSH, which in turn reduces thyroxine secretion. Maintaining water balance is another example.

- **Positive Feedback:** The system reacts to **increase the intensity of the change** in the same direction. A key example is **blood clotting**, where thrombin formation stimulates the production of more prothrombin activator, accelerating the clotting process. Other examples include milk ejection reflex and parturition (labour), both involving oxytocin secretion.

Basic Anatomical Terminologies

To communicate effectively and precisely in anatomy, specific terms are used, always referring to the body in the **anatomical position** (facing the observer, feet parallel, upper limbs hanging sideways, palms facing forward).

- **Regional Terms:** Describe specific regions of the body.

  - **Cephalic region (cranial):** Entire head region, including frontal (forehead), nasal (nose), occipital (base of skull), oral (mouth), and orbital/ocular (eyes).
  - **Cervical region:** Below the head, ending at the thorax, consisting of seven cervical vertebrae (C1-C7).
  - **Dorsal region:** Back portion of the body, immediately below the neck, up to the area below the waist, excluding the shoulders.
  - **Thorax region:** Upper area of the trunk, between the base of the neck and the bottom of the ribcage, including axillary (armpit), costal (ribs), deltoid (shoulder), mammary (breast), pectoral (chest), scapular (shoulder blade), sternal (breastbone), and vertebral (backbone).
  - **Abdomen region:** Starts along the bottom of the ribcage and extends up to the hips, divided into nine parts: right and left hypochondrium, epigastrium, right and left lumbar regions, umbilical region, right and left inguinal regions, and hypogastrium.

    - **Pelvic region:** Below the abdomen, takes up the area between the hip bones.
    - **Upper extremity region:** Includes antebrachial (forearm), antecubital (inner elbow), brachial (upper arm), carpal (wrist), cubital (elbow), digital (fingers/toes), manual (hand), and palmar (palm).
    - **Lower extremity region:** Includes crural (shin, front of lower leg), femoral (thigh), patellar (front of knee), pedal (plantar of arch of foot), popliteal (back of knee), sural (calf, back of lower leg), and tarsal (ankle).
- **Sectional Planes:** Describe cuts through the body.

    - **Frontal section (coronal plane):** A section that divides the body into **dorsal (back) and ventral (front) portions**.
    - **Midsagittal section (median plane):** A section that divides the body into **right and left halves**.
    - **Horizontal section (transverse plane):** A section that divides the body into **upper and lower portions**.

Tissue Level of Organisation

A **tissue** is a group of cells that usually share a common embryonic origin and work together to carry out specialised activities. The human body is composed of four primary types of tissues:

1. **Epithelial Tissue:** Covers body surfaces, lines hollow organs, body cavities, and ducts. It also forms glands.

    - **Structure:** Consists of cells arranged in **continuous sheets**, single or multiple layers. It has an **apical (free) surface** facing a body surface or cavity, a **basal surface** adhering to extracellular materials via **hemidesmosomes**, and **lateral surfaces** contacting adjacent cells. Apical surfaces may contain cilia or microvilli.

- **Location:** Forms **coverings and linings** throughout the body.
- **Functions:** Serves as **selective barriers** for substance transfer, provides **secretory surfaces** (releasing products onto free surfaces), and acts as **protective surfaces** against abrasion.
- **Types and Functions (Examples):**
  - **Simple squamous epithelium:** Allows material passage (e.g., air sacs of lungs, lining of blood vessels).
  - **Simple cuboidal epithelium:** Secretes and absorbs (e.g., ducts of small glands, kidney tubules).
  - **Simple columnar epithelium:** Absorbs and secretes mucus and enzymes (e.g., ciliated tissues in bronchi, uterus; smooth tissues in digestive tract, bladder).
  - **Pseudostratified columnar epithelium:** Secretes mucus, ciliated tissue moves mucus (e.g., trachea, upper respiratory tract).
  - **Stratified squamous epithelium:** Protects against abrasion (e.g., oesophagus, mouth, vagina).
  - **Stratified cuboidal epithelium:** Protective tissue (e.g., sweat glands, salivary glands, mammary glands).
  - **Stratified columnar epithelium:** Secretes and protects (e.g., male urethra, ducts of some glands).
  - **Transitional epithelium:** Allows urinary organs to expand and stretch (e.g., bladder, urethra, ureters).

2. **Muscular Tissue:** Generates physical force for body movement and heat. Consists of elongated cells called **muscle fibres** or myocytes that use ATP to generate force.

   - **Types:**
     - **Skeletal Muscle Tissue:**
       - **Description:** Long, cylindrical, striated fibres with many peripherally located nuclei; under **voluntary control**.

        - **Location:** Attached to bones by tendons.
        - **Function:** Motion, posture, heat production, protection.
    - **Smooth Muscle Tissue:**
        - **Description:** Spindle-shaped, nonstriated fibres with one centrally located nucleus; under **involuntary control**.
        - **Location:** Iris of the eyes, walls of hollow internal structures (blood vessels, airways, stomach, intestines, gallbladder, urinary bladder, ureters).
        - **Function:** Motion (e.g., constriction of blood vessels, propulsion of food).
    - **Cardiac Muscle Tissue:**
        - **Description:** Branched, striated fibres with one or two centrally located nuclei; contains **intercalated discs**; under **involuntary control**.
        - **Location:** Heart wall.
        - **Function:** Pumps blood to all parts of the body.
3. **Nervous Tissue:** Detects changes inside and outside the body, responds by generating action potentials (nerve impulses), and activates muscular contractions and glandular secretions.

    - **Structure:** Consists of **neurons (nerve cells)** with a cell body and processes (axon and dendrites) extending from it, and **neuroglia** (supporting cells). Neuroglia do not generate or conduct nerve impulses but provide important supporting functions.
    - **Location:** Nervous system.
    - **Function:** Exhibits **sensitivity to various stimuli**, converts stimuli into nerve impulses, and conducts impulses to other neurons, muscle fibres, or glands.
4. **Connective Tissue:** The most abundant and widely distributed tissue. It binds, supports, and strengthens other body tissues, protects and insulates internal organs,

compartmentalises structures (e.g., skeletal muscles), serves as a major transport system, stores energy, and is a primary site of immune responses.

- **General Features:** Consists of **extracellular matrix** (material between widely spaced cells) and cells. The extracellular matrix contains **protein fibres** (e.g., collagen, elastic, reticular) and **ground substance**, and its qualities determine the tissue's properties. Connective tissues are generally highly vascular and have a rich blood supply. Mesodermal embryonic cells called **mesenchymal cells** give rise to connective tissue cells. Mature cells have reduced capacities for cell division and matrix formation, mostly involved in maintaining the matrix.
- **Classification:**
  - **Embryonic Connective Tissue:**
    - **Mesenchyme:** Irregularly shaped mesenchymal cells embedded in a **semifluid ground substance with reticular fibres**. Found under skin, along developing bones of embryo, and along blood vessels. Forms all other types of connective tissue.
    - **Mucous Connective Tissue:** Widely scattered fibroblasts embedded in a **viscous, jelly-like ground substance** with fine collagen fibres. Found in the umbilical cord of the foetus, providing support.
  - **Mature Connective Tissue:**
    - **Loose Connective Tissue:**
      - **Areolar Connective Tissue:** Fibres (collagen, elastic, reticular) and cells (fibroblasts, macrophages, plasma cells, adipocytes, mast cells) embedded in a semifluid ground substance. Located deep to skin, in dermis, mucous membranes, around blood vessels, nerves, and body organs. Provides **strength, elasticity, and support**.

        - **Adipose Tissue:** Consists of **adipocytes** that store **triglycerides (fats)**, with large central lipid droplets and nuclei/cytoplasm located peripherally. Located in subcutaneous layer around heart, kidneys, yellow bone marrow, joint pads, and behind the eyeball. Reduces heat loss through skin, serves as an energy reservoir, and protects. Brown adipose tissue in newborns generates heat to maintain body temperature.
        - **Reticular Connective Tissue:** A network of interlacing **reticular fibres and reticular cells**. Forms the **stroma of organs** (e.g., liver, spleen, lymph nodes, red bone marrow), binds smooth muscle tissue cells, and filters/removes worn-out blood cells/microbes in spleen and lymph nodes.
    - **Dense Connective Tissue:**
        - **Dense Regular Connective Tissue:** Shiny white extracellular matrix of **collagen fibres arranged in bundles**, with fibroblasts in rows. Forms **tendons**, most **ligaments**, and **aponeuroses**. Provides **strong attachment** between various structures.
        - **Dense Irregular Connective Tissue:** Consists of **collagen fibres and few fibroblasts**. Located in fasciae, dermis of skin, periosteum, perichondrium, joint capsules, membrane capsules around organs, pericardium, and heart valves. Provides **strength**.
        - **Elastic Connective Tissue:** Consists of **branching elastic fibres** with fibroblasts. Found in lung tissue, walls of elastic arteries, trachea, bronchial tubes, true vocal cords, suspensory ligament of penis, and some ligaments between vertebrae. Allows for **stretching of various organs**.

- **Cartilage:**
  - **Hyaline Cartilage:** Bluish-white, shiny ground substance with thin, fine **collagen fibres and many chondrocytes**. Most abundant type. Located at ends of long bones, anterior ends of ribs, nose, parts of larynx, trachea, bronchi, bronchial tubes, and embryonic/foetal skeleton. Provides **smooth surfaces for movement at joints**, flexibility, and support.
    - **Fibrocartilage:** Chondrocytes scattered in **thick bundles of collagen fibres** within the extracellular matrix. Located in pubic symphysis, intervertebral discs, menisci (cartilage pads) of knee, and portions of tendons that insert into cartilage. Provides support and fusion.
    - **Elastic Cartilage:** Chondrocytes in a threadlike network of **elastic fibres** within the extracellular matrix. Located in the epiglottis, auricle, and Eustachian tubes. Gives support and maintains shape.
- **Bone Tissue:**
  - **Compact Bone Tissue:** Consists of **osteons** (Haversian systems) containing lamellae, lacunae, osteocytes, canaliculi, and central (Haversian) canals.
  - **Spongy Bone Tissue:** Consists of thin columns called **trabeculae**; spaces between trabeculae are filled with red bone marrow.
  - **Location:** Both compact and spongy bone tissue make up the various parts of bones in the body.
  - **Function:** Supports, protects, stores, forms blood, and acts with muscle tissue to enable **movement**.
- **Liquid Connective Tissue:**
  - **Blood:**

- **Description:** Consists of **blood plasma** and formed elements: **red blood cells (erythrocytes)**, **white blood cells (leukocytes)**, and **platelets (thrombocytes)**.
- **Location:** Within blood vessels (arteries, arterioles, capillaries, venules, and veins) and within the chambers of the heart.
- **Function:** Red blood cells transport **oxygen and carbon dioxide**; white blood cells carry out phagocytosis and are involved in allergic reactions and immune responses; platelets are essential for **blood clotting**.

This comprehensive overview highlights the intricate biological processes and structural organisation that underpin the human body, from the microscopic cellular level to complex organ systems and specialized tissues.