1. (a) Differentiate between :

(i) Sagittal and Coronal plane

- Sagittal plane:
    - The sagittal plane is a vertical plane that divides the body or an organ into right and left parts.
    - A midsagittal plane divides the body into equal right and left halves, passing through the midline.
    - Parasagittal planes divide the body into unequal right and left parts.
- Coronal plane:
    - The coronal (or frontal) plane is a vertical plane that divides the body or an organ into anterior (front) and posterior (back) parts.
    - It runs perpendicular to the sagittal plane.

(ii) Hyaline and fibrous cartilage

- Hyaline cartilage:
    - Hyaline cartilage is the most abundant type of cartilage in the body.
    - It has a smooth, glossy, bluish-white appearance.
    - Its matrix contains fine collagen fibers (Type II collagen) that are not visible under a light microscope.
    - It provides smooth surfaces for joint movement, flexibility, and support.
    - Location: Articular surfaces of bones, nose, trachea, bronchi, ends of ribs.
- Fibrous cartilage:

- Fibrous cartilage (or fibrocartilage) is the strongest type of cartilage.
- It contains numerous thick bundles of collagen fibers (Type I collagen) that are visible under a light microscope, giving it a fibrous appearance.
- It is designed to resist compression and tension, acting as a shock absorber.
- Location: Intervertebral discs, menisci of the knee, pubic symphysis, portions of tendons that insert into cartilage.

(iii) Iron deficiency anaemia and folic acid deficiency anaemia

- Iron deficiency anaemia:
  - Cause: Occurs due to insufficient iron in the body, which is essential for the synthesis of hemoglobin.
  - Red Blood Cells (RBCs): Characterized by microcytic (smaller than normal) and hypochromic (paler than normal) RBCs.
  - Symptoms: Fatigue, weakness, pallor, shortness of breath, brittle nails, pica (craving for non-food items).
  - Treatment: Iron supplementation, addressing underlying cause of iron loss or inadequate intake.
- Folic acid deficiency anaemia:
  - Cause: Results from inadequate intake or absorption of folic acid (Vitamin B9), which is crucial for DNA synthesis and RBC maturation.
  - Red Blood Cells (RBCs): Characterized by macrocytic (larger than normal) and megaloblastic (immature) RBCs.
  - Symptoms: Fatigue, weakness, pallor, sore tongue, gastrointestinal disturbances. Neurological symptoms are not typically seen, unlike B12 deficiency.

- Treatment: Folic acid supplementation, addressing underlying cause.

(iv) Calcification and Ossification

- Calcification:
  - Calcification is the process where calcium salts (primarily calcium phosphate) accumulate in a tissue.
  - It can occur in both normal and abnormal tissues.
  - In normal physiological processes, it is a precursor to ossification.
  - In pathological conditions, it can occur in soft tissues (dystrophic calcification) or due to hypercalcemia (metastatic calcification).
- Ossification:
  - Ossification (or osteogenesis) is the process of bone formation.
  - It involves the deposition of a mineralized matrix (primarily calcium phosphate and collagen) by specialized cells called osteoblasts, leading to the formation of true bone tissue.
  - It is a highly regulated biological process that involves the orderly deposition of bone matrix, often preceded by calcification of cartilage or fibrous tissue.
  - Two main types: Intramembranous ossification (forms flat bones directly from mesenchymal tissue) and endochondral ossification (forms most bones by replacing a cartilage model).

(b) Define :

(i) Motor end plate

- The motor end plate is a specialized region of the sarcolemma (muscle cell membrane) at the neuromuscular junction.

- It contains a high concentration of acetylcholine receptors and is responsible for receiving signals from motor neurons, leading to muscle contraction.

(ii) Anaemia

- Anaemia is a condition characterized by a lower-than-normal number of red blood cells (RBCs) or a reduced amount of hemoglobin in the blood.
- This leads to a decreased capacity of the blood to carry oxygen to the body's tissues, resulting in symptoms such as fatigue, pallor, and shortness of breath.

(iii) Myopia

- Myopia, commonly known as nearsightedness, is a vision condition in which close objects appear clear, but distant objects appear blurred.
- It occurs when the eyeball is too long or the cornea is too curved, causing light rays to focus in front of the retina instead of directly on it.

(iv) Chondroblast

- Chondroblasts are immature cells responsible for forming cartilage.
- They secrete the extracellular matrix of cartilage, which primarily consists of collagen fibers, elastic fibers, and ground substance (proteoglycans and hyaluronic acid).
- Once surrounded by matrix, chondroblasts mature into chondrocytes.

(v) Synapse

- A synapse is a specialized junction between two nerve cells (neurons), or between a neuron and an effector cell (like a muscle or gland cell), that allows for the transmission of electrical or chemical signals.

- It typically consists of a presynaptic terminal, a synaptic cleft, and a postsynaptic membrane.

(c) State True/False and justify (any four) :

(i) A nerve never shows all and none phenomenon.

- False.
- Justification: Individual nerve fibers (axons) within a nerve show the all-or-none phenomenon. This means that if a stimulus reaches the threshold intensity, the axon will fire a full-strength action potential, regardless of further increases in stimulus intensity. If the stimulus is below threshold, no action potential will be generated. However, a whole nerve (a bundle of many axons) does not show an all-or-none response because it contains nerve fibers with different thresholds. As the stimulus intensity increases, more and more individual fibers are recruited, leading to a graded response of the entire nerve.

(ii) In the blood smear of leukemic patients several band neutrophils are seen.

- True.
- Justification: Leukemia is a cancer of blood-forming tissues, leading to an overproduction of abnormal white blood cells (leukocytes). In many forms of leukemia, particularly acute myeloid leukemia (AML), there is a proliferation of immature myeloid cells. Band neutrophils are immature neutrophils (a type of white blood cell) that indicate a "left shift," meaning the bone marrow is releasing more immature forms into the blood in response to infection or, in this case, uncontrolled proliferation associated with leukemia. The presence of numerous band neutrophils, along with other immature forms (blasts), is characteristic of leukemic blood smears.

(iii) Injury to the epidermis does not lead to excessive bleeding.

- True.

- Justification: The epidermis, the outermost layer of the skin, is avascular, meaning it does not contain blood vessels. Therefore, superficial injuries limited to the epidermis (like a minor scratch or a first-degree burn) will not cause bleeding. Bleeding only occurs when the injury extends into the dermis, which is the vascularized layer beneath the epidermis.

(iv) Organ do not float inside our body.

- True.
- Justification: Organs within the body are held in place by various anatomical structures, including:
    - Connective tissues: Ligaments, mesenteries, and fascia provide support and anchor organs to the body wall or to other organs.
    - Serous membranes: Peritoneum (in the abdomen), pleura (around lungs), and pericardium (around heart) enclose organs and create fluid-filled spaces that reduce friction, but also contribute to their positioning.
    - Surrounding muscles and skeletal framework: The muscular and skeletal systems provide a framework that holds many organs.
    - Intrabody pressure: The pressure within body cavities (e.g., abdominal pressure) also contributes to keeping organs in their place. If organs were truly "floating," they would be subject to uncontrolled movement and could not function effectively.

2. Write short notes on :

(i) Platelet Plug formation

- Platelet plug formation is the second step in hemostasis (the process of stopping bleeding) after vascular spasm.

- It begins when there is damage to a blood vessel, exposing the underlying collagen fibers in the subendothelial layer.
- Platelets, small, anucleated cell fragments, adhere to the exposed collagen with the help of von Willebrand factor (vWF), which acts as a bridge. This process is called platelet adhesion.
- Upon adhesion, platelets become activated. They change shape, becoming spiky and sticky, and release the contents of their granules. These released substances include:
    - ADP (adenosine diphosphate): Potent activator of other platelets, causing them to become sticky.
    - Thromboxane A_2 (TXA_2): A prostaglandin that promotes vasoconstriction and further platelet aggregation.
    - Serotonin: A vasoconstrictor that also enhances platelet aggregation.
- These chemicals attract and activate more platelets, leading to platelet aggregation, where platelets stick to each other.
- The aggregated platelets form a loose mass called the platelet plug, which temporarily seals the break in the blood vessel wall, preventing further blood loss.
- This plug is initially unstable but provides a surface for the subsequent coagulation cascade, which forms a more stable fibrin clot.

(ii) Reflex and reflex arc

- Reflex:
    - A reflex is a rapid, involuntary, and unconscious response to a stimulus.
    - It is an automatic protective mechanism of the body, designed to maintain homeostasis or avoid injury.

- Reflexes are stereotypic, meaning they produce the same response every time the same stimulus is applied.

- Reflex arc:
  - A reflex arc is the neural pathway that mediates a reflex action. It is the basic functional unit of the nervous system responsible for reflexes.
  - A typical reflex arc involves five essential components:
    - Sensory receptor: Detects the stimulus (e.g., pain receptors in the skin).
    - Sensory neuron (Afferent neuron): Transmits the sensory information from the receptor to the central nervous system (CNS).
    - Integration center: One or more synapses within the CNS (spinal cord or brainstem) where the sensory neuron communicates with a motor neuron, often through an interneuron.
    - Motor neuron (Efferent neuron): Transmits the motor command from the CNS to the effector organ.
    - Effector organ: A muscle or gland that carries out the response (e.g., muscle contracting to withdraw a limb, gland secreting a substance).

(iii) Hemoglobin and its function

- Hemoglobin:
  - Hemoglobin (Hb) is a complex globular protein found within red blood cells (erythrocytes) in vertebrates.
  - It is responsible for the red color of blood.

- Structurally, adult hemoglobin (HbA) is composed of four polypeptide chains (two alpha (α) chains and two beta (β) chains), each associated with a heme group.
- A heme group contains a porphyrin ring coordinated with a central iron ion (Fe^{2+}) in the ferrous state. It is this iron atom that reversibly binds oxygen.

- Functions of Hemoglobin:
  - **Oxygen Transport:** This is the primary function of hemoglobin. In the lungs, where oxygen concentration is high, oxygen binds reversibly to the Fe^{2+} in the heme groups, forming oxyhemoglobin (HbO_2). This oxygenated blood is then transported to tissues throughout the body. In tissues, where oxygen concentration is low, oxygen is released from hemoglobin.
  - **Carbon Dioxide Transport:** Hemoglobin also plays a role in transporting carbon dioxide (CO_2). A small percentage of CO_2 binds directly to the amino groups of the globin chains, forming carbaminohemoglobin. However, most CO_2 is transported as bicarbonate ions in the plasma.
  - **pH Buffering:** Hemoglobin acts as a significant buffer in the blood, helping to maintain blood pH within a narrow physiological range. The amino acid residues in the globin chains can bind or release hydrogen ions (H^+), buffering changes in pH.
  - **Nitric Oxide (NO) Transport:** Hemoglobin can bind and transport nitric oxide, a vasodilator, which helps regulate blood flow and oxygen delivery to tissues.

(iv) Joints and their classification

- Joints (Articulations):

- Joints are sites in the body where two or more bones meet.
- They provide various degrees of movement, from immovable to freely movable, depending on their structure and function.

- Classification of Joints:
  - Joints are typically classified in two ways: structurally (based on the type of material binding the bones and the presence or absence of a joint cavity) and functionally (based on the amount of movement allowed).
  - **Structural Classification:**
    - **Fibrous Joints:**
      - Bones are joined by fibrous connective tissue. No joint cavity.
      - Provide little to no movement.
      - Examples: Sutures (in skull), Syndesmoses (e.g., tibiofibular joint), Gomphoses (teeth in sockets).
    - **Cartilaginous Joints:**
      - Bones are united by cartilage. No joint cavity.
      - Allow limited movement.
      - Examples: Synchondroses (e.g., epiphyseal plates, first rib to sternum - hyaline cartilage), Symphyses (e.g., pubic symphysis, intervertebral discs - fibrocartilage).
    - **Synovial Joints:**
      - Characterized by a fluid-filled synovial cavity between the articulating bones.

- Bones are covered with articular cartilage and enclosed within a joint capsule. Ligaments reinforce the joint.
- Allow for a wide range of movement (freely movable, diarthroses).
- Examples: Knee, hip, shoulder, elbow, wrist joints.

- **Functional Classification:**
  - **Synarthroses:** Immovable joints (e.g., sutures).
  - **Amphiarthroses:** Slightly movable joints (e.g., pubic symphysis, intervertebral discs).
  - **Diarthroses:** Freely movable joints (e.g., all synovial joints).

3. (a) A mountaineer was asked to stay at the base camp for a week before climbing till mountain peak. Give reasons for its stay and explain the pathophysiology of changes seen in blood.

- Reasons for stay (Acclimatization):
  - The primary reason for a mountaineer to stay at a base camp for a week before ascending to higher altitudes is to allow their body to **acclimatize** to the lower atmospheric pressure and reduced partial pressure of oxygen (hypoxia) present at high altitudes.
  - Acclimatization is a physiological adjustment process that improves the body's ability to deliver oxygen to tissues despite the lower ambient oxygen.
  - Without proper acclimatization, a rapid ascent to high altitudes can lead to acute mountain sickness (AMS), high-altitude cerebral edema (HACE), or high-altitude pulmonary edema (HAPE), which can be severe or even fatal. The week at base

camp allows the body to initiate crucial physiological adaptations.

- Pathophysiology of changes seen in blood (during acclimatization):
    - **Increased Erythropoiesis (RBC Production):**
        - Pathophysiology: The primary stimulus for acclimatization is hypobaric hypoxia (low oxygen pressure). When oxygen levels in the blood decrease, the kidneys detect this hypoxia and release the hormone erythropoietin (EPO).
        - EPO stimulates the bone marrow to increase the production of red blood cells (erythropoiesis).
        - Changes in blood: Over several days to weeks, there will be a significant increase in the red blood cell count (polycythemia) and hemoglobin concentration. This increases the oxygen-carrying capacity of the blood, allowing more oxygen to be delivered to tissues despite the lower partial pressure of oxygen in the atmosphere.
    - **Increased 2,3-Bisphosphoglycerate (2,3-BPG) levels:**
        - Pathophysiology: Chronic hypoxia also leads to an increase in the concentration of 2,3-BPG within red blood cells.
        - Changes in blood: 2,3-BPG binds to hemoglobin and reduces its affinity for oxygen, shifting the oxygen-hemoglobin dissociation curve to the right. This means that hemoglobin releases oxygen more readily to the tissues, especially crucial in oxygen-deficient environments.
    - **Increased Blood Volume (initially, then reduction):**

- Pathophysiology: Initially, in response to acute hypoxia, there might be a slight increase in plasma volume. However, as acclimatization progresses and erythropoiesis increases, there is often a compensatory decrease in plasma volume relative to the increase in red blood cells.
- Changes in blood: This leads to a higher hematocrit (percentage of blood volume occupied by red blood cells), further concentrating the oxygen-carrying capacity.

These blood changes, along with other cardiovascular and respiratory adaptations, enhance the mountaineer's ability to cope with the challenges of high-altitude environments, making the climb safer and more feasible.

(b) Describe the sympathetic response in a frightening situation for each of the following body parts: hair follicles, iris of eye, lungs, heart, arterioles of the abdominal viscera, and arterioles of skeletal muscles.

In a frightening situation, the sympathetic nervous system (part of the autonomic nervous system) activates the "fight-or-flight" response, preparing the body to deal with perceived threats. This involves a widespread release of norepinephrine from sympathetic nerve endings and epinephrine (adrenaline) from the adrenal medulla.

- **Hair follicles:**
  - Response: Contraction of arrector pili muscles.
  - Effect: Causes hairs to stand on end (piloerection), leading to "goosebumps." (In animals, this makes them appear larger to a predator).
- **Iris of eye:**
  - Response: Contraction of the radial (dilator) muscles of the iris.

- Effect: Pupillary dilation (mydriasis). This allows more light to enter the eye, improving vision in low-light conditions or increasing awareness of surroundings.

- **Lungs:**
  - Response: Relaxation of bronchial smooth muscle.
  - Effect: Bronchodilation (widening of airways). This reduces airway resistance and allows for increased airflow into and out of the lungs, facilitating greater oxygen intake and carbon dioxide expulsion.
- **Heart:**
  - Response: Increased heart rate and increased force of contraction.
  - Effect: Tachycardia and increased cardiac output. This pumps more oxygenated blood to the skeletal muscles and brain, preparing the body for physical exertion.
- **Arterioles of the abdominal viscera (e.g., digestive system, kidneys):**
  - Response: Vasoconstriction.
  - Effect: Reduced blood flow to non-essential organs. Blood is diverted away from digestive and excretory systems, which are not immediately needed for survival in an emergency.
- **Arterioles of skeletal muscles:**
  - Response: Vasodilation.
  - Effect: Increased blood flow to skeletal muscles. This supplies muscles with more oxygen and nutrients (glucose), preparing them for intense physical activity (running or fighting).

(c) Explain how the organization of actin and myosin in smooth muscle cells differs from their organization in striated muscle cells. What are the advantages of these differences?

- **Organization of Actin and Myosin:**
    - **Striated Muscle Cells (Skeletal and Cardiac Muscle):**
        - **Sarcomere Structure:** Actin (thin) and myosin (thick) filaments are arranged in highly organized, repeating units called sarcomeres. These sarcomeres are aligned end-to-end, creating the characteristic striations (bands) visible under a microscope.
        - **Myosin:** Myosin filaments are centrally located within the sarcomere (A band).
        - **Actin:** Actin filaments extend from Z-discs towards the center of the sarcomere, overlapping with myosin filaments.
        - **Z-discs:** Actin filaments are anchored to Z-discs, which mark the boundaries of each sarcomere.
        - **Contraction:** Contraction occurs via the sliding filament model, where actin filaments slide past myosin filaments, causing the sarcomeres to shorten.
    - **Smooth Muscle Cells:**
        - **No Sarcomeres/Striations:** Actin and myosin filaments are present, but they are not arranged into organized sarcomeres. Therefore, smooth muscle cells lack the visible striations.
        - **Myosin:** Myosin filaments are generally shorter and less abundant than in striated muscle.
        - **Actin:** Actin filaments are more numerous and attach to dense bodies (analogous to Z-discs) located in the

cytoplasm and on the cell membrane. These dense bodies are rich in α-actinin.

- **Crisscross Network:** The actin and myosin filaments are arranged in a crisscross or diagonal network within the cell, spanning the length and width of the cell.
- **Intermediate Filaments:** A network of intermediate filaments (e.g., desmin and vimentin) connects the dense bodies, forming a cytoskeletal framework that transmits the force of contraction throughout the cell, leading to a corkscrew-like shortening.

- **Advantages of these Differences:**
  - **Striated Muscle Advantages:**
    - **Rapid and Powerful Contraction:** The highly organized sarcomeric structure allows for very rapid and forceful contractions, essential for quick movements (skeletal muscle) and continuous pumping (cardiac muscle).
    - **Efficient Length-Tension Relationship:** The precise arrangement of filaments ensures optimal overlap for maximum force generation at specific muscle lengths.
    - **Fine Control:** The motor unit organization (one motor neuron innervating a specific number of muscle fibers) allows for graded and precise control of force.
  - **Smooth Muscle Advantages:**
    - **Greater Shortening Capacity:** Due to the crisscross arrangement and lack of fixed sarcomere lengths, smooth muscle cells can shorten to a much greater extent (up to 80% of their length) compared to striated muscle (around 30-40%). This is crucial for organs like the stomach or bladder that undergo large changes in volume.

- **Sustained Contraction (Latch Mechanism):** Smooth muscle can maintain prolonged contractions with very little energy expenditure (latch mechanism), which is vital for maintaining blood pressure (vascular smooth muscle) or tone in the digestive tract for hours.
- **Force Generation over a Wider Length Range:** The non-sarcomeric arrangement allows smooth muscle to generate contractile force even when stretched or significantly shortened, which is important for hollow organs that experience variable filling (e.g., bladder, uterus).
- **Resistance to Fatigue:** The ability to maintain contraction with low ATP consumption contributes to its resistance to fatigue.
- **Diverse Control Mechanisms:** Smooth muscle can be regulated by a variety of stimuli, including autonomic nervous system signals, hormones, local chemical changes, and intrinsic pacemaker activity, allowing for fine-tuned control of diverse physiological processes.

4. (a) Give Location and function of the following :

(i) Meissner corpuscle

- Location: Located in the dermal papillae, just beneath the epidermis, particularly abundant in hairless (glabrous) skin areas such as fingertips, palms, soles, eyelids, lips, and external genitalia.
- Function: Rapidly adapting (phasic) mechanoreceptors that detect light touch, gentle pressure, and low-frequency vibrations (e.g., detecting textures, light tapping). They are crucial for discriminative touch.

(ii) Arrector pili

- Location: Small bundles of smooth muscle fibers attached to the base of hair follicles and extending obliquely into the dermal connective tissue.
- Function: When they contract (e.g., in response to cold or fright), they pull the hair follicles upright, causing the hair to stand on end (piloerection or "goosebumps"). This action traps a layer of air close to the skin, providing insulation, and in animals, makes them appear larger.

(iii) Periosteum

- Location: A dense, irregular connective tissue membrane that covers the external surface of bones, except at articular surfaces (where hyaline cartilage is present).
- Function:
    - Protection: Protects the bone surface.
    - Attachment: Serves as an attachment point for tendons and ligaments.
    - Bone Growth and Repair: Contains osteoblasts (bone-forming cells) and osteoclasts (bone-resorbing cells), playing a crucial role in bone growth in width, bone remodeling, and fracture repair.
    - Nutrient Supply: Richly supplied with blood vessels and nerves that nourish the bone.

(iv) Sarcomere

- Location: The fundamental contractile unit of striated muscle tissue (skeletal and cardiac muscle). Sarcomeres are arranged longitudinally within myofibrils, which are found inside muscle fibers (cells).

- Function: The basic functional unit responsible for muscle contraction. During contraction, the actin and myosin filaments within the sarcomere slide past each other, causing the sarcomere to shorten, which in turn shortens the entire muscle fiber and generates force.

(v) Corpus Striatum

- Location: A subcortical part of the forebrain, located deep within the cerebral hemispheres. It consists of the caudate nucleus and the putamen (which together form the neostriatum), and sometimes includes the globus pallidus.
- Function: Primarily involved in the control of voluntary movement, learning, and reward. It receives extensive input from the cerebral cortex and acts as the main input nucleus of the basal ganglia, playing a critical role in initiating and modulating motor activity, procedural learning, and habit formation. Dysfunction is associated with Parkinson's and Huntington's diseases.

(vi) Circumvallate Papillae

- Location: Large, circular papillae arranged in an inverted "V" shape on the posterior part of the tongue, anterior to the sulcus terminalis. Each papilla is surrounded by a trench.
- Function: Contain numerous taste buds located on their lateral walls, allowing for the perception of taste sensations, particularly bitter tastes. They also contain serous glands (Von Ebner's glands) that secrete fluid to flush out taste pores.

(b) An unidentified dead body was found in a street. The dead body was rigid. It was handed over to the police. Why was the dead body rigid and what is that condition called? Why does damaged cartilage heal slowly?

- Why was the dead body rigid and what is that condition called?

- The condition where a dead body becomes rigid is called **rigor mortis**.
- **Justification:** After death, cellular respiration ceases, and the production of ATP (adenosine triphosphate) stops. ATP is crucial for muscle relaxation, as it is needed to detach the myosin heads from the actin filaments. Without ATP, the myosin heads remain bound to actin in a state of sustained contraction. This causes the muscles to become stiff and rigid. The process typically begins 2-6 hours after death, reaches maximum rigidity around 12-24 hours, and gradually subsides over 24-48 hours as proteolytic enzymes begin to break down the muscle proteins.

- Why does damaged cartilage heal slowly?
  - Damaged cartilage (especially hyaline cartilage) heals very slowly, if at all, for several key reasons:
    - **Avascularity:** Cartilage is avascular, meaning it lacks a direct blood supply. Nutrients and oxygen must diffuse through the extracellular matrix from the perichondrium (if present) or synovial fluid. This slow diffusion limits the delivery of essential nutrients, immune cells, and growth factors necessary for repair.
    - **Aneural:** Cartilage is also aneural (lacks nerves), so injuries may not be immediately detected, delaying intervention.
    - **Alymphatic:** It lacks lymphatic drainage.
    - **Low Metabolic Rate of Chondrocytes:** Chondrocytes, the cells within cartilage, have a relatively low metabolic rate and limited proliferative capacity, especially in adult cartilage. They are not highly active in repair.

- **Limited Inflammatory Response:** Due to avascularity, there is a very limited inflammatory response to injury in cartilage, which is critical for initiating the repair process and clearing debris.
- **Nature of the Matrix:** The dense, avascular, and often acellular nature of the cartilage matrix itself makes it a poor environment for cell migration and tissue regeneration. The matrix, once damaged, is difficult for chondrocytes to fully regenerate.
- **Lack of Perichondrium in Articular Cartilage:** Articular cartilage, which covers joint surfaces, lacks a perichondrium (a vascularized connective tissue layer that surrounds most other cartilages and contains chondroblasts). The absence of this regenerative layer further limits its healing potential.

5. (a) Describe the general features of epithelial tissue. How is the structure of the following kinds of epithelium related to their functions: simple squamous, ciliated simple columnar, stratified squamous (keratinized and nonkeratinized)?

- **General Features of Epithelial Tissue:**
  - **Closely Packed Cells:** Epithelial cells are tightly packed together with very little extracellular material between them, forming continuous sheets.
  - **Polarity:** Epithelial cells exhibit apical-basal polarity. The apical surface faces the exterior of the body or a lumen (internal space/cavity), while the basal surface adheres to underlying connective tissue via a basement membrane.
  - **Specialized Cell Junctions:** Cells are strongly bound to one another by various cell junctions (tight junctions, adherens junctions, desmosomes, gap junctions), which provide structural integrity and regulate permeability.

- **Avascularity:** Epithelial tissue is avascular, meaning it does not have its own blood supply. It receives nutrients by diffusion from the underlying connective tissue.
- **Innervated:** It is supplied by nerve endings.
- **High Regenerative Capacity:** Epithelial tissues have a high capacity for regeneration, as they are often exposed to wear and tear, and their cells are replaced frequently by cell division.
- **Supported by Connective Tissue:** Epithelial tissue is always supported by an underlying layer of connective tissue, separated by a basement membrane.

- **Relationship between Structure and Function of Epithelial Kinds:**
  - **Simple Squamous Epithelium:**
    - **Structure:** Consists of a single layer of flattened, thin, scale-like cells with disc-shaped nuclei. It is the thinnest of all epithelia.
    - **Function Related to Structure:** Its extreme thinness allows for rapid diffusion, filtration, and secretion of substances.
      - Location: Lung alveoli (gas exchange), lining of blood vessels (endothelium, for smooth flow and diffusion), serous membranes (mesothelium, for secretion of lubricating fluid), Bowman's capsule of kidney (filtration).
      - Advantage: Minimal barrier for efficient movement of gases, fluids, and nutrients.
  - **Ciliated Simple Columnar Epithelium:**
    - **Structure:** Composed of a single layer of tall, column-shaped cells. The apical surface of these cells is covered

with cilia (hair-like projections), and they often have goblet cells (mucus-secreting cells) interspersed.

- **Function Related to Structure:** The tall cells provide a protective and absorptive surface, while the cilia perform coordinated, unidirectional beating movements.
    - Location: Lining of the uterine tubes (fallopian tubes), small bronchi, parts of the nasal cavity.
    - Advantage: The cilia propel mucus, trapped particles, or reproductive cells (e.g., ovum) along the surface. The mucus secreted by goblet cells traps foreign particles, and the cilia move this mucus (and trapped particles) away, providing a cleansing mechanism (e.g., in the respiratory tract).

- **Stratified Squamous Epithelium (Keratinized and Nonkeratinized):**

    - **Structure:** Consists of multiple layers of cells, with the most superficial layers being flattened (squamous). The cells in the deeper layers are typically cuboidal or columnar and are actively mitotic.
    - **Function Related to Structure:** Its multi-layered structure provides significant protection against abrasion, friction, and invasion by pathogens. The superficial layers are continuously shed and replaced by cells from deeper layers.
        - **Keratinized Stratified Squamous Epithelium:**
            - Structure: The most superficial layers of cells are dead and filled with a tough, water-resistant protein called keratin. These layers lack nuclei and organelles.
            - Location: Epidermis of the skin.

- Advantage: Keratin provides a highly protective, dry, and impermeable barrier against physical trauma, desiccation (drying out), and microbial invasion, making it ideal for external surfaces.

- **Nonkeratinized Stratified Squamous Epithelium:**
  - Structure: The superficial cells are still flattened but retain their nuclei and are not filled with keratin. The surface remains moist.
  - Location: Lining of the mouth, esophagus, vagina, anus.
  - Advantage: Provides robust protection against abrasion in areas subject to friction but that require a moist surface. It can resist significant wear and tear while still allowing some flexibility.

(b) Explain the events of signal transmission at a chemical synapse. Distinguish between spatial and temporal summation.

- **Events of Signal Transmission at a Chemical Synapse:**
  - Signal transmission at a chemical synapse involves a series of steps to convert an electrical signal (action potential) in the presynaptic neuron into a chemical signal (neurotransmitter release) and then back into an electrical signal in the postsynaptic neuron.
  - **1. Action Potential Arrives:** An action potential arrives at the axon terminal (presynaptic terminal) of the presynaptic neuron.
  - **2. Voltage-Gated Ca^{2+} Channels Open:** The depolarization caused by the action potential opens voltage-gated calcium (Ca^{2+}) channels located in the presynaptic terminal membrane.

- **3. Calcium Influx:** Ca^{2+} ions flow from the extracellular fluid into the presynaptic terminal, driven by their electrochemical gradient.
- **4. Neurotransmitter Release:** The influx of Ca^{2+} triggers the fusion of synaptic vesicles (which contain neurotransmitters) with the presynaptic membrane. Neurotransmitters are then released into the synaptic cleft by exocytosis.
- **5. Neurotransmitter Diffusion:** Neurotransmitters diffuse across the synaptic cleft, a tiny space between the presynaptic and postsynaptic membranes.
- **6. Neurotransmitter Binding:** Neurotransmitters bind to specific receptor proteins located on the postsynaptic membrane.
- **7. Ion Channel Opening and Postsynaptic Potential (PSP) Generation:** The binding of neurotransmitters causes ligand-gated ion channels on the postsynaptic membrane to open. This leads to a change in the postsynaptic membrane potential, creating a Postsynaptic Potential (PSP).
    - If the ion channels allow positive ions (Na^{+}) to enter, it causes a depolarization (Excitatory Postsynaptic Potential - EPSP), making the postsynaptic neuron more likely to fire an action potential.
    - If the ion channels allow negative ions (Cl^{-}) to enter or positive ions (K^{+}) to leave, it causes a hyperpolarization or stabilization (Inhibitory Postsynaptic Potential - IPSP), making the postsynaptic neuron less likely to fire an action potential.
- **8. Neurotransmitter Removal:** Neurotransmitters are quickly removed from the synaptic cleft to terminate the signal and allow the synapse to be ready for the next signal. This removal can occur via:

- Enzymatic degradation (e.g., acetylcholine by acetylcholinesterase).
- Reuptake into the presynaptic terminal or glial cells.
- Diffusion away from the synapse.

- **Distinguish between Spatial and Temporal Summation:**
  - Summation is the process by which multiple subthreshold postsynaptic potentials (PSPs) combine to reach the threshold for an action potential in the postsynaptic neuron. Neurons typically receive thousands of synaptic inputs; summation allows these inputs to be integrated.
  - **Spatial Summation:**
    - Definition: Occurs when multiple presynaptic neurons simultaneously release neurotransmitters onto different locations on the postsynaptic neuron's dendrites or cell body.
    - Mechanism: The EPSPs (or IPSPs) generated at these different synaptic sites are added together in space. If the combined effect of these simultaneously occurring potentials reaches the threshold at the axon hillock, an action potential is generated.
    - Analogy: Multiple people pushing a car at the same time from different spots.
  - **Temporal Summation:**
    - Definition: Occurs when a single presynaptic neuron rapidly fires multiple action potentials in quick succession, releasing neurotransmitters repeatedly into the synaptic cleft.
    - Mechanism: Each successive release of neurotransmitter causes a new PSP. These PSPs occur so rapidly that

they add up in time before the previous PSP has fully decayed. If the combined effect of these rapidly occurring potentials reaches the threshold at the axon hillock, an action potential is generated.

- Analogy: One person repeatedly pushing a car, building up momentum.

6. (c) Give one word for the following :

(i) Bone building cells.

- Osteoblasts

(ii) Gap junctions of the cardiac muscle tissue.

- Intercalated discs (specifically, the gap junctions within them)

(iii) Supporting cells which line the cavities of the brain and spinal cord.

- Ependymal cells

(iv) Middle ear ossicle attached to oval window.

- Stapes (or Stirrup)

(v) Blood cells with kidney shaped nucleus.

- Monocytes

6. Draw well labelled diagram for the following structures.

(i) T.S. of Skin

- (Conceptual description of features to be labeled in a diagram of T.S. of Skin)
    - **Epidermis:**
        - Stratum corneum (outermost, dead, keratinized cells)
        - Stratum lucidum (in thick skin, translucent layer)

- Stratum granulosum (keratinization begins)
- Stratum spinosum (spiny appearance, desmosomes)
- Stratum basale (deepest, single layer, mitotic cells, melanocytes, Merkel cells)
- Melanocyte (in stratum basale)
- Keratinocyte (main cell type)

- **Dermis:**
  - Papillary layer (upper, loose connective tissue, dermal papillae)
  - Reticular layer (lower, dense irregular connective tissue, collagen and elastic fibers)
  - Blood vessels (arterioles, venules, capillaries)
  - Nerve fibers
  - Sensory receptors (e.g., Meissner corpuscle in papillary layer, Pacinian corpuscle deeper in reticular layer/hypodermis)
  - Hair follicle (with associated sebaceous gland and arrector pili muscle)
  - Sebaceous gland
  - Sweat gland (eccrine or apocrine)
- **Hypodermis (Subcutaneous tissue):** (Often included in skin diagrams, though technically not part of the skin)
  - Adipose tissue (fat cells)
  - Larger blood vessels and nerves

(ii) Types of bone cells

- (Conceptual description of features to be labeled in a diagram of Types of bone cells)
    - **Osteogenic Cell (Osteoprogenitor cell):**
        - Location: Periosteum, endosteum, central canals of osteons.
        - Appearance: Spindle-shaped stem cell.
    - **Osteoblast:**
        - Location: Bone surface, actively synthesizing matrix.
        - Appearance: Cuboidal or columnar cells, often aligned in a layer.
        - Feature: Actively secreting osteoid (unmineralized bone matrix).
    - **Osteocyte:**
        - Location: Lacunae (small spaces within the mineralized bone matrix).
        - Appearance: Star-shaped cell with long cytoplasmic processes extending into canaliculi.
        - Feature: Mature bone cell, maintains bone matrix.
    - **Osteoclast:**
        - Location: Resorption pits (Howship's lacunae) on bone surfaces.
        - Appearance: Large, multinucleated cell.
        - Feature: ruffled border (for bone resorption), lysosomes, phagocytic activity.

(iii) T.S. of a Muscle (Skeletal Muscle)

- (Conceptual description of features to be labeled in a diagram of T.S. of a Skeletal Muscle)
    - **Overall Muscle:**
        - Epimysium (outermost connective tissue covering entire muscle)
    - **Muscle Fascicle:**
        - Perimysium (connective tissue surrounding a bundle of muscle fibers, forming a fascicle)
        - Muscle fiber (muscle cell)
    - **Muscle Fiber (Cell):**
        - Endomysium (connective tissue surrounding individual muscle fibers)
        - Sarcolemma (muscle cell membrane)
        - Nuclei (multiple, peripheral, just beneath sarcolemma)
        - Myofibrils (bundles of contractile filaments within the muscle fiber)
        - Sarcoplasmic reticulum (ER of muscle cell, surrounds myofibrils)
        - Transverse tubules (T-tubules, invaginations of sarcolemma)
        - Mitochondria (numerous, for ATP production)
    - **Myofibril (cross-section showing banding patterns):**
        - A band (dark band, myosin filaments)
        - I band (light band, actin filaments)
        - H zone (center of A band, only myosin)

- M line (center of H zone)
- Z disc (divides sarcomeres, anchors actin)
- Sarcomere (the functional unit, from Z disc to Z disc)

- **Individual Filaments (within myofibril):**
  - Thick filament (myosin)
  - Thin filament (actin)