1. (a) Define any four of the following terms:

- **Plasminolysis:**
    - Plasminolysis is the enzymatic degradation of fibrin clots by plasmin. This process is crucial for dissolving blood clots and maintaining blood vessel patency after the vessel has healed.
- **Portal Triad:**
    - The portal triad is a distinctive anatomical structure found in the liver, located at the corners of the hepatic lobules. It consists of three main components: a branch of the hepatic portal vein, a branch of the hepatic artery, and a small bile duct.
- **Haustral Churning:**
    - Haustral churning is a type of muscular contraction that occurs in the large intestine. The haustra (pouches in the colon) fill with chyme, and when distended to a certain point, the walls contract, pushing the contents to the next haustrum. This movement aids in the absorption of water and electrolytes.
- **Lung compliance:**
    - Lung compliance refers to the ease with which the lungs and thoracic wall can be expanded. It is a measure of the distensibility of the respiratory system, specifically how much the lung volume changes for a given change in transpulmonary pressure. Higher compliance means the lungs are easier to inflate.
- **Herring-Breuer Reflex:**
    - The Herring-Breuer Reflex is a protective reflex that prevents overinflation of the lungs. It is initiated by stretch receptors located in the walls of the bronchi and bronchioles. When these receptors are stimulated by lung distension, they send inhibitory signals to the inspiratory area of the medulla oblongata, leading to termination of inspiration and initiation of expiration.

1. (b) Give the location and function of the following:

- **Bundle of His:**
    - **Location:** The Bundle of His (atrioventricular bundle) is located in the interventricular septum of the heart, extending from the atrioventricular (AV) node.
    - **Function:** It transmits electrical impulses from the AV node to the Purkinje fibers, distributing the excitation throughout the ventricles and coordinating ventricular contraction.
- **Chief cells:**
    - **Location:** Chief cells are primarily found in the gastric glands of the stomach.
    - **Function:** They secrete pepsinogen, an inactive precursor to the enzyme pepsin, and gastric lipase. Pepsinogen is activated by hydrochloric acid to pepsin, which begins the digestion of proteins.
- **Surfactant:**
    - **Location:** Surfactant is found lining the inner surface of the alveoli (air sacs) in the lungs.
    - **Function:** It is a complex mixture of phospholipids and lipoproteins that lowers the surface tension of alveolar fluid, preventing the collapse of the alveoli during exhalation and making breathing easier.
- **Macula densa:**
    - **Location:** The macula densa is a specialized group of cells located in the wall of the ascending limb of the loop of Henle, where it makes contact with the afferent arteriole of the same nephron.
    - **Function:** It senses the sodium chloride concentration in the filtrate flowing through the tubule and plays a crucial role in regulating glomerular filtration rate (GFR) and renin release via the tubuloglomerular feedback mechanism.

1. (c) Differentiate between the following (Any Two):

- **Afferent arteriole and Efferent arteriole:**
    - **Afferent Arteriole:**
        - Carries blood *towards* the glomerulus.
        - Generally has a wider diameter than the efferent arteriole.
        - Its constriction or dilation directly influences glomerular hydrostatic pressure and thus GFR.
    - **Efferent Arteriole:**
        - Carries blood *away* from the glomerulus.
        - Generally has a narrower diameter than the afferent arteriole.
        - Its constriction helps maintain high glomerular pressure and also contributes to the reabsorption process in the peritubular capillaries.

- **External and Internal Respiration:**
    - **External Respiration:**
        - Also known as pulmonary respiration.
        - Involves the exchange of gases (oxygen and carbon dioxide) between the alveoli of the lungs and the blood in the pulmonary capillaries.
        - This process occurs across the respiratory membrane.
    - **Internal Respiration:**
        - Also known as tissue respiration.
        - Involves the exchange of gases (oxygen and carbon dioxide) between the blood in the systemic capillaries and the tissue cells throughout the body.

        - Oxygen moves from blood to tissues, and carbon dioxide moves from tissues to blood.

- **Bicuspid and Tricuspid valves:**
    - **Bicuspid Valve (Mitral Valve):**
        - Located between the left atrium and the left ventricle of the heart.
        - Has two cusps (leaflets).
        - Prevents the backflow of blood from the left ventricle into the left atrium during ventricular systole.
    - **Tricuspid Valve:**
        - Located between the right atrium and the right ventricle of the heart.
        - Has three cusps (leaflets).
        - Prevents the backflow of blood from the right ventricle into the right atrium during ventricular systole.

1. (d) Expand the following:

- **CCK:** Cholecystokinin
- **GFR:** Glomerular Filtration Rate

1. (e) Give reason for the following:

- **Oxygen is more available to tissue cells when you have a fever.**
    - When you have a fever, your body temperature increases. An increase in temperature shifts the oxygen-hemoglobin dissociation curve to the right. This "right shift" means that hemoglobin's affinity for oxygen decreases, causing it to release oxygen more readily to the tissues, thus making oxygen more available to tissue cells.
- **Clot retraction requires an adequate number of platelets.**

- Clot retraction is the shrinking of a blood clot, which helps to pull the edges of a damaged vessel together. This process requires an adequate number of platelets because platelets release a protein called thrombosthenin, which, along with actin and myosin (contractile proteins within platelets), causes the platelets to contract. This contraction pulls on the fibrin threads of the clot, making the clot more compact and squeezing out serum. Without sufficient platelets, this contractile force is insufficient, and clot retraction will be impaired.

2. (a) Elaborate the mechanism of oxygen transport in blood.

- Oxygen is transported in the blood in two main forms:
  - **Bound to Hemoglobin (about 98.5%):**
    - The vast majority of oxygen is transported bound to hemoglobin, a protein found in red blood cells.
    - Each hemoglobin molecule consists of four polypeptide chains (two alpha and two beta chains) and four heme groups.
    - Each heme group contains an iron ion (Fe^{2+}) which can reversibly bind to one oxygen molecule.
    - Therefore, one hemoglobin molecule can carry up to four oxygen molecules.
    - The binding of the first oxygen molecule to hemoglobin increases the affinity of hemoglobin for subsequent oxygen molecules (cooperativity), making it easier for more oxygen to bind. This is known as positive cooperativity.
    - In the lungs, where the partial pressure of oxygen (PO_2) is high, oxygen readily binds to hemoglobin to form oxyhemoglobin (HbO_2).

- In the systemic capillaries, where the PO_2 is low due to cellular metabolism, oxygen dissociates from hemoglobin and diffuses into the tissue cells.
- The affinity of hemoglobin for oxygen is influenced by several factors (Bohr effect), including PO_2, pH (acidity), temperature, and the concentration of 2,3-bisphosphoglycerate (2,3-BPG). A decrease in pH, an increase in temperature, or an increase in 2,3-BPG shifts the oxygen-hemoglobin dissociation curve to the right, promoting oxygen release to tissues.

- **Dissolved in Plasma (about 1.5%):**
  - A small amount of oxygen is transported dissolved directly in the plasma.
  - This dissolved oxygen is crucial because it determines the partial pressure of oxygen (PO_2) in the blood, which in turn drives the binding and dissociation of oxygen with hemoglobin.
  - The amount of oxygen that can be dissolved in plasma is directly proportional to the partial pressure of oxygen in the alveoli.

2. (b) Describe the components of the Cardiac Conduction System.

- The cardiac conduction system is a specialized network of cardiac muscle fibers that initiate and distribute electrical impulses throughout the heart, ensuring a coordinated and efficient pumping action. Its components include:
  - **Sinoatrial (SA) Node:**
    - **Location:** Located in the wall of the right atrium, inferior to the opening of the superior vena cava.
    - **Function:** It is the primary pacemaker of the heart, initiating the electrical impulses that cause atrial contraction. It generates

impulses at the fastest rate (typically 60-100 beats per minute) and sets the rhythm for the entire heart.

- **Atrioventricular (AV) Node:**
  - **Location:** Located in the interatrial septum, just above the tricuspid valve.
  - **Function:** It receives impulses from the SA node (via the atrial muscle fibers). The AV node delays the impulse briefly (about 0.1 second) to allow the atria to complete their contraction and empty blood into the ventricles before ventricular contraction begins. It can also act as a secondary pacemaker if the SA node fails, albeit at a slower rate (40-60 beats per minute).
- **Bundle of His (Atrioventricular Bundle):**
  - **Location:** Extends from the AV node into the interventricular septum.
  - **Function:** It is the only electrical connection between the atria and the ventricles. It transmits the electrical impulse from the AV node to the bundle branches.
- **Right and Left Bundle Branches:**
  - **Location:** The Bundle of His divides into the right and left bundle branches, which descend through the interventricular septum towards the apex of the heart.
  - **Function:** These branches conduct the electrical impulses to the respective ventricles. The left bundle branch typically further divides into anterior and posterior fascicles.
- **Purkinje Fibers:**
  - **Location:** These are large-diameter fibers that arise from the bundle branches and rapidly distribute the electrical impulses throughout the ventricular myocardium, extending into the papillary muscles.

- **Function:** They ensure rapid and synchronized contraction of the ventricles, starting from the apex and moving upwards, which is essential for efficient ejection of blood.

3. (a) Discuss the hormonal regulation of tubular reabsorption and secretion.

- Tubular reabsorption and secretion in the kidneys are precisely regulated by several hormones to maintain fluid and electrolyte balance, as well as acid-base homeostasis.
    - **Antidiuretic Hormone (ADH) / Vasopressin:**
        - **Source:** Produced by the hypothalamus and released from the posterior pituitary gland.
        - **Stimulus for Release:** Increased plasma osmolarity (dehydration) or decreased blood volume/pressure.
        - **Action:** Increases the permeability of the principal cells in the late distal convoluted tubule and collecting ducts to water by inserting aquaporin-2 water channels into their apical membranes. This leads to increased water reabsorption, reducing urine volume and concentrating the urine.
    - **Aldosterone:**
        - **Source:** Produced by the adrenal cortex.
        - **Stimulus for Release:** Activation of the Renin-Angiotensin-Aldosterone System (RAAS) due to decreased blood volume/pressure or increased plasma potassium concentration.
        - **Action:** Acts on the principal cells of the late distal convoluted tubule and collecting ducts. It promotes increased reabsorption of sodium ions (Na^+) and secretion of potassium ions (K^+) and hydrogen ions (H^+). Water follows sodium, leading to increased water reabsorption, thus increasing blood volume and blood pressure.
    - **Angiotensin II:**

- **Source:** Formed in the blood from angiotensin I by Angiotensin-Converting Enzyme (ACE), often in response to renin release from the kidneys.
- **Stimulus for Formation:** Decreased blood volume/pressure, leading to renin release.
- **Action:** A potent vasoconstrictor that also directly stimulates Na^+ reabsorption in the proximal convoluted tubule, loop of Henle, and collecting ducts. It also stimulates the release of aldosterone and ADH, indirectly contributing to water and Na^+ reabsorption. It also stimulates thirst.

- **Atrial Natriuretic Peptide (ANP):**
  - **Source:** Produced by cells in the atria of the heart.
  - **Stimulus for Release:** Increased stretching of atrial walls due to high blood volume or blood pressure.
  - **Action:** Opposes the actions of ADH and aldosterone. It inhibits Na^+ reabsorption in the renal tubules, increases Na^+ excretion in urine (natriuresis), and also promotes diuresis (increased urine production) by inhibiting ADH release and dilating afferent arterioles while constricting efferent arterioles, thereby increasing GFR. This ultimately leads to a decrease in blood volume and blood pressure.

- **Parathyroid Hormone (PTH):**
  - **Source:** Produced by the parathyroid glands.
  - **Stimulus for Release:** Low plasma calcium levels.
  - **Action:** Increases reabsorption of calcium ions (Ca^{2+}) in the distal convoluted tubule and thick ascending limb of the loop of Henle. It also inhibits phosphate reabsorption in the proximal convoluted tubule, promoting phosphate excretion.

3. (b) Draw the histological structure of detailed structure of renal corpuscle.

The request to "Draw the histological structure of detailed structure of renal corpuscle" asks for a diagram. As per the instructions, I cannot create any diagrams.

4. (a) Describe the extrinsic and intrinsic pathway of blood clotting.

- Blood clotting, or hemostasis, involves a complex cascade of events leading to the formation of a stable fibrin clot. It proceeds through two main pathways: the extrinsic pathway and the intrinsic pathway, both converging on a common pathway.
    - **Extrinsic Pathway (Tissue Factor Pathway):**
        - **Initiation:** This pathway is initiated by external trauma to the blood vessel wall or surrounding tissues.
        - **Key Event:** Damaged tissue cells and subendothelial fibroblasts release a lipoprotein called **Tissue Factor (TF)**, also known as Factor III.
        - **Steps:**
            - Tissue Factor (Factor III) directly binds to and activates Factor VII (Factor VIIa) in the presence of calcium ions (Ca^{2+}).
            - The Tissue Factor-Factor VIIa complex then activates Factor X (Factor Xa). This activation is rapid and directly leads into the common pathway.
            - Factor VIIa also activates Factor IX, providing a link to the intrinsic pathway and amplifying the clotting response.
        - **Speed:** This pathway is typically faster, initiating clotting within seconds, as it bypasses many steps of the intrinsic pathway.
    - **Intrinsic Pathway (Contact Activation Pathway):**

- **Initiation:** This pathway is initiated by internal damage to the blood vessel wall, such as contact of blood with exposed collagen fibers (subendothelial collagen) due to endothelial injury, or by contact with negatively charged surfaces (e.g., glass in a test tube).
- **Key Event:** Activation of Factor XII (Hageman factor) upon contact with these surfaces.
- **Steps:**
    - Factor XII is activated to Factor XIIa upon contact with collagen or other negatively charged surfaces.
    - Factor XIIa then activates Factor XI (Factor XIa).
    - Factor XIa, in the presence of Ca^{2+}, activates Factor IX (Factor IXa).
    - Factor IXa, in complex with Factor VIIIa (activated by thrombin from the common pathway, indicating amplification) and platelet phospholipids (PF3) and Ca^{2+}, forms the "tenase complex."
    - This tenase complex activates Factor X (Factor Xa).
- **Speed:** This pathway is generally slower, taking several minutes to form a clot, as it involves more intermediate steps.

- **Common Pathway:**
    - Both the extrinsic and intrinsic pathways converge at the activation of **Factor X (Factor Xa)**.
    - **Steps:**
        - Factor Xa, in complex with Factor Va (activated by thrombin, also for amplification), platelet phospholipids (PF3), and Ca^{2+}, forms the **prothrombinase complex**.

- Prothrombinase converts prothrombin (Factor II) into **thrombin (Factor IIa)**.
- Thrombin is a crucial enzyme with multiple roles:
    - It converts soluble fibrinogen (Factor I) into insoluble fibrin monomers.
    - It activates Factor XIII (Fibrin Stabilizing Factor) to Factor XIIIa.
    - It activates Factor V and Factor VIII, significantly amplifying both intrinsic and common pathways (positive feedback).
- Factor XIIIa cross-links the fibrin monomers, forming a stable, insoluble fibrin polymer mesh that traps red blood cells and platelets, forming the definitive blood clot.

4. (b) Draw the detailed structure of haemoglobin and describe the different types of haemoglobin.

The request to "Draw the detailed structure of haemoglobin" asks for a diagram. As per the instructions, I cannot create any diagrams.

- **Different Types of Hemoglobin:**
    - Hemoglobin is a heterotetrameric protein, meaning it is composed of four protein subunits. The specific types of hemoglobin are determined by the combination of different globin chains.
    - **1. Hemoglobin A (HbA - Adult Hemoglobin):**
        - **Structure:** This is the most prevalent type of hemoglobin in adults, making up about 95-98% of total hemoglobin.
        - **Composition:** It consists of two alpha (α) globin chains and two beta (β) globin chains ($\alpha_2\beta_2$).
        - **Function:** Its primary role is oxygen transport in adult blood.

- **2. Hemoglobin A2 (HbA2):**
  - **Structure:** A minor component of adult hemoglobin, accounting for about 1.5-3.5% of total hemoglobin.
  - **Composition:** It consists of two alpha (α) globin chains and two delta (δ) globin chains ($\alpha_2\delta_2$).
  - **Function:** Its physiological significance is not fully understood, but it can be elevated in certain conditions like beta-thalassemia.
- **3. Hemoglobin F (HbF - Fetal Hemoglobin):**
  - **Structure:** This is the primary hemoglobin found during fetal development and in newborns. It constitutes less than 1% of total hemoglobin in adults.
  - **Composition:** It consists of two alpha (α) globin chains and two gamma (γ) globin chains ($\alpha_2\gamma_2$).
  - **Function:** HbF has a higher affinity for oxygen than HbA. This higher affinity is crucial for efficient oxygen transfer from the mother's blood to the fetal blood across the placenta, as the fetus needs to extract oxygen from an environment with a relatively lower oxygen partial pressure.
- **4. Embryonic Hemoglobins:**
  - **Structure:** These are found very early in embryonic development (first trimester) and are replaced by HbF as development progresses.
  - **Composition:** Examples include Gower-1 ($\zeta_2\epsilon_2$), Gower-2 ($\alpha_2\epsilon_2$), and Portland ($\zeta_2\gamma_2$). They involve zeta (ζ) and epsilon (ϵ) globin chains.
  - **Function:** Facilitate oxygen transport during the initial stages of embryonic life.

- **Abnormal Hemoglobins (e.g., Hemoglobin S, Hemoglobin C):**
    - These are variations in hemoglobin structure caused by genetic mutations in the globin genes.
    - **Hemoglobin S (HbS):** Results from a single amino acid substitution (valine for glutamic acid) in the beta-globin chain. This leads to sickle cell anemia, where red blood cells become rigid and sickle-shaped under low oxygen conditions, causing blockages and various complications.
    - **Hemoglobin C (HbC):** Another point mutation in the beta-globin chain (lysine for glutamic acid). Generally less severe than sickle cell anemia, but can cause mild hemolytic anemia.
    - Numerous other abnormal hemoglobins exist, often leading to various hemoglobinopathies or thalassemias, which affect oxygen-carrying capacity and red blood cell survival.

5. (a) Give a detailed account of phases of digestion.

- Digestion is the process of breaking down food into molecules small enough to be absorbed into the body. It occurs in several phases, primarily regulated by neural and hormonal mechanisms.
    - **1. Cephalic Phase:**
        - **Initiation:** This phase occurs even before food enters the mouth. It is triggered by the sight, smell, thought, or taste of food.
        - **Mechanism:** Sensory input (olfactory, visual, gustatory) sends signals to the cerebral cortex and then to the hypothalamus, medulla oblongata, and ultimately the vagus nerve (cranial nerve X).
        - **Effects:**
            - **Salivary Glands:** Increased salivation (production and secretion of saliva) to moisten food and begin

carbohydrate digestion (amylase) and lipid digestion (lingual lipase).

- **Stomach:** Increased gastric juice secretion (hydrochloric acid, pepsinogen, mucus) in anticipation of food arrival. Gastric motility also increases.

- **2. Gastric Phase:**
  - **Initiation:** This phase begins when food enters the stomach. It is regulated by the distension of the stomach, the presence of specific chemicals in the food (peptides, amino acids), and the pH of the gastric contents.
  - **Mechanism:**
    - **Neural Regulation:**
      - **Stretch Receptors:** Distension of the stomach wall activates stretch receptors, leading to local (enteric nervous system) and long (vagus nerve) reflexes. These reflexes stimulate increased gastric motility and secretion of gastric juice.
      - **Chemoreceptors:** Presence of peptides and a high pH (less acidic) stimulate chemoreceptors, leading to similar reflex responses.
    - **Hormonal Regulation:**
      - **Gastrin:** Peptides, amino acids, and distension of the stomach stimulate G cells in the pyloric antrum to release gastrin into the bloodstream. Gastrin promotes stomach motility and the secretion of HCl (from parietal cells) and pepsinogen (from chief cells).

        - **Histamine:** Gastrin also stimulates enterochromaffin-like (ECL) cells to release histamine, which further stimulates HCl secretion.

    - **Effects:** Vigorous churning of food, mixing with gastric juice to form chyme, and initiation of protein digestion.

- **3. Intestinal Phase:**

    - **Initiation:** This phase begins when chyme, in small squirts, enters the duodenum from the stomach.

    - **Mechanism:** It is largely inhibitory to gastric activity but stimulatory to intestinal, pancreatic, and gallbladder activity.

    - **Neural Regulation:**

        - **Enterogastric Reflex:** Distension of the duodenum, presence of fatty acids, glucose, and low pH in the chyme activate receptors in the duodenal wall. This initiates reflexes that inhibit gastric emptying (closing the pyloric sphincter) and gastric secretion, protecting the duodenum from excessive acidity and allowing time for digestion and absorption.

    - **Hormonal Regulation:**

        - **Cholecystokinin (CCK):** Released by I cells in the duodenal and jejunal mucosa in response to the presence of fatty acids and amino acids in chyme.

            - **Effects:** Stimulates pancreatic enzyme secretion, gallbladder contraction (releasing bile), and relaxation of the sphincter of Oddi. It also inhibits gastric emptying.

        - **Secretin:** Released by S cells in the duodenal mucosa in response to acidic chyme.

- **Effects:** Stimulates the pancreas to secrete bicarbonate-rich fluid (to neutralize stomach acid) and the liver to produce more bile. It also inhibits gastric acid secretion.

- **Gastric Inhibitory Peptide (GIP) / Glucose-Dependent Insulinotropic Peptide:** Released by K cells in the duodenal and jejunal mucosa in response to fatty acids and glucose.
    - **Effects:** Inhibits gastric acid secretion and gastric emptying. Its main role is to stimulate insulin release from the pancreas when glucose is present in the small intestine.

- **Effects:** Continued digestion and absorption of nutrients in the small intestine.

5. (b) Briefly explain absorption of fats in small intestine.

- The absorption of fats (lipids) in the small intestine is a complex process due to their hydrophobic nature, requiring emulsification and packaging into specific transport structures.
    - **1. Emulsification:**
        - Large lipid globules entering the small intestine are mechanically broken down by segmentation movements.
        - Bile salts, secreted by the liver and stored in the gallbladder, play a crucial role. They are amphipathic molecules (having both hydrophobic and hydrophilic parts) that surround the lipid globules, breaking them into smaller droplets. This process, called **emulsification**, increases the surface area for enzyme action.
    - **2. Digestion by Pancreatic Lipase:**

- Pancreatic lipase, secreted by the pancreas, acts on the emulsified lipid droplets.
- It hydrolyzes triglycerides (the most common dietary fat) into fatty acids and monoglycerides. Cholesterol esters are broken down into cholesterol and fatty acids, and phospholipids into fatty acids and lysophospholipids.

- **3. Micelle Formation:**
  - The digested fatty acids, monoglycerides, cholesterol, and other lipid-soluble substances (like fat-soluble vitamins) are still largely insoluble in the aqueous environment of the intestinal lumen.
  - Bile salts aggregate with these digested lipids to form small, spherical structures called **micelles**. Micelles have a hydrophilic outer surface (formed by bile salts) and a hydrophobic core, allowing them to remain suspended in the chyme.
  - Micelles transport the lipids to the surface of the absorptive epithelial cells (enterocytes) lining the villi of the small intestine.
- **4. Diffusion into Enterocytes:**
  - At the brush border of the enterocytes, the fatty acids and monoglycerides (and other lipid-soluble substances) diffuse out of the micelles and directly across the lipid bilayer of the enterocyte membrane. Bile salts are left behind in the lumen to be reabsorbed further down in the ileum and recycled (enterohepatic circulation).
- **5. Resynthesis of Triglycerides and Chylomicron Formation:**
  - Inside the enterocytes, the absorbed fatty acids and monoglycerides are re-esterified (recombined) to form triglycerides in the smooth endoplasmic reticulum.

- These newly synthesized triglycerides, along with cholesterol, phospholipids, and fat-soluble vitamins, are then packaged with specific proteins (apolipoproteins) within the endoplasmic reticulum and Golgi apparatus to form larger lipoprotein particles called **chylomicrons**.

- **6. Chylomicron Exocytosis and Lacteal Absorption:**
  - Chylomicrons are too large to directly enter the blood capillaries.
  - Instead, they are released from the basolateral side of the enterocytes by exocytosis.
  - They then enter specialized lymphatic capillaries called **lacteals**, which are located within the villi of the small intestine.
  - The lymphatic system eventually drains the chylomicron-rich lymph (chyle) into the bloodstream via the thoracic duct, which empties into the left subclavian vein.

- **7. Transport in Blood:**
  - Once in the bloodstream, chylomicrons are transported to various tissues. In capillaries of adipose tissue and muscle, the enzyme lipoprotein lipase (LPL), located on the endothelial cells, breaks down the triglycerides within chylomicrons into fatty acids and glycerol. These are then absorbed by the cells for energy or storage.
  - The remnants of the chylomicrons (chylomicron remnants) are taken up by the liver.

6. (a) Explain the pressure and volume changes that occur during the cardiac cycle.

- The cardiac cycle describes the sequence of events that occur during one complete heartbeat. It involves coordinated contractions and relaxations of the atria and ventricles, leading to characteristic pressure and volume

changes within the heart chambers and major blood vessels. The cycle is typically divided into systole (contraction) and diastole (relaxation).

- **1. Atrial Systole (0.1 sec):**
  - **Pressure Changes:**
    - Atrial pressure slightly increases as the atria contract, pushing the remaining blood into the ventricles.
    - Ventricular pressure remains low.
  - **Volume Changes:**
    - Ventricular volume slightly increases as atrial contraction contributes the final 20-30% of ventricular filling (atrial kick). The volume at the end of atrial systole is the **End-Diastolic Volume (EDV)**, typically around 120-130 mL.
  - **Valve Status:** AV valves (tricuspid and bicuspid) are open; semilunar valves (aortic and pulmonary) are closed.
- **2. Isovolumetric Contraction (Ventricular Systole - Part 1) (0.05 sec):**
  - **Initiation:** Begins with ventricular excitation and contraction.
  - **Pressure Changes:**
    - Ventricular pressure rises sharply and rapidly.
    - As ventricular pressure exceeds atrial pressure, the AV valves close, producing the **first heart sound (S1 - "lub")**.
    - Ventricular pressure continues to rise, but it is not yet high enough to open the semilunar valves.
    - Aortic and pulmonary pressures are high due to blood already in the arteries.

- **Volume Changes:**
    - Ventricular volume remains constant because all valves are closed, and no blood is entering or leaving the ventricles.
- **Valve Status:** All four valves are closed.

- **3. Ventricular Ejection (Ventricular Systole - Part 2) (0.25 sec):**
    - **Initiation:** Ventricular pressure continues to rise and eventually exceeds the pressure in the aorta and pulmonary artery.
    - **Pressure Changes:**
        - Ventricular pressure continues to rise initially, then falls as blood is ejected.
        - When ventricular pressure exceeds aortic/pulmonary pressure, the semilunar valves open.
        - Aortic and pulmonary artery pressures rise rapidly as blood is ejected into them, then fall as ejection continues.
    - **Volume Changes:**
        - Ventricular volume decreases rapidly as blood is ejected. The amount of blood ejected is the **Stroke Volume (SV)** (approx. 70 mL).
        - The volume remaining in the ventricle at the end of ejection is the **End-Systolic Volume (ESV)** (approx. 50-60 mL). SV = EDV - ESV.
    - **Valve Status:** Semilunar valves are open; AV valves are closed.
- **4. Isovolumetric Relaxation (Ventricular Diastole - Part 1) (0.08 sec):**

- **Initiation:** Begins as the ventricles start to relax (repolarization).
- **Pressure Changes:**
    - Ventricular pressure falls rapidly.
    - As ventricular pressure drops below aortic/pulmonary pressure, blood in the arteries flows back towards the ventricles, causing the semilunar valves to close, producing the **second heart sound (S2 - "dub")**. This closure is typically followed by a brief rebound in aortic pressure called the dicrotic notch (incisura).
    - Ventricular pressure continues to fall, but it is still higher than atrial pressure.
- **Volume Changes:**
    - Ventricular volume remains constant because all four valves are closed, and no blood is entering or leaving.
- **Valve Status:** All four valves are closed.

- **5. Ventricular Filling (Ventricular Diastole - Part 2) (0.42 sec):**
    - **Initiation:** Ventricular pressure continues to fall and eventually drops below atrial pressure.
    - **Pressure Changes:**
        - When ventricular pressure drops below atrial pressure, the AV valves open.
        - Atrial pressure also falls as blood drains into the ventricles, then gradually rises as venous return fills the atria again.
    - **Volume Changes:**

- Ventricular volume increases rapidly during the initial rapid filling phase (70-80% of filling).
- A slower filling phase follows as blood continues to flow from the atria into the ventricles passively.

- **Valve Status:** AV valves are open; semilunar valves are closed. This phase leads into the next atrial systole, completing the cycle.

6. (b) Describe the hormonal regulation of gastric secretion.

- Gastric secretion is primarily regulated by hormones released from the stomach and small intestine, in conjunction with neural control.
  - **1. Gastrin:**
    - **Source:** Produced by **G cells** located primarily in the pyloric antrum of the stomach.
    - **Stimuli for Release:**
      - Distension of the stomach (stretch receptors).
      - Presence of partially digested proteins (peptides and amino acids) in the stomach.
      - High pH (alkaline conditions) in the stomach.
      - Neural stimulation (vagus nerve, acetylcholine).
    - **Actions:**
      - Potent stimulator of **hydrochloric acid (HCl)** secretion from parietal cells.
      - Stimulates secretion of **pepsinogen** from chief cells.
      - Promotes gastric motility (mixing and emptying).
      - Stimulates the growth of gastric mucosa.

- Also stimulates the release of histamine from enterochromaffin-like (ECL) cells, which further stimulates HCl secretion.

- **2. Secretin:**
  - **Source:** Produced by **S cells** in the duodenal and jejunal mucosa of the small intestine.
  - **Stimuli for Release:**
    - Presence of highly acidic chyme (low pH, below 4.5) entering the duodenum from the stomach.
  - **Actions (related to gastric secretion):**
    - **Inhibits gastric acid secretion** from parietal cells.
    - Inhibits gastric emptying, slowing the rate at which acidic chyme enters the duodenum.
    - Its primary role is to stimulate bicarbonate secretion from the pancreas to neutralize the acidic chyme in the duodenum.
- **3. Cholecystokinin (CCK):**
  - **Source:** Produced by **I cells** in the duodenal and jejunal mucosa of the small intestine.
  - **Stimuli for Release:**
    - Presence of fatty acids and amino acids in chyme entering the duodenum.
  - **Actions (related to gastric secretion):**
    - **Inhibits gastric emptying**, providing more time for fat digestion in the small intestine.
    - Weakly inhibits gastric acid secretion.

- Its primary roles are to stimulate pancreatic enzyme secretion and gallbladder contraction.

- **4. Gastric Inhibitory Peptide (GIP) / Glucose-Dependent Insulinotropic Peptide:**
  - **Source:** Produced by **K cells** in the duodenal and jejunal mucosa of the small intestine.
  - **Stimuli for Release:**
    - Presence of fatty acids and glucose in chyme entering the duodenum.
  - **Actions (related to gastric secretion):**
    - **Inhibits gastric acid secretion** and gastric emptying.
    - Its most significant role is to stimulate insulin release from pancreatic beta cells in response to glucose.
- **5. Somatostatin:**
  - **Source:** Produced by **D cells** in the stomach and duodenum, as well as by cells in the pancreas and hypothalamus.
  - **Stimuli for Release:** Low pH in the stomach (high acidity).
  - **Actions:**
    - **Inhibits the release of gastrin** from G cells.
    - Directly inhibits HCl secretion from parietal cells.
    - Acts as a "brake" on digestive processes, reducing gastric acid output when stomach contents become highly acidic.

7. Write short notes on any three of the following:

- **(a) Regulation of Respiration:**

- Respiration is precisely regulated to maintain appropriate levels of oxygen and carbon dioxide in the blood. This regulation primarily involves neural mechanisms with chemical and other influences.
- **Neural Control:**
  - **Medullary Respiratory Center:** Located in the medulla oblongata, it contains two main groups of neurons:
    - **Dorsal Respiratory Group (DRG):** Primarily involved in inspiration, generating rhythmic inspiratory impulses that activate the diaphragm and external intercostals.
    - **Ventral Respiratory Group (VRG):** Contains both inspiratory and expiratory neurons, remaining inactive during quiet breathing but becoming active during forceful breathing to stimulate accessory muscles.
  - **Pontine Respiratory Group (PRG) / Pneumotaxic and Apneustic Centers:** Located in the pons, these centers modulate the activity of the medullary centers. The pneumotaxic center inhibits inspiration, promoting a shorter and faster breathing pattern, while the apneustic center prolongs inspiration, leading to longer, deeper breaths.
- **Chemical Control (Most Important):**
  - **Chemoreceptors:**
    - **Central Chemoreceptors:** Located in the medulla oblongata, highly sensitive to changes in H^+ concentration in the cerebrospinal fluid (CSF), which is primarily influenced by blood PCO_2. An increase in PCO_2 leads to increased H^+ in CSF, stimulating these receptors and increasing ventilation.
    - **Peripheral Chemoreceptors:** Located in the carotid bodies (at the bifurcation of the common carotid arteries)

and aortic bodies (in the aortic arch). They are sensitive to changes in PO_2, PCO_2, and H^+ in arterial blood. They are most strongly stimulated by a significant drop in PO_2 (below 60 mmHg) and also respond to increases in PCO_2 and H^+.

- **Role of PCO_2 and H^+:** PCO_2 is the most potent regulator of respiration. Even a slight increase in arterial PCO_2 (hypercapnia) strongly stimulates ventilation to blow off excess CO_2. Changes in H^+ (pH) also have a significant effect, with acidosis increasing ventilation.
- **Role of PO_2:** Under normal conditions, PO_2 has less influence on ventilation because hemoglobin is highly saturated with oxygen. However, in hypoxic conditions, a substantial drop in PO_2 becomes a strong stimulus.

- **Other Influences:**
  - **Proprioceptors:** Located in muscles and joints, they stimulate respiration during exercise.
  - **Inflation Reflex (Herring-Breuer Reflex):** Stretch receptors in the lungs inhibit inspiration when the lungs are overinflated, protecting against tissue damage.
  - **Limbic System & Hypothalamus:** Emotional states can alter breathing patterns.
  - **Temperature:** Fever increases respiratory rate.
  - **Pain:** Can alter breathing.
  - **Voluntary Control:** Cerebral cortex allows for conscious control of breathing (e.g., holding breath), but chemical factors override this eventually.

- **(b) Renal Blood Supply:**

- The kidneys receive a remarkably rich blood supply, essential for their filtration, reabsorption, and secretion functions, and for maintaining overall body homeostasis.
- **Route of Blood Flow:**
  - **Renal Arteries:** Originate directly from the abdominal aorta, typically one for each kidney. They carry a large volume of oxygenated blood (about 20-25% of resting cardiac output) to the kidneys.
  - **Segmental Arteries:** Inside the renal sinus, the renal artery divides into several segmental arteries, each supplying a distinct region of the kidney.
  - **Interlobar Arteries:** These arteries pass between the renal pyramids in the renal columns, extending towards the renal cortex.
  - **Arcuate Arteries:** At the base of the renal pyramids, the interlobar arteries arch over the bases of the pyramids to form arcuate arteries.
  - **Cortical Radiate (Interlobular) Arteries:** Branch off the arcuate arteries and radiate outwards into the renal cortex.
  - **Afferent Arterioles:** Each cortical radiate artery gives rise to numerous afferent arterioles, each supplying a single glomerulus. The afferent arteriole is crucial for regulating blood flow into the glomerulus and thus the glomerular filtration rate.
  - **Glomerulus:** A capillary network within the Bowman's capsule where filtration of blood occurs.
  - **Efferent Arterioles:** Blood exits the glomerulus via the efferent arteriole. Unlike typical capillary beds, the efferent arteriole does not lead directly into a venule; instead, it branches to form a second capillary bed.

- **Peritubular Capillaries:** These capillaries surround the renal tubules in the cortex, responsible for most of the reabsorption and secretion processes between the blood and the tubular fluid.
- **Vasa Recta:** In juxtamedullary nephrons (those with long loops of Henle extending deep into the medulla), the efferent arterioles give rise to specialized capillary loops called vasa recta. The vasa recta play a crucial role in maintaining the medullary osmotic gradient, which is essential for concentrating urine.
- **Cortical Radiate (Interlobular) Veins:** Blood from the peritubular capillaries and vasa recta drains into these veins.
- **Arcuate Veins:** Cortical radiate veins drain into arcuate veins.
- **Interlobar Veins:** Arcuate veins drain into interlobar veins.
- **Renal Vein:** Interlobar veins merge to form the renal vein, which exits the kidney and empties into the inferior vena cava.

- **Significance:** This unique vascular arrangement, particularly the afferent and efferent arterioles and the two capillary beds (glomerulus and peritubular/vasa recta), allows for precise regulation of filtration and efficient exchange of substances between blood and the tubular filtrate, critical for maintaining fluid, electrolyte, and waste balance.

- **(c) Coronary Circulation:**
  - Coronary circulation refers to the blood supply that nourishes the heart muscle (myocardium) itself. Although the heart is filled with blood, its muscle tissue does not directly extract oxygen and nutrients from the blood within its chambers. Instead, it relies on its own dedicated arterial and venous supply.
  - **Coronary Arteries:**

- The primary coronary arteries originate from the base of the aorta, just beyond the aortic valve. When the aortic valve closes during diastole, blood flows into these arteries.
- **Left Coronary Artery (LCA):** Typically branches into:
    - **Anterior Interventricular Artery (LAD or Left Anterior Descending):** Supplies the anterior part of both ventricles and most of the interventricular septum. It is often called the "widowmaker" due to the severity of blockages.
    - **Circumflex Artery:** Supplies the left atrium and the posterior and lateral walls of the left ventricle.
- **Right Coronary Artery (RCA):** Supplies the right atrium, most of the right ventricle, and parts of the posterior wall of the left ventricle and the interventricular septum. It typically gives rise to:
    - **Marginal Branches:** Supply the anterior surface of the right ventricle.
    - **Posterior Interventricular Artery (PDA or Posterior Descending Artery):** Supplies the posterior part of both ventricles and the posterior interventricular septum (in most individuals, this branches from the RCA, making them "right dominant").

- **Coronary Veins:**
    - After blood passes through the capillary beds of the myocardium, it collects in various cardiac veins.
    - Most of the deoxygenated blood from the myocardial capillaries drains into the **coronary sinus**, a large venous channel on the posterior surface of the heart.
    - The coronary sinus then empties directly into the right atrium.

        - Some smaller anterior cardiac veins drain directly into the right atrium, and some Thebesian veins drain directly into the heart chambers.
    - **Significance:**
        - The coronary circulation is crucial for the continuous and high metabolic demands of the heart muscle.
        - Disruptions to this blood flow (e.g., due to atherosclerosis, plaque formation) can lead to myocardial ischemia (reduced blood flow), angina pectoris (chest pain), myocardial infarction (heart attack) due to tissue death, and ultimately heart failure.

- **(d) Formation of Platelet Plug:**
    - The formation of a platelet plug is the second step in hemostasis (the process that stops bleeding), following vascular spasm and preceding blood coagulation (clotting). It rapidly seals small breaks in blood vessels.

    - **Steps in Platelet Plug Formation:**
        - **1. Platelet Adhesion:**
            - When a blood vessel is damaged, the underlying collagen fibers (subendothelial collagen) become exposed to the blood.
            - Platelets contain receptors that bind to this exposed collagen.
            - **Von Willebrand Factor (vWF)**, a plasma protein secreted by endothelial cells and platelets, acts as a bridge, facilitating the binding of platelets to collagen. This initial attachment is known as platelet adhesion.
        - **2. Platelet Release Reaction (Activation):**

- Upon adhesion, platelets become activated and undergo a rapid change in shape, becoming spiky and irregular.
- They then release the contents of their granules into the surrounding area, including:
    - **Adenosine Diphosphate (ADP):** A powerful aggregator that causes other platelets to become sticky and aggregate.
    - **Serotonin:** A vasoconstrictor that enhances vascular spasm.
    - **Thromboxane A2 (TXA_2):** A prostaglandin derivative synthesized by activated platelets. It is a potent vasoconstrictor and a powerful inducer of platelet aggregation.
    - **Other factors:** Platelet factor 3 (PF3 - a phospholipid surface for clotting factors), platelet-derived growth factor (PDGF - for vessel repair), and calcium ions.

- **3. Platelet Aggregation:**
    - ADP and TXA_2 released by activated platelets attract more platelets to the site of injury.
    - These newly recruited platelets also become activated, release their contents, and begin to adhere to the first layer of activated platelets, forming a growing mass.
    - This process is facilitated by fibrinogen (a plasma protein), which forms bridges between the GPIIb/IIIa receptors on the surface of adjacent platelets, linking them together.
    - This accumulation of platelets forms a loose, temporary seal called the **platelet plug**.

- **Significance:** The platelet plug is essential for stopping blood loss from small to medium-sized vessel injuries quickly. While initially loose, it provides the framework upon which the more stable fibrin clot (formed by coagulation) will eventually develop. The substances released by activated platelets also play a role in promoting the coagulation cascade.