B. PHARMACY 1ST SEMESTER

REMEDIAL BIOLOGY

UNIT – 2 🧬

BODY FLUIDS AND CIRCULATION 💉

DIGESTION AND ABSORPTION 🍽️

BREATHING AND RESPIRATION 🫁

UNIT – 2 (A) BODY FLUIDS AND CIRCULATION 💉

⚖️

TOPICS COVERED IN THIS SECTION 📚

→ COMPOSITION OF BLOOD
→ BLOOD GROUPS
→ COAGULATION OF BLOOD
→ COMPOSITION AND FUNCTIONS OF LYMPH
→ HUMAN CIRCULATORY SYSTEM
→ STRUCTURE OF HUMAN HEART AND BLOOD VESSELS
→ CARDIAC CYCLE, CARDIAC OUTPUT AND ECG

COMPOSITION OF BLOOD 🩸

➤ INTRODUCTION 🔬

Blood is a specialized connective tissue that serves as the transport medium for the human body. It is a complex fluid consisting of cellular components suspended in a liquid matrix called plasma. Blood constitutes approximately 7-8% of total body weight in healthy adults and performs vital functions including transportation, regulation, and protection.

Physical Properties of Blood:

- Color: Bright red (arterial) to dark red (venous)
- pH: Maintained at 7.35-7.45 (slightly alkaline)
- Viscosity: 3-4 times thicker than water
- Temperature: Approximately 38°C (100.4°F)
- Volume: 5-6 liters in average adult

➤ PLASMA COMPOSITION 💧

Plasma constitutes approximately 55% of total blood volume and serves as the liquid medium in which blood cells are suspended. It is a complex aqueous solution containing numerous dissolved substances essential for physiological functions.

Major Plasma Components:

Water Content (90-92%):

- Primary solvent for all dissolved substances
- Maintains blood volume and pressure
- Facilitates transport of nutrients and waste products
- Regulates body temperature through heat distribution

Plasma Proteins (7-8%):

- **Albumin (3.5-5.0 g/dL):** Maintains oncotic pressure, transports fatty acids and hormones
- **Globulins (2.0-3.5 g/dL):** Include immunoglobulins (antibodies) and transport proteins
- **Fibrinogen (0.2-0.4 g/dL):** Essential for blood clotting mechanism
- **Prothrombin:** Precursor to thrombin in coagulation cascade

Dissolved Substances (1-2%):

- **Nutrients:** Glucose, amino acids, lipids, vitamins
- **Waste Products:** Urea, creatinine, uric acid, bilirubin
- **Electrolytes:** Sodium, potassium, calcium, chloride, bicarbonate
- **Hormones:** Insulin, cortisol, thyroid hormones
- **Gases:** Dissolved oxygen, carbon dioxide, nitrogen

➤ CELLULAR COMPONENTS 🔴

Blood cells, also called formed elements, constitute approximately 45% of total blood volume and include three distinct types of cells, each with specialized functions.

❖ RED BLOOD CELLS (ERYTHROCYTES) 🔴

Red blood cells are the most abundant cells in blood, specialized for oxygen transport throughout the body.

Morphological Characteristics:

- Shape: Biconcave disc structure for maximum surface area
- Size: 7-8 micrometers in diameter
- Nucleus: Absent in mature cells (anucleated)
- Color: Red due to hemoglobin content
- Lifespan: Approximately 120 days

Physiological Functions:

- **Oxygen Transport:** Hemoglobin binds oxygen in lungs and releases it in tissues
- **Carbon Dioxide Transport:** Carries CO_2 from tissues to lungs for elimination
- **pH Buffering:** Hemoglobin acts as an important buffer system
- **Carbonic Anhydrase Activity:** Facilitates CO_2 transport as bicarbonate

Normal Values:

- Men: 4.5-5.5 million cells per microliter
- Women: 4.0-5.0 million cells per microliter
- Hematocrit: 40-45% (men), 36-42% (women)

❖ WHITE BLOOD CELLS (LEUKOCYTES)

White blood cells are nucleated cells responsible for immune defense and inflammatory responses. They are classified into different types based on their structure and function.

Classification and Functions:

Granulocytes (Contain Granules):

- **Neutrophils (60-70%):** First responders to bacterial infections, perform phagocytosis
- **Eosinophils (2-4%):** Combat parasitic infections and allergic reactions
- **Basophils (0.5-1%):** Release histamine and heparin during inflammatory responses

Agranulocytes (No Visible Granules):

- **Lymphocytes (20-25%):** B cells produce antibodies, T cells provide cellular immunity
- **Monocytes (3-8%):** Develop into macrophages, perform phagocytosis of large particles

Normal Values:

- Total WBC count: 4,000-11,000 cells per microliter
- Differential count varies by cell type
- Increase indicates infection or inflammatory conditions

❖ PLATELETS (THROMBOCYTES) 🩹

Platelets are small, anucleated cell fragments derived from megakaryocytes in bone marrow, essential for hemostasis and blood clotting.

Structural Characteristics:

- Size: 2-3 micrometers in diameter
- Shape: Disc-shaped when inactive, irregular when activated

- Nucleus: Absent (cell fragments)
- Organelles: Contain dense granules with clotting factors

Physiological Functions:

- **Primary Hemostasis:** Form platelet plugs at injury sites
- **Clot Formation:** Provide surface for coagulation cascade
- **Vasoconstriction:** Release substances that constrict blood vessels
- **Wound Healing:** Promote tissue repair and regeneration

Normal Values:

- Count: 150,000-450,000 platelets per microliter
- Lifespan: 8-10 days
- Production: Continuous formation in bone marrow

BLOOD GROUPS 🅰️

➤ ABO BLOOD GROUP SYSTEM 🔤

The ABO blood group system is the most clinically significant blood typing system, discovered by Karl Landsteiner in 1901. This system is based on the presence or absence of specific antigens on red blood cell surfaces and corresponding antibodies in plasma.

❖ GENETIC BASIS 🧬

The ABO system is determined by alleles at a single gene locus on chromosome 9. Three main alleles exist: A, B, and O.

Allele Characteristics:

- **A Allele:** Codes for A antigen production
- **B Allele:** Codes for B antigen production
- **O Allele:** Recessive allele, no antigen production

Inheritance Patterns:

- **Type A:** Genotypes AA or AO
- **Type B:** Genotypes BB or BO
- **Type AB:** Genotype AB (codominant expression)
- **Type O:** Genotype OO (recessive)

❖ ANTIGEN-ANTIBODY RELATIONSHIPS 🔬

Each blood type has characteristic antigens on red blood cells and corresponding antibodies in plasma, following specific immunological rules.

Blood Type A:

- **Surface Antigens:** A antigens on red blood cells
- **Plasma Antibodies:** Anti-B antibodies (β antibodies)
- **Reaction:** Agglutinates with Type B or Type AB blood

Blood Type B:

- **Surface Antigens:** B antigens on red blood cells
- **Plasma Antibodies:** Anti-A antibodies (α antibodies)
- **Reaction:** Agglutinates with Type A or Type AB blood

Blood Type AB:

- **Surface Antigens:** Both A and B antigens present
- **Plasma Antibodies:** No anti-A or anti-B antibodies
- **Clinical Significance:** Universal plasma donor

Blood Type O:

- **Surface Antigens:** No A or B antigens present
- **Plasma Antibodies:** Both anti-A and anti-B antibodies
- **Clinical Significance:** Universal red cell donor

➤ RH BLOOD GROUP SYSTEM ®

The Rh blood group system is the second most important blood typing system, particularly significant in pregnancy and transfusion medicine.

❖ RH FACTOR CHARACTERISTICS

The Rh system involves multiple antigens, with the D antigen being most clinically significant.

Rh Positive (Rh+):

- Presence of D antigen on red blood cells
- Frequency: Approximately 85% of population
- Antibody Status: No naturally occurring anti-D antibodies
- Clinical Significance: Can receive Rh+ or Rh- blood

Rh Negative (Rh-):

- Absence of D antigen on red blood cells

- Frequency: Approximately 15% of population
- Antibody Development: Can develop anti-D antibodies upon exposure
- Clinical Significance: Should receive only Rh- blood

❖ CLINICAL IMPLICATIONS 🩺

Hemolytic Disease of Newborn (HDN):

- **Mechanism:** Rh- mother carrying Rh+ fetus
- **Sensitization:** First pregnancy sensitizes mother's immune system
- **Subsequent Pregnancies:** Maternal anti-D antibodies attack fetal red blood cells
- **Prevention:** RhoGAM injection prevents maternal sensitization

COAGULATION OF BLOOD 🩹

➤ HEMOSTASIS OVERVIEW 🛡️

Hemostasis is the complex physiological process that prevents and stops bleeding following vascular injury. This protective mechanism involves coordinated interactions between blood vessels, platelets, and coagulation factors to maintain vascular integrity while preserving blood flow.

Three Sequential Phases:

1. **Vascular Phase:** Immediate vasoconstriction
2. **Platelet Phase:** Platelet adhesion and aggregation
3. **Coagulation Phase:** Fibrin clot formation

➤ MECHANISM OF BLOOD COAGULATION ⚙️

Blood coagulation involves a complex cascade of enzymatic reactions that ultimately convert soluble fibrinogen into insoluble fibrin, forming a stable blood clot.

❖ INTRINSIC PATHWAY 🔄

The intrinsic pathway is activated by factors present within the blood itself and does not require external tissue factors.

Activation Sequence:

- **Factor XII Activation:** Contact with damaged endothelial surfaces
- **Factor XI Activation:** Activated by Factor XIIa
- **Factor IX Activation:** Activated by Factor XIa in presence of calcium
- **Factor VIII Complex:** Forms tenase complex with Factor IXa
- **Factor X Activation:** Common pathway convergence point

Key Characteristics:

- Slower activation compared to extrinsic pathway
- Requires all clotting factors to be present in blood
- Important for maintaining hemostasis in minor injuries
- Measured by Partial Thromboplastin Time (PTT)

❖ EXTRINSIC PATHWAY 🚀

The extrinsic pathway is rapidly activated by tissue factor released from damaged tissues outside the blood vessel.

Activation Mechanism:

- **Tissue Factor Release:** From damaged endothelial cells and tissues
- **Factor VII Activation:** Tissue factor activates Factor VII
- **Factor X Activation:** Direct activation by Factor VIIa-tissue factor complex
- **Rapid Response:** Faster than intrinsic pathway

Clinical Significance:

- Primary pathway for hemostasis initiation
- Measured by Prothrombin Time (PT)
- Target for anticoagulant therapy monitoring

❖ COMMON PATHWAY 🔗

Both intrinsic and extrinsic pathways converge at Factor X activation, leading to the final common pathway of clot formation.

Final Clotting Steps:

1. **Prothrombinase Complex Formation:** Factor Xa + Factor Va + calcium + phospholipids
2. **Thrombin Generation:** Prothrombinase converts prothrombin to thrombin
3. **Fibrinogen Conversion:** Thrombin converts fibrinogen to fibrin monomers
4. **Fibrin Polymerization:** Fibrin monomers form fibrin polymers
5. **Clot Stabilization:** Factor XIIIa cross-links fibrin for stable clot

➤ ANTICOAGULATION MECHANISMS 🚫

The body maintains balance between clot formation and clot prevention through natural anticoagulant mechanisms.

Natural Anticoagulants:

- **Heparin:** Activates antithrombin III, inhibits thrombin and Factor Xa
- **Protein C:** Inactivates Factors Va and VIIIa
- **Protein S:** Cofactor for Protein C activity
- **Antithrombin III:** Primary inhibitor of thrombin and other clotting factors

Fibrinolytic System:

- **Plasminogen:** Inactive precursor to plasmin
- **Tissue Plasminogen Activator (tPA):** Converts plasminogen to plasmin
- **Plasmin:** Enzyme that degrades fibrin clots
- **Regulation:** Controlled by plasminogen activator inhibitors

COMPOSITION AND FUNCTIONS OF LYMPH 🌊

➤ LYMPH COMPOSITION 💧

Lymph is a colorless or pale yellow fluid that circulates through the lymphatic system, derived from interstitial fluid that has entered lymphatic vessels.

Physical Properties:

- **Color:** Colorless to pale yellow (milky white after fat absorption)

- **Specific Gravity:** 1.015-1.023
- **pH:** 7.35-7.45 (similar to blood)
- **Volume:** 2-4 liters total lymph in body

Chemical Composition:

Plasma-like Fluid:

- **Water (95%):** Primary component
- **Proteins (2-5%):** Lower concentration than blood plasma
- **Lipids:** Variable depending on intestinal absorption
- **Electrolytes:** Similar to interstitial fluid
- **Glucose:** Lower than blood glucose levels

Cellular Components:

- **Lymphocytes:** Primary cell type (95% of cells)
- **Monocytes:** Small percentage
- **Few Neutrophils:** Minimal presence
- **No Red Blood Cells:** Under normal conditions
- **No Platelets:** Absent in lymph

➤ FUNCTIONS OF LYMPH 🎯

Lymph performs several critical physiological functions that complement the cardiovascular system and maintain tissue homeostasis.

❖ FLUID BALANCE MAINTENANCE ⚖️

Lymph plays a crucial role in maintaining proper fluid distribution between intravascular and interstitial compartments.

Mechanism:

- **Interstitial Fluid Collection:** Collects excess fluid from tissue spaces
- **Protein Recovery:** Returns proteins that leaked from capillaries
- **Volume Regulation:** Prevents tissue edema formation
- **Pressure Maintenance:** Helps maintain tissue fluid pressure

Clinical Significance:

- **Lymphedema:** Occurs when lymphatic drainage is impaired
- **Edema Prevention:** Normal lymph flow prevents tissue swelling
- **Protein Conservation:** Prevents loss of valuable plasma proteins

❖ IMMUNE FUNCTIONS

The lymphatic system serves as a critical component of the body's immune defense mechanism.

Immune Cell Transport:

- **Lymphocyte Circulation:** Transports immune cells throughout body
- **Antigen Presentation:** Carries antigens to lymph nodes for immune recognition
- **Antibody Distribution:** Distributes immunoglobulins to tissues
- **Immune Surveillance:** Monitors tissues for foreign substances

Lymph Node Functions:

- **Filtration:** Removes bacteria, cancer cells, and debris from lymph
- **Immune Response:** Site of lymphocyte activation and proliferation
- **Antibody Production:** B cell differentiation and antibody synthesis

❖ FAT ABSORPTION 🥑

Lymph plays a unique role in the absorption and transport of dietary fats from the intestine.

Chylomicron Transport:

- **Fat Absorption:** Long-chain fatty acids absorbed into lymphatic system
- **Chyle Formation:** Lymph becomes milky due to fat content
- **Systemic Distribution:** Transports fats to systemic circulation
- **Bypass Portal Circulation:** Avoids immediate liver processing

HUMAN CIRCULATORY SYSTEM 🫀

➤ OVERVIEW OF CIRCULATION 🔄

The human circulatory system is a closed-loop transport system consisting of the heart, blood vessels, and blood. This system ensures continuous circulation of blood to deliver oxygen and nutrients while removing metabolic wastes.

❖ TYPES OF CIRCULATION 🌐

Pulmonary Circulation:

- **Route:** Heart → Lungs → Heart

- **Function:** Gas exchange (oxygenation of blood)
- **Pressure:** Low pressure system
- **Blood Type:** Deoxygenated blood to lungs, oxygenated blood from lungs

Systemic Circulation:

- **Route:** Heart → Body Tissues → Heart
- **Function:** Nutrient and oxygen delivery, waste removal
- **Pressure:** High pressure system
- **Blood Type:** Oxygenated blood to tissues, deoxygenated blood from tissues

Portal Circulation:

- **Hepatic Portal System:** Intestines → Liver → Heart
- **Renal Portal System:** Limited in humans
- **Function:** Allows liver processing of absorbed nutrients

➤ BLOOD VESSELS 🩸

The circulatory system consists of different types of blood vessels, each specialized for specific functions in blood transport.

❖ ARTERIES 🔴

Arteries carry blood away from the heart and are designed to withstand high pressure from cardiac contractions.

Structural Features:

- **Thick Muscular Walls:** Contain smooth muscle for pressure regulation
- **Elastic Fibers:** Allow expansion during systole and recoil during diastole
- **Three Layers:** Tunica intima, tunica media, tunica adventitia
- **No Valves:** High pressure prevents backflow

Functional Characteristics:

- **High Pressure Transport:** Withstand systolic pressures up to 120 mmHg
- **Pressure Regulation:** Smooth muscle contraction controls blood flow
- **Pulse Generation:** Elastic recoil creates pulse waves
- **Oxygen-Rich Blood:** Carry oxygenated blood (except pulmonary artery)

❖ **VEINS** 🔵

Veins return blood to the heart and operate under much lower pressure than arteries.

Structural Adaptations:

- **Thin Walls:** Less muscular tissue than arteries
- **Large Lumens:** Greater internal diameter for low-pressure flow
- **Valves:** Prevent backflow of blood toward tissues
- **Compliance:** High capacity for blood storage

Functional Roles:

- **Venous Return:** Return deoxygenated blood to heart
- **Blood Reservoir:** Store approximately 60% of total blood volume
- **Venous Pump:** Muscle contractions assist blood return
- **Pressure Buffering:** Accommodate volume changes

❖ CAPILLARIES 🌐

Capillaries are the smallest blood vessels where actual exchange of materials occurs between blood and tissues.

Exchange Mechanisms:

- **Diffusion:** Gases and small molecules cross capillary walls
- **Filtration:** Hydrostatic pressure forces fluid into tissues
- **Reabsorption:** Osmotic pressure draws fluid back into capillaries
- **Pinocytosis:** Transport of larger molecules across endothelium

STRUCTURE OF HUMAN HEART AND BLOOD VESSELS 💖

➤ HEART ANATOMY 🫀

The human heart is a four-chambered muscular pump that maintains continuous blood circulation throughout the body.

❖ HEART CHAMBERS 🏠

Atria (Upper Chambers):

- **Right Atrium:** Receives deoxygenated blood from body via vena cavae

- **Left Atrium:** Receives oxygenated blood from lungs via pulmonary veins
- **Wall Thickness:** Thin walls due to low pressure filling
- **Function:** Collect blood and prime ventricles for filling

Ventricles (Lower Chambers):

- **Right Ventricle:** Pumps blood to lungs via pulmonary artery
- **Left Ventricle:** Pumps blood to body via aorta
- **Wall Thickness:** Thick muscular walls for high-pressure pumping
- **Left Ventricular Dominance:** Thicker wall due to higher systemic pressure

❖ HEART VALVES

Heart valves ensure unidirectional blood flow and prevent regurgitation during the cardiac cycle.

Atrioventricular Valves:

- **Tricuspid Valve:** Between right atrium and right ventricle (3 cusps)
- **Mitral Valve:** Between left atrium and left ventricle (2 cusps)
- **Chordae Tendineae:** Fibrous cords prevent valve prolapse
- **Papillary Muscles:** Contract to tension chordae during systole

Semilunar Valves:

- **Pulmonary Valve:** Between right ventricle and pulmonary artery
- **Aortic Valve:** Between left ventricle and aorta

- **Three Cusps Each:** Pocket-like structures that close with pressure reversal
- **High Pressure Function:** Withstand high ventricular pressures

❖ HEART WALL STRUCTURE 🧱

Epicardium (Outer Layer):

- **Composition:** Visceral layer of pericardium
- **Function:** Smooth outer surface, reduces friction
- **Blood Supply:** Contains coronary blood vessels
- **Protection:** Outer protective covering

Myocardium (Middle Layer):

- **Composition:** Specialized cardiac muscle tissue
- **Function:** Contractile layer responsible for pumping action
- **Fiber Arrangement:** Spiral arrangement for efficient contraction
- **Conduction System:** Contains specialized conduction fibers

Endocardium (Inner Layer):

- **Composition:** Smooth endothelial tissue
- **Function:** Reduces friction during blood flow
- **Valve Formation:** Continuous with heart valve structure
- **Blood Contact:** Direct interface with circulating blood

CARDIAC CYCLE, CARDIAC OUTPUT AND ECG ⚡

➤ CARDIAC CYCLE 🔄

The cardiac cycle represents one complete sequence of heart contraction and relaxation, typically lasting approximately 0.8 seconds at normal heart rate.

❖ PHASES OF CARDIAC CYCLE ⏰

Diastole (Relaxation Phase):

- **Duration:** Approximately 0.5 seconds
- **Ventricular Filling:** Atria fill with blood, AV valves open
- **Pressure Changes:** Low ventricular pressure allows filling
- **Volume Changes:** Ventricular volume increases to ~120-130 mL

Systole (Contraction Phase):

- **Duration:** Approximately 0.3 seconds
- **Ventricular Ejection:** Ventricles contract, semilunar valves open
- **Pressure Generation:** High pressure forces blood into arteries
- **Volume Changes:** Ventricular volume decreases to ~50-60 mL

❖ PRESSURE AND VOLUME CHANGES 📊

Ventricular Pressure Variations:

- **Diastolic Pressure:** 0-10 mmHg during filling
- **Systolic Pressure:** 120 mmHg (left), 25 mmHg (right)
- **Pressure Gradients:** Drive blood flow through circulation
- **Valve Operation:** Pressure differences control valve opening/closing

Stroke Volume: Volume of blood ejected per heartbeat (~70 mL) **End-Diastolic Volume:** Maximum ventricular volume (~130 mL) **End-Systolic Volume:** Minimum ventricular volume (~60 mL) **Ejection Fraction:** Percentage of blood ejected (55-70% normal)

➤ CARDIAC OUTPUT 📈

Cardiac output represents the volume of blood pumped by the heart per minute and is a critical measure of cardiovascular function.

❖ CALCULATION AND FACTORS 🔢

Mathematical Formula: Cardiac Output (CO) = Stroke Volume (SV) × Heart Rate (HR)

Normal Values:

- **Resting Cardiac Output:** 5-6 liters per minute
- **Stroke Volume:** 70 mL per beat
- **Heart Rate:** 70-75 beats per minute
- **Cardiac Index:** CO adjusted for body surface area (2.5-4.0 L/min/m^2)

Factors Affecting Cardiac Output:

Preload (Venous Return):

- **Definition:** Volume of blood returning to heart
- **Frank-Starling Mechanism:** Increased filling leads to stronger contraction
- **Venous Pressure:** Affects ventricular filling

- **Blood Volume:** Total circulating volume influences preload

Afterload (Arterial Pressure):

- **Definition:** Resistance against which heart must pump
- **Blood Pressure:** Higher pressure reduces stroke volume
- **Vascular Resistance:** Arterial constriction increases afterload
- **Ventricular Work:** Higher afterload increases cardiac workload

Contractility (Myocardial Function):

- **Definition:** Intrinsic ability of heart muscle to contract
- **Sympathetic Stimulation:** Increases contractility
- **Calcium Availability:** Affects contraction strength
- **Metabolic Factors:** Oxygen, pH, and energy availability

➤ ELECTROCARDIOGRAM (ECG) 📊

The electrocardiogram is a recording of the electrical activity of the heart, providing valuable information about cardiac function and pathology.

❖ ECG COMPONENTS 📈

P Wave:

- **Origin:** Atrial depolarization
- **Duration:** 0.08-0.10 seconds
- **Amplitude:** 0.1-0.3 mV
- **Clinical Significance:** Reflects atrial electrical activity

QRS Complex:

- **Origin:** Ventricular depolarization
- **Duration:** 0.06-0.10 seconds
- **Amplitude:** 0.5-2.0 mV
- **Components:** Q (downward), R (upward), S (downward deflections)

T Wave:

- **Origin:** Ventricular repolarization
- **Duration:** 0.10-0.25 seconds
- **Amplitude:** 0.2-0.5 mV
- **Clinical Significance:** Reflects ventricular recovery

❖ ECG INTERVALS AND SEGMENTS ⏱️

PR Interval:

- **Measurement:** From P wave start to QRS complex start
- **Normal Duration:** 0.12-0.20 seconds
- **Significance:** AV conduction time
- **Abnormalities:** Prolonged in heart blocks

ST Segment:

- **Measurement:** From QRS end to T wave start
- **Normal Appearance:** Isoelectric (flat)
- **Clinical Significance:** Myocardial injury indicator
- **Elevation/Depression:** Indicates cardiac pathology

QT Interval:

- **Measurement:** From QRS start to T wave end
- **Normal Duration:** 0.35-0.45 seconds
- **Significance:** Total ventricular electrical activity
- **Rate Correction:** QTc accounts for heart rate variations

---

UNIT – 2 (B) DIGESTION AND ABSORPTION 🍽️

🔄

HUMAN ALIMENTARY CANAL AND DIGESTIVE GLANDS

➤ ALIMENTARY CANAL STRUCTURE 🌊

The alimentary canal is a continuous muscular tube extending from the mouth to the anus, approximately 8-10 meters in length. This complex system is specialized for the mechanical and chemical breakdown of food substances.

❖ MAJOR COMPONENTS 🗺️

Mouth (Oral Cavity):

- **Function:** Initial food breakdown through mastication
- **Structures:** Teeth, tongue, salivary glands
- **Chemical Digestion:** Salivary amylase begins starch breakdown
- **Mechanical Processing:** Teeth reduce food particle size

Esophagus:

- **Length:** Approximately 25 cm muscular tube
- **Function:** Transport food from mouth to stomach
- **Peristalsis:** Wave-like muscular contractions propel food
- **Sphincters:** Upper and lower esophageal sphincters control passage

Stomach:

- **Capacity:** 1-2 liters when distended
- **Regions:** Fundus, body, antrum, pylorus
- **Functions:** Food storage, acid production, protein digestion initiation
- **Gastric Juice:** Contains hydrochloric acid, pepsinogen, and intrinsic factor

Small Intestine:

- **Length:** 6-7 meters, divided into duodenum, jejunum, ileum
- **Function:** Primary site of chemical digestion and nutrient absorption
- **Surface Area:** Increased by villi and microvilli (brush border)
- **Absorption:** 80% of digestion and absorption occurs here

Large Intestine (Colon):

- **Length:** 1.5 meters, larger diameter than small intestine
- **Function:** Water absorption, electrolyte balance, feces formation
- **Bacterial Flora:** Beneficial bacteria synthesize vitamins
- **Storage:** Temporary storage of waste materials

➤ DIGESTIVE GLANDS 🏭

❖ SALIVARY GLANDS 💧

The salivary glands produce saliva, which initiates digestion and maintains oral health.

Types of Salivary Glands:

- **Parotid Glands:** Largest salivary glands, produce serous saliva
- **Submandibular Glands:** Mixed serous and mucous secretion
- **Sublingual Glands:** Primarily mucous secretion
- **Minor Salivary Glands:** Scattered throughout oral cavity

Saliva Composition and Functions:

- **Water (99%):** Primary component
- **Enzymes:** Salivary amylase for starch digestion
- **Antimicrobial Agents:** Lysozyme, lactoferrin, immunoglobulins
- **Lubricants:** Mucins facilitate swallowing
- **pH Buffer:** Bicarbonate maintains oral pH

❖ LIVER 🟫

The liver is the largest internal organ and performs numerous digestive and metabolic functions.

Digestive Functions:

- **Bile Production:** 500-1000 mL bile produced daily
- **Bile Composition:** Bile salts, cholesterol, bilirubin, phospholipids

- **Fat Emulsification:** Bile salts break down large fat globules
- **Storage:** Bile stored and concentrated in gallbladder

Metabolic Functions:

- **Glucose Metabolism:** Glycogen synthesis and breakdown
- **Protein Metabolism:** Amino acid deamination, urea synthesis
- **Lipid Metabolism:** Cholesterol synthesis, lipoprotein production
- **Detoxification:** Metabolizes drugs and toxins

❖ **PANCREAS** 🤲

The pancreas has both endocrine and exocrine functions, with the exocrine portion crucial for digestion.

Exocrine Function:

- **Pancreatic Juice Production:** 1.5-2.0 liters daily
- **Alkaline Secretion:** pH 8.5-9.0 neutralizes gastric acid
- **Enzyme Production:** Multiple digestive enzymes
- **Bicarbonate Secretion:** Maintains optimal pH for enzyme activity

Pancreatic Enzymes:

- **Pancreatic Amylase:** Continues starch digestion
- **Pancreatic Lipase:** Primary fat-digesting enzyme
- **Trypsinogen/Chymotrypsinogen:** Protein-digesting enzyme precursors
- **Carboxypeptidases:** Complete protein digestion

ROLE OF DIGESTIVE ENZYMES ⚗️

➤ ENZYME CLASSIFICATION 🔬

Digestive enzymes are specialized proteins that catalyze the breakdown of complex food molecules into simpler, absorbable units.

❖ CARBOHYDRATE-DIGESTING ENZYMES 📦

Salivary Amylase (Ptyalin):

- **Source:** Parotid and submandibular salivary glands
- **Substrate:** Starch and glycogen molecules
- **Products:** Maltose, maltotriose, and α-dextrins
- **Optimal pH:** 6.8-7.0 (slightly alkaline)
- **Clinical Significance:** Begins carbohydrate digestion in mouth

Pancreatic Amylase:

- **Source:** Pancreatic acinar cells
- **Function:** Continues starch digestion in small intestine
- **Activity:** More potent than salivary amylase
- **Products:** Same as salivary amylase but more complete breakdown
- **Regulation:** Stimulated by cholecystokinin (CCK)

Brush Border Enzymes:

- **Maltase:** Converts maltose to glucose
- **Sucrase:** Breaks sucrose into glucose and fructose

- **Lactase:** Hydrolyzes lactose to glucose and galactose
- **α-Dextrinase:** Completes α-dextrin digestion
- **Location:** Intestinal epithelial cell membrane

❖ PROTEIN-DIGESTING ENZYMES 🥩

Pepsin:

- **Source:** Gastric chief cells (secreted as pepsinogen)
- **Activation:** Requires acidic environment (pH 1.5-3.5)
- **Function:** Initiates protein hydrolysis
- **Products:** Large polypeptides and proteoses
- **Specificity:** Cleaves peptide bonds adjacent to aromatic amino acids

Pancreatic Proteases:

- **Trypsin:** Activated from trypsinogen by enterokinase
- **Chymotrypsin:** Activated from chymotrypsinogen by trypsin
- **Elastase:** Digests elastic fibers in meat
- **Carboxypeptidase A:** Removes aromatic amino acids from C-terminus
- **Carboxypeptidase B:** Removes basic amino acids from C-terminus

Intestinal Peptidases:

- **Aminopeptidases:** Remove amino acids from N-terminus
- **Dipeptidases:** Split dipeptides into individual amino acids
- **Tripeptidases:** Convert tripeptides to amino acids
- **Location:** Brush border of intestinal epithelium

❖ **FAT-DIGESTING ENZYMES** 🥑

Pancreatic Lipase:

- **Source:** Pancreatic acinar cells
- **Cofactors:** Requires bile salts and colipase for activity
- **Substrate:** Triglycerides (triacylglycerols)
- **Products:** Monoglycerides and free fatty acids
- **Optimal Conditions:** Alkaline pH, presence of bile

Phospholipase A_2:

- **Function:** Hydrolyzes phospholipids
- **Products:** Lysophospholipids and fatty acids
- **Clinical Significance:** Important for membrane lipid digestion
- **Activation:** Requires calcium ions for activity

Cholesterol Esterase:

- **Function:** Hydrolyzes cholesterol esters
- **Products:** Free cholesterol and fatty acids
- **Source:** Pancreatic secretion
- **Importance:** Enables cholesterol absorption

➤ **ENZYME REGULATION** 🎛️

❖ **NEURAL REGULATION** 🧠

Parasympathetic Stimulation:

- **Mechanism:** Vagus nerve stimulation
- **Effects:** Increases enzyme secretion
- **Gastric Phase:** Stimulates pepsinogen release
- **Pancreatic Phase:** Enhances pancreatic enzyme secretion

Sympathetic Inhibition:

- **Mechanism:** Reduces digestive activity during stress
- **Effects:** Decreases enzyme production and secretion
- **Blood Flow:** Diverts blood from digestive organs

❖ **HORMONAL REGULATION** 🧪

Gastrin:

- **Source:** G cells in stomach antrum
- **Trigger:** Protein in stomach, vagal stimulation
- **Effects:** Stimulates acid and pepsinogen secretion
- **Duration:** Prolonged action compared to neural stimulation

Cholecystokinin (CCK):

- **Source:** I cells in duodenum and jejunum
- **Trigger:** Fatty acids and amino acids in intestine
- **Effects:** Stimulates pancreatic enzyme secretion, gallbladder contraction
- **Coordination:** Coordinates fat digestion processes

Secretin:

- **Source:** S cells in duodenum
- **Trigger:** Acidic chyme entering duodenum
- **Effects:** Stimulates pancreatic bicarbonate secretion
- **pH Regulation:** Neutralizes gastric acid for optimal enzyme function

DIGESTION, ABSORPTION AND ASSIMILATION OF DIGESTED FOOD 🔄

➤ CARBOHYDRATE DIGESTION AND ABSORPTION 📦

❖ DIGESTION PROCESS ⚗️

Oral Phase:

- **Enzyme:** Salivary amylase (ptyalin)
- **Action:** Breaks α-1,4 glycosidic bonds in starch
- **Products:** Maltose, maltotriose, α-limit dextrins
- **Duration:** Limited due to brief contact time
- **pH Inactivation:** Gastric acid stops salivary amylase activity

Intestinal Phase:

- **Pancreatic Amylase:** Completes starch digestion
- **Brush Border Enzymes:** Final breakdown to monosaccharides
- **Location:** Duodenum and jejunum
- **Efficiency:** Nearly 100% of digestible carbohydrates absorbed

❖ ABSORPTION MECHANISMS 📥

Glucose and Galactose Absorption:

- **Mechanism:** Sodium-glucose cotransporter (SGLT1)
- **Location:** Apical membrane of enterocytes
- **Energy:** Secondary active transport using sodium gradient
- **Efficiency:** High-capacity, saturable transport system

Fructose Absorption:

- **Mechanism:** Facilitated diffusion via GLUT5 transporter
- **Energy:** Passive transport, no energy required
- **Rate:** Slower than glucose absorption
- **Location:** Primarily in jejunum

Basolateral Transport:

- **Mechanism:** GLUT2 transporters move sugars into blood
- **Regulation:** Insulin-independent glucose transport
- **Distribution:** Monosaccharides enter portal circulation

➤ PROTEIN DIGESTION AND ABSORPTION 🥩

❖ DIGESTION STAGES 🔄

Gastric Digestion:

- **Pepsin Activity:** Cleaves internal peptide bonds
- **Optimal Conditions:** pH 1.5-3.5, adequate pepsinogen activation
- **Products:** Large polypeptides, proteoses, peptones

- **Limitation:** Only 10-15% of total protein digestion

Pancreatic Digestion:

- **Endopeptidases:** Trypsin, chymotrypsin, elastase cleave internal bonds
- **Exopeptidases:** Carboxypeptidases remove terminal amino acids
- **Activation Cascade:** Trypsinogen activated by enterokinase
- **Products:** Small peptides (2-6 amino acids)

Final Digestion:

- **Brush Border Peptidases:** Complete peptide hydrolysis
- **Products:** Individual amino acids, dipeptides, tripeptides
- **Location:** Intestinal epithelial cell surface
- **Efficiency:** Nearly complete protein digestion achieved

❖ ABSORPTION MECHANISMS 📥

Amino Acid Transport:

- **Multiple Transporters:** Different carriers for different amino acid groups
- **Sodium-Dependent:** Most amino acids use sodium cotransport
- **Specificity:** Separate systems for neutral, basic, and acidic amino acids
- **Competition:** Amino acids compete for transport sites

Peptide Transport:

- **PepT1 Transporter:** Transports dipeptides and tripeptides
- **Intracellular Hydrolysis:** Peptides broken down inside enterocytes

- **Efficiency:** Often more efficient than free amino acid absorption
- **Clinical Application:** Basis for peptide-based drug delivery

➤ FAT DIGESTION AND ABSORPTION 🥑

❖ LIPID DIGESTION 🧈

Gastric Phase:

- **Gastric Lipase:** Minimal fat digestion in stomach
- **Acid Environment:** Limits lipase activity
- **Emulsification:** Mechanical churning begins fat breakdown
- **Products:** Limited free fatty acids

Intestinal Phase:

- **Bile Salt Action:** Emulsifies fats into smaller droplets
- **Pancreatic Lipase:** Primary fat-digesting enzyme
- **Colipase Requirement:** Cofactor necessary for lipase activity
- **Products:** Monoglycerides and free fatty acids

❖ ABSORPTION PROCESS 🌊

Micelle Formation:

- **Components:** Bile salts, phospholipids, monoglycerides, fatty acids
- **Function:** Solubilize lipid digestion products
- **Transport:** Deliver lipids to brush border membrane
- **Critical Micelle Concentration:** Minimum bile salt concentration required

Enterocyte Processing:

- **Fatty Acid Uptake:** Passive diffusion across apical membrane
- **Triglyceride Resynthesis:** Reformation of triglycerides in smooth ER
- **Chylomicron Formation:** Packaging with proteins for transport
- **Lymphatic Transport:** Chylomicrons enter lymphatic system

Fat-Soluble Vitamin Absorption:

- **Vitamins A, D, E, K:** Require micelle formation for absorption
- **Mechanism:** Incorporated into chylomicrons
- **Storage:** Liver storage of fat-soluble vitamins
- **Deficiency Risk:** Malabsorption syndromes affect vitamin status

➤ ASSIMILATION OF DIGESTED FOOD 🔄

❖ PORTAL CIRCULATION 🌐

Hepatic Portal System:

- **Function:** Transports absorbed nutrients directly to liver
- **Components:** Portal vein, hepatic sinusoids, hepatic veins
- **Processing:** Liver processes nutrients before systemic circulation
- **Regulation:** Controls nutrient release to body

Nutrient Processing in Liver:

- **Glucose Regulation:** Glycogen synthesis and gluconeogenesis
- **Amino Acid Metabolism:** Protein synthesis, deamination

- **Lipid Processing:** Lipoprotein synthesis, cholesterol metabolism
- **Storage Functions:** Vitamins, minerals, glycogen storage

❖ **CELLULAR UPTAKE** 📥

Glucose Utilization:

- **Immediate Energy:** Glycolysis for ATP production
- **Storage:** Glycogen synthesis in liver and muscle
- **Fat Synthesis:** Excess glucose converted to fatty acids
- **Regulation:** Insulin controls glucose uptake and metabolism

Protein Utilization:

- **Tissue Repair:** Amino acids for protein synthesis
- **Enzyme Production:** Synthesis of digestive and metabolic enzymes
- **Energy Production:** Deamination for glucose production
- **Nitrogen Disposal:** Urea formation from amino acid catabolism

---

UNIT – 2 (C) BREATHING AND RESPIRATION 🫁

🌫️

HUMAN RESPIRATORY SYSTEM 💪

➤ RESPIRATORY SYSTEM STRUCTURE 🧬

The human respiratory system is designed for efficient gas exchange between the atmosphere and the body's circulatory system. This complex

system includes conducting airways and respiratory surfaces optimized for oxygen uptake and carbon dioxide elimination.

❖ CONDUCTING ZONE

Upper Respiratory Tract:

- **Nasal Cavity:** Filters, warms, and humidifies incoming air
- **Pharynx:** Common pathway for respiratory and digestive systems
- **Larynx:** Contains vocal cords, prevents food aspiration
- **Trachea:** Main airway, reinforced with cartilaginous rings

Lower Respiratory Tract:

- **Bronchi:** Primary bronchi divide into secondary and tertiary bronchi
- **Bronchioles:** Terminal bronchioles lead to respiratory zone
- **Function:** Air conduction, filtration, and conditioning
- **Ciliary Action:** Mucociliary escalator removes particles and pathogens

❖ RESPIRATORY ZONE

Alveolar Structure:

- **Alveoli:** Approximately 300 million gas exchange units
- **Surface Area:** 70 square meters total exchange surface
- **Wall Thickness:** 0.2-0.5 micrometers for efficient diffusion
- **Surfactant:** Reduces surface tension, prevents alveolar collapse

Gas Exchange Membrane:

- **Respiratory Membrane:** Alveolar epithelium + capillary endothelium
- **Thickness:** Less than 1 micrometer
- **Barrier Components:** Alveolar cells, basement membranes, capillary cells
- **Perfusion:** Dense capillary network ensures efficient gas exchange

➤ RESPIRATORY MUSCLES 💪

❖ MUSCLES OF INSPIRATION 📈

Diaphragm:

- **Primary Muscle:** Most important inspiratory muscle
- **Innervation:** Phrenic nerves (C3, C4, C5)
- **Action:** Dome flattens, increases thoracic cavity volume
- **Contribution:** 75% of quiet inspiration

External Intercostal Muscles:

- **Location:** Between adjacent ribs
- **Action:** Elevate ribs, expand chest cavity
- **Innervation:** Intercostal nerves
- **Function:** Assist diaphragmatic breathing

Accessory Inspiratory Muscles:

- **Scalene Muscles:** Elevate first two ribs
- **Sternocleidomastoid:** Elevates sternum and clavicle
- **Pectoralis Minor:** Elevates ribs 3-5

- **Activation:** During forced inspiration or respiratory distress

❖ MUSCLES OF EXPIRATION 📉

Passive Expiration:

- **Mechanism:** Elastic recoil of lungs and chest wall
- **Energy:** No muscular energy required during quiet breathing
- **Forces:** Surface tension and elastic fibers compress alveoli
- **Duration:** Longer than inspiration (1:2 ratio)

Active Expiration:

- **Internal Intercostals:** Depress ribs, reduce chest cavity volume
- **Abdominal Muscles:** Increase intra-abdominal pressure
- **Rectus Abdominis:** Compresses abdominal contents
- **Activation:** During forced expiration, coughing, or exercise

MECHANISM OF BREATHING AND ITS REGULATION 🔄

➤ BREATHING MECHANICS ⚙️

❖ PRESSURE CHANGES 📊

Boyle's Law Application:

- **Principle:** Pressure inversely related to volume at constant temperature
- **Inspiration:** Volume increases, pressure decreases below atmospheric
- **Expiration:** Volume decreases, pressure increases above atmospheric

- **Pressure Gradient:** Drives air flow into and out of lungs

Pressure Measurements:

- **Atmospheric Pressure:** 760 mmHg at sea level
- **Intrapulmonary Pressure:** Varies ±1-3 mmHg during quiet breathing
- **Intrapleural Pressure:** Always negative (-4 to -6 mmHg)
- **Transpulmonary Pressure:** Difference maintaining lung inflation

❖ COMPLIANCE AND RESISTANCE 🏋️

Lung Compliance:

- **Definition:** Measure of lung elasticity and distensibility
- **Normal Value:** 200 mL/cmH_2O pressure change
- **Factors:** Elastic fibers, surfactant, chest wall elasticity
- **Pathology:** Decreased in fibrosis, increased in emphysema

Airway Resistance:

- **Definition:** Opposition to air flow through respiratory passages
- **Primary Site:** Medium-sized bronchi contribute most resistance
- **Regulation:** Smooth muscle contraction/relaxation
- **Pathology:** Increased in asthma, bronchitis

➤ RESPIRATORY REGULATION 🎛️

❖ NEURAL CONTROL 🧠

Respiratory Centers:

- **Medullary Center:** Primary control in medulla oblongata
- **Pontine Center:** Modifies medullary rhythm
- **Voluntary Control:** Cerebral cortex can override automatic control
- **Protective Reflexes:** Coughing, sneezing, bronchoconstriction

Medullary Respiratory Center:

- **Inspiratory Center:** Generates basic respiratory rhythm
- **Expiratory Center:** Active during forced expiration
- **Pre-Bötzinger Complex:** Primary rhythm generator
- **Bilateral Control:** Controls both sides of respiratory muscles

Pontine Respiratory Centers:

- **Pneumotaxic Center:** Fine-tunes breathing pattern
- **Apneustic Center:** Promotes prolonged inspiration
- **Integration:** Coordinates with medullary centers
- **Modulation:** Adjusts respiratory rate and depth

❖ **CHEMICAL REGULATION** 🧪

Chemoreceptor Control:

- **Central Chemoreceptors:** Medulla, respond to CO_2/H^+ changes
- **Peripheral Chemoreceptors:** Carotid and aortic bodies, respond to O_2, CO_2, pH
- **Primary Drive:** CO_2 levels most important for breathing control
- **Sensitivity:** Small changes in CO_2 produce large ventilation changes

Carbon Dioxide Response:

- **Mechanism:** CO_2 crosses blood-brain barrier, forms H^+
- **Sensitivity:** 1 mmHg CO_2 increase causes 2-3 L/min ventilation increase
- **Adaptation:** Chronic CO_2 elevation reduces sensitivity
- **Clinical Significance:** Primary drive for breathing in healthy individuals

Oxygen Response:

- **Threshold:** Activated when PO_2 falls below 60 mmHg
- **Mechanism:** Peripheral chemoreceptors detect hypoxia
- **Secondary Role:** Less important than CO_2 in normal conditions
- **Pathological Conditions:** Becomes primary drive in chronic lung disease

EXCHANGE OF GASES, TRANSPORT OF GASES AND REGULATION OF RESPIRATION 🔁

➤ GAS EXCHANGE 💨

❖ PULMONARY GAS EXCHANGE 🫁

Diffusion Principles:

- **Fick's Law:** Rate proportional to surface area and concentration gradient
- **Driving Force:** Partial pressure differences across respiratory membrane

- **Surface Area:** 70 square meters available for gas exchange
- **Membrane Thickness:** 0.2-0.5 micrometers optimizes diffusion

Oxygen Exchange:

- **Alveolar PO_2:** 104 mmHg
- **Venous Blood PO_2:** 40 mmHg
- **Gradient:** 64 mmHg pressure difference drives O_2 uptake
- **Arterial PO_2:** 95-100 mmHg after gas exchange

Carbon Dioxide Exchange:

- **Venous PCO_2:** 45 mmHg
- **Alveolar PCO_2:** 40 mmHg
- **Gradient:** 5 mmHg difference drives CO_2 elimination
- **Efficiency:** High solubility makes CO_2 exchange very efficient

❖ **TISSUE GAS EXCHANGE** 🔁

Oxygen Delivery:

- **Arterial PO_2:** 95-100 mmHg
- **Tissue PO_2:** 20-40 mmHg
- **Gradient:** Large pressure difference ensures O_2 delivery
- **Venous PO_2:** 40 mmHg after tissue extraction

Carbon Dioxide Pickup:

- **Tissue PCO_2:** 45-50 mmHg

- **Arterial PCO_2:** 40 mmHg
- **Gradient:** Drives CO_2 from tissues into blood
- **Venous PCO_2:** 45 mmHg carrying CO_2 to lungs

➤ OXYGEN TRANSPORT 🚚

❖ HEMOGLOBIN TRANSPORT 🔴

Hemoglobin Structure:

- **Composition:** Four protein chains (globin) + four heme groups
- **Iron Content:** Each heme contains one iron atom
- **Oxygen Capacity:** Each hemoglobin molecule carries 4 oxygen molecules
- **Concentration:** 12-16 g/dL in normal blood

Oxygen-Hemoglobin Dissociation:

- **Sigmoid Curve:** S-shaped relationship between PO_2 and saturation
- **P50 Value:** PO_2 at 50% saturation (26-27 mmHg)
- **Cooperative Binding:** Each O_2 binding increases affinity for next O_2
- **Physiological Range:** 75% (venous) to 97% (arterial) saturation

Factors Affecting Oxygen Affinity:

- **Temperature:** Increased temperature decreases affinity (Bohr effect)
- **pH:** Decreased pH decreases affinity (facilitates O_2 release)
- **2,3-DPG:** Increases with altitude, decreases hemoglobin affinity
- **Carbon Dioxide:** Higher CO_2 levels decrease O_2 affinity

❖ **DISSOLVED OXYGEN** 💧

Physical Solution:

- **Solubility:** 0.003 mL O_2/dL blood/mmHg
- **Contribution:** Only 1-2% of total oxygen transport
- **Clinical Significance:** Important at high inspired oxygen concentrations
- **Measurement:** Directly proportional to partial pressure

➤ **CARBON DIOXIDE TRANSPORT** 🌫️

❖ **TRANSPORT MECHANISMS** 🚚

Dissolved CO_2 (7-10%):

- **Physical Solution:** CO_2 dissolved directly in plasma
- **Solubility:** 20 times more soluble than oxygen
- **Partial Pressure:** Directly proportional to dissolved amount
- **Contribution:** Smallest fraction but important for regulation

Bicarbonate Transport (65-75%):

- **Mechanism:** $CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$
- **Carbonic Anhydrase:** Enzyme catalyzes CO_2 hydration
- **Chloride Shift:** HCO_3^- exchanged for Cl^- in red blood cells
- **Primary Mechanism:** Most important CO_2 transport method

Carbaminohemoglobin (15-25%):

- **Formation:** CO_2 binds directly to amino groups on hemoglobin
- **Binding Site:** Different from oxygen binding site
- **Regulation:** Binding influenced by oxygen saturation
- **Haldane Effect:** Deoxygenated blood carries more CO_2

❖ CO_2 REGULATION 🎯

Central Chemoreceptors:

- **Location:** Medulla oblongata
- **Sensitivity:** Detect H^+ changes from CO_2 levels
- **Response Time:** Rapid response to CO_2 changes
- **Primary Control:** Most important regulatory mechanism

Peripheral Chemoreceptors:

- **Location:** Carotid and aortic bodies
- **Function:** Detect O_2, CO_2, and pH changes
- **Hypoxic Response:** Activated when PO_2 < 60 mmHg
- **Integration:** Send signals to respiratory centers

RESPIRATORY VOLUMES 📏

➤ LUNG VOLUMES AND CAPACITIES 📊

❖ BASIC LUNG VOLUMES 📐

Tidal Volume (TV):

- **Definition:** Volume of air inhaled or exhaled during quiet breathing

- **Normal Value:** 500 mL in healthy adults
- **Variation:** Can increase significantly during exercise
- **Measurement:** Easily measured with spirometry

Inspiratory Reserve Volume (IRV):

- **Definition:** Maximum volume that can be inhaled after normal inspiration
- **Normal Value:** 3000-3100 mL
- **Function:** Provides reserve for increased oxygen demands
- **Clinical Significance:** Reduced in restrictive lung diseases

Expiratory Reserve Volume (ERV):

- **Definition:** Maximum volume that can be exhaled after normal expiration
- **Normal Value:** 1100-1200 mL
- **Function:** Allows forced expiration during exercise or coughing
- **Pathology:** Reduced in obstructive diseases

Residual Volume (RV):

- **Definition:** Volume remaining in lungs after maximum expiration
- **Normal Value:** 1000-1200 mL
- **Function:** Prevents alveolar collapse, maintains gas exchange
- **Measurement:** Cannot be measured directly with spirometry

❖ **LUNG CAPACITIES** 📈

Inspiratory Capacity (IC):

- **Calculation:** TV + IRV
- **Normal Value:** 3500-3600 mL
- **Function:** Total inspiratory ability
- **Clinical Use:** Assesses inspiratory muscle strength

Functional Residual Capacity (FRC):

- **Calculation:** ERV + RV
- **Normal Value:** 2200-2400 mL
- **Function:** Lung volume at resting expiratory level
- **Importance:** Determines baseline for gas exchange

Vital Capacity (VC):

- **Calculation:** IRV + TV + ERV
- **Normal Value:** 4600-4800 mL
- **Function:** Maximum breathable lung volume
- **Clinical Significance:** Important indicator of respiratory health

Total Lung Capacity (TLC):

- **Calculation:** VC + RV
- **Normal Value:** 5800-6000 mL
- **Function:** Maximum lung volume
- **Measurement:** Requires specialized techniques (helium dilution)

Respiratory Volumes Table 📊

Volume/Capacity	Abbreviation	Normal Value (mL)	Description
Tidal Volume	TV	500	Air moved during quiet breathing
Inspiratory Reserve Volume	IRV	3000-3100	Maximum inhalation after normal inspiration
Expiratory Reserve Volume	ERV	1100-1200	Maximum exhalation after normal expiration
Residual Volume	RV	1000-1200	Air remaining after maximum expiration
Inspiratory Capacity	IC	3500-3600	TV + IRV
Functional Residual Capacity	FRC	2200-2400	ERV + RV
Vital Capacity	VC	4600-4800	IRV + TV + ERV
Total Lung Capacity	TLC	5800-6000	All four basic volumes combined

Blood Gas Values Table 🩸

Parameter	Arterial Blood	Venous Blood	Alveolar Air
PO_2 (mmHg)	95-100	40	104
PCO_2 (mmHg)	40	45	40
pH	7.35-7.45	7.30-7.40	-
O_2 Saturation (%)	97-98	75	-
HCO_3^- (mEq/L)	22-26	24-28	-

Cardiac Output and Respiratory Parameters Table 💓

Parameter	Normal Value	Exercise Value	Clinical Significance
Heart Rate (bpm)	70-75	150-180	Increases with oxygen demand
Stroke Volume (mL)	70	100-120	Enhanced by training
Cardiac Output (L/min)	5-6	20-25	Direct measure of cardiac function
Respiratory Rate (breaths/min)	12-16	30-40	Responds to metabolic demands
Minute Ventilation (L/min)	6-8	100-120	Total air moved per minute

➤ FACTORS AFFECTING RESPIRATORY VOLUMES 🎯

❖ PHYSIOLOGICAL FACTORS 🧬

Age-Related Changes:

- **Childhood:** Smaller absolute volumes, higher respiratory rate

- **Adult Peak:** Maximum lung function achieved around age 20-25
- **Aging Effects:** Gradual decline in vital capacity, increased residual volume
- **Elderly:** Reduced elasticity, weakened respiratory muscles

Gender Differences:

- **Male Values:** Generally 20-25% higher than females
- **Hormonal Influences:** Estrogen affects respiratory muscle strength
- **Body Size:** Larger chest cavity in males
- **Physical Activity:** Training can minimize gender differences

Physical Conditioning:

- **Athletic Training:** Increases vital capacity and respiratory efficiency
- **Cardiovascular Fitness:** Improved oxygen delivery and utilization
- **Respiratory Muscle Strength:** Enhanced inspiratory and expiratory capacity
- **Adaptation:** Chronic exercise produces beneficial respiratory changes

❖ PATHOLOGICAL CONDITIONS 🩺

Restrictive Diseases:

- **Characteristics:** Reduced lung volumes and capacities
- **Examples:** Pulmonary fibrosis, chest wall deformities
- **Pattern:** Decreased vital capacity, normal or increased RV/TLC ratio
- **Mechanism:** Reduced lung compliance or chest wall mobility

Obstructive Diseases:

- **Characteristics:** Airway obstruction with air trapping
- **Examples:** Asthma, chronic bronchitis, emphysema
- **Pattern:** Increased residual volume, decreased expiratory flow rates
- **Mechanism:** Increased airway resistance, loss of elastic recoil

Mixed Patterns:

- **Combined Effects:** Both restrictive and obstructive components
- **Complex Changes:** Multiple volume and capacity alterations
- **Clinical Challenge:** Requires comprehensive pulmonary function testing
- **Management:** Addresses both underlying pathophysiological mechanisms