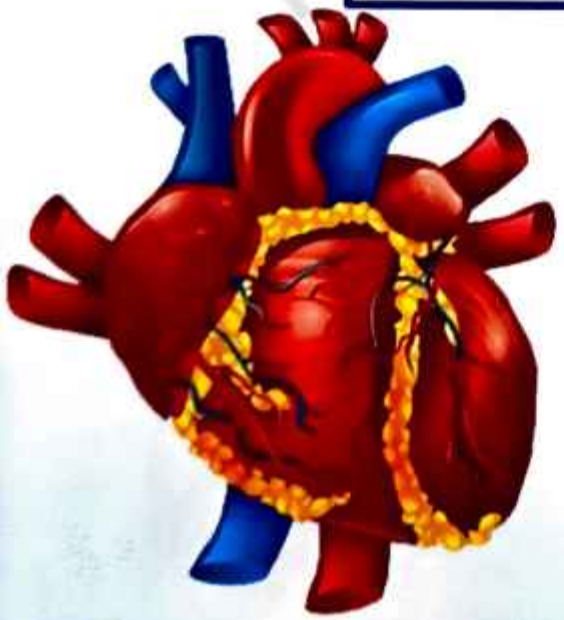
BODY FLUID AND CIRCULATION

Contents to be covered in this topic

- 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



BODY FLUID AND CIRCULATION

❑ INTRODUCTION

Different types of fluids are present in different cavities in human body

There are two types of fluids present in human body:

1. **Intracellular fluid**
2. **Extracellular fluid**

INTRACELLULAR FLUID: **The fluid which is present inside cells is called as intracellular fluid (ICF).**

EXTRACELLULAR FLUID: **The fluid which is present outside cells is called as extracellular fluid (ECF). The ECF fluid which is present in small spaces between cells of tissues is known as interstitial fluid**

ECF differs depending on its location in the body:

(a) Blood plasma: It is the ECF within blood vessels.

(b) Lymph: It is the ECF present in within lymphatic vessels.

(c) Cerebrospinal fluid: It is the ECF present in and around the brain and spinal cord.

(d) Synovial fluid: It is the ECF in joints.

(e) Aqueous humor and vitreous body: It is the ECF present in the eyes

❑ CARDIOVASCULAR SYSTEM

All cells of our body require **continuous supply of nutrients and oxygen** for cellular activities. They also require system to remove waste products formed during various activities. Most of the body cells are located at some distance from the nutrient sources such as the digestive tract and sites of waste disposal such as kidneys. Cardiovascular system plays an important role in these activities. **It connects different systems in body through network of blood vessels and blood.**

The cardiovascular system which consists of:

1. **Blood**
2. **The heart**
3. **Blood vessels**

BLOOD

❑ COMPOSITION OF BLOOD, BLOOD GROUPS, COAGULATION OF BLOOD

Blood is a **connective tissue** composed of a blood plasma and different types of cells and cell fragments.

➢ **Composition of Blood:**

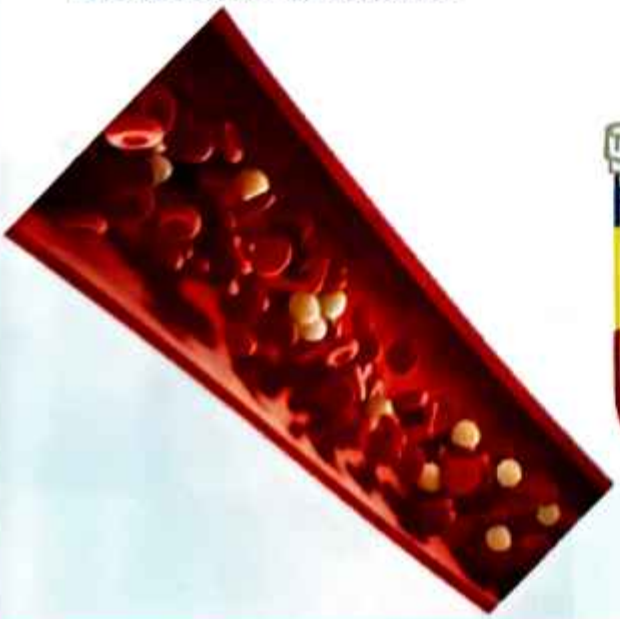
1. **Blood plasma**
2. **Formed elements**

Blood plasma

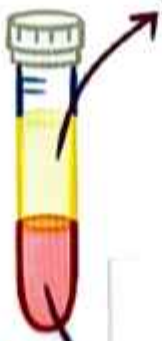
- Blood plasma is a liquid extracellular matrix mainly consisting of water and dissolved substances.
- Blood consists of 55% blood plasma.
- Blood plasma is composed of about 91.5% water and 8.5% solutes.
- The solutes are mainly proteins (7%) and others like gases, nutrients, waste products, electrolytes (1.5%).

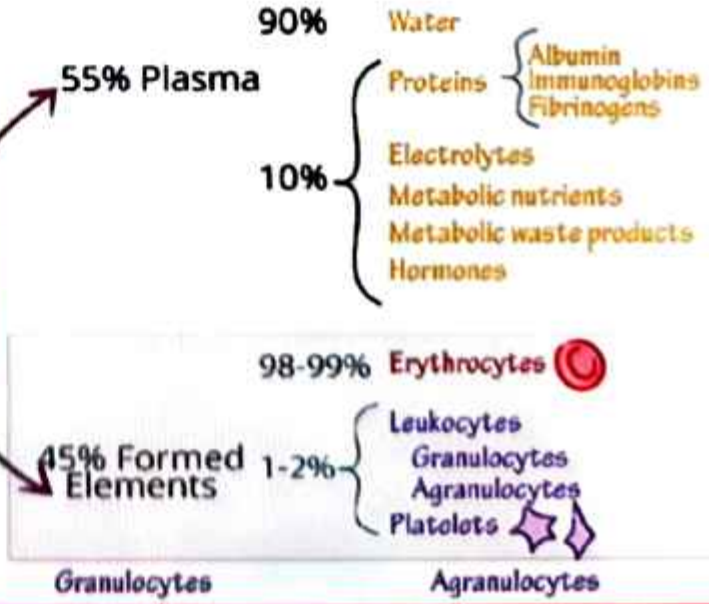
Formed elements:

- Formed elements are various types of cells and cell fragments.
- Blood contains about 45% formed elements.
- Normally, more than 99% of the formed elements are cells named for their red colour, red blood cells (RBCs) and Pale, colourless white blood cells (WBCs) and platelets which are cell fragments and occupy less than 1% of the formed elements.



Blood Composition





The straw-coloured liquid, called serum, which is part of plasma.

- **Serum + Clotting proteins = Plasma**
- **Clotting proteins- Plasma = Serum**

➢ **Functions of Blood:**

1. Blood **transports carbon dioxide** from the body cells to the lungs and oxygen from the lungs to the cells of the body.
2. Blood **transfers nutrients** from the gastrointestinal tract to cells.
3. It transports hormones from endocrine glands to cells.
4. Blood also carries heat and waste products to various organs for elimination from the body.
5. Blood helps to **regulate pH** through the use of buffers.
6. Blood also helps to **adjust body temperature.**
7. Blood clotting protects against its excessive loss from body after an injury.
8. White blood cells protect against disease by carrying on **phagocytosis.**

➢ **Blood Groups:**

✓ **Introduction**

- A blood group also called a **Blood Type**
- Determination of **ABO blood groups** depends upon the **immunological reaction between antigen and antibody. Antigens are also called agglutinogens** because of their capacity to cause **agglutination of RBCs.**
- These **antigens may be proteins, carbohydrates, glycoproteins, or glycolipids**, depending on the blood group system
- The **ABO blood group system** is the most important blood type system (or blood group system) in **human blood transfusion**
- ABO blood types are also present in some other animals for example rodents and apes such as **chimpanzees, bonobos and gorillas**

✓ **History**

Karl Landsteiner discovered the ABO Blood Group System in 1901

ABO BASICS

Based on the **presence or absence of antigen A and antigen B**, blood is divided into four groups: **'A, B, AB and 'O' group.**

- Blood with antigen B and **α-antibody belongs to 'B' group.**
- If both the antigens are present, blood group is called 'AB' group and serum of this group does not contain any antibody
- If both antigens are absent, the blood group is called 'O' group and both α and β antibodies are present in the serum

Antigen and Antibody Present in ABO Blood Group

ABO GROUP	ANTIGEN PRESENT	ANTIGEN MISSING	ANTIBODY PRESENT
A	A	B	Anti-B
B	B	A	Anti-A
O	None	A and B	Anti-A&B
AB	A and B	None	None

✓ **Principle of Blood Grouping**

- Blood grouping is done on the basis of agglutination.
- Agglutination means the collection of separate particles like RBCs into clumps or masses.
- Agglutination occurs if an antigen is mixed with its corresponding antibody which is called isoagglutinin, i.e. occurs when A antigen is mixed with anti-A or when B antigen is mixed with anti-B

Rh blood group:

The **Rh blood group** is so named because the antigen was discovered in the blood of the Rhesus monkey. People whose RBCs have Rh antigens are designated Rh+ (Rh positive); those who **lack Rh antigens** are designated Rh- (Rh negative)

✓ **Blood Coagulation:**

- In normal condition, blood is always in liquid form when it is within blood vessels
- When it comes out from blood vessel, it thickens and forms a gel. In due course, the gel splits from the liquid. The gel is called a clot
- Clot is composed of network of insoluble protein fibres called fibrin
- The process of gel formation, is called clotting or coagulation

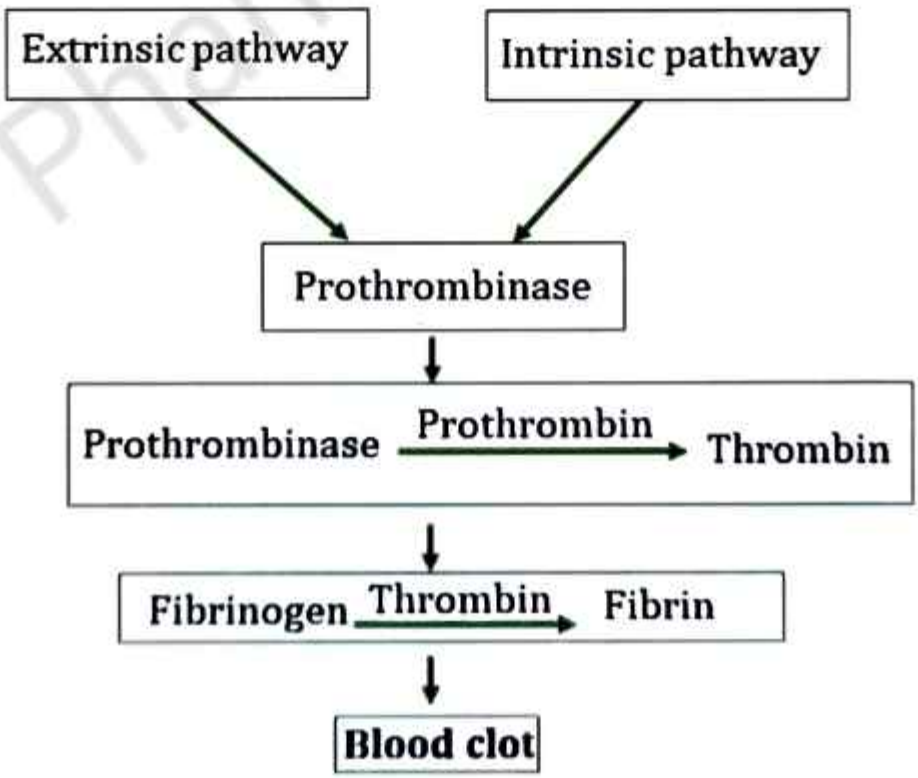
- Blood clotting or coagulation is a series of chemical reactions that ends in development of fibrin threads
- The process of clotting involves several elements known as clotting (coagulation) factors

Process of Blood (Clotting) Coagulation:

Blood clotting is a complex cascade of enzymatic reactions in which each clotting fact activates many molecules of the next one in a fixed sequence. Finally, a large quantity product (the insoluble protein fibrin) is formed.

Clotting can be divided into three stages:

1. **Two pathways,** called the **extrinsic pathway** and the **intrinsic pathway,** lead to the formation of prothrombinase
2. **Once prothrombinase is formed,** the steps involved in the next two stages of clottin are the same for both the extrinsic and intrinsic pathways, and together these tv stages are referred to as the common pathway. Prothrombinase converts prothrombin (a plasma protein formed by the liver) in the **enzyme thrombin.**
3. **Thrombin** converts soluble fibrinogen (another plasma protein formed by the live into insoluble fibrin. Fibrin forms the threads of the clot.



Process of blood clotting

LYMPH

❑ COMPOSITION AND FUNCTIONS OF LYMPH

✓ **Lymphatic system is made up of the following components:**

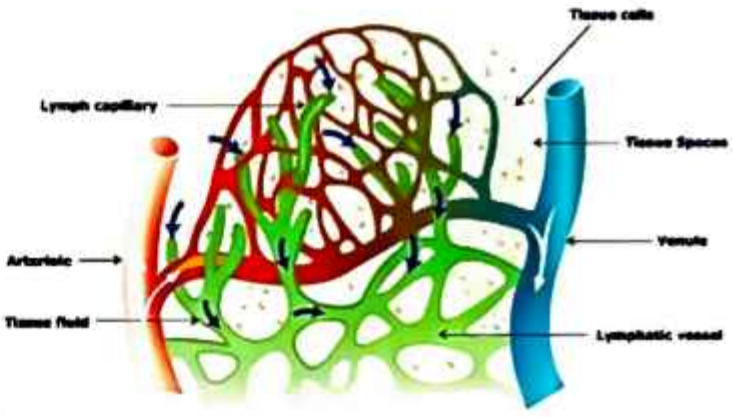
1. **A fluid called lymph**
2. **Lymphatic capillaries, Lymphatic vessels, Lymph trunk and Lymph duct**
3. **Lymphatic organs are:**
   a. Tonsils
   b. Lymph nodes
   c. Spleen
   d. Thymus
4. **Lymphatic tissue**
   a. Lymphatic nodules (follicles)
5. **Red bone marrow**

✓ **Functions of the Lymphatic System:**

1. It **drains excess interstitial fluid** from tissue spaces and return it to the blood
2. It transports lipids and lipid-soluble vitamins **(A, D, E and K)** absorbed by the gastrointestinal tract
3. It initiates highly specific **immune responses** directed against particular microbes or abnormal cells

✓ **Composition of Lymph:**

- Most constituents of **blood plasma filter through blood capillary** walls to form interstitial fluid. After interstitial fluid passes into **lymphatic vessels,** it is **called lymph**



- The major difference between interstitial fluid and lymph is the **location**: Interstitial fluid is found between **cells,** and lymph is located within **lymphatic vessels and lymphatic tissue**

- Constituents of **blood plasma like gases, nutrients and hormones,** etc. filter freely through the capillary walls to form interstitial fluid
- A considerable amount of **fluid is filtered out of blood capillaries.** The extra filtered fluid drains into lymphatic vessels and becomes **lymph.** As plasma proteins are too big to leave blood vessels, interstitial fluid contains lesser amount of proteins.
- The proteins can, however, move readily through the more permeable lymphatic capillaries into lymph
- Lymph consists of **lymphocytes**
- Lymph also consists of proteins called as **Globulin.** These are actually **antibodies.**
- Other components of the lymph plasma are very much like that of blood plasma, i.e., **organic, inorganic substances, water, etc.**
- An important function of lymph is to return the lost plasma proteins and plasma to the bloodstream

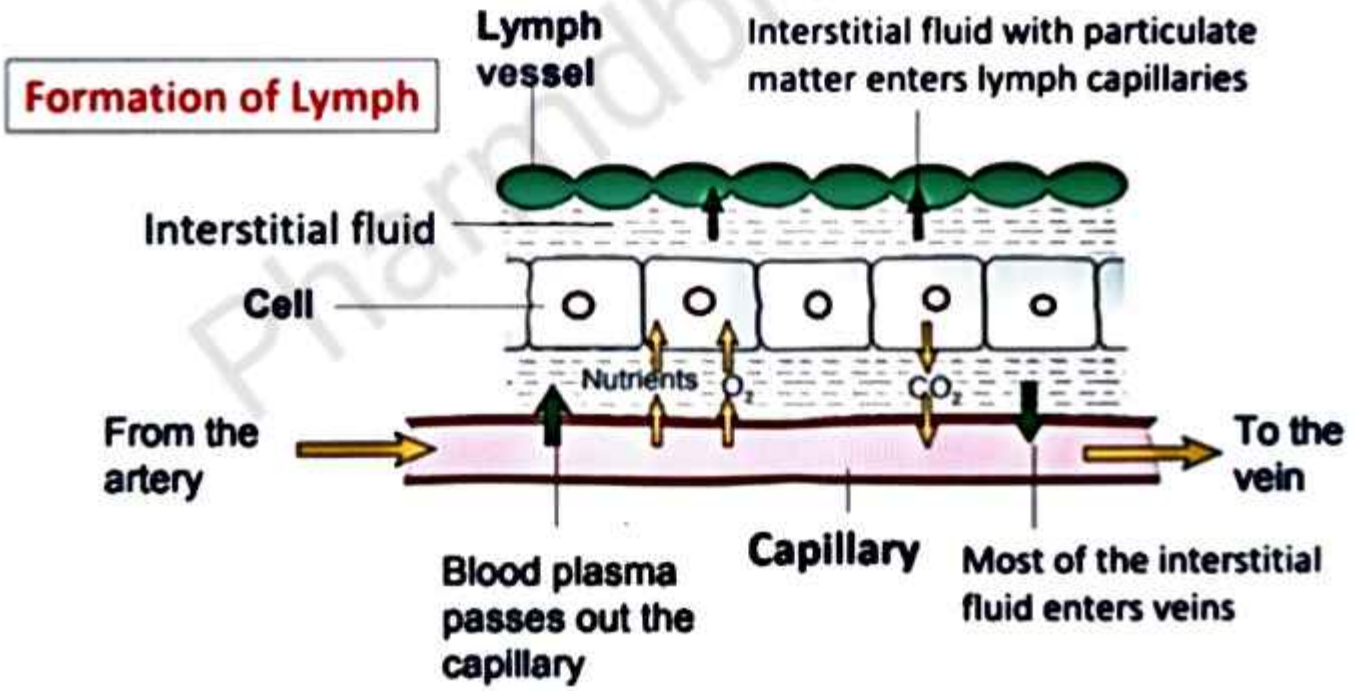


Fig. Formation of Lymph

HUMAN CIRCULATORY SYSTEM

Human circulatory system, also called the **blood vascular system** consists of a muscular chambered heart, a network of **closed branching blood vessels and blood**, the fluid which is circulated.

Heart, the mesodermally derived organ, is **situated in the thoracic cavity,** in between the two lungs, slightly tilted to the left. It has the size of a clenched fist.

- Heart circulates blood in two circuits called **pulmonary and systemic circulations.**
- The **left side of heart is for systemic circulation** and **right side for pulmonary circulation**
- The **right atrium receives** systemic blood relatively low in oxygen **(deoxygenated)** from various body parts.
- This **deoxygenated in right atrium** is transferred to the right ventricle, which pumps it into the lungs for addition of oxygen and removal of carbon dioxide.
- Exchange of **oxygen and carbon dioxide occurs in the lungs,** and blood high in oxygen (oxygenated) returns to the left atrium.
- This oxygenated blood is transferred to left ventricle, which in turn pumps it into the aorta and to all body parts.

❑ STRUCTURE OF HUMAN HEART

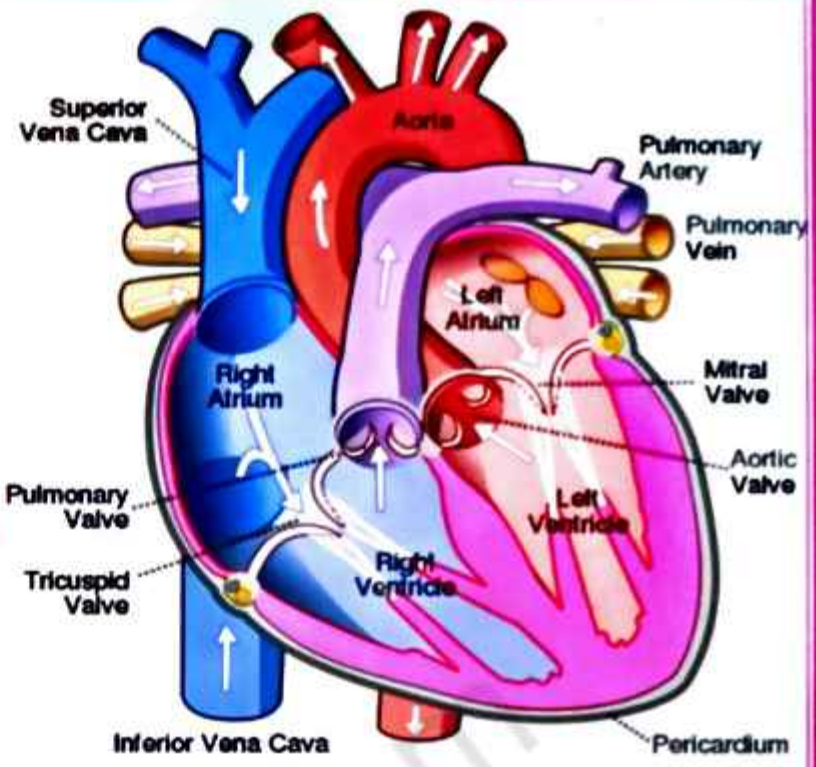
Heart is an important organ of **cardiovascular system.** It acts like a **pump,** which is responsible for **circulating blood to all body parts.**

Dimensions of heart are as follows:

- **Length:** 12 cm
- **Width:** 9 cm at its broadest point
- **Thickness:** 6 cm
- **Weight:** 250 g in adult females and 300 g in adult males.
- **Location:** The heart is located in a space between two lungs of thoracic cavity called **mediastinum**. The heart is surrounded by its own cavity called as **pericardial cavity.**

The pointed **apex** of heart is directed inferiorly, and to the left and it rests on the diaphragm. The **base** of the heart is its posterior surface.

The sheath that surrounds and protects the heart is called as the **pericardium.** The **pericardium** consists of two fused layers: an **outer fibrous pericardium** and an **inner parietal pericardium (epicardium).**



Between the pericardial sac and the heart there is the **pericardial cavity**, which is filled with **lubricating serous fluid.**

The wall of the heart consists of three layers:

- The outer layer called as the **epicardium**
- The middle layer called as the **myocardium**
- The inner layer called as the **endocardium**
- Heart is composed of four chambers: **2 atria** (right atrium and left atrium) and **2 ventricles** (right ventricle and left ventricle).
- Atria are **receiving chambers** and ventricles are **pumping chambers** of heart
- The atria receive blood from blood vessels called as veins. Ventricles pump blood into blood vessels called as **arteries.**
- The **septa** are the **partitions that separate the chambers of the heart**
- They include the **interatrial septum** which separates right and left atria The **interventricular septum** separates right and left ventricles.
- Right atrium is connected to right ventricle through an opening. This opening is guarded by the **atrioventricular valve** called the right **tricuspid valve.**

- Left atrium is connected to left ventricle through an opening. The opening is guarded by a valve called left **mitral valve or Bicuspid valve**
- These **valves prevent the backflow of blood**.
- The pulmonary valve is located at the base of the pulmonary trunk, and the left **semilunar valve** is located at the base of the aorta.
- The **right and left coronary arteries** are the first to branch of the aorta and arise from two of the three sinuses located near the base of the aorta and are generally located in the sulci

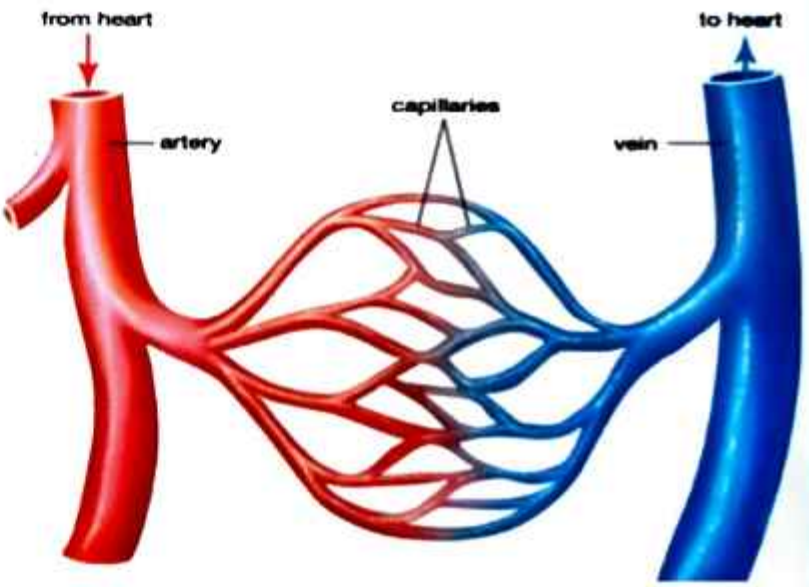
❑ BLOOD VESSELS

Blood vessels have important function of **distributing blood from heart to different tissues** and also returns it to heart.

There are five main types of **blood vessels:**

1. **Arteries**
2. **Arterioles**
3. **Capillaries**
4. **Venules**
5. **Veins**

- The **blood vessels** which **carry blood away from the heart** to other organs are called as **arteries.** They leave the heart and divide into medium sized, muscular arteries that branch out into the various regions of the body



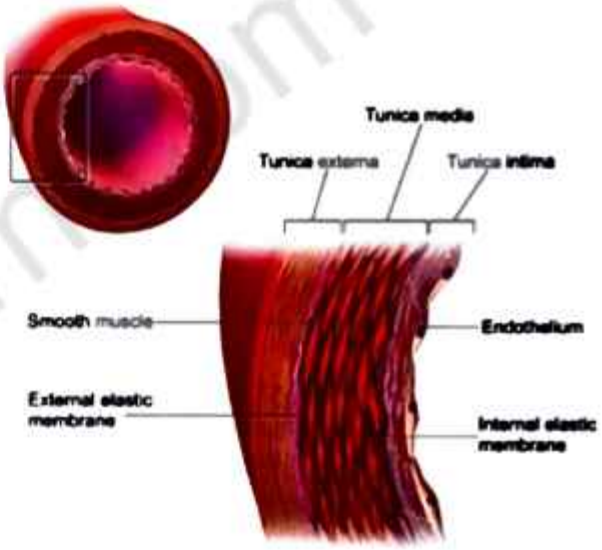
- Medium sized arteries then split into **small arteries,** which in turn split into still smaller arteries called **arterioles**
- As the arterioles enter a tissue, they branch into numerous **minute vessels called capillaries**
- **Groups of capillaries** within a tissue reunite to form small veins called **venules**
- These in turn merge to form progressively larger blood vessels called veins.
- Veins are the blood vessels that convey blood from the tissues back to the heart

✓ **Structure:**

The wall of a blood vessel consists of three layers, also called as tunicas.

The three structural layers are:

1. The innermost layer is called as **tunica interna.** It is made up of epithelial tissue.
2. The middle layer is called as **tunica media.** It is made up of smooth muscles.

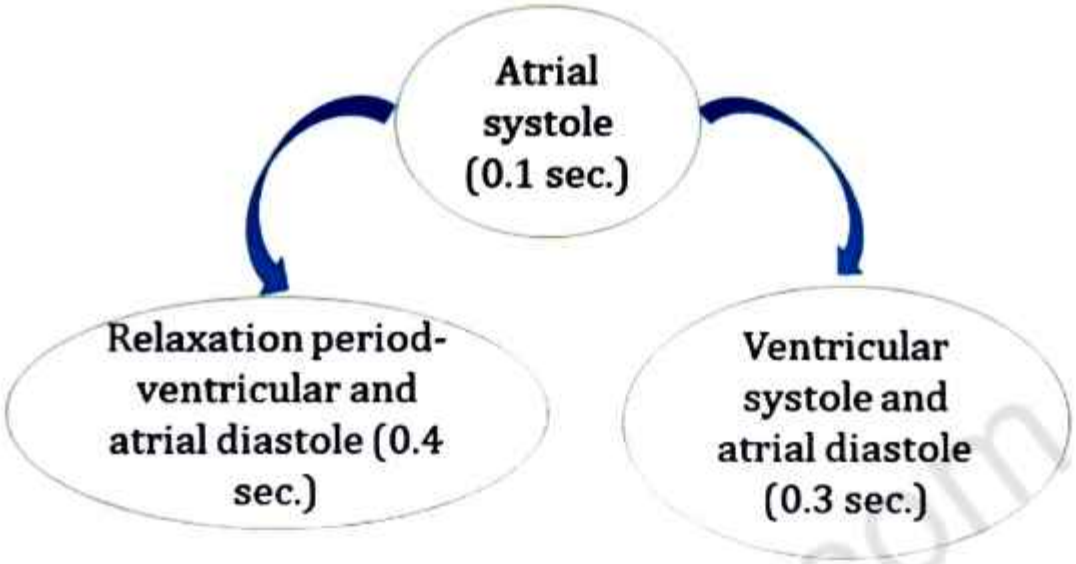


3. The outmost layer is called as **tunica externa.** It is made up of elastic and collagen fibres

❑ CARDIAC CYCLE

- The period of time that begins with contraction of the atria and ends with ventricular relaxation is known as the **cardiac cycle**
- The phase of contraction that the heart undergoes while it pumps blood into circulation is called **systole**
- The phase of relaxation that occurs as the chambers fill with blood is called **diastole**
- Both the atria and ventricles undergo systole and diastole, and it is essential that these components be carefully regulated and co-ordinated to ensure blood is pumped efficiently to the body.

- In each cardiac cycle, the atria and ventricles alternately contract and relax, forcing blood from areas of higher pressure to areas of lower pressure.
- When heart rate is 75 beats/min, a cardiac cycle lasts 0.8 sec.



❑ CARDIAC OUTPUT (CO)

Cardiac output is the volume of blood ejected from the left ventricle (or the right ventricle) into the aorta (or pulmonary trunk) each minute

Cardiac output equals the stroke volume **(SV)**, the volume of blood ejected by the ventricle during each contraction, multiplied by the heart rate (HR), the number of heartbeats per minute:

Cardiac output = SV (ml/beat) x HR (beat/min.)

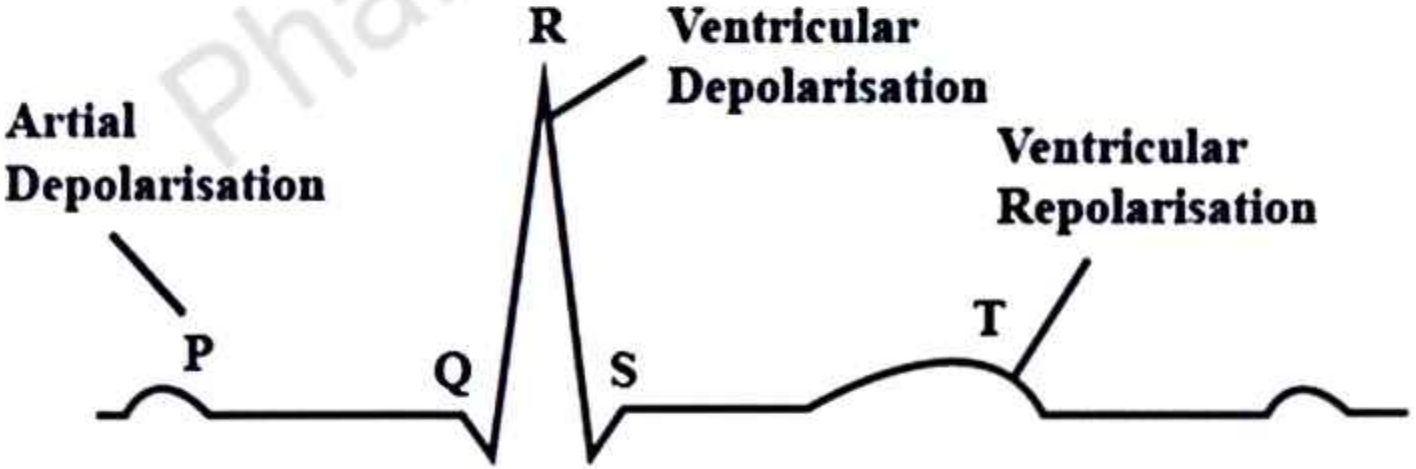
❑ ELECTROCARDIOGRAM (ECG)

This type of machine (electro-cardiograph) is used to **obtain an electrocardiogram (ECG).** ECG is a graphical representation of the electrical activity of the heart during a cardiac cycle. To obtain a standard ECG

Each peak in the ECG is identified with a letter from **P to T** that corresponds to a specific **electrical activity of the heart.** The **P-wave** represents the **electrical excitation** (or depolarisation) of the atria, which leads to the contraction of both the atria. The **QRS complex** represents the **depolarisation of the ventricles,** which initiates the ventricular contraction. The contraction starts shortly after Q and marks the beginning of the systole

The **T-wave** represents the return of the ventricles from excited to normal state **(repolarisation).** The end of the **T-wave** marks the end of systole.

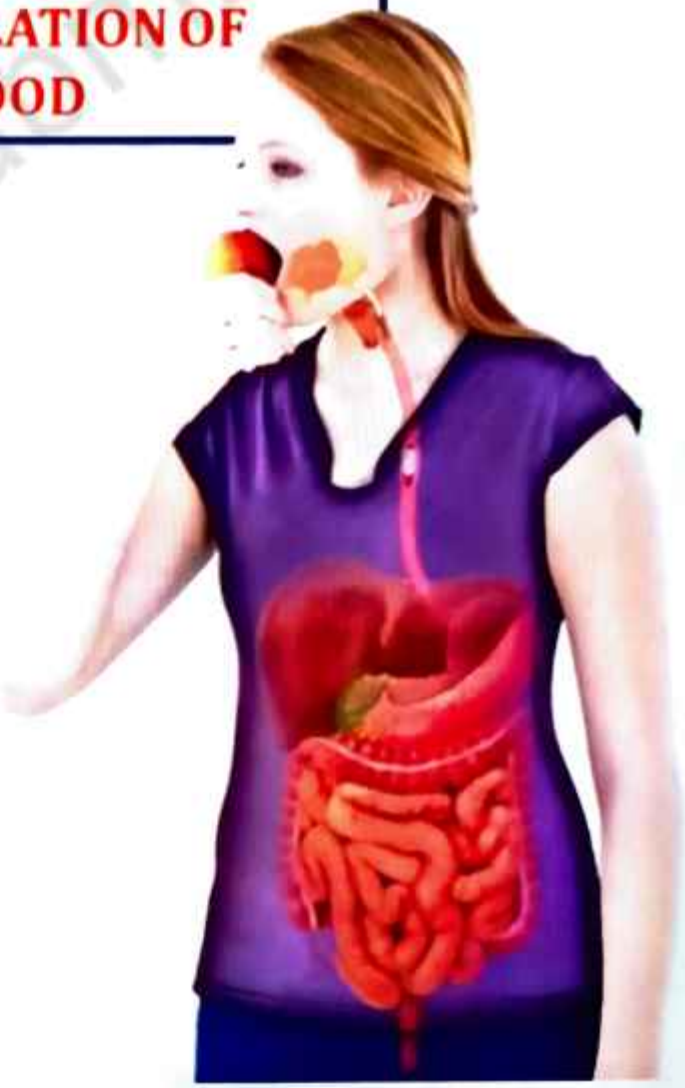
Obviously, by counting the number of **QRS complexes** that occur in a **given time period,** one can determine the heart beat rate of an individual.



DIGESTION AND ABSORPTION

Contents to be covered in this topic

- HUMAN ALIMENTARY CANAL AND DIGESTIVE GLANDS
- ROLE OF DIGESTIVE ENZYMES
- DIGESTION, ABSORPTION AND ASSIMILATION OF DIGESTED FOOD



DIGESTION AND ABSORPTION

❑ INTRODUCTION

Digestive system is composed of two parts:

(1) The alimentary canal or the gastrointestinal (GI) tract

(2) The accessory digestive organs

✓ **The alimentary canal or the gastrointestinal (GI) tract**

- It is a continuous tube that extends from the **mouth to the anus**

Organs of the alimentary canal or the gastrointestinal (GI) tract are:

Mouth , Pharynx, Esophagus, Stomach, Small Intestine, Large Intestine

- The **length of the alimentary canal** is about **5-7 meters** (16.5-23 ft).

The accessory Digestive Organs:

- **The accessory digestive organs include:**

(i) Teeth

(ii) Tongue

(iii) Salivary glands

(iv) Liver

(v) Gall bladder

(vi) Pancreas

➢ Functions of Digestive System:

1. **Ingestion:** This process involves taking **foods and liquids into the mouth** (eating)
2. **Secretion: Alimentary canal and accessory digestive organs** releases a water, acid, buffers and various enzymes space of the canal.
3. **Mixing and propulsion:** Alternating contractions and relaxations of smooth muscle in the walls of the **GI tract mix.** Food material and various secretions from alimentary canal and accessory digestive organs are mixed with movement of GI tract.
4. **Digestion:** The food which we eat is **broken down to small molecules** with the **help of acid, enzymes etc.,** this process is called as digestion.
5. **Absorption:** The **small molecules, ions are taken through lumen cells** of the GI tract to blood, this is called absorption.

6. **Defecation:** Indigestible, waste material, which **cannot be absorbed is excreted out** through the anus. This process is called defecation. The waste material which is thrown out is called as feces.

❑ DIGESTIVE ENZYMES

Digestive enzymes produced by the **salivary glands, tongue, stomach, pancreas, and small intestine**

The various enzymes secreted by various parts of GI tract and their roles are as follows:

1. **Salivary amylase:** It is secreted by **salivary glands**. This enzyme is responsible for **breakdown of starch**
2. **Lingual lipase:** It is secreted by **lingual glands** in tongue. This enzyme is responsible for **breakdown of triglycerides**
3. **Pepsin:** It is **secreted by stomach**. This enzyme is responsible for **breakdown of proteins**
4. **Gastric lipase:** It is secreted by **stomach.** This enzyme is responsible for **breakdown of triglycerides**
5. **Pancreatic amylase:** It is secreted by pancreas. This enzyme is responsible for breakdown of starch.
6. **Trypsin, chymotrypsin, carboxypeptidase, and elastase:** These enzymes are secreted by pancreas. These enzymes are responsible for breakdown of proteins.
7. **Pancreatic lipase:** It is secreted by pancreas. This enzyme is responsible for breakdown of triglycerides.
8. **Ribonuclease and deoxyribonuclease:** These enzymes are secreted by pancreas. These enzymes are responsible for breakdown of nucleic acids.
9. **Dextrinase, maltase, sucrase, and lactase:** These enzymes are secreted by small intestine. These enzymes are responsible for breakdown of carbohydrates.
10. **Aminopeptidase and dipeptidase:** These enzymes are secreted by small intestine. These enzymes are responsible for breakdown of proteins.

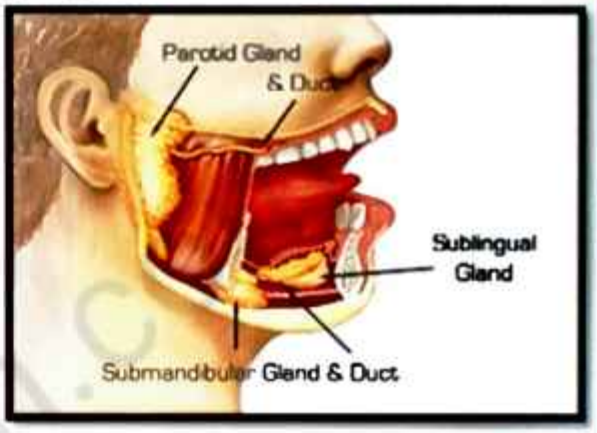
11. Nucleosidases and phosphatases: These enzymes are secreted by small intestine. These enzymes are responsible for breakdown of nucleotides.

❑ DIGESTIVE GLANDS

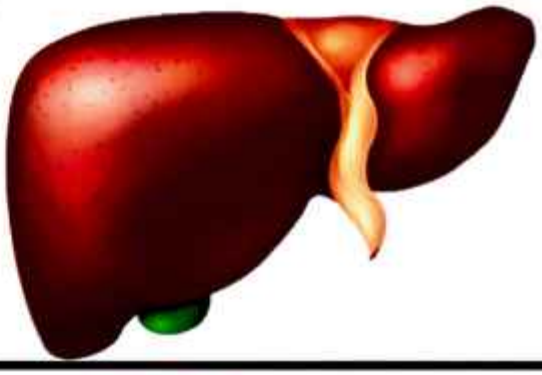
The digestive glands associated with the alimentary canal include the salivary glands, the liver and the pancreas.

SALIVA is mainly produced by **three pairs of salivary glands**

i. **Parotids (cheek)** gland
ii. **Sub- maxillary/sub-mandibular** (lower jaw) gland
iii. **Sub-linguals (below the tongue)** gland



LIVER is the largest gland of the body weighing about **1.2 to 1.5 kg** in an adult human. It is situated in the **abdominal cavity,** just below the diaphragm and has two lobes. The hepatic lobules are the **structural and functional units of liver** containing **hepatic cells** arranged in the form of cords. Each lobule is covered by a thin connective tissue sheath called the **Glisson's capsule.** The bile secreted by the hepatic cells passes through the hepatic ducts and is stored and concentrated in a thin muscular sac called the **gall bladder.** The duct of gall bladder (cystic duct) along with the hepatic duct from the liver forms the common **bile duct.** The **bile duct and the pancreatic duct open together into the duodenum** as the common hepato-pancreatic duct which is guarded by a sphincter called the **sphincter of Oddi.**



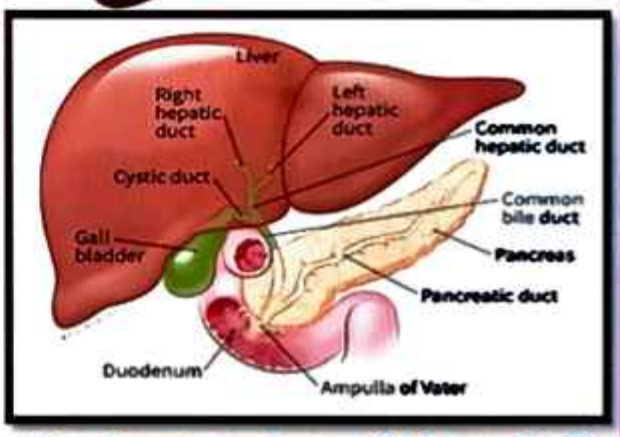


Fig. Duct system of Liver, Gall bladder and Pancreas

PANCREAS is a compound (both exocrine and endocrine) elongated organ situated between the limbs of the **'C' shaped duodenum.**

The **exocrine portion** secretes an **alkaline pancreatic juice** containing enzymes and the **endocrine portion** secretes **hormones, insulin and glucagon.**

❑ DIGESTION OF FOOD

✓ Digestion in Mouth:

- **Chewing of food material** which we take in mouth, is carried out with the help of the tongue. The food material minced by the teeth, and mixed with saliva. This activity leads to **softening of the food** which is to easy to swallow. This softened mass of food is called a **bolus (lump).**
- Food material starts dissolving in the water in saliva.
- **Salivary amylase,** which is secreted by the salivary glands, initiates the breakdown of starch.
- **Lingual lipase**, which is secreted by lingual glands in the tongue. This enzyme becomes activated in the acidic environment of the stomach and thus starts to work after food is swallowed.

✓ Digestion in the Stomach:

- After food enters the stomach, movement of stomach mixes food with secretions of the gastric glands, and reduce it to a soupy liquid called chyme.
- Digestion by salivary amylase continues in stomach. Acidic environment in stomach activates lingual lipase, which breaks triglycerides into fatty acids and diglycerides.
- **Pepsin in stomach** digests the proteins.
- **Gastric lipase** breaks the **short-chain triglycerides** in fat molecules.

✓ Digestion in the Small Intestine

- **Carbohydrates like sucrose, lactose, and maltose** are broken down in small intestine.
- **Sucrase breakdowns sucrose into a molecule of glucose** and a molecule of fructose.
- **Lactase digests lactose into a molecule of glucose** and a molecule of galactose

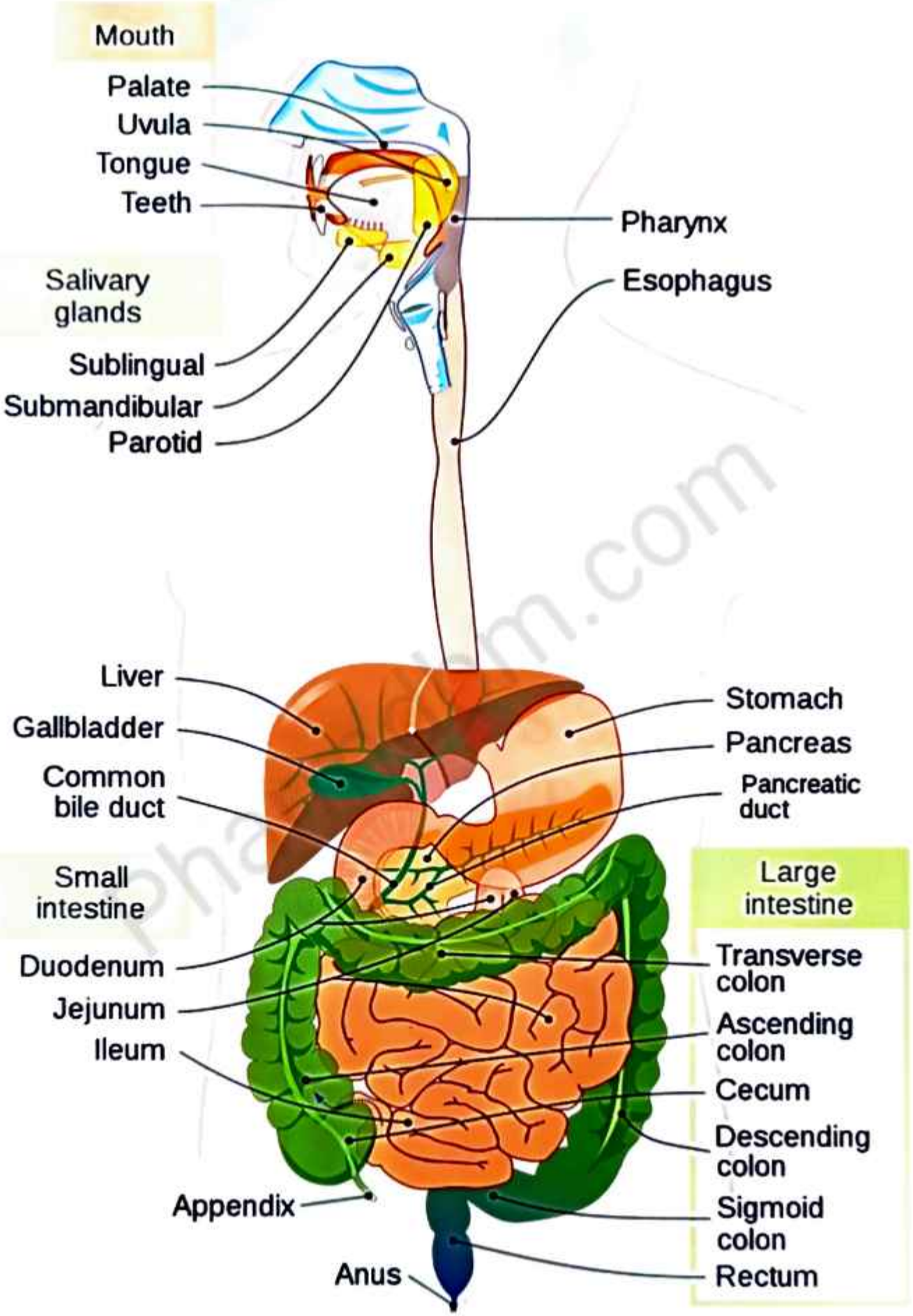


Fig. Human digestive system

- **Maltase** breaks **maltose and maltotriose** into two or **three molecules of glucose,** Digestion of carbohydrates ends with the production of monosaccharides, which the digestive system is able to absorb.
- **Protein** digestion is completed by two **peptidases** in the brush border: aminopeptidase and dipeptidase
- **Aminopeptidase** cleaves off the amino acid at the amino end of a **peptide**
- **Dipeptidase** splits dipeptides (two amino acids joined by a peptide bond) into single amino acids

❑ ABSORPTION OF DIGESTED PRODUCTS

Absorption is the process by which the end products of digestion pass through the intestinal mucosa into the blood or lymph.

- It is carried out by passive, active or facilitated transport mechanisms.
- Small amounts of **monosaccharides like glucose, amino acids and some electrolytes** like chloride ions are generally absorbed by simple diffusion.
- The **passage of these substances into the blood depends upon the concentration gradients.**
- some substances like **glucose and amino acids are absorbed with the help of carrier proteins.** This mechanism is called the **facilitated transport.**
- Transport of water depends upon the **osmotic gradient.**
- Transport occurs against the concentration gradient and hence requires energy.
- Various nutrients like **amino acids, monosaccharides like glucose, electrolytes like Na^+** are absorbed into the blood by this mechanism.
- **Fatty acids and glycerol** being insoluble, **cannot be absorbed into the blood.** They are first incorporated into small droplets called micelles which move into the intestinal mucosa. They are re-formed into very small protein coated fat globules called the **chylomicrons** which are transported into the lymph vessels **(lacteals)** in the **villi.** These lymph vessels ultimately release the absorbed substances into the blood stream.
- **Maximum absorption occurs in the small intestine.**

Sites of absorption and substances absorbed

MOUTH	STOMACH	SMALL INTESTINE	LARGE INTESTINE
Certain drugs coming in contact with the mucosa of mouth and lower side of the tongue are absorbed into the blood capillaries lining them.	Absorption of water, simple sugars, and alcohol etc. takes place.	Principal organ for absorption of nutrients. The digestion is completed here and the final products of digestion such as glucose, fructose, fatty acids, glycerol and amino acids are absorbed through the mucosa into the blood stream and lymph. Large	Absorption of water, some minerals and drugs takes place.

❑ ASSIMILATION OF FOOD

- Assimilation of food starts only after digestion of food. One has to remember that food digested is not food assimated. Carbohydrates and proteins are digested first, in the stomach by the action of strong acid and enzymes, while the fats digested to fatty acids in intestine.
- Assimilation takes place only in small intestine. Intestine is provided with tiny projections known as **microvilli** on the preface of the cells lining the intestine which are known as epithelial cells. These epithelial cells take nutrients from intestine and pump into the blood, where from it is distributed to body for growth and repair.

The absorbed substances finally reach the tissues which utilize them for their activities. This process is called **assimilation.**

- Constituents of **blood plasma like gases, nutrients and hormones**, etc. filter freely through the capillary walls to form interstitial fluid
- A considerable amount of **fluid is filtered out of blood capillaries.** The extra filtered fluid drains into lymphatic vessels and becomes **lymph**. As plasma proteins are too big to leave blood vessels, interstitial fluid contains lesser amount of proteins.
- The proteins can, however, move readily through the more permeable lymphatic capillaries into lymph
- Lymph consists of **lymphocytes**
- Lymph also consists of proteins called as **Globulin**. These are actually **antibodies.**
- Other components of the lymph plasma are very much like that of blood plasma, i.e., **organic, inorganic substances, water, etc.**
- An important function of lymph is to return the lost plasma proteins and plasma to the bloodstream

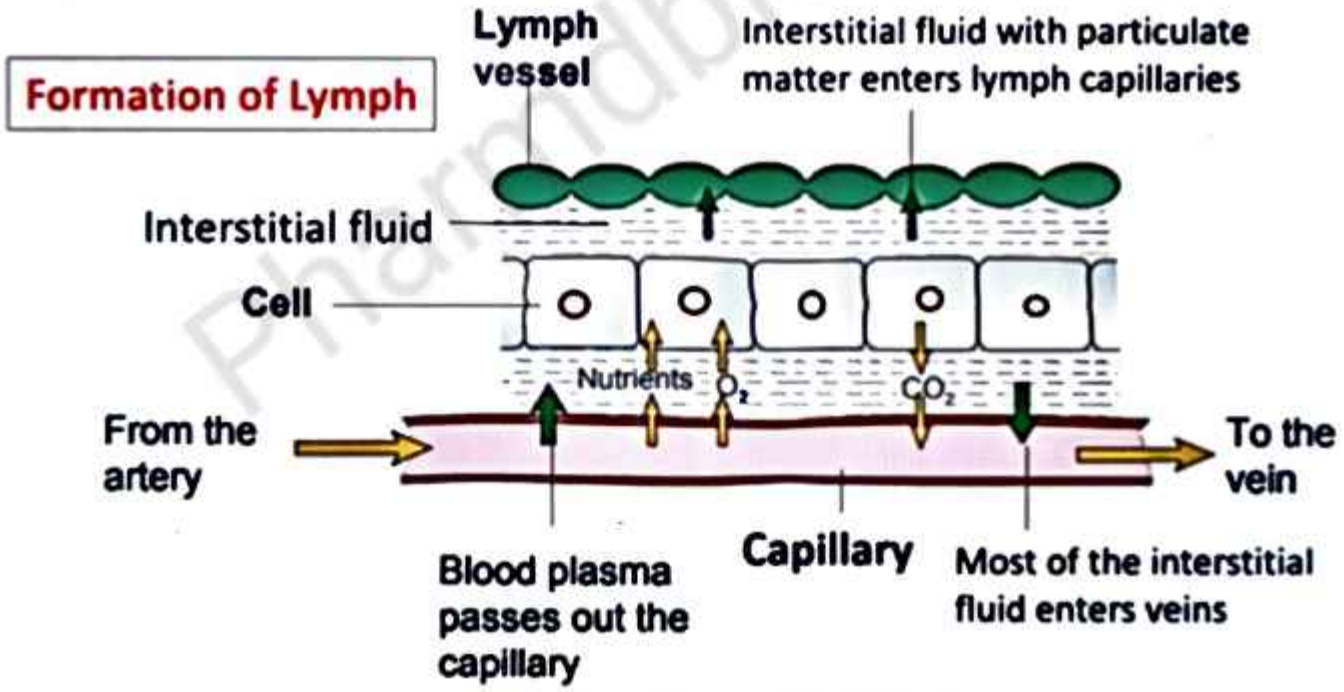
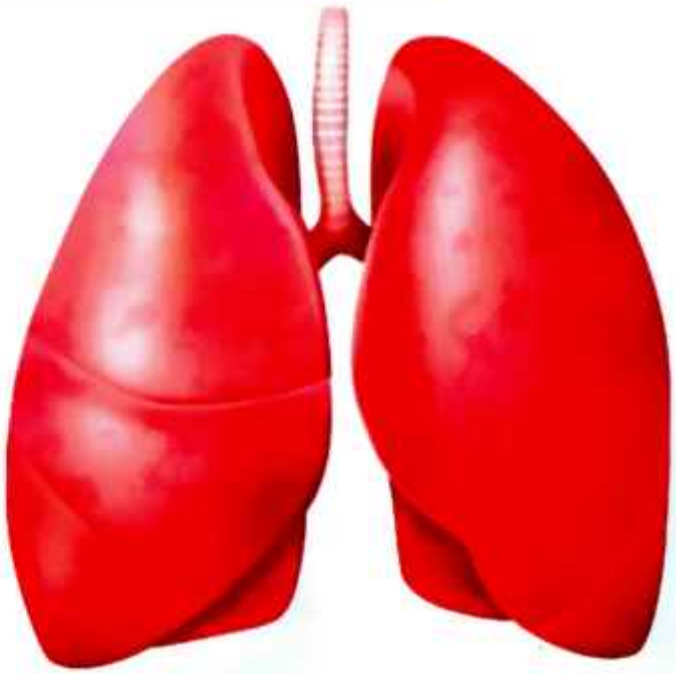


Fig. Formation of Lymph

BREATHING AND RESPIRATION

Contents to be covered in this topic

- HUMAN RESPIRATORY SYSTEM
- MECHANISM OF BREATHING AND ITS REGULATION
- EXCHANGE OF GASES, TRANSPORT OF GASES AND REGULATION OF RESPIRATION
- RESPIRATORY VOLUMES



❑ HUMAN RESPIRATORY SYSTEM

➢ **Introduction**

The human respiratory system consists of :

i. **The nose**
ii. **Pharynx (throat)**
iii. **Larynx (voice box)**
iv. **Trachea (windpipe)**
v. **Bronchi**
vi. **Lungs**

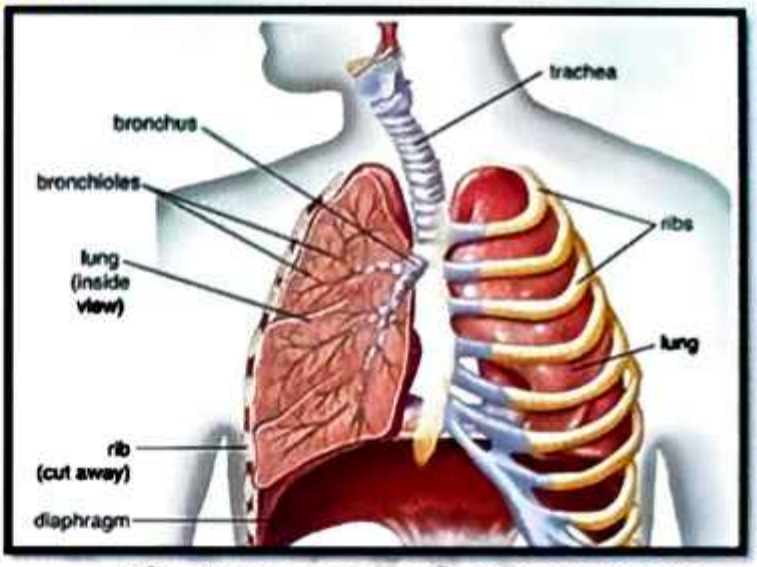


Fig. Human respiratory system

i. **The nose** - We have a pair of external nostrils opening out above the upper lips. It leads to a nasal chamber through the nasal passage.

ii. **Pharynx (throat)** - a portion of which is the common passage for food and air

iii. **Larynx (voice box)** - Larynx is a cartilaginous box which helps in sound production and hence called the sound box

iv. **Trachea (windpipe)** - Trachea is a straight tube extending up to the mid-thoracic cavity, which divides at the level of 5th thoracic vertebra into a right and left primary bronchi

v. **Bronchi** - Each bronchi undergoes repeated divisions to form the secondary and tertiary bronchi and bronchioles ending up in very thin terminal bronchioles

vi. **Bronchioles** - Each bronchi undergoes repeated divisions to form the secondary and tertiary bronchi and bronchioles ending up in very thin terminal bronchioles

vii. **Alveoli** - The **tracheae, primary, secondary and tertiary bronchi,** and initial bronchioles are supported by **incomplete cartilaginous rings**

viii. **Lungs** -We have **two lungs** which are covered by a **double layered pleura,** with pleural fluid between them. It **reduces friction on the lung-surface.**

The outer pleural membrane is in close contact with the thoracic lining whereas the inner pleural membrane is in contact with the lung surface.

The lungs are **situated in the thoracic chamber** which is anatomically an air-tight chamber. The anatomical setup of lungs in thorax is such that any change in the volume of the thoracic cavity will be reflected in the lung (pulmonary) cavity. Such an arrangement is essential for breathing, as we cannot directly alter the pulmonary volume.

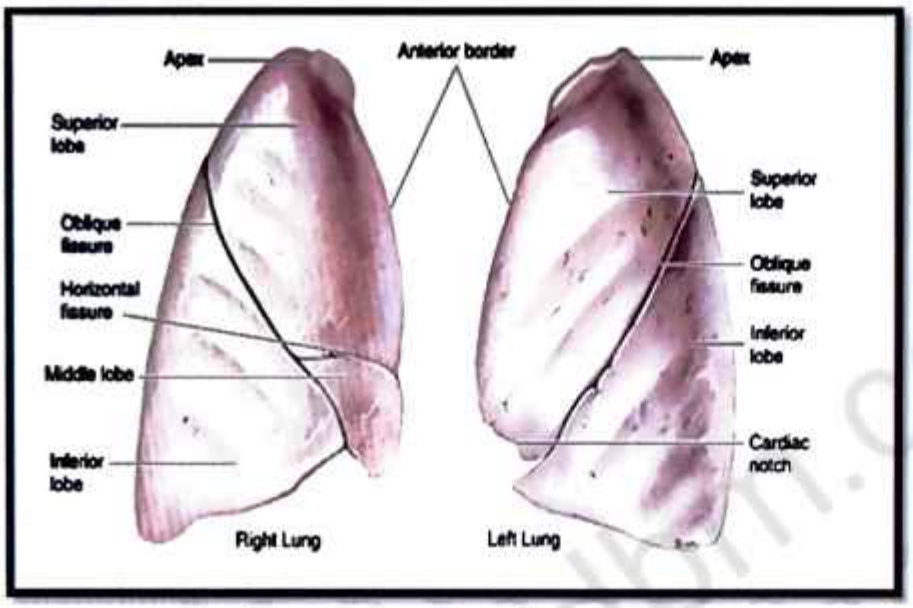


Fig structure of lung

❖ **Respiration involves the following steps:**

(i) Breathing or pulmonary ventilation by which atmospheric air is drawn in and CO_2 rich alveolar air is released out

(ii) Diffusion of gases (O^2 and CO^2) across alveolar membrane

(iii) **Transport of gases by the blood**

(iv) Diffusion of O^2 and CO^2 between blood and tissues

(v) Utilization of O^2 by the cells for catabolic reactions and resultant release of CO^2

➢ **Functions of Respiratory System:**

1. Respiratory system is responsible for gaseous exchange i.e. intake of O_2 which required by body cells and elimination of CO2, which is formed as waste product by body cells.
2. Respiratory system also helps to **regulate blood pH.**
3. It filters inspired air, involved in production of vocal sounds (phonation).
4. Respiratory system also **excretes small amounts of water and heat.**

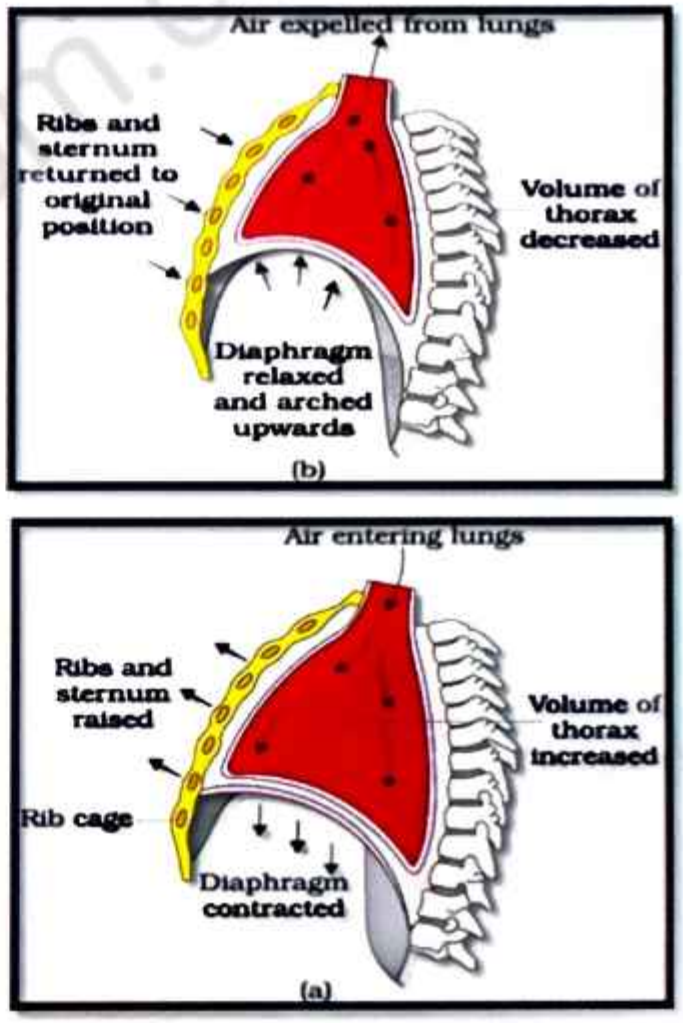
❑ MECHANISM OF BREATHING

Breathing involves two stages :

Inspiration during which **atmospheric air is drawn in** and **expiration by which the alveolar air is released out.** The **movement of air into and out of the lungs is carried out by creating a pressure gradient between the lungs and the atmosphere.** Inspiration can occur if the pressure within the lungs **(intra-pulmonary pressure)** is less than the atmospheric pressure, i.e., there is a **negative pressure** in the lungs with respect to atmospheric pressure

Expiration takes place when the **intra-pulmonary pressure is higher than the atmospheric pressure.** The **diaphragm** and a specialized set of muscles – external and internal intercostals between the ribs, help in generation of such gradients. **Inspiration** is initiated by the **contraction of diaphragm** which **increases the volume of thoracic chamber** in the antero-posterior axis. The contraction of external inter-costal muscles lifts up the ribs and the sternum causing an increase in the volume of the thoracic chamber in the dorso-ventral axis.

The overall **increase in the thoracic volume causes a similar increase in pulmonary volume**. An **increase in pulmonary volume decreases the intra-pulmonary pressure** to less than the atmospheric pressure which forces the air from outside to move into the lungs, i.e., inspiration. Relaxation of the diaphragm and the inter-costal muscles returns the diaphragm and sternum to their normal positions and reduce the thoracic volume and thereby the **pulmonary volume.** This leads to an increase in intra-pulmonary pressure to slightly above the atmospheric pressure causing the expulsion of air from the lungs, i.e., expiration. We have the ability to increase the strength of inspiration and expiration with the help of additional muscles in the abdomen. On an average, a healthy human breathes **12-16 times/minute.**



Mechanism of breathing showing : (a) inspiration (b) expiration

- The volume of air involved in breathing movements can be estimated by using a **spirometer** which helps in clinical assessment of pulmonary functions

❑ REGULATION OF RESPIRATION

Respiratory center regulates the process of respiration. Respiratory center is widely dispersed group of neurons, located bilaterally in the medulla oblongata and pons of the brain stem.

It can be divided into three areas:

i. **The medullary rhythmicity area** in the medulla oblongata: It controls the basic rhythm of respiration

ii. **The pneumotaxic area in the pons:** It co-ordinates the transition between inhalation and exhalation

iii. **The apneustic area, also in the pons:** It co-ordinates the transition between inhalation and exhalation

❑ EXCHANGE OF GASES

- **Alveoli** are the **primary sites of exchange of gases.**
- Exchange of gases also occur **between blood and tissues.**
- O_2 and CO_2 are exchanged in these sites by simple diffusion mainly based on **pressure/concentration gradient.**
- Pressure contributed by an individual gas in a mixture of gases is called **partial pressure** and is represented as pO_2 for oxygen and pCO_2 for carbon dioxide.

Partial Pressures (in mm Hg) of Oxygen and Carbon dioxide at Different Parts Involved in Diffusion in Comparison to those in Atmosphere :

Respiratory Gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O2	159	104	40	95	40
CO2	0.3	40	45	40	45

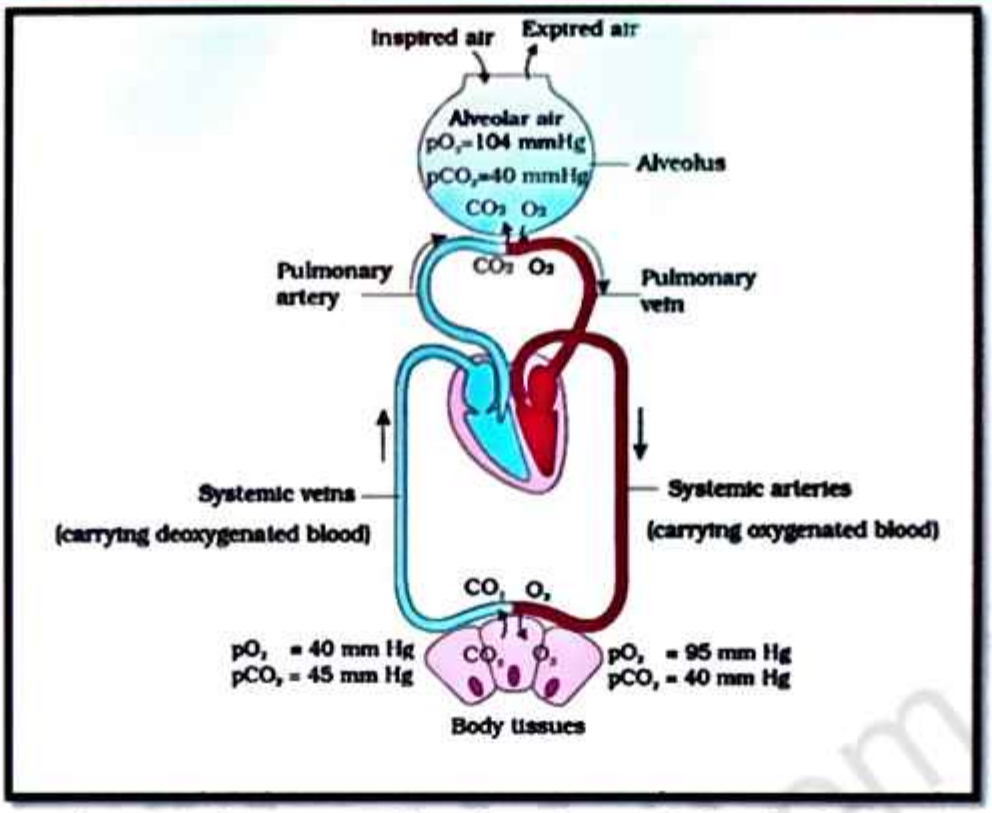


Fig. Exchange of gases at the alveolus and the body tissues with blood and transport of oxygen and carbon dioxide

a gradient is present for CO_2 in the opposite direction, i.e. from tissues to blood and blood to alveoli. As the solubility of CO_2 is 20-25 times higher than that of O_2 , the amount of CO_2 that can diffuse through the diffusion membrane per unit difference in partial pressure is much higher compared to that of O_2 . The **diffusion membrane** is made up of three major layers namely, the thin **squamous epithelium** of alveoli, the **endothelium of alveolar capillaries** and the basement substance in between them. However, its total thickness is much less than a millimetre. Therefore, all the factors in our body are favorable for diffusion of O_2 from alveoli to tissues and that of CO_2 from tissues to alveoli.

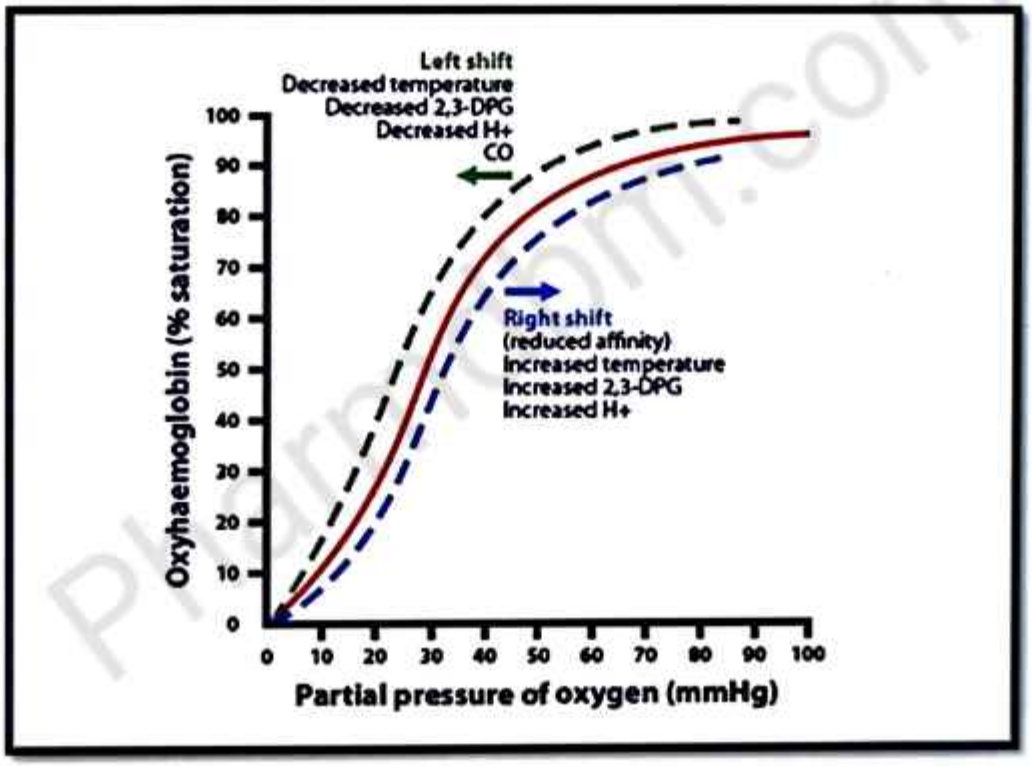
❑ TRANSPORT OF GASES

Blood is the medium of transport for O_2 and CO_2 . About **97 per cent** of O_2 is transported by RBCs in the blood. The remaining 3 per cent of O_2 is carried in a dissolved state through the plasma. Nearly **20-25 per cent** of CO_2 is transported by RBCs whereas **70 per cent** of it is carried as bicarbonate. About **7 per cent** of CO_2 is carried in a dissolved state through plasma.

✓ Transport of Oxygen

Hemoglobin is a **red coloured iron containing** pigment present in the RBCs. **O_2** can bind with haemoglobin in a **reversible manner** to form oxyhaemoglobin. Each haemoglobin molecule can carry a maximum of four molecules of O_2. Binding of oxygen with haemoglobin is primarily related to partial pressure of O_2. **Partial pressure of CO_2** , hydrogen ion concentration and temperature are the other factors which can interfere with this binding.

A **sigmoid curve** is obtained when percentage saturation of haemoglobin with O_2 is plotted against the **pO_2**. This curve is called the **Oxygen dissociation curve** and is highly useful in studying the effect of factors like pCO_2 , H+ concentration, etc. on binding of O_2 with haemoglobin.



✓ Transport of Carbon dioxide

CO_2 is carried by **haemoglobin** as **carbamino-haemoglobin** (about 20-25 per cent). This binding is related to the **partial pressure of CO_2** . pO_2 is a major factor which could affect this binding. When **pCO_2** is high and pO_2 is low as in the tissues, more binding of carbon dioxide occurs whereas, when the pCO_2 is low and pO_2 is high as in the alveoli, dissociation of CO_2 from carbamino-haemoglobin takes place, i.e., CO_2 which is bound to haemoglobin from the

tissues is delivered at the alveoli. RBCs contain a very high concentration of the enzyme, carbonic anhydrase and minute quantities of the same is present in the plasma too. This enzyme facilitates the following reaction in both directions. of CO_2 from carbamino-haemoglobin takes place, i.e., CO_2 which is bound to haemoglobin from the tissues is delivered at the alveoli. RBCs contain a very high concentration of the enzyme, carbonic anhydrase and minute quantities of the same is present in the plasma too. This enzyme facilitates the following reaction in both directions

$$CO_2 + H_2O \xrightleftharpoons{\text{Carbonic anhydrase}} H_2CO_3 \xrightleftharpoons{\text{Carbonic anhydrase}} HCO_3^- + H^+$$

At the tissue site where partial pressure of CO_2 is high due to catabolism, CO2 diffuses into blood (RBCs and plasma) and forms HCO_3 – and H+,. At the alveolar site where pCO_2 is low, the reaction proceeds in the opposite direction leading to the formation of CO_2 and H_2O. Thus, CO_2 trapped as bicarbonate at the tissue level and transported to the alveoli is released out as CO_2. Every 100 ml of deoxygenated blood delivers approximately 4 ml of CO2 to the alveoli.

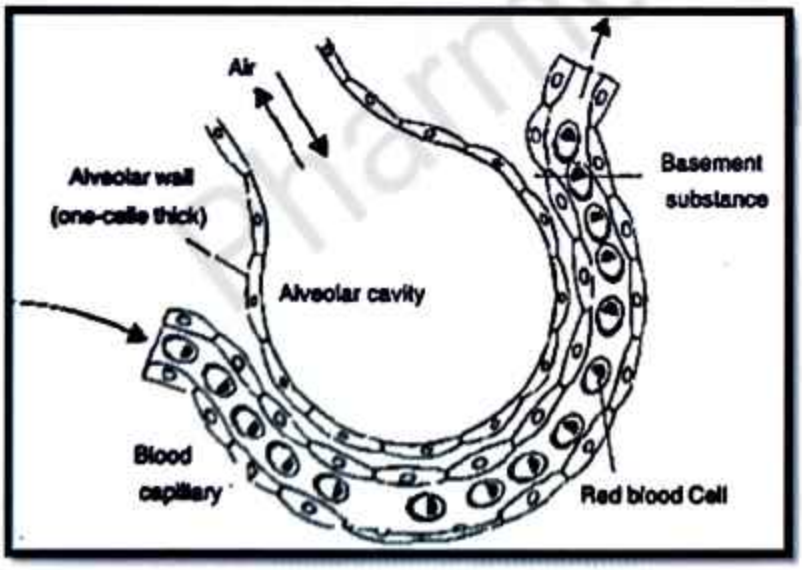


Fig. Section of an alveolus with a pulmonary capillary.

❑ RESPIRATORY VOLUMES AND CAPACITIES

TIDAL VOLUME (TV): Volume of air inspired or expired during a normal respiration. It is approx. **500 ml.** i.e., a healthy man can inspire or expire approximately **6000 to 8000 mL** of air per minute.

INSPIRATORY RESERVE VOLUME (IRV): Additional volume of air, a person can inspire by a forcible inspiration. This averages **2500 mL to 3000 mL.**

EXPIRATORY RESERVE VOLUME (ERV): Additional volume of air, a person can expire by a forcible expiration. This averages **1000 mL to 1100 mL**

RESIDUAL VOLUME (RV): Volume of air remaining in the lungs even after a forcible expiration. This averages **1100 mL to 1200 mL**

INSPIRATORY CAPACITY (IC): Total volume of air a person can inspire after a normal expiration. This includes **(TV+ IRV)**

EXPIRATORY CAPACITY (EC): Total volume of air a person can expire after a normal inspiration. This includes **(TV + ERV).**

FUNCTIONAL RESIDUAL CAPACITY (FRC): Volume of air that will remain in the lungs after a normal expiration. This includes **ERV + RV**

VITAL CAPACITY (VC): The maximum volume of air a person can **breathe in** after a forced expiration. This includes **ERV, TV and IRV** or the maximum volume of air a person can breathe out after a forced inspiration

TOTAL LUNG CAPACITY: Total volume of air accommodated in the lungs at the end of a forced inspiration. This includes **RV, ERV, TV and IRV or vital capacity + residual volume.**