8 Respiration and Circulation

Can you recall?

1. Definition of respiration.
2. The types of cellular respiration.
3. Why should we respire all the time?

All living organisms require energy to carry out various life processes. The energy that is stored in the body in the form of complex organic compounds (potential energy) is however not usable by the organisms unless it is converted into usable form. This conversion is achieved through the process of respiration.

Respiration : It is a biochemical process of oxidation of organic compounds in an orderly manner for the liberation of chemical energy in the form of ATP.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6\,CO_2 + 6H_2O + 38\ ATP$$

For this, the process of gaseous exchange takes place between the organism and the environment. The site of gaseous exchange is called the respiratory surface.

Use your brain power

What would happen if respiration take place in one single step?

8.1 Organs of Respiratory Exchange :

Respiratory exchange is a simple physical process. For efficient gaseous exchange, the respiratory surface should have the following features :

a. It should have a large surface area.
b. It should be thin, highly vascular and permeable to allow exchange of gases.
c. It should be moist.

Gaseous exchange in plants :

The shape and structure of plants facilitate gaseous exchange by diffusion. A terrestrial flowering plant has many air spaces between the cells of stem, leaf and root. These air spaces are continuous. Oxygen diffuses into the air space through stomata (the pores on leaves and young stems), carbon dioxide and water vapour diffuse out. In the aerated soil, the oxygen dissolves in the film of moisture or water around the root tissue and enters it by diffusion.

Woody flowering plants (trees and shrubs) have an external impervious bark. Here, gaseous exchange occurs through small pores in the stem surface, called lenticels.

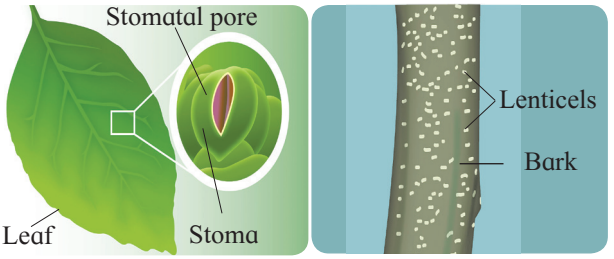


Fig. 8.1 : Organs of gaseous exchange in plants

Curiosity Box :

1. What are the main features of respiratory surface?
2. Which are the parts of plant that help in the process of gaseous exchange?

Respiration in Animals :

As compared to plants, animals show wide variety of respiratory surfaces or organs. The respiratory surfaces differ in various animals. In animals, depending upon the complexity of organization and the surrounding medium, certain parts of the body have become specialized into different types of respiratory organs. In the higher animals, these respiratory organs are also associated with a transport system.

Organism	Habitat	Respiratory surface/ organ
Protists, Sponges and Coelenterates	Aquatic	Plasma membrane
Flatworms like Planaria, Annelids (earthworm, nereis, leech), amphibians (frog)	Aquatic or semiquatic	Plasma membrane, general body surface (moist skin)
Insects	Terrestrial	Tracheal tubes and spiracles
Arachnids like spiders and scorpions	Terrestrial	Book lungs
Limulus (Arthropod)	Aquatic	Book gills
Amphibian tadpoles of frog, salamanders and newts	Aquatic	External gills
Fish	Aquatic	Internal gills
Reptiles, Birds and Mammals	Terrestrial	Lungs
Turtles	Underwater	cloaca

Table 8.2 : Respiratory surface/ organ in organisms

Use your brain power

Why large animals can not carry out respiration without the help of circulatory system?

8.2 Human Respiratory system:

The respiratory system brings about inspiration, expiration and exchange of gases in the lungs. These are then transported by blood from the lungs to the different tissues and parts of the body. The respiratory system and be divided into an upper respiratory system having external nares, nasal cavities, internal nares, nasopharynx, nose, throat and associated structures. The lower respiratory system refers to the larynx, trachea, bronchi, bronchioles and lungs.

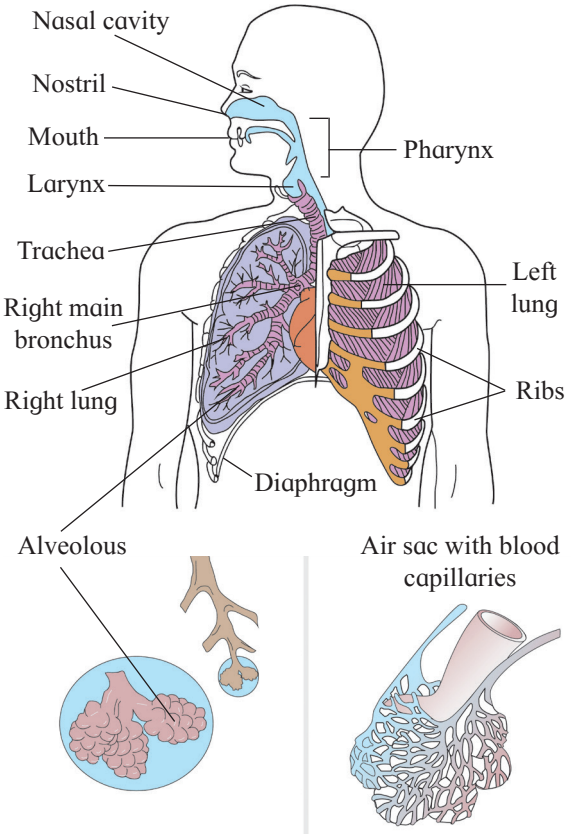


Fig. 8.3 : Human Respiratory system

Nose :

The nose has a pair of slit like openings called external nares or nostrils for entry of air into the nasal cavity. The nasal cavity is divisible into right and left nasal chambers by a **mesethmoid cartilage**. Each nasal chamber is further divided into three regions.

i. **Vestibule :** It is the proximal part about the nostrils. Its skin has hair for filtering the air and traping the dust and suspended particles in the inhaled air.

ii. **Respiratory part (conditioner) :** The middle thin walled highly vascular part for warming and moistening the inhaled air.

iii. **Olfactory or sensory chamber :** The uppermost part is lined by olfactory epithelium for detection of smell.

Pharynx :

It is divisible into three parts. The nasopharynx is the uppermost part from the nasal chamber it leads into oropharynx (common passage for food and air). This

continues below as the **laryngopharynx**. Between the nasopharynx and oropharynx is the palate bone. The pharynx has a set of lymphoid organs called **tonsils**.

Larynx :

It is called voice box. It is the part of the respiratory tract which contains vocal cords for producing sound. The larynx extends from the laryngopharynx and the hyoid bone to the trachea. It is a hollow, tubular structure. Its wall is made up of cartilage plates held by membranes and muscles. Internally, it is lined by a pair of folds of elastic vocal cords (true vocal cords). Voice is produced by passage of air between the vocal cords and modulations created by tongue, teeth, lips and nasal cavity. The larynx opens into the laryngopharynx through a slit like opening called glottis. This opening of the trachea or wind pipe is guarded by a leaf like flap called **epiglottis**. It prevents the entry of food into trachea.

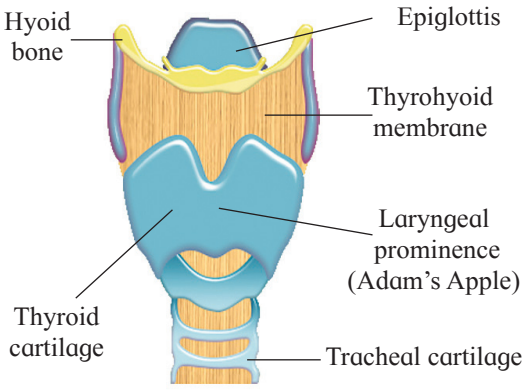


Fig. 8.4 : Larynx

Trachea (wind pipe) :

It is a long tube 10 to 12 cm in length. It runs through the neck in front of the oesophagus and extends into and upto the middle of thoracic cavity. It is supported by 'C' shaped 16 to 20 rings of cartilage which prevent the collapse of trachea. It is lined internally with ciliated, pseudostratified epithelium and mucous glands that trap the unwanted particles preventing their entry into the lungs.

Find out

- Kavya underwent a surgical procedure called Rhinoplasty. What could have been the reason for such a surgery? On which part of the body is it carried out?
- What is the role of tonsils in our body? How many pairs of tonsils do we have?

Do you know ?

- Shreyas choked while eating dinner. How can you help him? What is the immediate help that can be given to him?
- What is a role of epiglottis?

Bronchi :

The trachea divides into right and left primary bronchi as it reaches the middle of the thoracic cavity. The bronchi are supported internally by 'C' shaped incomplete rings of cartilage. The primary bronchi divide to form secondary and tertiary bronchi which lead into terminal bronchioles ending into alveoli.

Lungs :

These are the main respiratory organs of humans. One pair of spongy and elastic lungs are present in the thoracic cavity. Each lung is enclosed and protected by a double pleural membrane, outer parietal and inner visceral membrane. Between the two pleura is a pleural cavity filled with a lubricating fluid called pleural fluid. It is secreted by the membranes. The right lung is larger and divided into 3 lobes, while the left lung is smaller and divided into 2 lobes. Each lobe of the lung has the terminal bronchioles ending in a bunch of air sacs, each with 10 to 12 alveoli.

Alveoli :

These are thin walled lobulated structures, like a bunch of grapes. Each alveolus is surrounded by a network of capillaries of pulmonary arteries and veins. These have highly elastic wall made up of a single layer

of squamous epithelium resting on a basement membrane of connective tissue. There are about 700 million alveoli in the lungs and they provide the surface area for exchange of gases.

Internet my friend

1. What is the importance of pleural fluid?
2. Find the total surface covered by the alveoli.

Diaphragm : It is a muscular septum that separates the thoracic and abdominal cavity. It is dome shaped and on contraction it becomes flattened.

8.3 Mechanism of respiration :

Respiration is a biological process involving exchange of gases between the atmosphere and the lungs and it results in the formation of ATP. It includes the following processes:

A. Breathing
B. External respiration
C. Internal respiration
D. Cellular respiration

Try This

Count the number of breaths you take in the following situations (a). After a good night's sleep (b). During a vigorous activity (running, climbing stairs etc) (c). After the vigorous activity. Do you find any difference in the count?

A. Breathing :

It is a physical process by which gaseous exchange takes place between the atmosphere and the lungs. It involves inspiration and expiration (see fig. 8.5). Both these steps involved parts of the thoracic cage, the ribs, sternum and the intercostal muscles and muscles of the diaphragm.

Inspiration : During inspiration, the atmospheric air is taken in to the lungs. It occurs due to the pressure gradient formed between the lungs and the atmosphere. It is an active process in which the diaphragm becomes flat and goes downward, the external intercostal muscles contract so the ribs and sternum move upward and outward. This leads to an increase in the thoracic volume and a decrease in pressure of thorax and the lungs. To equalize the low pressure inside the lungs, air from the atmosphere rushes into lungs. This is inspiration.

Expiration : During expiration, the thorax contracts causing air to be exhaled. The diaphragm relaxes and is pushed upwards. It becomes dome shaped. The intercostal muscles also relax pulling the rib cage inward and downward. This causes a decrease in thoracic volume and leads to increase in pressure in the thorax and the lungs as compared to the atmospheric pressure. So air from the lungs rushes out. This is expiration.

One inspiration and one expiration is one breath.

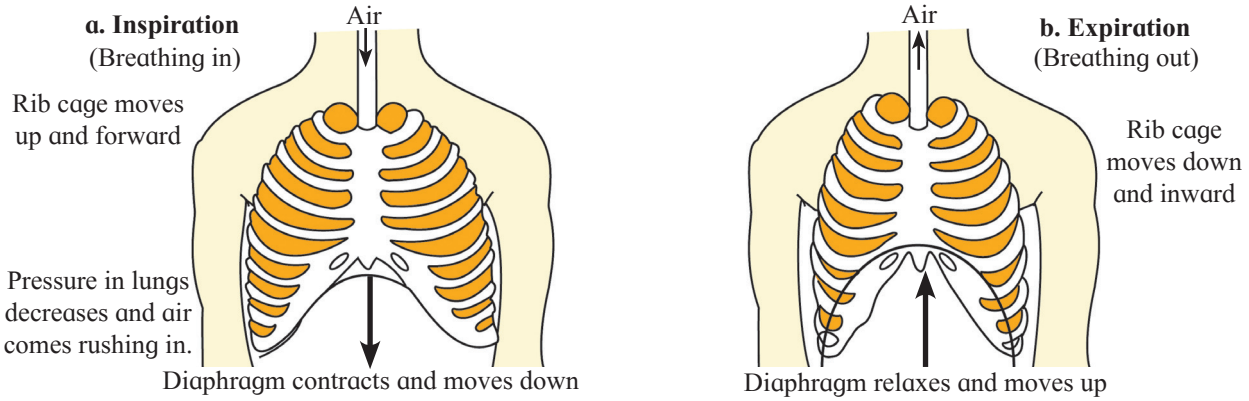


Fig. 8.5 : Breathing

B. External respiration/ Exchange of gases at the alveolar level :

An alveolus consists of a layer of simple squamous epithelium resting on a basement membrane. It is intimately associated with a dense network of capillaries. The capillary wall is also made up of simple squamous epithelium resting on a thin basement membrane. Both the layers have similar structure and are thin walled. Together they make up the respiratory membrane through which gaseous exchange occurs i.e. between the alveolar air and the blood.

Diffusion of gases will take place from an area of higher partial pressure (pp) to an area of lower partial pressure until the partial pressure in the two regions reaches equilibrium.

The partial pressure of carbon-dioxide (pCO_2) of blood entering the pulmonary capillaries is 45 mmHg while partial pressure of carbon-dioxide in alveolar air is 40 mmHg. Due to this difference, carbon dioxide diffuses from the capillaries into the alveolus.

Similarly, partial pressure of oxygen (pO_2) of blood in pulmonary capillaries is 40 mmHg while in alveolar air it is 104 mmHg. Due to this difference oxygen diffuses from alveoli to the capillaries.

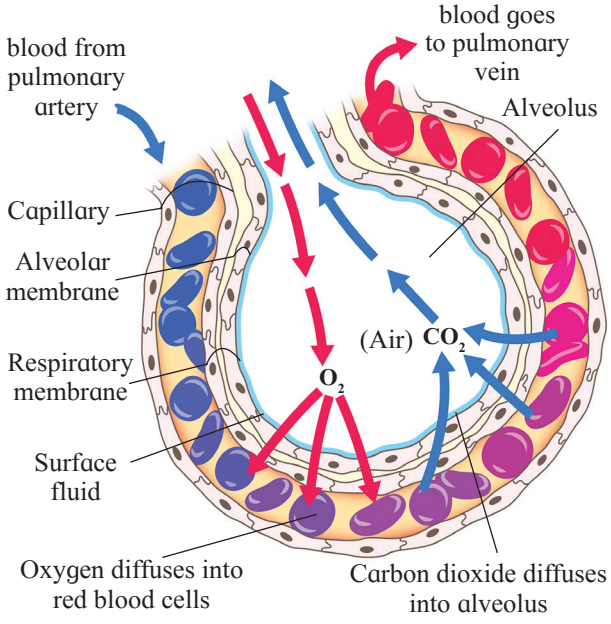


Fig. 8.6 : Exchange of gases between alveolus and capillary

Pulmonary volumes and capacities (Normal values)

Lung Volumes :

Tidal volume (T.V.) : It is the volume of air inspired or expired during normal breathing. It is 500 ml.

Inspiratory reserve volume (IRV) : The maximum volume of air, or the extra volume of air, that is inspired during forced breathing in addition to T.V. Its value is 2000 to 3000ml.

Expiratory reserve volume (ERV) : The maximum volume of air that is expired during forced breathing after normal expiration. Its value is 1000 to 1100ml.

Dead space (DS) : The volume of air that is present in the respiratory tract (from nose to the terminal bronchioles), but not involved in gaseous exchange. It is 150 ml.

Residual volume (RV) : The volume of air that remains in the lungs and the dead space even after maximum expiration. It is 1100 to 1200ml.

Lung capacities :

Total Lung capacity : The maximum amount of air that the lungs can hold after a maximum forceful inspiration (5200 to 5800ml).

Vital capacity (VC) : The maximum amount of air that can be breathed out after a maximum inspiration. It is the some total of TV, IRV and ERV and is 4100 to 4600ml.

Use your brain power

Why gas exchange in the alveolar region is very rapid?

C. Internal respiration :

The two main components of blood involved in transport of the respiratory gases- CO_2 and O_2, are the RBCs and the plasma.

i. Transport of oxygen :

Of the total oxygen transported only 3% is transported in a dissolved state by the plasma. The remaining 97% is bound to the haemoglobin (Hb) present in the RBCs.

Haemoglobin acts as the respiratory carrier. It has a high affinity for O_2 and combines with it to form oxyhaemoglobin. Theoretically, one molecule of Hb has 4 Fe^{++}, each of which can pick up a molecule of oxygen (O_2).

$$Hb + 4O_2 \longrightarrow Hb(4O_2)$$

Oxyhaemoglobin is transported from lungs to the tissues where it readily dissociates to release O_2.

$$Hb(4O_2) \longrightarrow Hb + 4O_2$$

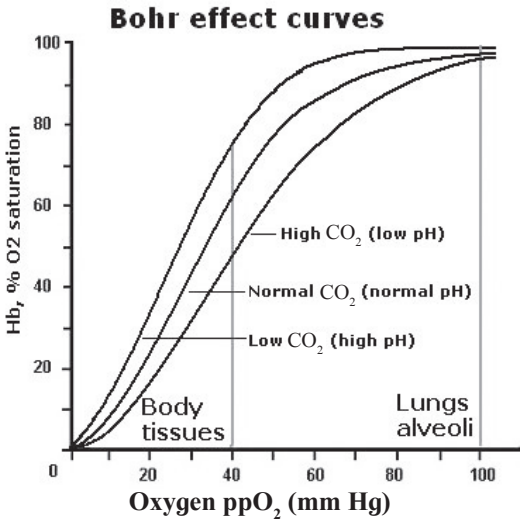
However, the degree of saturation of Hb with O_2 depends upon the O_2 tension i.e. ppO_2.

- 100% saturation is rare.
- Maximum saturation of 95 to 97% is at ppO_2 in alveoli (100 mmHg).
- Degree of saturation decreases with the drop in ppO_2. This begins the dissociation of HbO_2.
- At 30 mmHg of ppO_2, only 50% saturation can be maintained.
- The relationship between HbO_2 saturation and oxygen tension (ppO_2) is called **oxygen dissociation curve**. This oxygen - haemoglobin dissociation curve is a sigmoid curve and it shifts towards the right due to - increase in H^+ concentration, increase in $ppCO_2$ and rise in tempreature and rise in DPG (2, 3 diphosphoglycerate), formed in the RBCs during glycolysis. It lowers the affinity of haemoglobin for oxygen.

Bohr effect : It is the shift of oxyhaemoglobin dissociation curve due to change in partial pressure of CO_2 in blood.

Haldane effect : Oxyhaemoglobin functions as an acid. It decreases pH of blood. Due to increase in the number of H^+ ions, HCO_3^- changes into H_2O and CO_2.

In the alveoli where ppO_2 is high and $ppCO_2$ is low, oxygen binds with haemoglobin, but in the tissues, where ppO_2 is lower and $ppCO_2$ is high, haemoglobin does not hold as much O_2. It releases O_2 for diffusion into the tissue cells.



Graph 8.7 : Oxyhaemoglobin dissociation curve (pp = partial pressure)

Carbon monoxide poisoning :

Affinity of haemoglobin for carbon monoxide is about 250 times more, than for oxygen. In the presence of carbon monoxide, haemoglobin readily combines to form a stable compound carboxyhaemoglobin. The haemoglobin is blocked by carbon monoxide, preventing oxygen from binding with haemoglobin. Thus, less haemoglobin is available for oxygen transport depriving the cells of oxygen. This is carbon monoxide poisoning.

Use your brain power

While working with the car engine in a closed garage, John suddenly felt dizzy and fainted. What is the possible reason?

ii. Transport of CO_2 :

Carbon dioxide is readily soluble in water and is transported by RBCs and plasma in three different forms.

a. By plasma in solution form (7%) : Only 7% of CO_2 is transported in a dissolved form as carbonic acid (which can breakdown into CO_2 and H_2O).

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$

b. By bicarbonate ions (70%) : Nearly 70% of carbondioxide released by the tissue cells diffuses into the plasma and then into the RBCs.

- In the RBCs, CO_2 combines with water in the presence of a Zn containing enzyme, **carbonic anhydrase** to form carbonic acid.
- Carbonic anhydrase enzyme is found in the RBCs and not in the plasma.
- The rate of formation of carbonic acid inside the RBC is very high as compared to its formation in the plasma.
- Carbonic acid being unstable almost immediately dissociates into HCO_3^- and H^+ in the presence of the enzyme carbonic anhydrase (CA) leading to large accumulation of HCO_3^- inside the RBCs.

$$CO_2 + H_2O \underset{}{\overset{CA}{\rightleftharpoons}} H_2CO_3 \overset{CA}{\rightleftharpoons} H^+ + HCO_3^-$$

- It thus moves out of the RBCs. This would bring about imbalance of the charge inside the RBCs. To maintain the ionic balance between the RBCs and the plasma, Cl^- diffuses into the RBCs. This movement of chloride ions is known as **chloride shift** or **Hamburger's phenomenon**.
- HCO_3^- that comes into the plasma joins to Na^+ / K^+ forming $NaHCO_3$ / $KHCO_3$ (to maintain pH of blood).

$$HCO_3^- + Na^+ \longrightarrow NaHCO_3$$

Sodium bicarbonate

- H^+ is taken up by protein (haemoglobin).

$$Hb + H^+ \longrightarrow HHb$$

(Reduced Hb)

These H^+ ions might be expected to lower blood pH, but they are buffered by haemoglobin by the formation of deoxyhaemoglobin (reduced haemoglobin).

- At the **level of the lungs** in response to the low partial pressure of carbon dioxide ($ppCO_2$) of the alveolar air, hydrogen ion

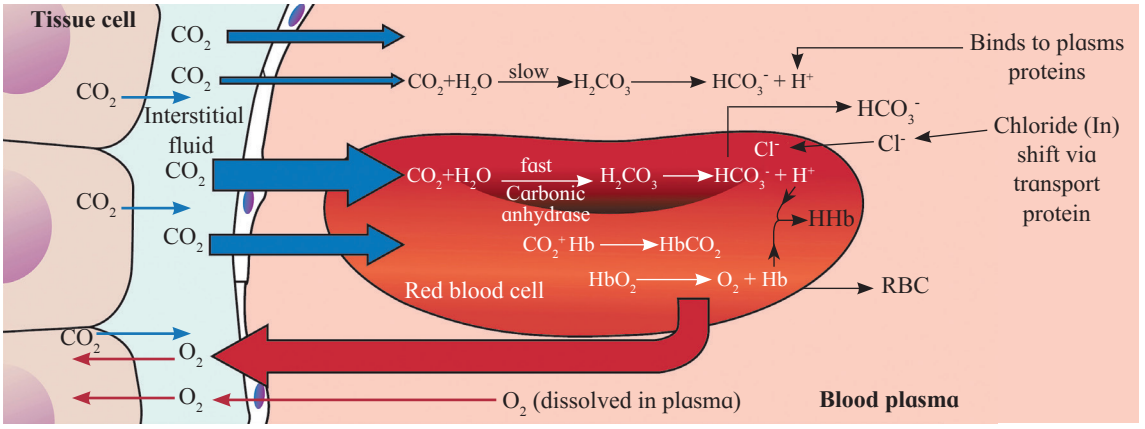


Fig. 8.8 : Oxygen release and carbon dioxide pickup at the tissue

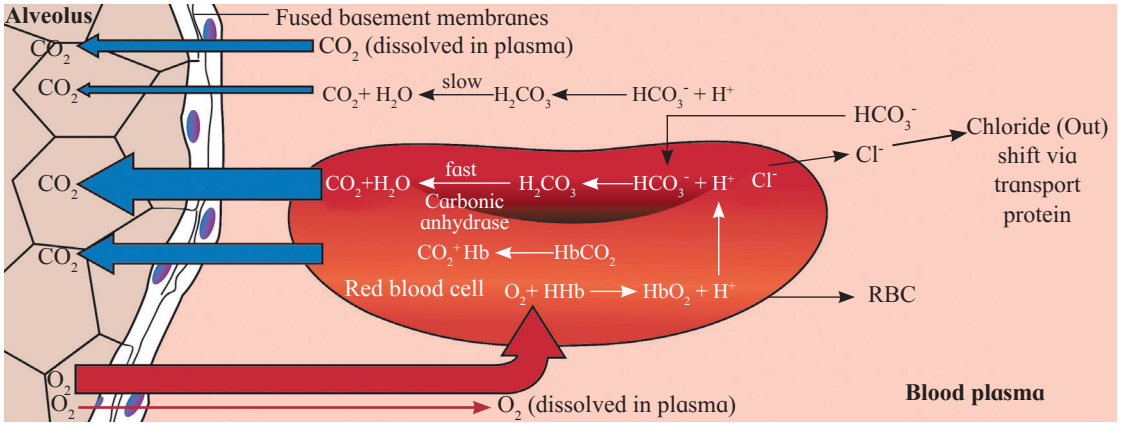


Fig. 8.9 : Oxygen pickup and carbon dioxide release in the lungs

and bicarbonate ions recombine to form carbonic acid and under the influence of carbonic anhydrase yields carbon dioxide and water.

$$H^+ + HCO_3^- \xrightleftharpoons{CA} H_2CO_3 \xrightleftharpoons{CA} CO_2 + H_2O$$

c. By red blood cells (23%) : Carbon dioxide binds with the amino group of the haemoglobin and form a loosely bound compound carbaminohaemoglobin. This molecule readily decomposes in region where the partial pressure of carbon dioxide ($ppCO_2$) is low (alveolar region), releasing the carbon dioxide.

$$Hb + CO_2 \rightleftharpoons HbCO_2$$

Use your brain power

1. What is the role of haemoglobin in the transport of oxygen in the blood?
2. Write a note on chloride shift.

D. Cellular Respiration :

It is the last step taking place inside the cell where food is oxidized and ATP is generated. It can be shown by two steps:

a. Oxidation : Breaking down of complex organic molecules into simple inorganic molecules with release of heat energy.

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 686\ Kcal$$

b. Phosphorylation : It involves trapping the heat energy in the form of high energy bond of ATP molecule. ATP is used to carry out vital life processes and so is called as energy currency of the cell.

$$ADP + iP + 7.3\ Kcal \longrightarrow ATP$$

8.4 Regulation of Breathing :

Respiration is under dual control : nervous and chemical. Human adults breathe about 12 times/minute while a new born about 44 times/minute. Normal breathing is an involuntary process. Steady rate of respiration is controlled by neurons located in the **pons** and **medulla** and are known as the **respiratory centres**. It regulates the rate and depth of breathing. It is divided into three groups : dorsal group of neurons in the medulla (inspiratory center), ventro lateral group of neurons in medulla (inspiratory and expiratory center) and pneumotaxic center located in pons (primarily limits inspiration, slow wave sleep and rapid eye movement sleep). Apneustic center in the medulla is antagonistic to the neumotaxic center. It controls non rapid eye movement, sleep and wakefulness.

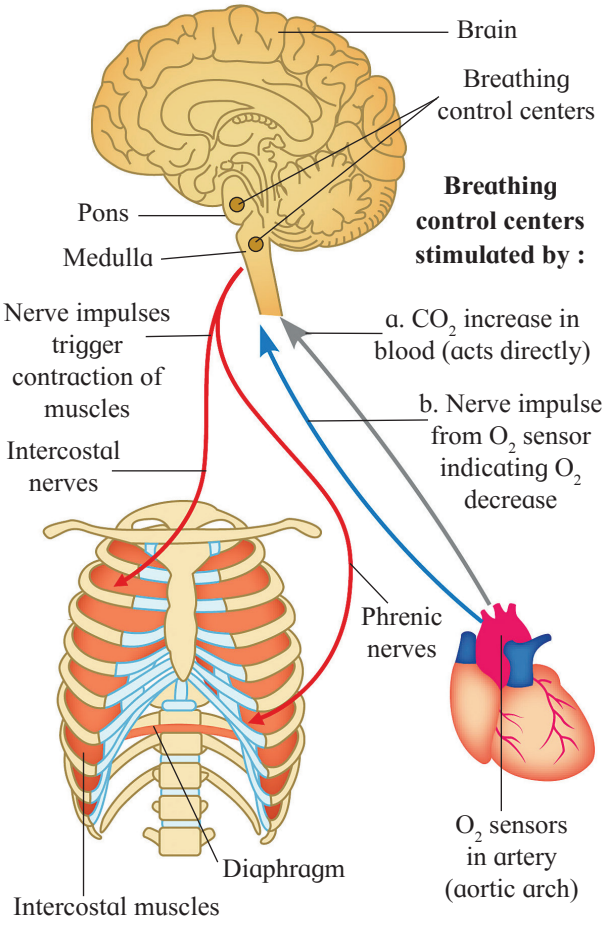


Fig. 8.10 : Regulation of Breathing

During inspiration when the lungs expand to a critical point, the stretch receptors are stimulated and impulses are sent along the vagus nerves to the expiratory centre. It then sends out inhibitory impulses to the inspiratory center.

The inspiratory muscles relax and expiration follows. As air leaves the lungs during expiration, the lungs are deflated and the stretch receptors are no longer stimulated. Thus, the inspiratory centre is no longer inhibited and a new respiration begins. These

events are called the ***Hering-Breuer reflex***. The ***Hering-Breuer reflex*** controls the depth and rhythm of respiration. It also prevents the lungs from inflating to the point of bursting.

The respiratory centre has connections with the cerebral cortex which means we can voluntarily change our pattern of breathing. Voluntary control is protective because it enables us to prevent water or irritating gases from entering the lungs. But the ability to stop breathing is also limited by the build up of carbon dioxide in the blood.

8.5 Modified Respiratory Movements :

Some respiratory movements are different from the normal movements and help express emotion or clear the air passage. Of these movements some may be reflexes, but others can be initiated voluntarily e.g. coughing and yawning.

Internet my friend

1. Find out information about the various modified respiratory movements and write it in a tabular form.
2. What is the significance of such movements?

8.6 Common disorders of respiratory system:

The given table shows a list of some common respiratory disorders, their symptoms, cause and treatment.

Table 8.11 : Common disorders of respiratory system

Disorder	Symptoms	Cause	Treatment
Emphysema	Breakdown of alveoli, shortness of breath	Smoking, air pollution	Quit smoking, avoid polluted air, administer oxygen to relieve symptoms
Chronic bronchitis	Coughing, shortness of breath	Smoking, air pollution	Quit smoking, avoid polluted air, if possible move to warmer, drier climate
Acute bronchitis	Inflammation of bronchi, shortness of breath, yellow mucous coughed up.	Viruses and bacteria	If bacterial, take antibiotics, cough medicine, use vaporizer
Sinusitis	Inflammation of the sinuses, mucous discharge	Viruses and bacteria	If bacterial, take antibiotics and decongestants, use vaporizer
Laryngitis	Inflammation of larynx, vocal cords, sore throat, hoarseness of voice, mucous build up and cough	Viruses and bacteria	If bacterial, take antibiotics, cough medicines, voice rest, avoid irritants like smoke
Pneumonia	Inflammation of lungs ranging from mild to severe, cough and fever, shortness of breath, chills, sweating, chest pain, blood in mucous	Bacteria, viruses	Consult physician immediately, antibiotics, cough medicines, stay warm
Asthma	Constriction of bronchioles, mucus build up in bronchioles, periodic wheezing, difficulty in breathing.	Allergy to pollen, some foods, food additives, pet hair, etc.	Use of inhalants to open passage ways, avoid irritants
Occupational Respiratory Disorders- silicosis, asbestosis	Inflammation fibrosis, lung damage.	Long term exposure to dust particles, silica and asbestos, particles during occupation	Protective mask and gear during work.

Think about it

Why is it difficult to hold one's breath beyond a limit?

Artificial ventilation :

It is also called artificial respiration. It is the method of inducing breathing in a person when natural respiration has ceased or is faltering. If used properly and quickly, it can prevent death due to drowning, choking, suffocation, electric shock, etc. The process involves two main steps : establishing and maintaining an open air passage from the upper respiratory tract to the lungs and force inspiration and expiration as in mouth to mouth respiration or by mechanical means like ventilator.

Ventilator :

A ventilator is a machine that supports breathing and is used during surgery, treatment for serious lung diseases or other conditions when normal breathing fails. It is mainly used in hospitals as part of life support system. Ventilators do the following,

1. Get oxygen into the lungs.
2. Remove carbon dioxide from the lungs.
3. Help the patient breathe.

8.7 Transportation in living organisms :

All living organisms, whether unicellular or multicellular show an important property of exchange of material with their surrounding as well as between various parts of the their cell or body.

Can you recall?

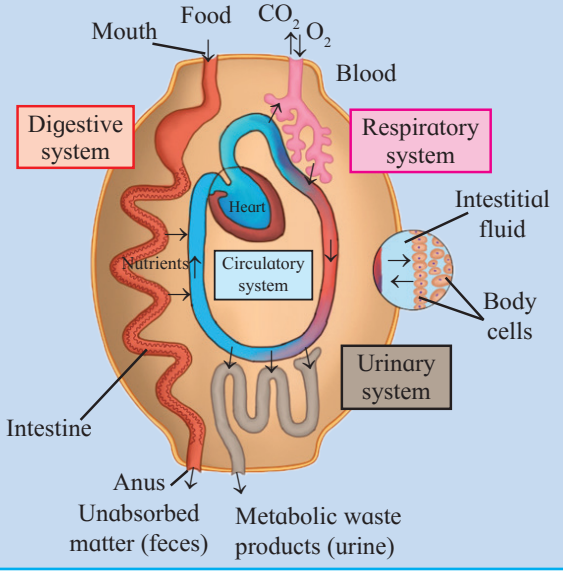
Which type of circulation is present in cockroach? How is it different from that of humans?

Organisms take up oxygen and nutrients from the surrounding, these are circulated within the body for various metabolic activities. The wastes generated within are given out into the surrounding.

Transportation in organisms and animals occurs by **diffusion** and by **active transport** between the cells. This mechanism is suitable where the surface area of body is large and the distance between parts of the body in the organism is extremely small. **Cyclosis** is the streaming movement of the cytoplasm shown by almost all living organisms e.g. *Paramoecium*, *Amoeba*, root hair cells of many plants and WBCs in animals. It is for transportation within the cell or **intracellular transport**. In sponges and coelenterates the surrounding water is circulated through the body cavities. In flat worms there is parenchymal circulation. In round worms there are no blood vessels and the body fluid is moved around the viscera by contraction of body wall and muscles. This is **extracellular transport**.

Observe and Discuss

Observe the diagram and discuss the process with your friends.



Internet my friend

1. Which is type of circulation present in amphibians and reptiles?
2. Enlist organisms without a proper transport system.

Use your brain power

What is the co-relationship between activeness of organism and complexity of transport system?

8.8 Circulation in animals :

In higher animals the circulation is carried out by special fluids - blood and lymph.

Blood vascular system :

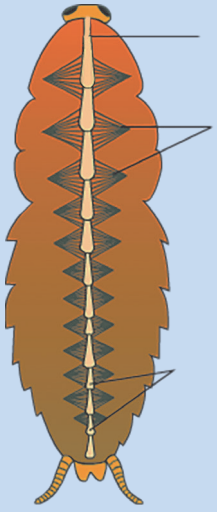
Higher animals from Annelida to chordata have a special circulating fluid, the blood which is pumped to the tissues by the heart through the blood vessels.

Types of blood vascular system :

1. **Open circulation :** In animals having an open circulation, blood is circulated through the body cavities (haemocoels). The visceral organs lie in the blood filled body cavity. Exchange of material takes place directly between blood and cells or tissues of the body. The blood flows with low pressure and usually does not contain any respiratory pigment like haemoglobin, so it does not transport respiratory gases. e.g. Arthropods (cockroach, studied in 11th std.) and Molluscs.

Observe and Discuss

Observe the diagram and give appropriate labels.



2. **Closed circulation :** In all the vertebrates, higher molluscs and annelids, blood is circulated all over the body through a network of blood vessels. In this type of circulation, blood flows within the blood vessels and does not come in direct contact with cells and body tissues. Exchange of material between blood and body tissues is through an intermediate fluid called lymph. Blood flows with high pressure and contains respiratory pigments like haemoglobin for transportation of respiratory gases.

The closed circulation can be divided into two main types : single and double circulation.

Single circulation : In single circulation, the blood passes through heart only once during each cycle as in fishes. Deoxygenated blood is pumped from heart towards gills, where it undergoes oxygenation. This oxygenated blood moves towards various body parts, gets deoxygenated and returns back to heart for next cycle.

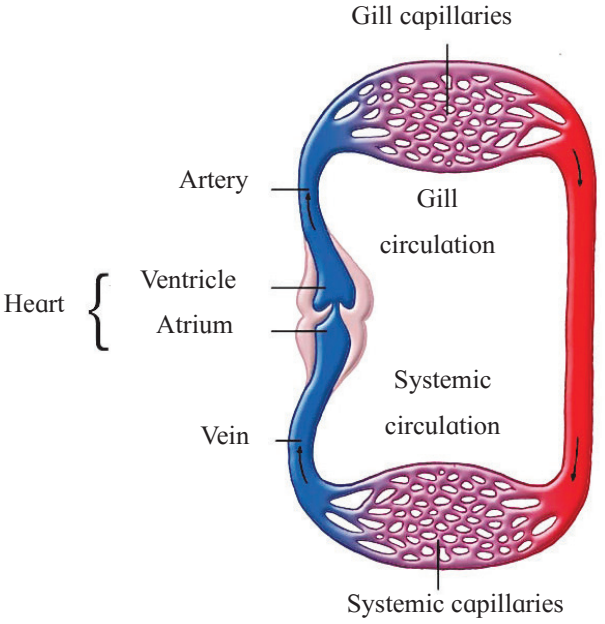


Fig. 8.12 : Single circulation

Since, the heart of fish carries only deoxygenated blood, it also called '**venous heart**'.

Double circulation : In double circulation, blood passes through heart twice during each cycle; it occurs in birds and mammals. In these animals, heart pumps deoxygenated blood to lungs for oxygenation and it returns to heart as oxygenated blood. This is '**pulmonary circulation**'. The oxygenated blood is pumped from the heart towards various body parts (except lungs) and returns back to the heart as deoxygenated blood. This is '**systemic circulation**'. Human heart shows double circulation.

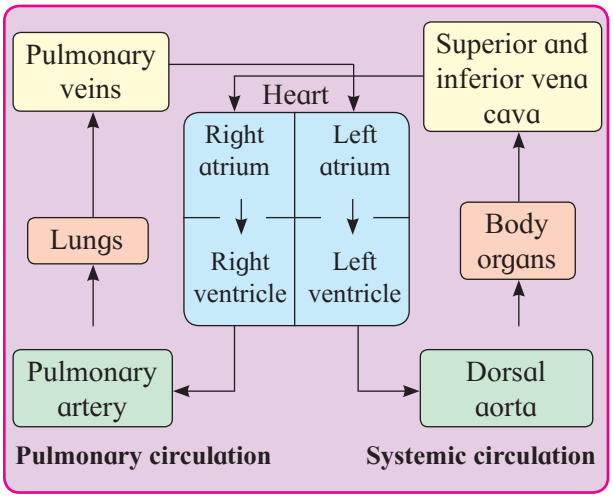


Fig. 8.13 : Double circulation (Diagrammatic)

Internet my friend

1. Find out the difference between coelom and haemocoel?
2. Name respiratory pigments present in the blood of different animals.

8.9 Circulatory System in Human :

The human circulatory system is composed of blood vascular and lymphatic system.

Blood vascular system :

In human beings it consists of blood, heart and blood vessels. It is responsible for various functions like transport, homeostasis and protection.

Blood Composition and Coagulation : Study of blood is called haematology. An average adult has about 4 to 6 liters of blood. It is a red coloured fluid connective tissue derived from embryonic mesoderm. It is slightly alkaline (pH 7.4), salty and viscous fluid. It is heavier than water. It has two main components- the fluid plasma (55%) and the formed elements i.e. blood cells (44%). These can be separated by centrifugation.

Plasma : It constitutes 55% of the blood. It is a straw-coloured, slightly alkaline, viscous fluid and consists of following:

Table 8.14 : Composition of plasma

Contents	Percentage
1. Water	90 %
2. Proteins (albumen, globulin, properdin, prothrombin, fibrinogen)	7 to 8 %
3. Inorganic salts (Na, K, Mg, Ca, Fe, Mn and Cl^-, HCO^-_3 and PO^{3-}_4)	1 %
4. Others :	1 to 2 %
a. Food (glucose, amino acids, fatty acids, triglycerides)	
b. Wastes (urea, uric acid and creatinine)	
c. Regulators (hormones, enzymes, vitamins)	
d. Anticoagulants (heparin)	
e. Cholesterol and antibodies	
f. Dissolved gases (O_2, CO_2, N_2)	

Internet my friend

1. Find out the percentage and functions of different blood proteins.
2. What is the clinical importance of haematokrit value?
3. Differentiate between plasma and serum.

Formed elements :

The blood cells that are produced in the body are collectively called formed elements. Human blood contains three types of formed elements as red blood corpuscles (RBCs), white blood corpuscles (WBCs) and platelets.

8.10 Red blood corpuscles / Erythrocytes :

Erythrocytes are the most abundant cells in the human body. They are circular, biconcave and enucleated (in camel and llama they are nucleated).

The red colour or RBCs is due to an oxygen carrying pigment, the haemoglobin, in their cytoplasm. In males, their average number is about 5.1-5.8 million/mm^3 (per µL) and in females about 4.3-5.2 million/mm^3. This is called total RBC count. The average life span of RBCs is 120 days. The process of formation of RBCs is called **erythropoiesis**.

RBCs are produced from haemocytoblasts / reticulocytes. The erythropoeitic organ of the foetus is the liver and spleen and in the adult, it is mainly the red bone marrow. Vitamin B_{12}, folic acid, iron and heme protein are required for production of RBCs The old and worn out RBCs are destroyed in the liver and spleen (graveyard of RBCs). Condition with increase in the number of RBCs is called **polycythemia** and with decrease in number of RBCs is called as **erythrocytopenia**. The hormone erythropoeitin produced by the kidney cells stimulates the bone marrow for production of RBCs.

Mature erythrocyte is devoid of nucleus, mitochondria or other membrane bound cell organelles. Its cytoplasm (stroma) is rich in haemoglobin and O_2 carrying proteinaceous pigment that gives red colour to the RBCs and blood. It also contains an enzyme, carbonic anhydrase.

Erythrocytes are responsible for the transport of respiratory gases O_2 and CO_2, maintaining pH and viscosity of blood. They also contribute in the process of blood clotting. The **hematocrit** is ratio of the volume of RBCs to total blood volume of blood. It is different for men and women.

Do you know ?

Each erythrocyte approximately contains 270 million molecules of haemoglobin. Normal content of haemoglobin in blood of men is about 14 – 17 gm% and in women it is about 13 – 15 gm%. Condition with less number of RBCs or less amount of haemoglobin or both is called as anaemia.

Each molecule of haemoglobin is a protein-iron complex. It consists of four polypeptide (globin) chains 2 alpha and 2 beta chains. An iron – porphyrin (haem) group is attached to each chain and all four chains are bound together. Each haem group can carry one O_2 molecule and thus one haemoglobin molecule can carry four O_2 forming oxyhaemoglobin. CO_2 interacts with amino acid residues of globin chains and forms carbaminohaemoglobin. After haemolysis, haemoglobin is broken down. Its globin part is broken to recycle the amino acids. Iron of heme group is stored as ferritin in the liver and porphyrin group of heme is converted into green pigment biliverdin and then into red-orange coloured bilirubin. These pigments (mainly bilirubin) are added to bile and finally removed out of body along with faeces.

Internet my friend

1. Compare between myoglobin and haemoglobin.
2. In the erythrocytes, nucleus and mitochondria are absent. Explain?

8.11 White blood corpuscles / Leucocytes:

Leucocytes are colourless, nucleated and amoeboid cells larger than RBCs.Due to their amoeboid movement they can move out of the capillary walls by a process called **diapedesis**. A normal adult has on an average, 5000-11000 WBCs per mm^3 of blood. Decrease in number of

WBCs (<4000) is called **leucopenia** (common in HIV, AIDS and TB patients or those exposed to radiations, shock, etc). Temporary increase in number of WBCs is called as **leucocytosis**. It is due to infection. It also occurs during pregnancy and in newborn babies. Uncontrolled increase in number of WBCs is a type of blood cancer called **leukemia**. WBCs are mainly concerned with defense mechanism i.e. protection.

Types of WBCs :

These are colourless, irregular nucleated cells and show **polymorphism** (exist in variable forms). They can be classified into two main types such as granulocytes and agranulocytes.

A. Granulocytes :

These are WBCs with a **granular cytoplasm**, also called **Polymorpho nuclear leucocyte (PMN)** cells. They have lobulated nuclei in different shapes. Granulocytes are formed from myeloid stem cells and once formed, do not divide. Granulocytes constitute about **72%** of total WBCs. Granules are actually secretory vesicles which contain various secretions, enzymes, etc. Depending upon staining property of the granules, these granulocytes are classified into three types as neutrophils, basophils and acidophills.

Think about it

What are the granules in granulocytes?

a. Neutrophils : Granules are very fine, large in number, evenly distributed and stained with neutral stains (dyes). Neutrophils are about **70%** of total WBCs. These cells are spherical and nucleus is several lobed (2-7). These are able to perform amoeboid movements and phagocytosis. They are responsible for destroying pathogens by the process of **phagocytosis**. 'Pus' is mixture of dead neutrophils, damaged tissues and dead microbes.

Think about it

Why and when do the leucocytes perform diapedesis?

b. Basophils / Cyanophils : These cells have very few granules of large size, and stain with basic stains like methylene blue. Basophils are non-phagocytic, small, spherical cells and are about 0.5-1% of total WBCs.. Nucleus is twisted. They are present in infected and allergic conditions only. Basophils secrete heparin, histamine and serotonin.

c. Eosinophils / Acidophills : Acidophills contain lysosomal granules that are stained to red colour with acidic stains like eosin. Eosinophils are about 1 – 3 % of total WBCs. Nucleus is bilobed. They destroy antigen-antibody complex by phagocytosis. Their number increases in allergic condition and they show antihistaminic property. They are also responsible for detoxification as they produce antitoxins.

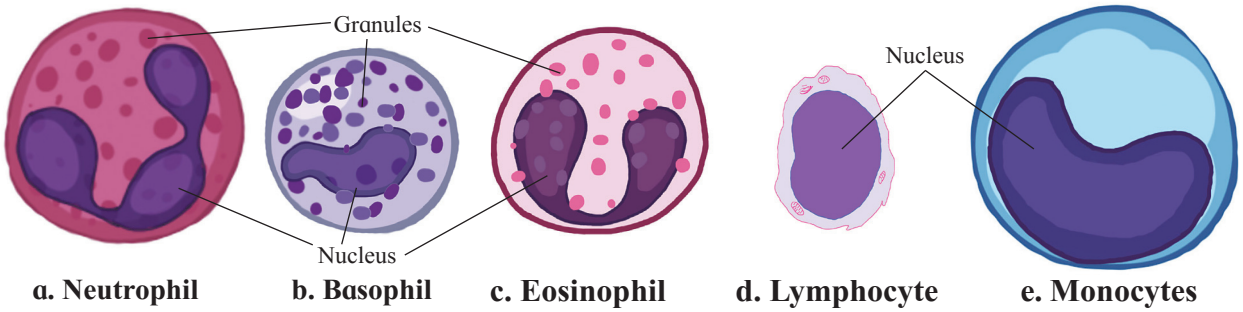


Fig. 8.15 : Granulocytes and Agranulocytes

B. Agranulocytes :

Agranulocytes are about 28% of total WBCs. Cytoplasm of these leucocytes is without granules. They are formed from lymphoid stem cells and can divide by mitosis. Nuclei of agranulocytes are large in size but are not lobulated like the granulocytes. There are two types of agranulocytes - Lymphocytes and Monocytes.

a. Lymphocytes : Lymphocytes are the smallest of all WBCs and have a large spherical nucleus. They constitute about 25-30% of total WBCs. Depending upon function, two types of lymphocytes are present as B-lymphocytes and T-lymphocytes. B-lymphocytes mature in bone marrow and are responsible for antibody production/humoral immunity. It is a highly specific antigen, antibody immunity T-lymphocytes mature in thymus and are responsible for cell-mediated immunity. Helper T-cells, killer T-cell, memory T-cells and suppressor T-cells are four main subtypes of T-lymphocytes.

b. Monocytes : Monocytes are the largest of all the WBCs. Its nucleus is large and bean or kidney shaped. They form 3-5% of WBCs. Monocytes are actively motile and give rise to macrophages. They are mainly phagocytic and destroy the bacteria and dead or damaged tissue by phagocytosis.

Internet my friend

1. What are the reasons for changes in number of neutrophils and the importance of complete blood count (CBC)?
2. Why and when are heparin, histamine and serotonin secreted? Are these biomolecules secreted by any other cell/ organ in our body?

8.12 Thrombocytes / Platelets:

Thrombocytes are cellular fragments formed from the large cells called megakaryocytes. These are produced in bone marrow. They are very small, oval shaped cell fragments without nucleus. Normal count of thrombocytes in human blood is about 2.5 – 4.5 lakh / mm^3 of blood. If number of thrombocytes decreases than normal, condition is called as **thrombocytopenia**. This condition causes internal bleeding (haemorrhage). Platelets secrete platelet factors which are essential in blood clotting. They also seal the ruptured blood vessels by formation of **platelet plug/ thrombus**. They secrete **serotonin** a local **vasoconstrictor**.

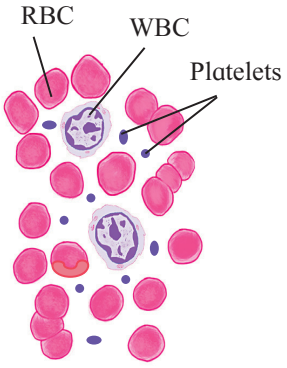


Fig. 8.16 : Blood smear

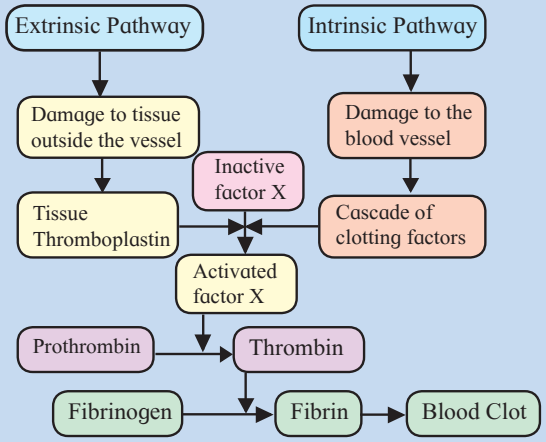
Blood Clotting/ Coagulation of blood :

Clotting or coagulation is the process of converting the liquid blood into a solid form. This process may be initiated by contact of blood with any foreign surface (intrinsic process) or with damaged tissue (extrinsic process). Intrinsic and extrinsic processes involve interaction of various substances called **clotting factors** by a step wise or cascade mechanism. There are in all twelve clotting factors numbered as I to XIII (factor VI is not in active use). Interaction of these factors in a cascade manner leads to formation of the enzyme thrombin. Thromboplastin, helps in the formation of enzyme prothrombinase. This enzyme inactivates heparin and it also converts inactive prothrombin into its active thrombin.

Thrombin converts soluble blood protein-fibrinogen into insoluble fibrin. Fibrin forms a mesh in which platelets and other blood cells are trapped to form the clot. Blood clotting occurs as shown in the following flowchart.

Observe and Discuss

Observe the flow chart and discuss the process with your friends.



Curiosity

1. What is blood clotting? How and when does it occur?
2. What is immunity? Name its types.
3. Why does the platelet count decrease in dengue patient?
4. Why does our immune system fail against pathogens like *Trypanosoma* and *Plasmodium*?
5. What is the relation between immunity and organ transplantation?
6. How do monocytes perform amoeboid movement and phagocytosis?
7. How do monocytes modify into macrophages?

8.13 Heart :

Heart is the main pumping organ of the circulatory system. It is reddish brown in colour, hollow, muscular organ, roughly the size of one's fist. Its average weight is about 300gm in males and 250gm in females. It is conical in shape and lies in **mediastenum**- i.e. the space between two lungs. It is broader at upper end (base) and conical at lower end (apex). Conical end is slightly tilted to left side and rests above the diaphragm.

Heart is enclosed in a membranous sac called **pericardium**. Pericardium is formed of two main layers - outer **fibrous** and inner **serous pericardium**.

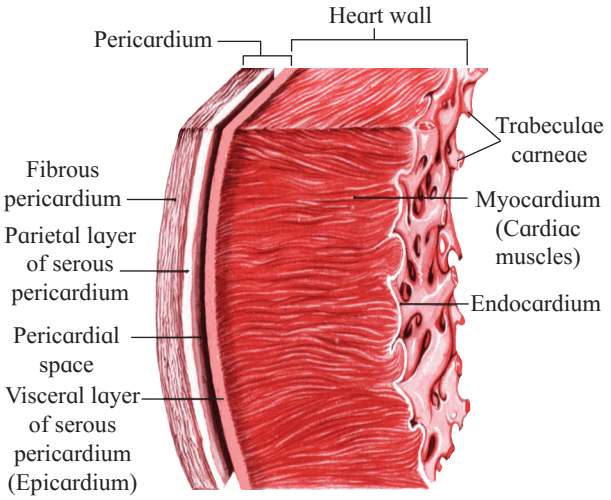


Fig. 8.17 : Heart wall and Pericardium

Serous pericardium is soft, moist and elastic. It is formed of squamous epithelium and is further divisible into two layers as **parietal** and **visceral layer**. Parietal and visceral layers of serous pericardium are separated by a pericardial space. This space is filled with **pericardial fluid** (about 50ml) which acts as a shock absorber and protects the heart from mechanical injuries. It also keeps the heart moist and acts as lubricant.

Heart wall :

The heart is mesodermal in origin. Its wall is formed of three layers, outer **epicardium**, middle **myocardium** and inner **endocardium**. Epicardium is thin and formed of a single layer of flat squamous epithelium resting on basement membrane. Myocardium is the middle thick layer formed of cardiac muscles. Endocardium is a single thin layer formed of squamous epithelium. The epicardium and endocardium are protective in function whereas myocardium is responsible for contraction and relaxation of heart.

External structure of heart :

The human heart is four chambered. The two superior chambers are called **atria** (auricles) and inferior two are called **ventricles**. Externally, the atria are separated from ventricles by a transverse groove called **coronary sulcus** or **atrioventricular groove**. The two ventricles are externally separated from each other by two grooves, the anterior and posterior **inter-ventricular sulci**. Coronary arteries and coronary veins run through these sulci. Pulmonary trunk arising from right ventricle and aorta from left ventricle are present on anterior surface of heart. The pulmonary trunk bifurcates into right and left pulmonary arteries. Aorta (systemic aorta) is divisible into three regions as ascending aorta, systemic arch /aortic arch and descending aorta. The **Ligamentum arteriosum** joins pulmonary trunk and aortic arch. It is the remnant of an embryonic duct called **ductus arteriosus**. The aortic arch gives out three arteries viz. brachiocephalic (innominate) artery, left common carotid and left sub-clavian. The right atrium recieves **superior** and **inferior vena cava** along its dorsal surface. **Pulmonary veins** open into left atrium along the dorsal surface of heart.

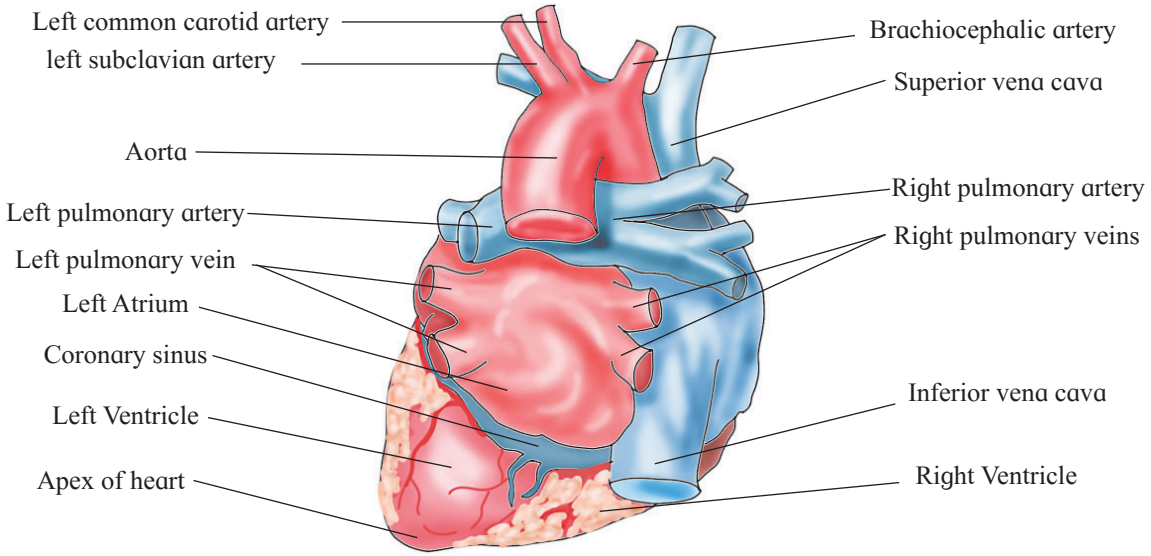


Fig. 8.18 : Posterior (dorsal) view : External structure of human heart

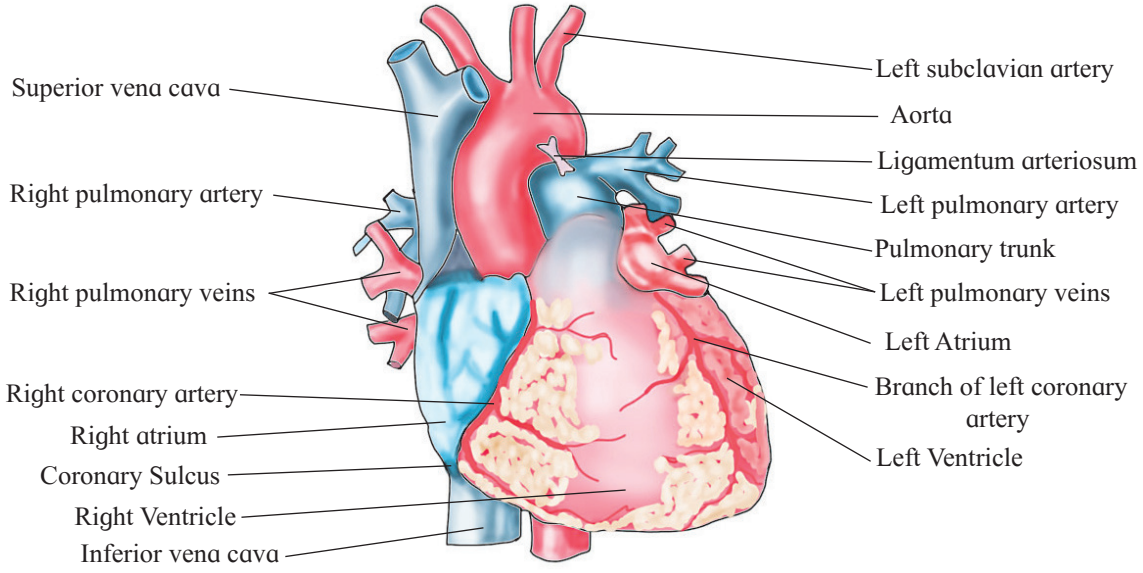


Fig. 8.19 : Anterior (ventral) view : External structure of human heart

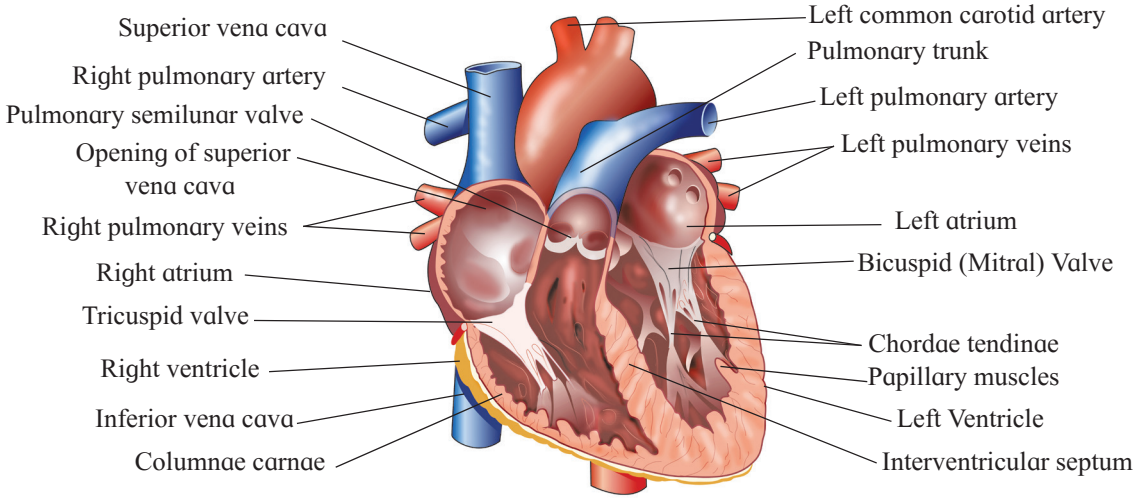


Fig. 8.20 : Internal structure of human heart

Internal structure of heart:

Atria : These are the thin-walled receiving chambers of heart. They are separated from each other by inter-auricular septum. Inter-auricular septum has an oval depression called **fossa ovalis**. It is a remnant of the embryonic aperture called **foramen ovalis**.

Superior vena cava (precaval), inferior vena cava (postcaval) and coronary sinus open into the right atrium. Opening of the postcaval is guarded by a **Eustachian valve** while the **Thebesian valve** guards the opening of coronary sinus into right atrium. Four pulmonary veins open into the left atrium. These openings are without valves.

Both the atria open into the ventricles of their respective sides by atrioventricular apertures. These openings are guarded by cuspid valves. The **tricuspid valve** is present in the right AV aperture and **bicuspid valve** (mitral valve) is present in the left AV aperture. All these heart valves help in maintaining a unidirectional flow of blood. They also avoid back flow of blood.

Ventricles : These are inferior, thick-walled pumping chambers of the heart. The right and left ventricles are separated by an inter-ventricular septum. Wall of the left ventricle is more muscular and about 3-times thicker than the right ventricle. Inner surface of the ventricles shows several ridges called **columnae carnae** or **trabeculae carnae** which divide the lumen of ventricle into small pockets or fissures. The lumen of ventricles also shows inelastic fibers called **chordae tendinae**. These attach the bicuspid and tricuspid valves to the ventricular wall (papillary muscles) and regulate their opening and closing.

The right ventricle opens into the **pulmonary aorta** and left ventricle opens into the **aorta**. These openings are guarded by three semilunar valves each. These valves prevent the backward flow of blood into the ventricles.

Pumping action of heart :

The heart acts as the main pumping organ of the circulatory system. The pumping action is brought about by a rhythmic contraction and relaxation of the cardiac muscles or heart muscles. Contraction of heart muscles is **systole** and relaxation of heart muscles is **diastole**.

A single systole followed by diastole makes one **heart beat**. The heart beats 70 to 72 times per minute. This is called **heart rate**. During each heart beat ventricles pump about 70 ml of blood this is called **stroke volume**. It means heart pumps about 72 (heart rate) x 70 ml (stroke volume) = 5040 ml ≈ 5 liters of blood per minute this is called **cardiac output**.

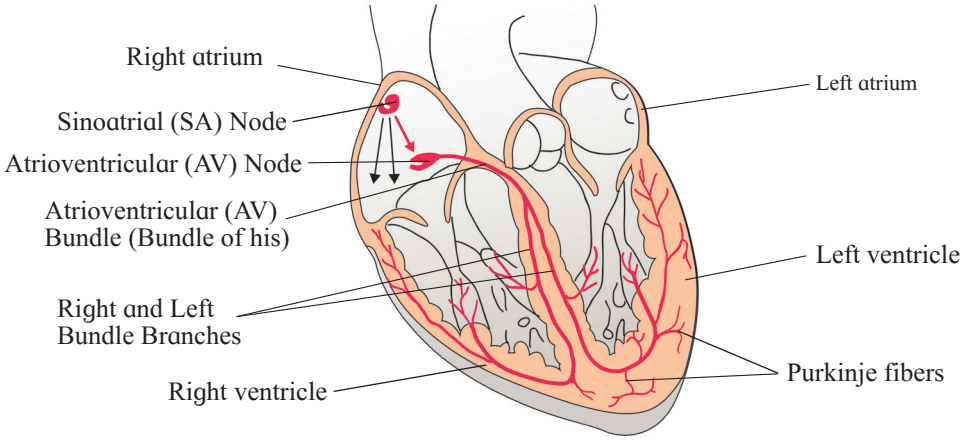


Fig. 8.21 : Conducting system of human heart

Conducting tissue of heart:

The human heart is **myogenic** i.e. the heart is capable of generating a cardiac contraction independent of nervous input. It also shows auto rhythmicity i.e. it can generate its own rhythm by specialized muscles. A specialized cardiac musculature called the nodal tissue is distributed in the heart. A part of this nodal tissue is present in the upper right corner of the right atrium. It is called **SA Node** or **Sino-atrial node**. It lies at the base of opening of superior vena cava. Another mass of nodal tissue, the modified muscular fibers also called autorhythmic fibers (conducting tissue) control the beating rate of heart. Conducting (nodal) tissue consists of SA node, AV node, bundle of His and Purkinje fibers.

Conducting system of the heart :

SA node (sinu-atrial node) is present in the right atrium. It acts as pacemaker of heart because it has the power of generating a new wave of contraction and making the pace of contraction. SA node passes the contraction to the left ventricle and also to the AV node. AV node (atrio-ventricular node) is present in the right atrial wall near the base of interatrial septum. It acts as pace setter of heart.

Bundle of His/ Tawara branches start from AV node and pass through interventricular septum. Bundle of His forms two branches, the right and left bundles, one for each ventricle. These branches form network in ventricular walls and these are called Purkinje fibers. Bundle of His and Purkinje fibers spread impulses in ventricles. As a result both the ventricles contract simultaneously.

Do you know ?

Sometimes, valves are defective. Due to this, abnormal or adventitious sound is heard, called 'heart murmuring' or 'hissing.'

8.14 Working mechanism of human heart : Cardiac Cycle :

Human heart alternately contracts and relaxes. Contraction is called **systole** and relaxation is called **diastole**. Atria and ventricles contract alternately. Consecutive systole and diastole constitutes a single heartbeat or **cardiac cycle**. It is completed in **0.8 sec**. On an average, 72 beats are completed in one minute in an adult, at rest.

a. Atrial systole (AS):

Right atrium receives deoxygenated blood and left atrium receives oxygenated blood. When both the atria are completely filled with blood, pressure is exerted on the wall. In response to this pressure, SA node gets excited and generates cardiac impulse. Due to this, cardiac muscles in the atrial wall contract causing atrial systole. During atrial systole, blood is pumped into ventricles. Blood

is prevented from going back to the veins and coronary sinus by Eustachian and Thebesian valve respectively. After completing systole the atria go into diastole.

In normal conditions, atrial systole (AS) is for 0.1 sec. and atrial diastole (AD) is for 0.7 sec.

b. Ventricular systole (VS):

The impulse which started from SA node now reaches the AV node and it gets excited. AV node sends impulses to bundle of His and from bundle of His to Purkinje fibers. Purkinje fibers spread impulses all over the wall of ventricles. Due to this, ventricular wall contracts causing ventricular systole. During ventricular systole, right ventricle pumps deoxygenated blood into pulmonary trunk and left ventricle pumps oxygenated blood into aorta. During ventricular systole the cuspid valves close both the atrioventricular apertures preventing blood flow into atria (lubb sound is heard).

In normal conditions, ventricular systole lasts for 0.3 sec. and ventricular diastole (VD) lasts for 0.5 sec. During ventricular diastole, semilunar valves are closed, preventing backflow of blood from pulmonary trunk and systemic aorta into ventricles (dub sound is heard).

For about 0.4 second, both atria and ventricles are in diastole. When all the chambers of heart are in diastole, this condition is called **joint diastole** or **complete diastole**. Thus, duration of one cardiac cycle is 0.8 sec.

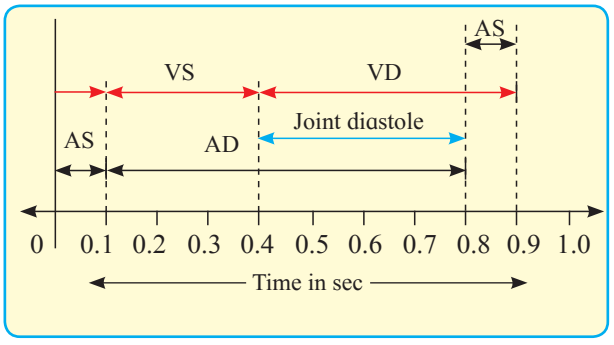


Fig. 8.22 : Diagramatic representation of cardiac cycle

Right side of heart contains deoxygenated and left contains oxygenated blood. Total volume of blood pumped during one ventricular systole is called stroke volume (SV) and it is it approximately 70 ml.

Cardiac output (CO):

It is the volume of blood pumped out per min. For a normal adult human being it is calculated as follows :

$$(CO) = SV \times HR$$
$$= 70 \times 72 = 5040 \text{ ml/min}$$

Regulation of cardiac activity :

Though human heart is **myogenic**, it is also under dual control, the nervous as well as hormonal. The nervous control includes the part of autonomic nervous system. Sympathetic system (with hormone epinephrine as neurotransmitter) increase the rate of heartbeat during emergency. Parasympathetic system (with acetylcholine as neurotransmitter) reduces rate of heartbeat.

Nervous control includes the part of the autonomous nervous system- its cardiovascular center lies in the medulla oblongata. It controls rate of heart beat in response to inputs from various receptors like proprio-receptors (which monitor the position of limbs and muscles), chemoreceptors (monitoring chemical changes in blood) and baroreceptors (monitoring the stretching of main arteries and veins).

Chemical control of the heart rate includes the conditions like hypoxia, acidosis, alkalosis causing decreased cardiac activity, hormones like epinephrine and norepinephrine enhance the cardiac activity. Besides, concentration of cations like K^+, Ca^{++} and Na^+ have major effect on cardiac activity. Cardiac activity decreases with the elevated blood level of K^+ and Na^+

8.15 Blood vessels :

There are three main types of blood vessels in the human circulatory system viz, arteries, veins and capillaries.

Arteries :

These blood vessels carry blood from heart to various parts/organs of the body, there they branch into arterioles and further into fine capillaries. They normally carry oxygenated blood to all parts of the body (except the pulmonary artery which carries deoxygenated blood). They are usually situated deep in the body except a few like the radial, brachial, femoral, etc. which are superficially located. In a **T. S. of artery,** its wall shows three layers.

1. Tunica externa or tunica adventitia
2. Tunica media
3. Tunica interna or intima

The outermost tunica externa is a thick, tough layer of collagen fibers. The tunica media is made up of smooth muscles and elastic fibres. This thick muscular and elastic layer makes the arterial wall pulsatile. The innermost tunica interna is a single layer of flat compact endothelial cells surrounding the lumen. The angular margin around the lumen shows **tesselations**. Arterial lumen is devoid of valves and blood flows through it rapidly and with high pressure.

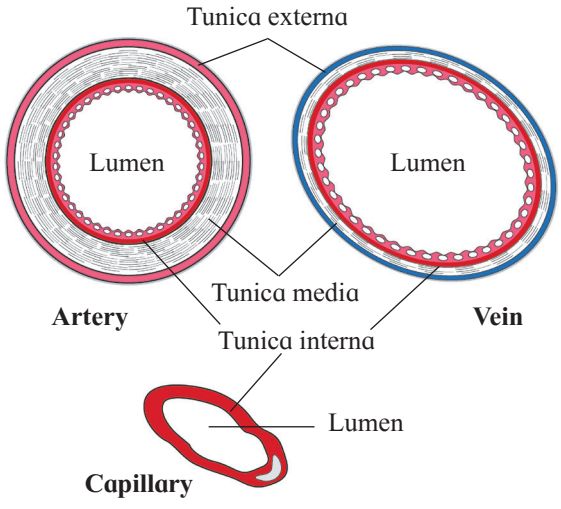


Fig. 8.23 : T. S. of Artery, Vein and Capillary

Veins :

Veins are thin walled, mostly superficial vessels which carry blood from the organs towards the heart. The capillaries around the various organs join to form the veins. Except for the pulmonary veins or other veins of the body carry deoxygenated blood towards the heart.

Portal vein : A portal vein e.g. hepatic portal vein, differs from the other normal veins in that its starts as capillaries from one organ and capillarises in some intermediate organ e.g. liver, before taking the blood towards the heart. Histologically, the veins also show the three layers like in the arteries. The tunica externa, tunica media and tunica interna. However, the tunica media is comparitively thiner and their lumen is wide and narrow. Internal valves at regular intervals can be seen. Blood flows with flow pressure and the valves prevent backflow of blood.

Capillary :

These are a network of minute blood vessels. They are thin walled having a single layer of flat squamous epithelium resting on a single basement membrane. They are mainly involved in exchange of materials. Wall of capillaries is formed of single layer of squamous epithelium and it is stretchable. Blood flows through the capillaries under high pressure. Wall of capillaries bear small endothelial pores or fenestrae through which blood cells (WBCs) can escape by the process called as diapedesis.

Pulse : It is a series of pressure waves that travel through the arteries due to ventricular systole. It is the strongest in arteries closer to the heart and gradually becomes weak in arteries away from heart. It can be felt easily in the superficial arteries like radial artery in the wrist and carotid artery in the neck. The pulse can be felt at particular points on the body. All locations where the pulse can be felt are shown in the figure 8.24.

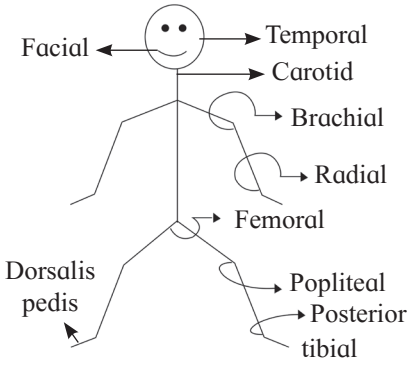


Fig. 8.24 : Pulse points

Pulse rate is equal to heart rate. Pulse rate higher than normal (above 100 beats/min) is called tachycardia and slower pulse rate (below 60 beats/min) than normal is called bradycardia.

Use your brain power

Why do the veins have valves?

8.16 Blood pressure (B. P.):

The pressure exerted by blood on the wall of the blood vessels is called blood pressure. It is measured by the sphygmomanometer. It is usually measured from the arteries.

Arterial Blood Pressure:

Pressure exerted by blood on the wall of artery is arterial blood pressure. Pressure on arterial wall during ventricular contraction (systole) is systolic pressure (SP). For a normal healthy adult the average value is 120 mmHg.

Pressure on arterial wall during relaxation of ventricles is diastolic pressure (DP). For a normal healthy adult it is 80 mmHg.

$$B\ P = SP / DP$$
$$= 120/80\ mmHg$$

Blood pressure is normally written as 120/80 mmHg. Difference between systolic and diastolic pressure is called **pulse pressure**. Normally, it is 40 mmHg.

Deviations from normal blood pressure value indicate malfunctioning of heart. It may be due to high or low blood volume, arterial inelasticity or hardening of arteries (arteriosclerosis), deposition of fats like cholesterol in the arteries (atherosclerosis), renal diseases and emotion induced hormonal changes, obesity, etc. Blood pressure lower than normal i.e. below 90/60 mmHg is called hypotension and blood pressure higher than normal i.e. above 140/90 mmHg is hypertension.

Various factors that affect the blood pressure are cardiac output, peripheral resistance, blood volume, length and diameter of blood vessels, viscosity of blood, age, gender, venous return, sleep, emotions, exercise, anxiety, etc.

Think about it

Why are obese persons prone to hypertension?

Normal cardiac output is 5 lit/min. Increase in cardiac output increases systolic pressure. Peripheral resistance depends upon the diameter of blood vessels. Decrease in diameter of arterioles and capillaries under the effect of vasoconstrictors like vasopressin or ADH cause increase in peripheral resistance and thereby increase in blood pressure. Blood loss in accidents decreases blood volume and thus the blood pressure. Blood pressure is directly proportional to Viscosity of blood.

Blood pressure increases with age due to increase in inelasticity of blood vessels. Amount of blood brought to the heart via the veins per unit time is called the venous return and it is directly proportional to blood pressure. Blood pressure is also directly proportional to the total length of the blood vessel. Blood pressure can also be affected by vaso constriction or vaso dilation. Female (before menopause) has slightly lower BP than males of her age. However, the risk of high B. P. increases in the females after menopause sets in.

Internet my friend

Surf the internet for video-clips of angiography, angioplasty and by-pass surgery. Gather more information about these medical procedures.

Think about it

1. Why the heart-recipient has to rely upon life-time supply of immunosupressants?
2. Why the transplanted heart beats at higher rate than normal?

Measurement of blood pressure:

Blood pressure is measured with the help of an instrument called **sphygmomanometer**. This instrument consists of inflatable rubber bag cuff covered by a cotton cloth. It is connected with the help of tubes to a mercury manometer on one side and a rubber bulb on the other side. During measurement, the person is asked to lie in a sleeping position. The instrument is placed at the level of heart and the cuff is tightly wrapped around upper arm. The cuff is inflated till the brachial artery is blocked due to external pressure. Then pressure in the cuff is slowly lowered till the first pulsatile sound is heard.

At this moment, pressure indicated in manometer is systolic pressure. Sounds heard during measurement of blood pressure are called as *Korotkoff* sounds. Pressure in the cuff is further lowered till any pulsatile sound cannot be heard due to smooth blood flow. At this moment, pressure indicated in manometer is diastolic pressure. An optimal blood presure (normal) level reads **120/80 mmHg**.

Fig. 8.25 : (a) Sphygmomanometer (b) Stethoscope

Hypertension :

Persistently raised blood pressure higher than the normal is called hypertension. 140/90 mmHg is called as threshold of hypertension and the 180/120 mmHg and higher readings are dangerous to the health. It may damage the heart, brain and kidneys.

Under the condition of hypertension, heart uses more energy for pumping which causes angina pectoris- the chest pains due to lowered blood supply to cardiac muscles and may lead to myocardial infarction. There are more chances of brain hemorrhage due to hypertension as arteries in brain are less protected by surrounding tissues as compared to other organs. In kidney, hypertension may cause kidney failure.

Coronary Artery Disease (CAD) :- It is also known as atherosclerosis. In this disease, calcium, fat cholesterol and fibrous tissues get deposited in blood vessels supplying blood to the heart muscles, making the lumen narrow.

Angina Pectoris :

It is the pain in the chest resulting from a reduction in the blood supply to the cardiac muscles because of atherosclerosis or arteriosclerosis. It is charactarized by severe pain and heaviness in the chest. The pain may spread to the neck, lower jaw, left arm and left shoulder. The pain usually results from exertion, when there is more demand of oxygen by the heart, but the supply does not meet the requirement.

Angiography :

X-ray imaging of the cardiac blood vessels to locate the position of blockages

is called angiography. Depending upon the degree of blockage, remedial procedures like angioplasty or by-pass surgery are performed. In angioplasty, a stent is inserted at the site of blockage to restore the blood supply while in by-pass surgery, the atherosclerotic region is by-passed with part of vein or artery taken from any other suitable part of the body, like hands or legs.

Heart Transplant :

Replacement of severely damaged heart by normal heart from brain-dead or recently dead donor is called heart transplant. Heart transplant is necessary in case of patients with end-stage heart failure and severe coronary arterial disease.

Silent Heart Attack :

Silent heart attack, also known as silent myocardial infarction is a type of heart attack that lacks the general symptoms of classic heart attack like extreme chest pain, hypertension, shortness of breath, sweating and dizziness. Symptoms of silent heart attack are so mild that a person often confuses it for regular discomfort and thereby ignores it. It has been studied that men are more affected by silent heart attack than women.

Know the Scientist :

Akash Manoj, a teenager from Chennai invented the non-invasive technique to predict the possibility of a silent heart attack. Interestingly, he invented this technique when he was in class-X.

For his innovation, he had been invited to the Rashtrapati Bhavan as a guest of the President of India under the Innovation Scholars In-Residence Programme.

His innovative kit analyses the level of FABP3 (Fatty Acid Binding Protein-3) with the help of UV light. It is the smallest protein in the blood.

Find out more information about.....

8.17 Electrocardiogram:

Graphical recording of electrical variations detected at the surface of body during their propagation through the wall of heart is **electrocardiogram (ECG)**. This recording may be in the form of printout or onscreen display. The instrument used for this recording is the **ECG machine** or **electrocardiograph**. This instrument detects and amplifies the signals.

Various electrodes are used for recording of signals. Four electrodes are positioned on limbs; two on arms and two on legs. These are limb electrodes. Six electrodes are positioned on chest. These are chest electrodes.

In a normal record, three different waves are recognized as P-wave, QRS complex and T-wave. **P-wave** is a small upward deflection from baseline of graph. It represents the atrial depolarization. The **QRS complex** starts as a slight downward deflection from baseline, continues as sharp and large upright wave and ends as a downward wave. QRS complex represents the ventricular depolarization. **T-wave** is small, wide and upwardly elevated wave. It represents the ventricular repolarization.

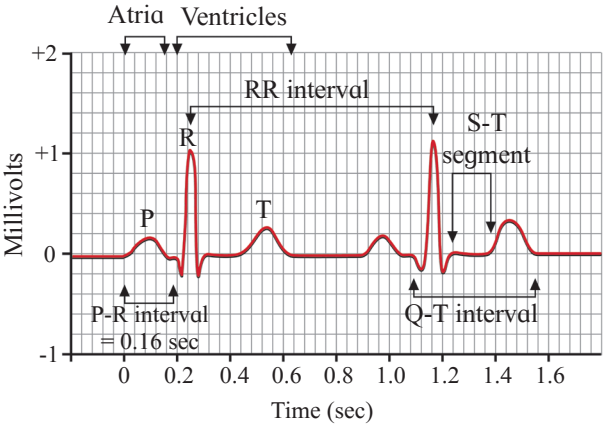


Fig. 8.26 : Normal ECG

ECG helps to diagnose the abnormality in conducting pathway, enlargement of heart chambers, damages to cardiac muscles, reduced blood supply to cardiac muscles and

causes of chest pain. A physician can find out the defect in the heart by examining the wave pattern and the time interval betwen them.

8.18 Lymphatic System :

Lymphatic system consists of lymph, lymphatic vessels, some organs and tissues. The word 'lymph' means 'clear water' and it is a fluid connective tissue with almost similar composition to the blood except RBCs, platelets and some proteins. Fluid from intercellular spaces of the body tissue enters into the lymphatic vessels, from here it is discharged into the blood vessels (veins) through the thoracic duct and the right lymphatic duct.

Curiosity

1. What is depolarization and repolarization?
2. What is the correlation between depolarization and repolarization as ell as contraction and relaxation of the heart?
3. How are the signals detected and amplified by electrocardiograph?
4. Who discovered ECG?

Internet my friend

Location of lymph nodes in human body.

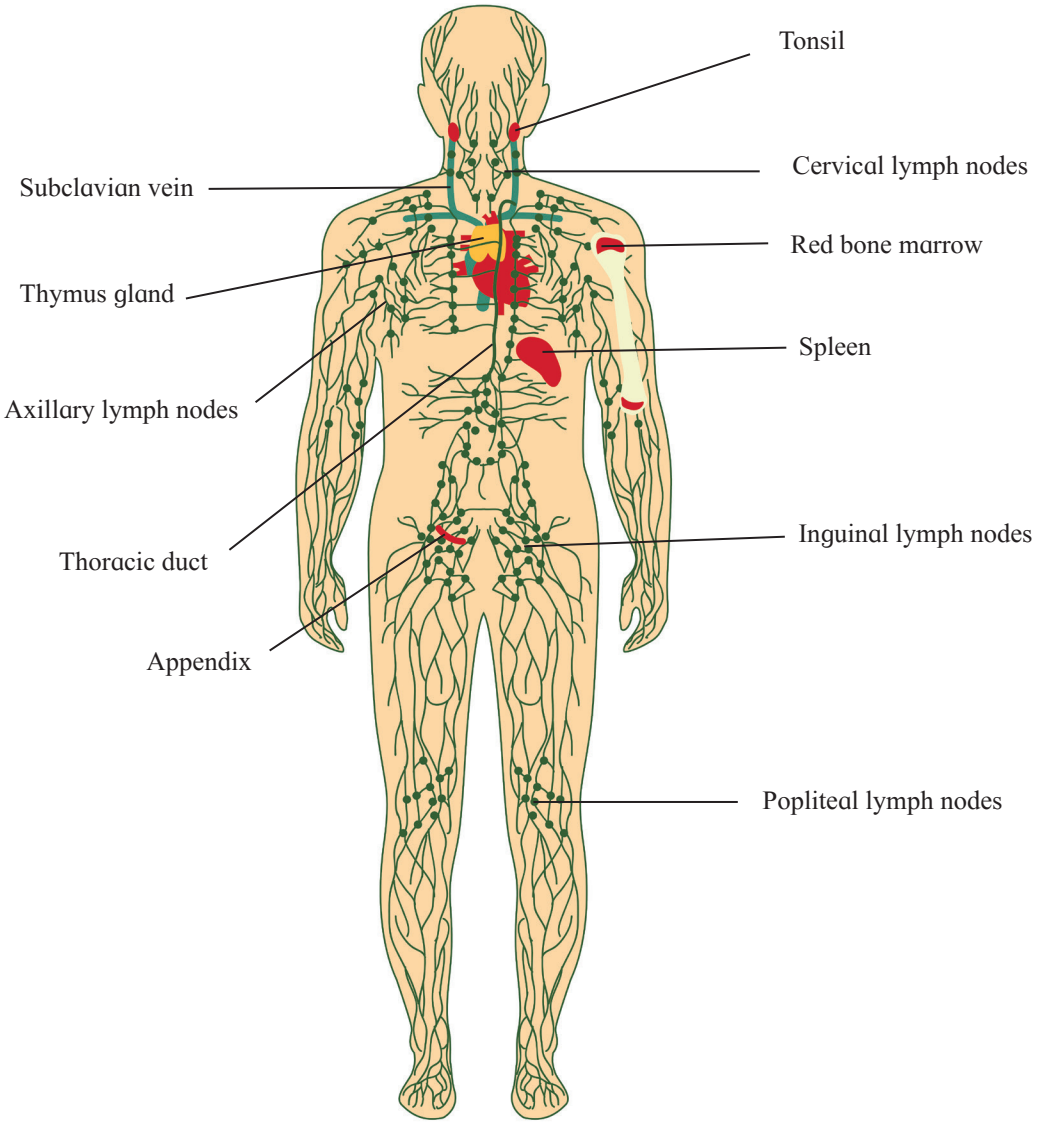
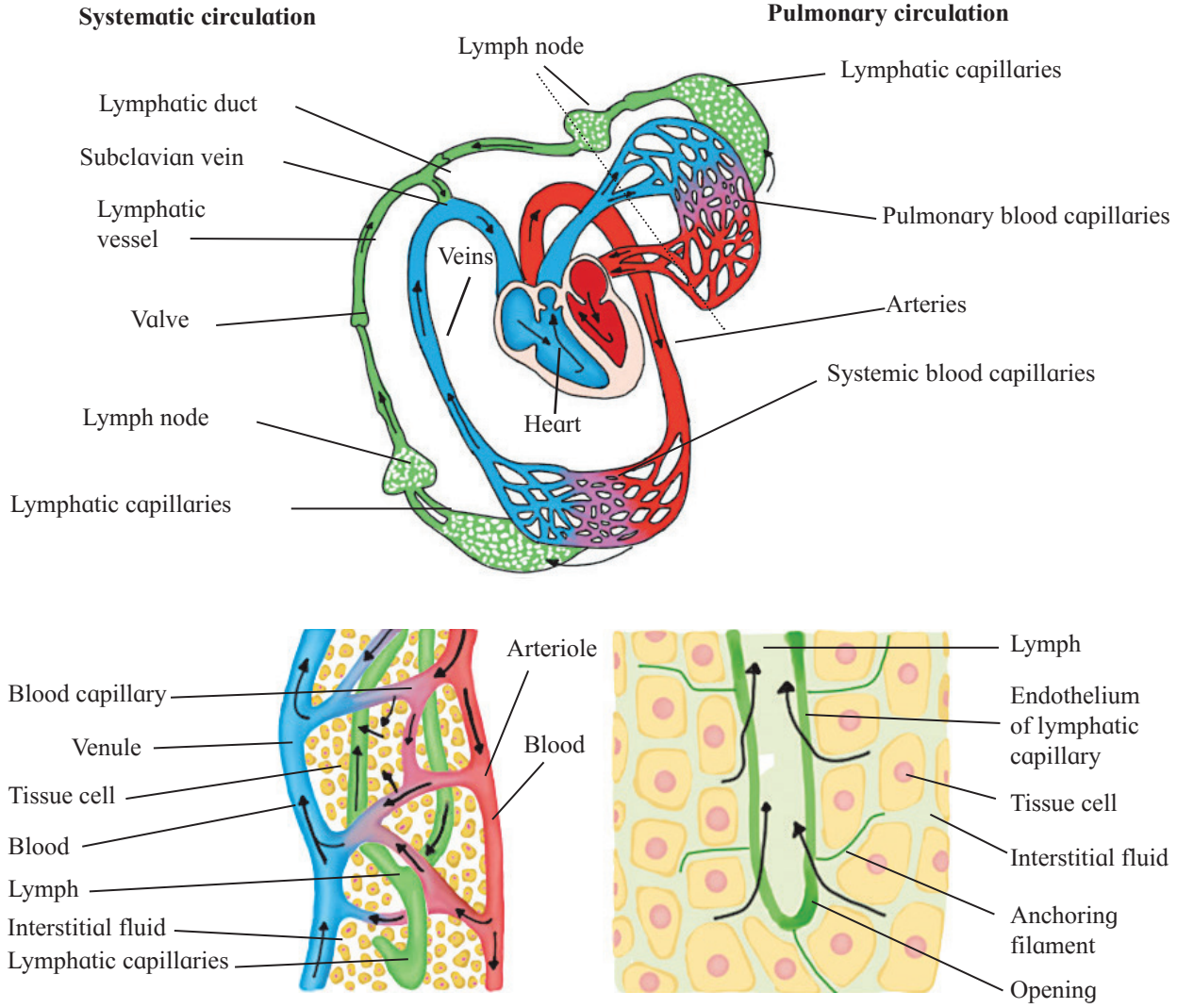


Fig. 8.27 : Lymphatic System

Do you know ?

Tonsils are small lymphatic nodules in pharyngeal region. Normally there are five tonsils strategically positioned to fight against inhaled and ingested foreign substances. Inflammation of tonsils is called as tonsillitis. It is caused due to viral or bacterial infection. Symptoms include sore throat, fever, swollen lymph nodes, nasal congestion, difficulty in swallowing, headache, etc. Viral tonsillitis cures naturally but bacterial tonsillitis needs antibiotic treatment. Tonsillectomy is performed in some patients who do not respond to the treatment.



a. Relationship of lymphatic capillaries to tissue cells and blood capillaries

b. Details of lymphatic capillary

Fig. 8.28 : Circulation and Lymphatic System

Activity :

1. Prepare chart for different types of heart muscles and their functions.

2. Differentiate between the functioning of heart in frog and human.

Human Heart	Frog Heart

Exercise

Q. 1 Choose the correct alternatives from those given below and complete the statements.

1. The muscular structure that separates the thoracic and abdominal cavity is _____.
   a. pleura b. diaphragm
   c. trachea d. epithelium
2. What is the minimum number of plasma membrane that oxygen has to diffuse across to pass from air in the alveolus to haemoglobin inside a R.B.C.?
   a. Two b. Three c. Four d. Five
3. _____ is a sound producing organ,
   a. Larynx b. Pharynx
   c. Tonsils d. Trachea
4. The maximum volume of gas that is inhaled during breathing in addition to T.V is _____.
   a. residual volume b. I.R.V.
   c. G.R.V. d. vital capacity
5. _____ muscles contract when the external intercostal muscles contract
   a. Internal abdominal
   b. Jaw
   c. Muscles in bronchial walls
   d. Diaphragm
6. Movement of cytoplasm in unicellular organisms is called _____.
   a. diffusion b. cyclosis
   c. circulation. d. thrombosis.
7. Which of the following animals do not have closed circulation?
   a. Earthworm. b. Rabbit
   c. Butterfly d. Shark
8. Diapedesis is performed by _____.
   a. erythrocytes b. thrombocytes
   c. adipocytes d. leucocytes
9. Pacemaker of heart is _____.
   a. SA node b. AV node
   c. His bundle d. Purkinje fibers
10. Which of the following is without nucleus?
    a. Red blood corpuscle b. Neutrophill
    c. Basophill d. Lymphocyte
11. Cockroach shows which kind of circulatory system?
    a. Open b. Closed
    c. Lymphatic d. Double
12. Diapedesis can be seen in _____ cell.
    a. RBC b. WBC
    c. Platelet d. neuron
13. Opening of inferior vena cava is guarded by _____.
    a. bicuspid valve
    b. tricuspid valve
    c. Eustachian valve
    d. Thebesian valve
14. _____ wave in ECG represent atrial depolarization.
    a. P b. QRS complex
    c. Q d. T
15. The fluid seen in the intercellular spaces in Human is _____
    a. blood b. lymph
    c. interstitial fluid d. water

Q. 2 Match the Respiratory surface to the organism in which it is found.

Respiratory surface	Organism
Plasma membrane	Insect
Lungs	Salamander
External gills	Bird
Internal Gills	Amoeba
Trachea	Fish

Q. 3 Very short answer questions.

1. Why does trachea have 'C' shaped rings of cartilage?
2. Why is respiration in insect called direct respiration?
3. Why is gas exchange very rapid at alveolar level.
4. Name the organ which prevents the following the entry of food into the trachea while eating.

Q 4. Short answer questions.

1. Why is it advantageous to breathe through the nose than through the mouth?
2. Identify the incorrect statement and correct it,
   a. A respiratory surface area should have a large surface area.
   b. A respiratory surface area should be kept dry.
   c. A respiratory surface area should be thin, may be 1mm or less.
3. Given below are the characteristics of some modified respiratory movement. Identify them.
   a. Spasmodic contraction of muscles of expiration and forceful expulsion of air through nose and mouth.
   b. An inspiration followed by many short convulsive expiration accompanied by facial expression.
4. Write a note on blood plasma.
5. Explain blood clotting in short.
6. Describe pericardium.
7. Describe valves of human heart.
8. What is role of papillary muscles and chordae tendinae in human heart?
9. Explain in brief the factors affecting blood pressure.

Q. 5 Give scientific reason.

1. Closed circulation is more efficient than open circulation.
2. Human heart is called as myogenic and autorhythmic.
3. Person who has undergone heart transplant needs lifetime supply of immunosupressants.
4. Arteries are thicker than veins.
5. Left ventricle is thick than all other chambers of heart.

Q. 6 Distinguish between :

1. Open and closed circulation.
2. Artery and vein.
3. Blood and lymph.
4. Blood capillary and lymph capillary.
5. Intrinsic and extrinsic process of clotting.

Q. 7 Long answer questions.

1. Smita was working in a garage with the doors closed and automobiles engine running. After some time she felt breathless and fainted. What would be the reason? How can she be treated?
2. Shreyas went to a garden on a wintry morning. When he came back, he found it difficult to breath and started wheezing. What could be the possible condition and how can he be treated?
3. Why can you feel a pulse when you keep a finger on the wrist or neck but not when you keep them on a vein?
4. A man's pulse rate is 68 and cardiac output is 5500 cm^3.Find the stroke volume.
5. Which blood vessel of the heart will have the maximum content of Oxygen and why?
6. If the duration of the atrial systole is 0.1 sec and that of complete diastole is 0.4 sec, then how does one cardiac cycle complete in 0.8 sec?
7. How is blood kept moving in the large veins of the legs?
8. Describe histological structure of artery, vein and capillary.
9. What is blood pressure? How is it measured? Explain factors affecting blood pressure.
10. Describe human blood and give its functions.

Project :

- Visit pathological laboratory to study various blood tests like Hb detection, CBC, blood groups.
- Visit hospital to study how to take ECG, stress test, measurement of BP, etc.
- Evaluation of ECG on broad basis.
- Use of stethoscope.
- Differential count of WBCs.