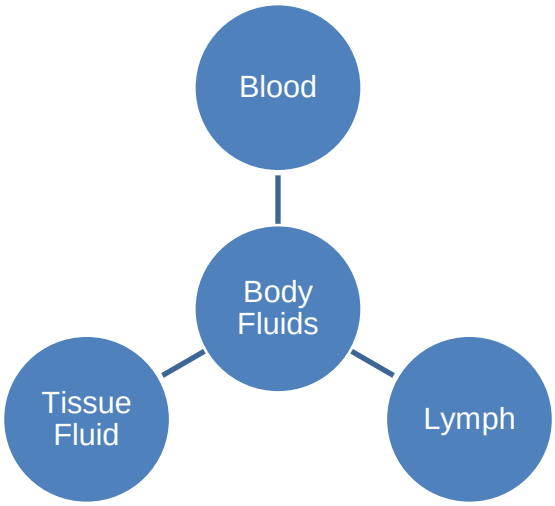
# The Circulatory System

Every organ in our body requires the involvement of the circulating body fluids.




## Blood

Blood is a never-stationary fluid and it is always in motion from the heart to the arteries and back through the veins.

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|---|---|
| **Colour** | Bright red when taken from an artery and deep red when taken from a vein. |
| **Volume** | An average adult human has 5 to 6 litres blood. |
| **Taste** | Salty.<br>Blood is slightly alkaline with a pH of 7.3 to 7.45. |

### Functions of Blood

- Blood forms a clot which serves to prevent the loss of blood and the entry of disease-causing germs.
- White blood cells protect the body from diseases by engulfing bacteria which may have entered the body.
- Antibodies produced by the blood neutralise poisonous substances or kill germs which enter the body.
- Blood transports digested food from the alimentary canal to the tissues.
- It transports excretory materials from the tissues to the liver, kidneys or skin for elimination.
- Blood helps in keeping the temperature of the body uniform by distributing heat.
- Haemoglobin of RBCs combines with oxygen to form oxyhaemoglobin which reaches tissues to deliver the oxygen.

### Composition of Blood

Blood is made up of plasma and the blood corpuscles.

## Plasma

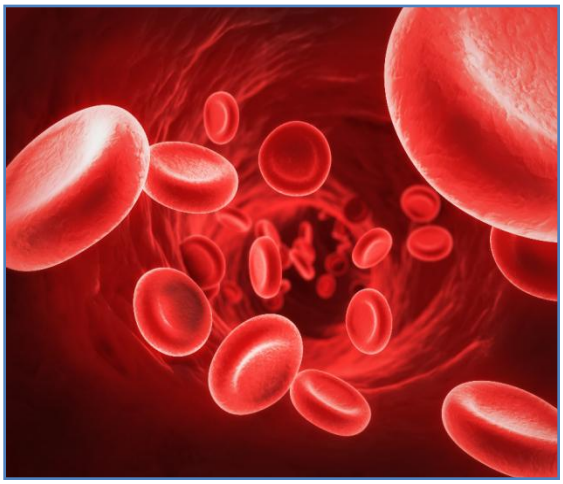
It is a light yellow-coloured alkaline liquid.
It mainly consists of

| | |
|---|---|
| **Water** | **90–92%** |
| **Proteins** | **7–8%** |
| **Inorganic Salts** | **1%** |
| **Other Substances** | **Trace amounts** |

## Cellular Elements

There are three kinds of cellular elements found in the blood:

**Red Blood Cells (RBCs/Erythrocytes)**



**Red Blood Cells (RBCs)**

- RBCs are minute, disc-like structures.
- RBCs are 7 µ in diameter.
- In adults, RBCs are produced in the marrow of long bones such as ribs, breast bone and ileum of the hip girdle.
- In children, RBCs are produced in the bone marrow of all the cells until 5 years of age.
- Mature RBCs do not have nuclei.
- The average life of RBCs is 120 days.

## Haemoglobin

Haemoglobin is a respiratory pigment present in the stroma of RBCs.
It combines readily with oxygen to form an unstable compound **oxyhaemoglobin**. This compound delivers oxygen to tissues.
Haemoglobin has a very strong affinity for carbon monoxide. When combined with carbon monoxide, it forms a stable compound **carboxyhaemoglobin**.
Carboxyhaemoglobin reduces the capacity of the blood in transporting oxygen, sometimes even resulting in death.

## White Blood Cells (WBCs/Leucocytes)

**White Blood Cell (WBC)**

- WBCs are amoeboid.
- WBCs are produced in the bone marrow, lymph nodes and sometimes even in the liver and spleen.
- The average life of WBCs is about 2 weeks.
- WBCs are classified into two categories based on their shape and characteristics:

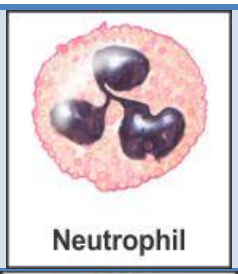
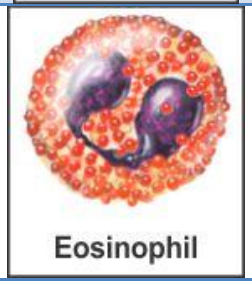
1. Granular
2. Agranular

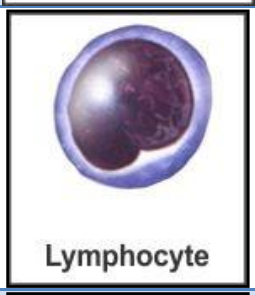
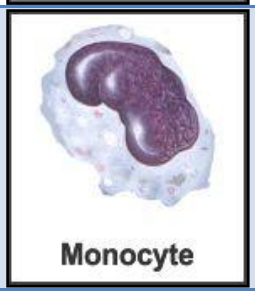
- Leukaemia is a cancer in which the number of WBCs increases manifold at the cost of RBCs.
- Leucopenia is the abnormal decrease in the number of WBCs.

**Functions of WBCs**

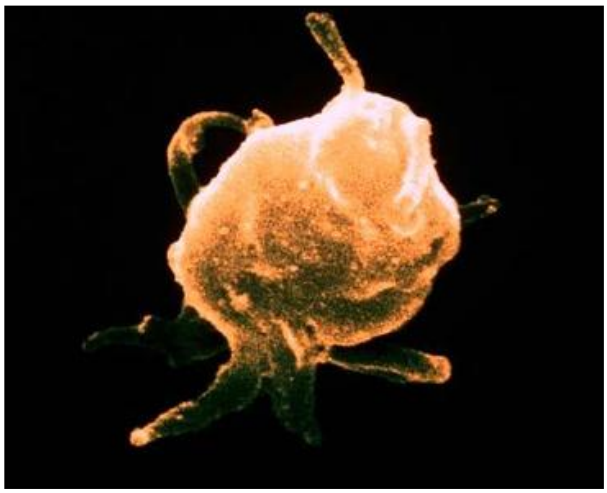
1. Phagocytosis: WBCs, particularly neutrophils, engulf foreign substances, especially bacteria. This defensive mechanism against germs is called **phagocytosis**.
2. Inflammation: Inflammation occurs due to the reaction of tissues to injury and to localised invasion of germs.
   Leucocytes especially monocytes migrate through the walls of the blood vessels by **diapedesis** and fight the germs.
3. Formation of Antibodies: WBCs, especially lymphocytes, produce antibodies which kill or neutralise germs.

## Different types of White Blood Cells

| Categories of WBCs | Types of WBCs | Appearance | Distinguishing Features | Functions | Location Produced |
|---|---|---|---|---|---|
| **A. Granular**<br>- Cytoplasm contains granules | **1.Neutrophils (62%)** |  <br>Neutrophil | • Nucleus with 3–4 lobes<br>• Stain with neutral dyes | • Destroy bacteria by phagocyto sis | Bone marrow |
| | **2.Eosinophils (2.3%)** |  <br>Eosinophil | • Nucleus with 2 lobes<br>• Stain dark red with eosin (acid dye) | • Destroy bacteria | Bone marrow |

| | | | | | |
|---|---|---|---|---|---|
| | **3.Basophils (0.4%)** |  Basophil | • Nucleus large, indistinctly lobed<br>• Stain with basic dyes (methylene blue) | Release chemicals for inflammation which dilates blood vessels | Bone marrow |
| **B. Agranular**<br>- Cytoplasm does not contain granules | **4.Lymphocytes (30%)** |  Lymphocyte | • Single large nucleus | Produce antibodies | Bone marrow, spleen, tonsils |
| | 5. **Monocytes** (5.3%) |  Monocyte | • Nucleus large, kidney-shaped | Ingest germs | Bone marrow |

**Blood Platelets (Thrombocytes)**



**Blood Platelet**

- Blood platelets are minute, oval or round, non-nucleated structures floating in the blood.
- Platelets are derived from megakaryocytes in the red bone marrow.
- Their life span is 3 to 5 days.
- Blood platelets play an important role in blood clotting.

## Clotting of Blood (Coagulation)

Injured cells and platelets disintegrate at the site of the wound and release thrombokinase or thromboplastin.

↓

Thrombokinase with the help of calcium ions converts prothrombin of the plasma into thrombin.

↓

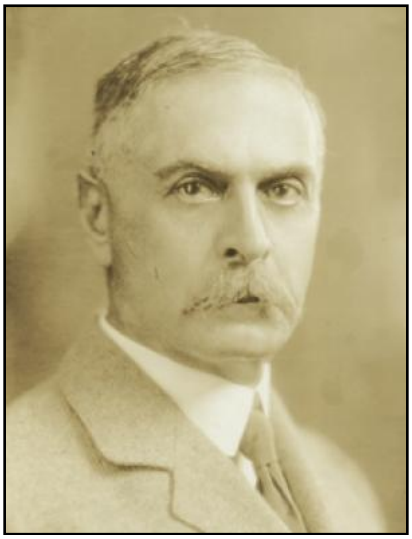
Thrombin in the presence of calcium ions reacts with the soluble fibrinogen and converts it into insoluble fibrin. Fibrin forms threads and a meshwork at the site of the wound.

↓

Blood cells are trapped in the network of the fibrin. The blood shrinks and squeezes out the rest of the plasma in the form of a clear liquid. The solid mass which is left behind is called a **clot** or **thrombus**.

## Blood Transfusion

- Sometimes, it is necessary to inject blood into the body of patients undergoing surgery. This is called **blood transfusion**.
- The German biochemist **Karl Landsteiner** was the first to suggest that the blood of different individuals vary.



**Karl Landsteiner**

There are several systems of blood grouping. The ABO system and the Rh system are the most important.

### ABO System

- According to the ABO blood group system, there are four blood groups A, B, AB and O.
- O type blood can be given to persons of all types of blood, i.e. O, A, B and AB. Hence, a person with O type of blood is called a **universal donor**.
- A person with AB type of blood can receive blood from all types, i.e. AB, A, B and O. Hence, such a person is called a **universal recipient**.

### Compatibility and Incompatibility in the ABO System

| **Blood Group of Donor** | **Blood Group of Recipient** | | | |
|---|---|---|---|---|
| | A | B | AB | O |
| **A** | ✓ | **X** | ✓ | **X** |
| **B** | **X** | ✓ | ✓ | **X** |
| **AB** | **X** | **X** | ✓ | **X** |
| **O** | ✓ | ✓ | ✓ | ✓ |

### Rh System

- The blood of most people contains a substance called **Rh factor**.
- Rh stands for Rhesus, our common primate ancestor in which this factor was first discovered.
- When the blood of an Rh positive ($Rh^+$) individual is transfused into a person lacking the Rh factor, the blood of the recipient develops antibodies against the Rh factor which may even lead to death.

## Tissue Fluid (Intercellular Fluid)

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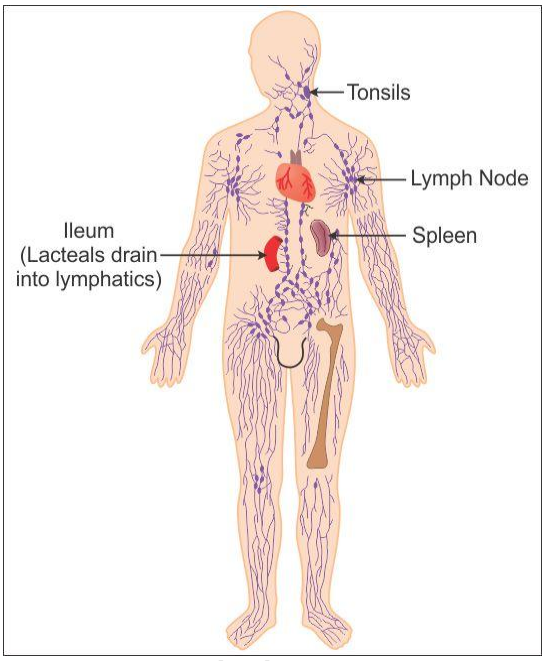
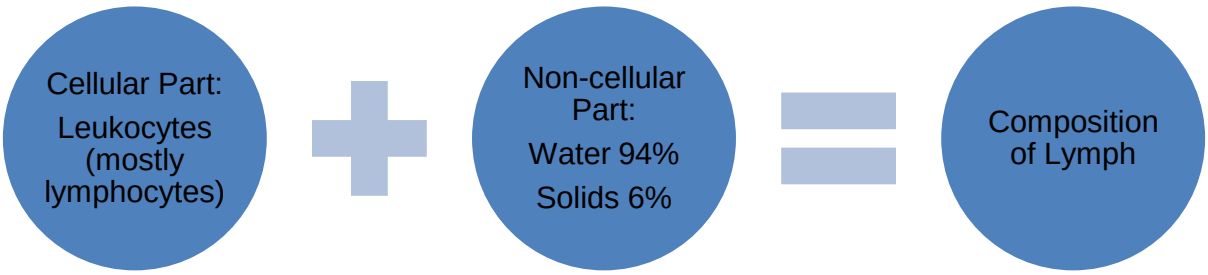
- As blood flows in the capillaries of tissues, the plasma of leucocytes leaks out through their walls and bathes the cells. This fluid is called **tissue fluid** or **intercellular fluid**.
- Cells absorb oxygen and other nutrients and give out carbon dioxide to the tissue fluid.

# Lymph and Lymphatic System

- Most of the tissue fluid enters another set of vessels called **lymphatic vessels**, and this fluid is called **lymph**.
- Lymph vessels drain lymph into lymph nodes.
- From lymph nodes, through lymph vessels again, lymph enters the vena cava just before its entry into the right auricle.




**Lymphatic System**




## Function of Lymph

- Supplies nutrition and oxygen to parts where blood cannot reach.
- Drains away excess tissue fluid and metabolites.
- Lymphocytes and monocytes of the lymph help in the defense mechanism of the body.

## The Spleen

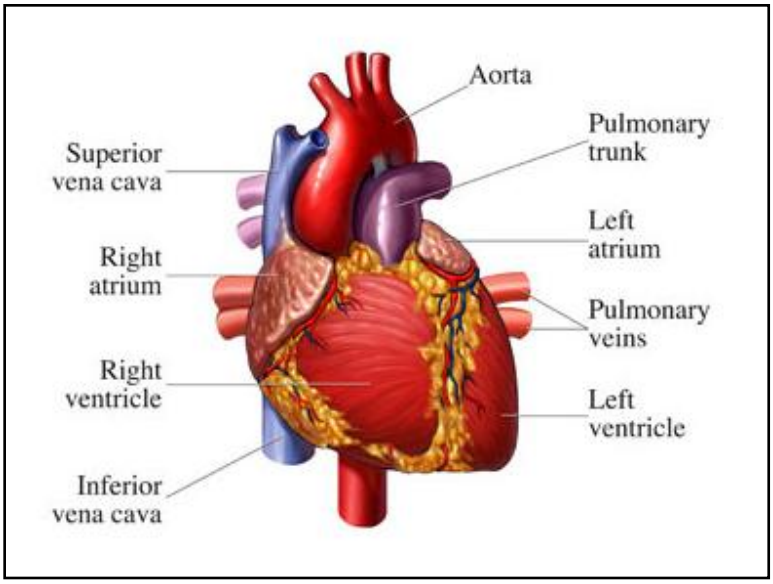
- The spleen is a large lymphatic organ, about the size of a clenched fist.
- It is reddish brown in colour and situated in the abdomen behind the stomach and above the left kidney.

| Functions of the spleen | |
|---|---|
| I. | Acts as a blood reservoir. |
| II. | Produces lymphocytes. |
| III. | Destroys worn out RBCs. |
| IV. | In an embryo, it produces RBCs. |

## The Circulatory System

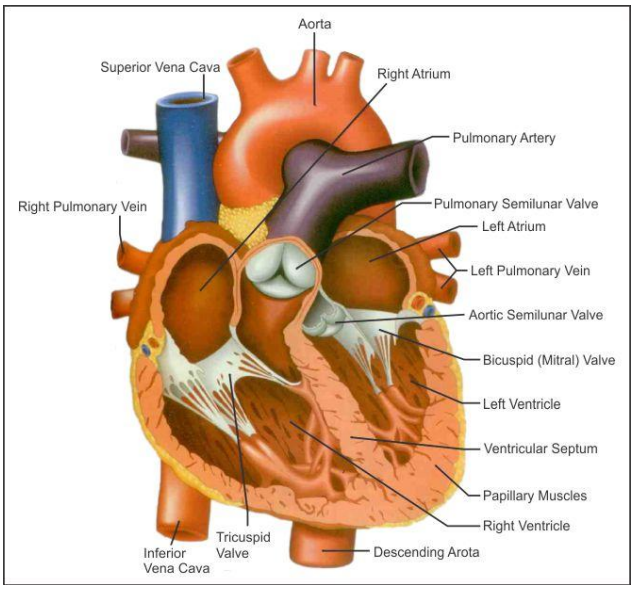
- Blood in our body circulates in a closed manner, i.e. through blood vessels, all the time. Such type of blood circulation is called a **closed vascular system**.
- In animals such as insects, the blood mostly flows through open spaces, and such type of circulation is called **open vascular system**.
- The human blood circulatory system consists of heart, arteries, veins and blood capillaries.

## The Heart




**Human Heart**

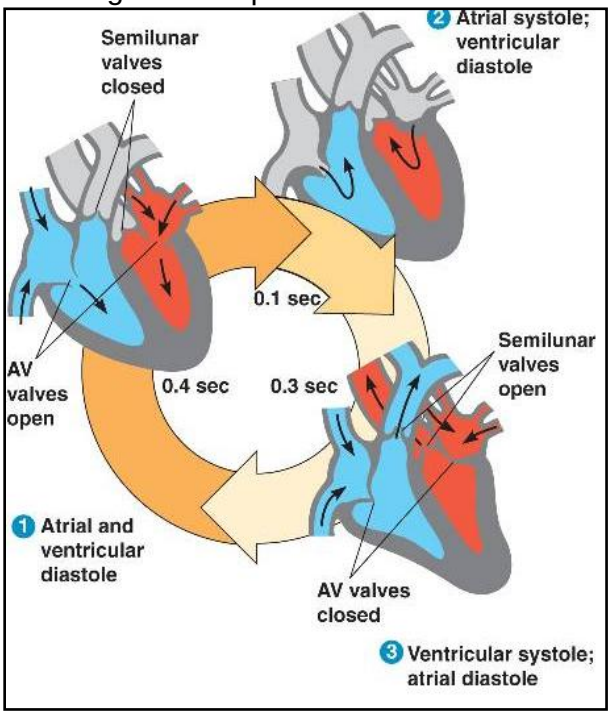
| | |
|---|---|
| **Location** | In the centre between the lungs and above the diaphragm. |
| **Dimensions** | 12 cm in length and 9 cm in width. |
| **Size** | In adult humans, it is about the size of one's fist. |
| **Covering** | Covered by a double membrane **pericardium**.<br>It contains lubricating **pericardial fluid** which protects the heart from mechanical injuries. |
| **Chambers of the Heart** | Two upper atria and two lower ventricles. |
| **Blood Vessels Entering the Heart** | **Superior vena cava (anterior vena cava/precaval)** brings deoxygenated blood from the anterior part of the body, i.e. head, chest and arms. |
| | **Inferior vena cava (posterior vena cava/postcaval)** brings blood from the posterior region of the body including abdomen and legs. |
| | **Pulmonary veins** carry oxygenated blood from the lungs to the left atrium. |
| **Blood Vessels Leaving the Heart** | The **pulmonary artery** arises from the right ventricle and carries deoxygenated blood to the lungs for oxygenation. |
| | The **aorta** arises from the left ventricle and carries oxygenated blood to supply it to all parts of the body. |
| **Coronary Arteries** | **Two coronary arteries** rising from the base of the aorta supply blood to heart muscles, i.e. cardiac muscles. |
| **Heart Valves** | **Tricuspid valve (right atrio-ventricular valve)** is located between the right atrium and the right ventricle. |
| | **Bicuspid valve (left atrio-ventricular valve)** is located between the left atrium and the left ventricle. |
| | **Pulmonary semilunar valves** are located at the opening of the right ventricle in the pulmonary artery. |
| | **Aortic semilunar valves** are located at the opening of the left ventricle in the aorta. |




**Internal Structure of the Human Heart and Associated Blood Vessels**

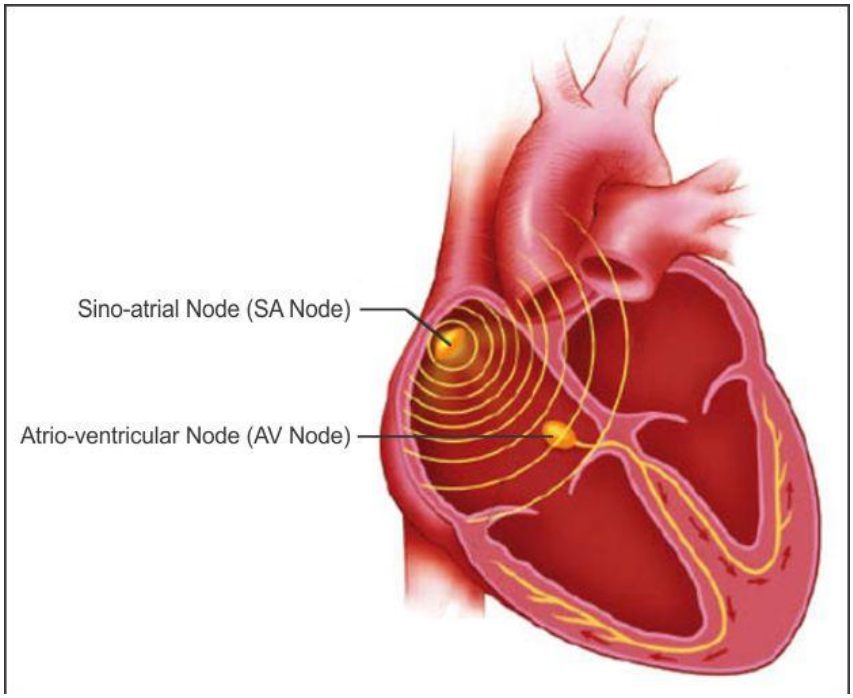
## Circulation of Blood in the Heart

The circulation of blood in the heart occurs due to alternate contraction and relaxation of the heart chambers.
Contraction is also known as **systole**, while relaxation is also known as **diastole**.
The series of events which occur during one complete beat of the heart is called **cardiac cycle**.




| | |
|---|---|
| Atrial Systole and Ventricular Diastole | • Blood from the atria passes into the ventricles.<br>• Tricuspid and bicuspid valves open and blood enters into the corresponding ventricles. |
| Ventricular Systole and Atrial Diastole | • Tricuspid and bicuspid valves close preventing the backflow of blood into the respective atria.<br>• Both the semilunar valves open, and the ventricular blood enters the pulmonary artery from the right ventricle and the aorta from the left ventricle. |
| Ventricular Diastole<br>(At stage end of ventricular systole, ventricles start relaxing. For a short period, both atria and ventricles are in diastole; this state is known as joint diastole). | • Pulmonary and aortic semilunar valves close to prevent the backflow of blood into the ventricles. |

- Cardiac muscles contract rhythmically in response to self-generated impulses.
- The pacemaker of the sino-atrial node (SA node) is located in the upper wall of the right atrium. It triggers an impulse which causes an atrial systole.
- This impulse quickly reaches the atrio-ventricular node (AV node) located at the bottom of the right atrium which initiates a ventricular systole.

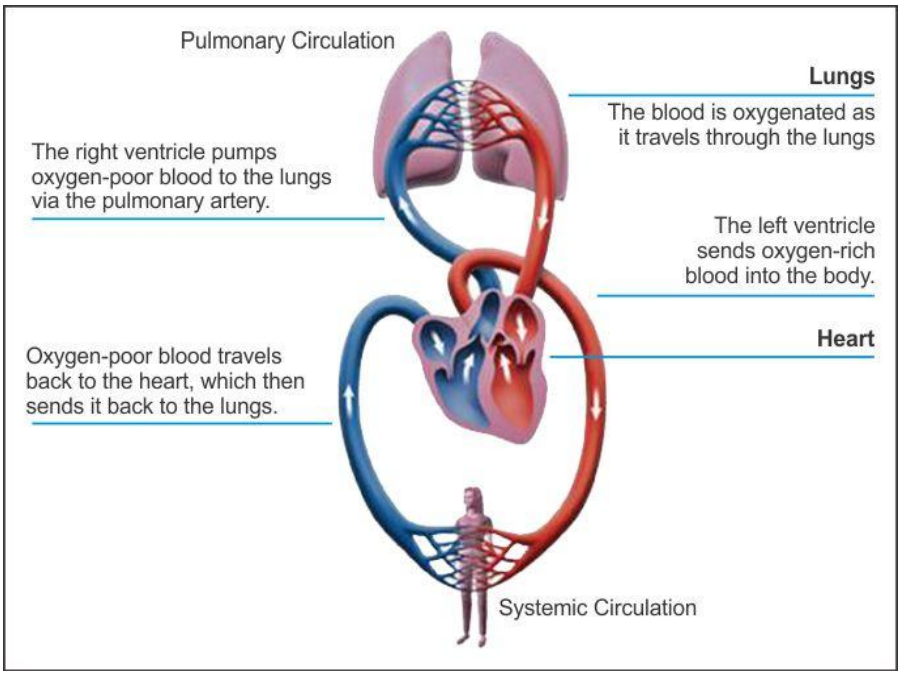



The rate of the heart beat varies among different species. Smaller the size of the animal, faster is the heart rate.

## Blood Vessels

The blood vessels are branched tubes extending from the heart to all parts of the body.
An artery is a vessel which carries blood away from the heart towards any organ.
A vein is a vessel which carries blood away from an organ towards the heart.
A capillary is a very narrow tube of about 8 µm in diameter.

# Pulmonary and Systemic Circulation

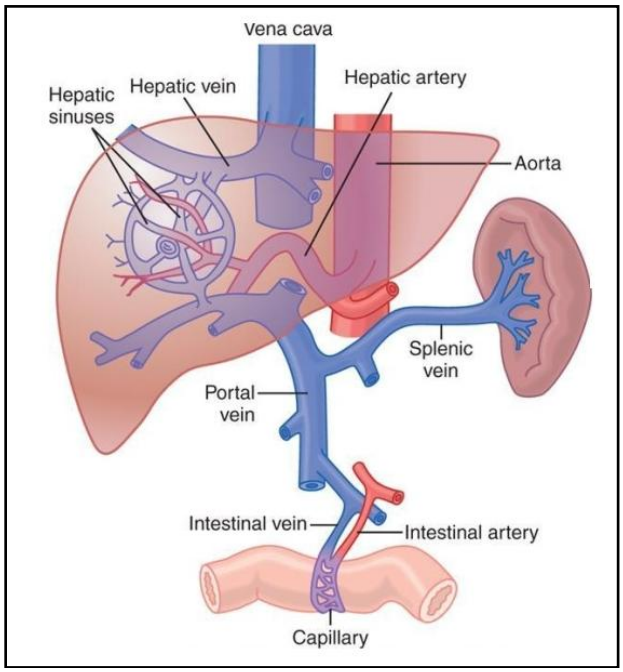



## Pulmonary and Systemic Circulation

**Pulmonary circulation** pertains to the lungs. It starts in the pulmonary artery. It sends the deoxygenated blood to the lungs. Pulmonary veins collect oxygenated blood from the lungs and carry it back to the heart.

**Systemic circulation** pertains to the major circulation of the body. The aorta receives blood from the heart and sends it to the various parts of the body. Veins collect the deoxygenated blood from body parts and pour it back into the heart.

## Hepatic Portal System




- Before conveying the blood to the posterior vena cava, the veins of the stomach and intestine enter the liver as a combined **hepatic portal vein**.
- The hepatic portal vein divides into capillaries and then forms a new **hepatic vein**.
  **Portal Vein**: It is a vein which starts with capillaries and ends in capillaries.
- In the liver, excess nutrients are stored, toxic substances are detoxified and excess amino acids are broken down.

## Pulse

- The **pulse** is the alternate expansion and elastic recoil of the wall of the artery during ventricular systole.

## Blood Pressure

- **Blood pressure** is the pressure which the blood flowing through the arteries exerts on their walls.
- There are two kinds of blood pressure:
- **Systolic Pressure:** The upper limit of the pressure. It occurs each time when the heart contracts and fresh blood is pumped into arteries.
- **Diastolic Pressure:** The lower limit of the pressure. It occurs each time when the heart is in diastole, i.e. this pressure is observed between two heart beats.
- The **normal blood pressure** of an adult human is **100–140 mm (systolic)** and **60–80 mm (diastolic)**.
- A sphygmomanometer is an instrument used to measure blood pressure.