UNIT 4

INTRODUCTION TO CIRCULATORY SYSTEM

BLOOD

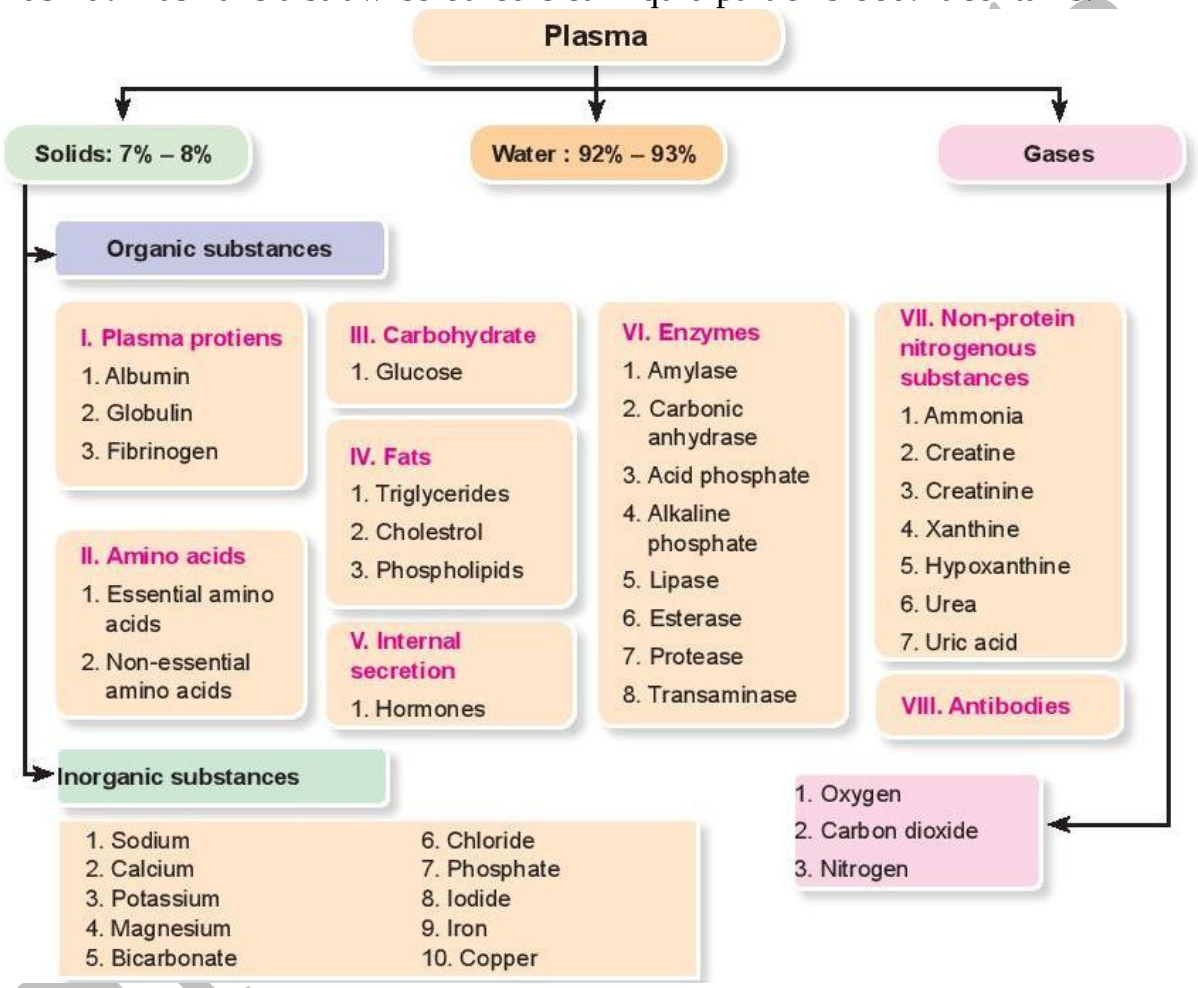
Blood is a fluid connective tissue which circulates constantly around the body, propelled by the pumping action of the heart through the blood vessels (arteries, veins and capillaries).

COMPOSITION OF BLOOD

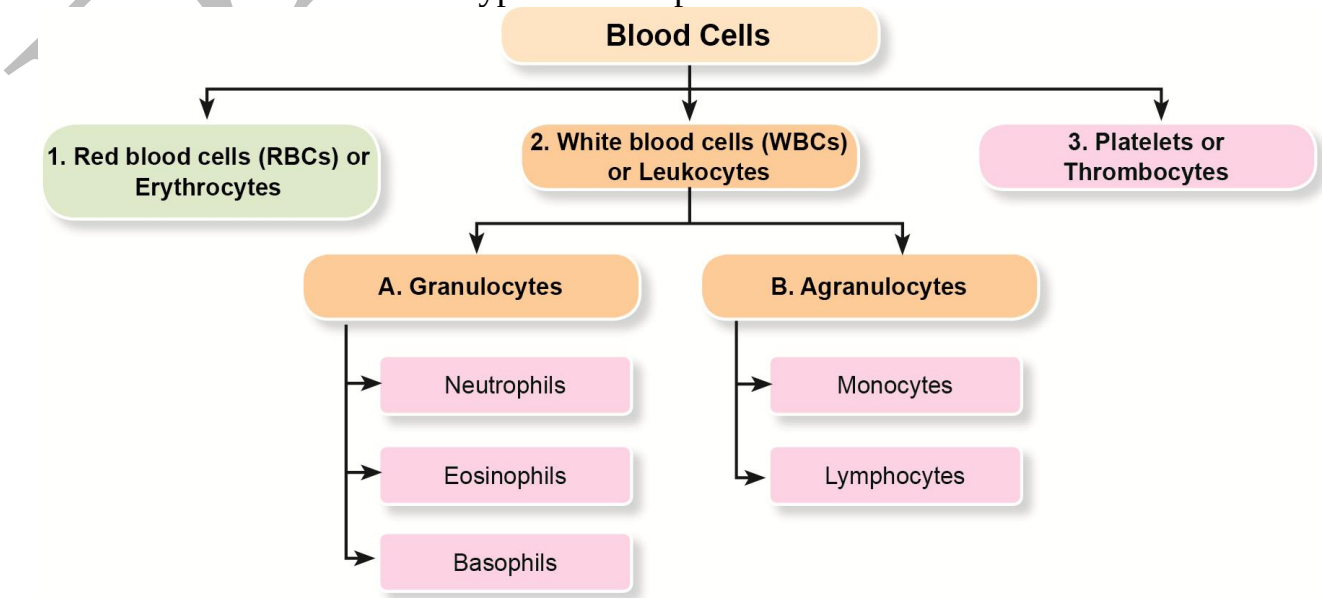
Blood contains:

- Plasma : 55 %
- Blood cells : 45 %

1. Plasma: Plasma is a straw-coloured clear liquid part of blood. It contains:



2. Blood cells : There are three types of cells present in the blood:



FUNCTIONS OF BLOOD

1. **Nutritive function**: Blood transports nutritive substances like glucose, amino acids, lipids and vitamins from gastrointestinal tract to different parts of the body for growth and production of energy.
2. **Respiratory function**: Blood transports oxygen from alveoli of the lungs to different tissue and carbondioxide from the tissue to alveoli of lungs.
3. **Excretory function**: The waste products formed in the tissues during various metabolic activities are removed by blood and carried to the excretory organs like kidney, skin, liver, etc. for excretion.
4. **Storage function**: Blood serves as a storage site for water, proteins, glucose, sodium and potassium are released constantly when they are required by tissues.
5. **Regulation of water balance**: Blood helps in regulation of water content of the body by inter exchange with interstitial fluid.
6. **Regulation of acid-base balance**: Blood buffer (plasma proteins and haemoglobin) helps in the regulation of acid base balance in the body.
7. **Regulation of body temperature**: Blood helps in maintaining of body temperature by thermoregulatory mechanism (balance between heat loss and heat gain in the body).
8. **Transport of hormones and enzymes**: Hormones which are secreted by endocrine glands are released directly into the blood and transported to their target organs or tissues. Blood also transports enzymes.
9. **Defensive function:** The white blood cells plays important role in the defense of the body.

COAGULATION OF BLOOD

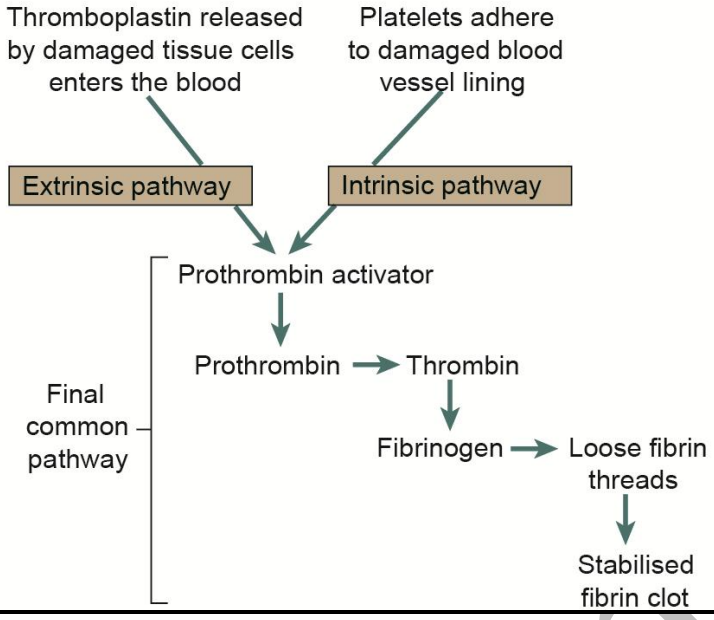
Coagulation or clotting is the process in which blood loses its fluidity and becomes a jelly-like mass few minutes after it is shed out or collected in a container. During this process, the fibrinogen is converted into fibrin. Fibrin threads get attached to the loose platelet plug, which blocks the ruptured part of blood vessels and prevents further blood loss completely.

Factors Involved in Blood Clotting

Coagulation of blood occurs through a series of reactions due to the activation of a group of substances. Substances necessary for clotting are known as clotting factors. Thirteen clotting factors are identified:

FACTOR I	Fibrinogen
FACTOR II	Prothrombin
FACTOR III	Thromboplastin (tissue factor)
FACTOR IV	Calcium
FACTOR V	Labile factor (Proaccelerin or accelerator globulin)
FACTOR VI	Pretense has not been proved
FACTOR VII	Stable factor
FACTOR VIII	Antihemophilic factor
FACTOR IX	Christmas factor
FACTOR X	Stuart-Prower factor
FACTOR XI	Plasma Thromboplastin antedent
FACTOR XII	Hegman factor (contact factor)
FACTOR XIII	Fibrin stabilizing factor (Fibrinase)

Mechanism of Clotting (Coagulation)



BLOOD GROUPS

Blood groups are determined by protein molecules present on the surface of red blood cells or cell membrane. The discovery of blood groups was done by the Austrian scientist Karl Landsteiner in 1901.

Blood Group System

Landsteiner discovered two blood group systems called the ABO system and the Rh system.

1. **ABO system**
   According to this system entire population is divided into four different blood groups. They are labeled according to type of agglutinogen present on red blood cell membrane.
   - Persons having "A" agglutinogen are called "A" group persons.
   - Persons having "B" agglutinogen are called "B" group persons.
   - Persons having "A" and "B" agglutinogen are celled "AB" group persons.
   - Persons having no agglutinogen called "O" persons.
2. **Rhesus factor (Rh factor)**
   The persons having D antigen are called 'Rh positive' and those without D antigen are called 'Rh negative'.

Importance of Blood Group

1. It is important during blood transfusions and in tissue transplants.
2. One should know his or her own blood group and become a member of the blood donor's club so that he or she can be approached for blood donation during emergency conditions.
3. It general among the couples, knowledge of blood groups helps to prevent the complications due to Rh incompatibility and save the child from the disorders like erythroblastosis fetalis.

HEART

Heart is a vital organ which is a roughly cone-shaped (conical), hollow, blunt, muscular pumping organ and it pumps blood to various parts of the body to meet their nutritive requirements. It is about 10 cm long and weighs about 300 gm in males and 250 gm in females.

Location (position) of Heart

The heart lies in the mediastinal area of thoracic cavity between the lungs. It is situated obliquely behind the sternum, a little more to the left than the right.

STRUCTURE OF HEART WALL

The heart wall is composed up of three layers of tissues:

1. Pericardium
2. Myocardium
3. Endocardium

1. **Pericardium**

   Pericardium is the outer covering of the heart. It is made up of two layers.

   a. Fibrous pericardium
   b. Serous pericardium

a. **Fibrous pericardium:** The outer layer of pericardium is known as fibrous pericardium. It is formed by fibrous connective tissue. It protects the heart from over stretching.

b. **Serous pericardium** The inner layer of pericardium is known as serous pericardium. It is formed by squamous epithelium cells which secrete a small amount of fluid known as pericardial fluids. The serous pericardium consists of two layers:

- **Parietal pericardium:** The outer layer of serous pericardium is known as parietal pericardium.
- **Visceral pericardium:** The inner layer of serous pericardium is known as visceral pericardium. It is made up of epithelium cells. The visceral pericardium is also known as **epicardium.**

Between these two layers of serous pericardium (parietal and visceral pericardium) present a narrow space known as pericardial space or pericardial cavity. The pericardial space filled with pericardial fluid. This fluid prevents friction and allows the free movement of heart within pericardium, when it contracts and relaxes. The total volume of this fluid is only about 25 to 35ml.

2. **Myocardium:** The middle layer of heart wall is known as myocardium (types of muscular tissue). It is also known as cardiac muscle or heart muscle.
3. **Endocardium:** The inner layer of heart wall is known as endocardium. It is made up of epithelial tissue.

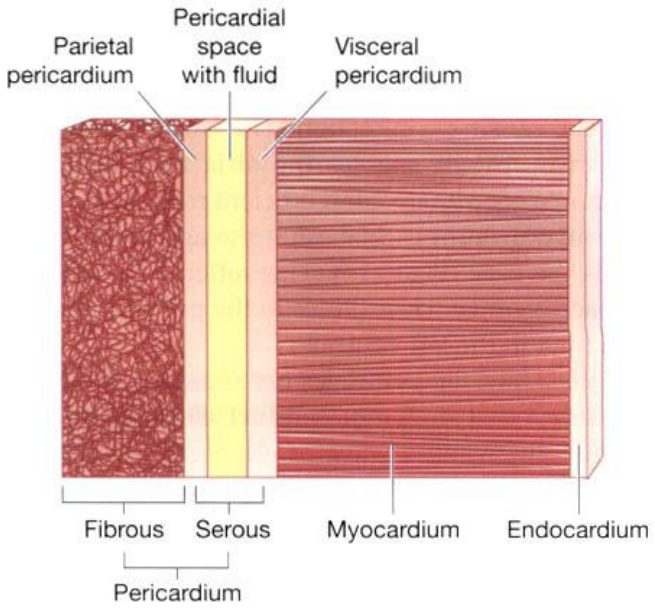


Fig. Layers of the heart wall

INTERNAL STRUCTURE OF HEART

The internal structure of heart is made up of:

- Chambers of heart
- Valves of heart

1. **Chambers of heart**: The heart is made up of four chambers. The upper two chambers are known as atrium (right atrium and left atrium) and lower two chambers are known as ventricles (right ventricle and left ventricle).

a. **Atrium**
- The right and left atrium are thin walled chambers separated by inter-atrial septum.
- The right atrium receives venous (deoxygenated) blood through the opening of superior venacava, inferior venacava and coronary sinus.
- The left atrium receives oxygenated blood from the lungs through four opening of the pulmonary veins (two right and two left pulmonary veins).

b. **Ventricles**
- The ventricles are thick wall chambers internally separated by inter- ventricular septum.
- The pulmonary artery arises from right ventricle. It carries the venous (deoxygenated) blood from right ventricle to the lungs.
- The aorta arises from the left ventricle. The left ventricle pumps the oxygenated blood to different parts of the body through the systemic aorta.

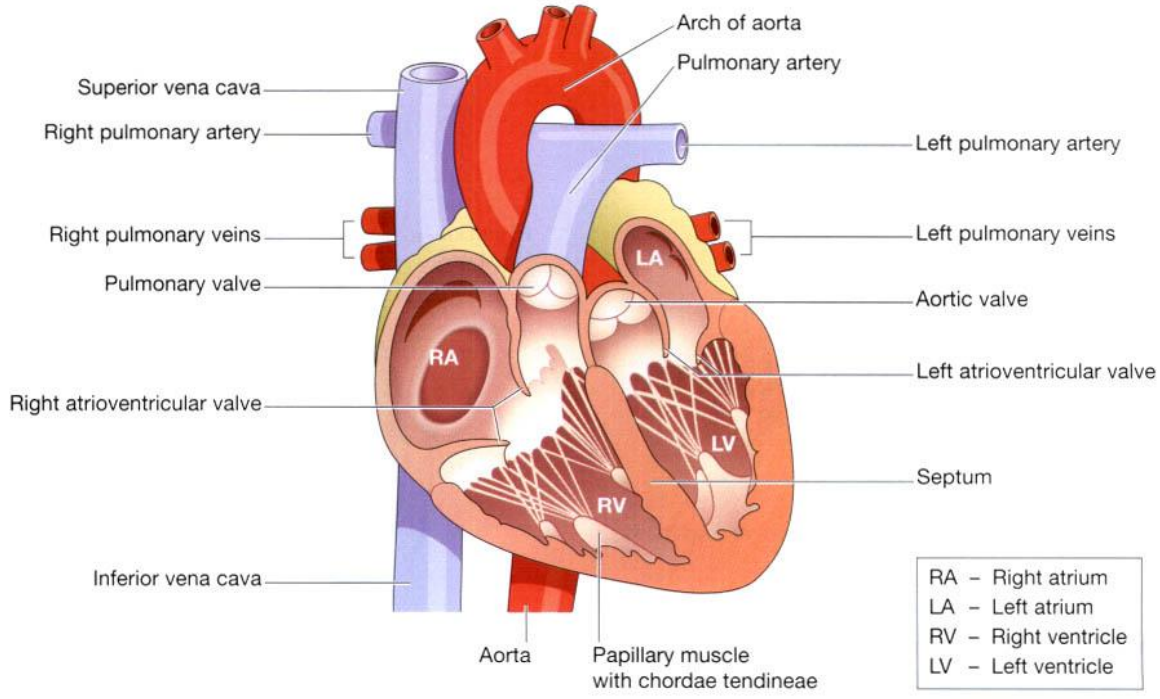
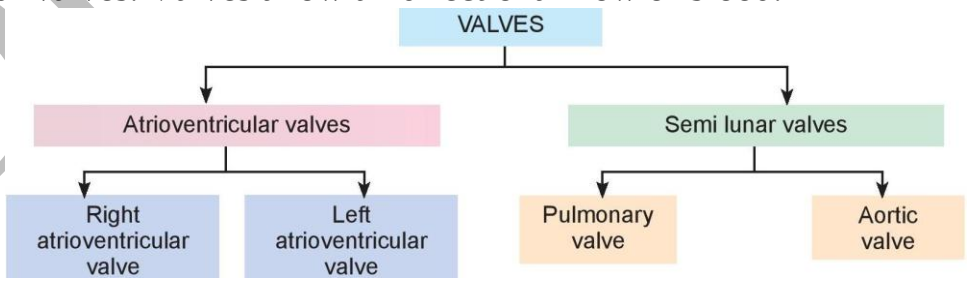


Fig. Internal structure of heart

2. Valves of heart: There are four valves in human heart, two atrioventricular valves and two semilunar valves. Valves allow unidirectional flow of blood.



a. Atrioventricular valves: The atrioventricular valves lie between the atrium and ventricles of heart. The atrioventricular valves are of two types:
- **Right atrioventricular valve**: The right atrioventricular valve lies between right atrium and right ventricle. It is also known as tricuspid valve and is made up of three cusps.
- **Left atrioventricular valve:** The left atrioventricular valve lies between left atrium and left ventricle. It is also known as bicuspid valve or mitral valve and is made up of two cusps.

b. Semilunar valves: The semilunar valves are half-moon shaped valves. It opens only towards the aorta and pulmonary artery and prevents the backflow of blood into the ventricles. The semilunar valves are of two types:

- **Aortic valve:** Aortic valve present at the opening of aorta in left ventricle
- **Pulmonary valve:** Pulmonary valve present at the opening of pulmonary trunk into the right ventricle.

Blood Supply of the Heart (Coronary Circulation)

1. **Arterial supply**: The heart is supplied with arterial blood (oxygenated blood) by the right and left coronary arteries which are branch of the aorta. The coronary arteries receive about 5% of the blood pumped from the heart.
2. **Venous drainage**: Most of the venous blood (deoxygenated blood) is collected into a number of cardiac veins that join to form the coronary sinus, which opens into the right atrium.

Nerve Supply to the Heart

Heart is supplied by autonomic nervous system (Sympathetic and parasympathetic) originating in the cardiovascular center in the medulla oblongata.

Function of Heart

The heart functions as a double pump:

1. The right half of the heart receives deoxygenated blood, i.e. blood is low in oxygen and pumps to the lungs through pulmonary trunk and pulmonary arteries.
2. The left half of the heart receives oxygenated blood, i.e. oxygen rich blood from the lungs and pumps to the rest of the body through aorta and its branches.

FLOW OF BLOOD THROUGH THE HEART

The right atrium receives deoxygenated blood from the superior venacava and inferior venacava

↓

Right atrium

↓ Through tricuspid valve

Right ventricle

↓ Through pulmonary artery

Lungs

↓ Through 4 pulmonary veins

Left atrium

↓ Through bicuspid valve

Left ventricle

↓

Aorta

↓

Systemic circulation

CONDUCTIVE SYSTEM OF HEART

The small groups of specialized neuromuscular cells in the myocardium initiate and conduct impulses causing co-ordinate and synchronized contraction of the heart muscle is known as conductive system of heart. The conductive system consists of following structures:

1. Sinoatrial node (SA node):
2. Atrioventricular node (AV node):
3. Atrioventricular bundle (AV bundle or bundle of His):
4. Purkinje fibers

BLOOD VESSELS

The blood vessels are the part of the circulatory system that transports blood throughout the body.

Type of Blood Vessels

The blood vessels are of three types:

1. **Artery:** Artery is a type of blood vessel, which carry blood away from the heart to different organs. Its diameter is 4 mm. The smallest parts of artery are known as arteriole.
2. **Vein:** Vein is a type of blood vessels, which carry blood towards the heart from different parts of the body. Its diameter is 5 mm. The smallest parts of vein are known as venule.
3. **Capillary:** Capillaries are the network of microscopic endothelial tubes interposed between the arterioles and venules. The average diameter of capillaries is 6-8 micron.

Structure of Blood Vessels

The wall of blood vessels (arteries and veins) is composed of three layers:

1. **Tunica adventitia:** It is the outer layer of blood vessels, composed of fibrous tissue.
2. **Tunica media:** It is the middle layer of blood vessels, composed of smooth muscle and elastic tissue.
3. **Tunica interna:** It is the inner layer of blood vessels, composed of squamous epithelium known as endothelium.

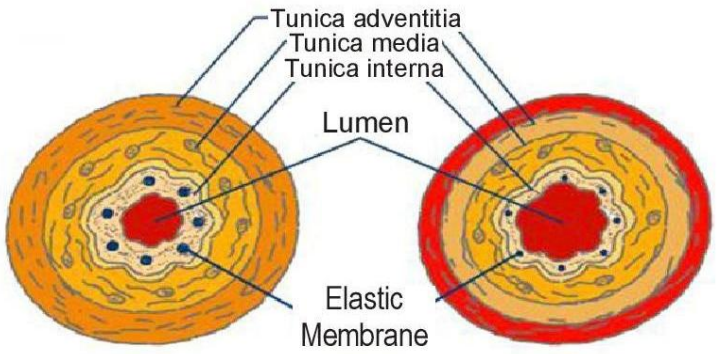


Fig.: Structure of Blood Vessels

Differences between Arteries and Veins

No	Arteries	Veins
1.	It carries blood away from the heart to different organs.	It carries blood towards the heart from different parts of the body.
2.	Its diameter is about 4 mm.	Its diameter is about 5 mm.
3.	It is most deeply situated in the body.	It is superficial and deep situated in the body.
4.	It is thick wall.	It is thin wall.
5.	It passes narrow lumen.	It passes wider lumen.
6.	It is red in colour.	It is blue in colour.
7.	It has high elasticity.	It has low elasticity.
8.	The artery blood pressure is high.	The vein blood pressure is low.
9.	The internal valves are absent.	The internal valves are present.

BLOOD CIRCULATION

The circulation in which the blood leaving the heart flowing through the arteries, veins & capillaries and return back to the heart is known as blood circulation.

Types of Circulation

1. **Pulmonary circulation:** The passage of blood from right ventricle to the lungs and from the lungs to the left atrium is known as pulmonary circulation.

Right ventricle
↓
Pulmonary valve
↓
Pulmonary arteries
↓
Only to lungs
↓
Deoxygenated blood get oxygenated
↓
Four pulmonary veins
↓
Left atrium

2. **Systemic circulation:** The passage of blood from left ventricle to the tissues and from the tissues to the right atrium is known as systemic circulation.

Left ventricle
↓
Aortic valve
↓
Aorta
↓
Oxygenated blood to all tissues except lungs
↓
Venous blood collected
↓
Superior venacava and inferior venacava
↓
Right atrium

3. **Portal circulation:** The blood from one organ is first transported to another organ through portal vein is known as portal circulation.

Types of portal circulation

The portal circulation is of two types:

a. **Hepatic portal circulation:** The nutrient rich blood from the intestinal tract is directly transmitted to liver for metabolism is known as hepatic portal circulation.

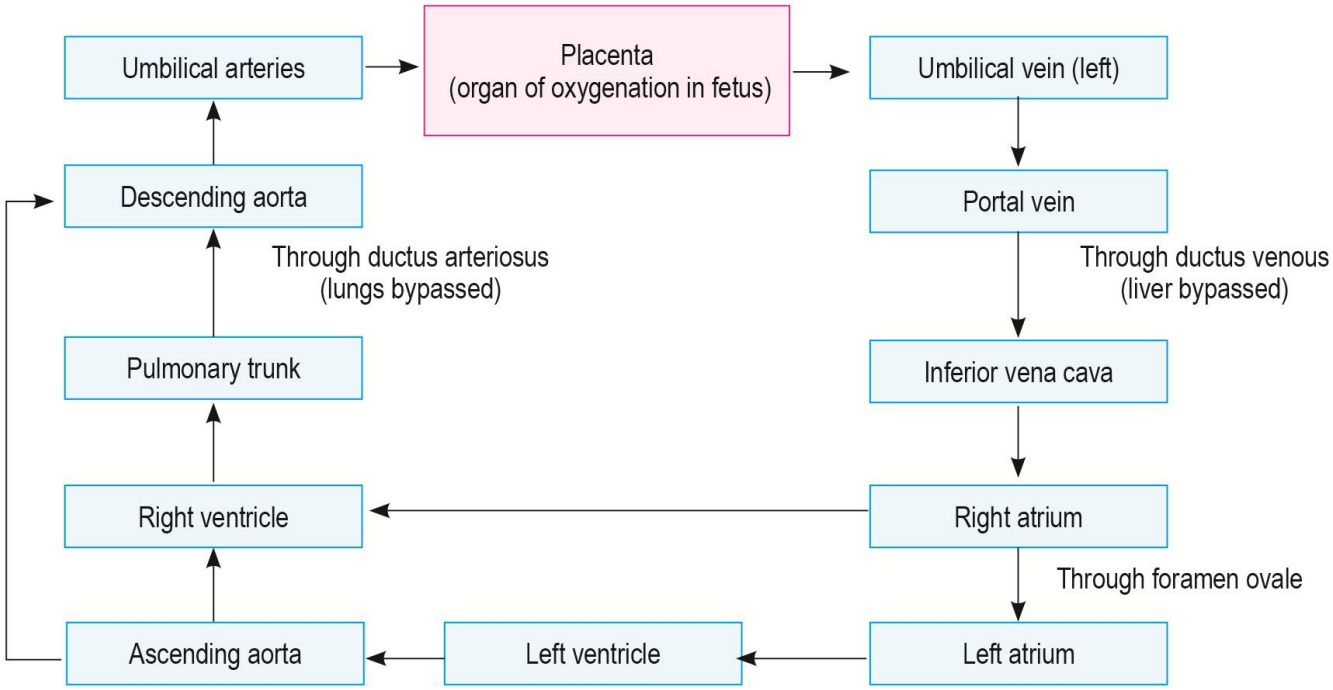
b. **Hypothalamic portal circulation:** The hormones are released from hypothalamus is directly transmitted to pituitary gland is known as hypothalamic portal circulation.

4. **Fetal circulation**

The flow of deoxygenated blood from the fetus to the placenta through the umbilical artery and the returning of oxygenated blood from the placenta to the fetus through the umbilical vein are known as fetal circulation.

- The umbilical vein carries oxygenated blood from fetus.
- Ductus venous is a continuation of umbilical vein that returns blood directly into inferior venacava and most of the blood therefore bypass the non-functional liver.
- Foramen ovale forms a valve like opining allowing blood to flow between right and left atrium, so that most of the blood bypass non-functional lungs.

- Ductus arteriosus, a small vessel that connects the pulmonary artery to descending aorta, diverts more blood into systemic circulation, meaning that very little blood pass through fetal lungs.
- Two umbilical arteries which are extension of internal iliac artery carry deoxygenated blood to placenta.



CARDIAC CYCLE

The rhythmic contraction and relaxation of heart chamber in cyclic pattern is known as cardiac cycle. During each heart beat or cardiac cycle the heart contract and then relax. The period of contraction is known as systole and the period of relaxation is known as diastole. The complete cardiac cycle is of 0.8second.

Stages of Cardiac Cycle

The cardiac cycle consists of three stages:

- Atrial systole = 0.1 sec.
- Ventricular systole = 0.3 sec.
- Complete cardiac diastole = 0.4 sec.

a. **Atrial systole**

- Simultaneous contractions of both atria.
- Opens atrioventricular valves (tricuspid & bicuspid valves).
- Blood flows within the ventricles of respective sides.
- No heart sound is produced.
- It completes within 0.1 sec.

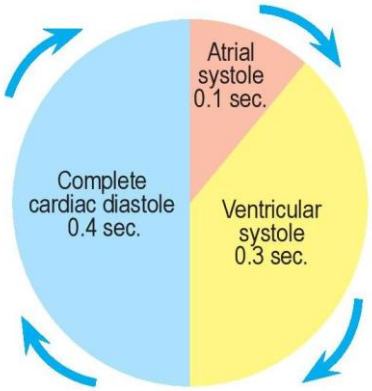
b. **Ventricular systole**

- Simultaneous contraction of both ventricles.
- Atrioventricular valves (bicuspid and tricuspid valves) get closed so that first heart sound (LUBB) is produced.
- Blood is forced into pulmonary artery and aorta.
- It completes within 0.3sec.

c. **Complete cardiac diastole**

- Relaxation of both atria and ventricles together.

- Both atria get filled with blood.
- Pulmonary and aortic valves get closed to prevent back flow of blood so that second heart sound (DUBB) is produced.
- It completes within 0.4 sec.



Control of Cardiac Cycle

The cardiac cycle is controlled by the Sinoatrial node (SA Node) present within the heart. The SA node rhythmically generates the impulses throughout the life time.

HEART SOUND

The vibratory motions of the heart produced during the different events of the cardiac cycle are known as heart sounds. The four heart sounds are produced during each cardiac cycle:

1. **First heart sound (LUBB):** The first heart sound is produced during ventricular systole due to the simultaneous closure of bicuspid and tricuspid valves (atrioventricular valves).It has long, soft and low pitched sound. It resembles the spoken word 'LUBB'. The duration of this sound is about 0.10 to 0.17 second.
2. **Second heart sound (DUBB):** The second heart sound produced during complete cardiac diastole due to the simultaneous closure of pulmonary and aortic valves (semi lunar valves). It has short, sharp and high pitch sound. It resembles the spoken word 'DUBB'. The duration of this sound is about 0.10 to 0.14 second.

Importance of Heart Sounds

Study of heart sounds has important diagnostic value in clinical practice because alteration in the heart sounds indicates cardiac diseases involving valves of the heart.

CARDIAC OUTPUT

The amount of blood pumped from each ventricle in per minute is known as cardiac output. It is also known as minute volume. The cardiac output depends upon the stroke volume and heart rate.

Stroke volume: The amount of blood pumped from each ventricle during each beat is known as stroke volume. The normal value of stroke volume is about 70ml (60 to 80 ml) when the heart rate is normal 72/minute.

Cardiac output = Stroke volume × Heart rate

Cardiac output = 70 ml/beat× 72 beat/minute

= 5.040 ml/ per minute

Normal value of cardiac output is about 5 liter/ventricle in per minute.

PULSE

Arterial pulse is defined as the rhythmic expansion of the arterial wall due to transmission of pressure waves along the walls of the arteries. Pulse rate is equivalent to measuring the heart rate. Pulse rate is the number of pulse per minute. Average pulse rate in adults is 72 per minute. Pulse rate at different age is given in table.

Age	Pulse rate/ min
In fetus	150 to 180
At birth	130 to 140
At 10 years of age	About 90
After puberty	About 72

Variation of Pulse Rate

Conditions which alter the heart rate alter pulse rate also.

Conditions when pulse rate increases:

- Exercise
- Pregnancy
- Emotional conditions
- Fever
- Anemia
- Hypersecretion of catecholamines
- Hyperthyroidism

Conditions when pulse rate decreases

Sleep, Hypothermia, Hypothyroidism, Incomplete heart block

Measurement of Pulse

The pulse rate can be measured at any point on the body where, the arteries pulsation is transmitted to the surface by pressuring it with the three fingers index, middle and ring fingers, often it is compressed against an underlying structure like bone. The thumb should not be used for measuring another person's pulse rate, as its strong pulse may interfere with correct perception of the target pulse. The possible points for measuring the pulse rate are:

No	Pulse point	Area of palpation
1.	Temporal pulse	Over the temple, in front of ear on superficial temporal artery
2.	Facial pulse	On facial artery at the angle of jaw
3.	Carotid pulse	In the neck along anterior border of sternocleidomastoid muscle on common carotid artery
4.	Axillary pulse	In axilla on axillary artery
5.	Brachial pulse	In cubital fossa along medial border of biceps muscle on brachial artery
6.	Radial pulse	Over the thumb side of wrist between tendons of brachioradialis and flexor carpi radialis muscles on radial artery
7.	Ulnar pulse	Over the little finger side of wrist on ulnar artery
8.	Femoral pulse	In the groin on femoral artery
9.	Popliteal pulse	Behind knee, in the popliteal fossa on popliteal artery
10.	Dorsalis pedis pulse	Over the dorsum of foot on dorsalis pedis artery
11.	Tibial pulse	Over the back of the ankle, behind medial malleolus on posterior tibial artery

BLOOD PRESSURE

Blood pressure (arterial blood pressure) is the force or pressure of blood exerted on the wall of the blood vessels especially in arteries. Generally, the blood pressure is expressed in following terms:

1. **Systolic blood pressure:** Systolic blood pressure is defined as the maximum pressure exerted in the arteries during the systole (contraction) of heart. The normal systolic blood pressure is 120 mmHg (100 to 120 mmHg).
2. **Diastolic blood pressure:** Diastolic blood pressure is defined as the minimum pressure in the arteries during the diastole (relaxation) of heart. The normal diastolic blood pressure is 80 mmHg (60 to 80 mmHg).

3. **Pulse pressure:** The difference between the systolic pressure and diastolic pressure is known as pulse pressure. The normal pulse pressure is 40 mmHg (120 – 80 = 40).

Variation of Blood Pressure/Factors affecting Blood Pressure

a. **Age:** Blood pressure increases with age.
b. **Sex:** In females, up to the period of menopause, arterial pressure is 5 mmHg, less than in males of same age. After menopause, the pressure in females becomes equal to that in males of same age.
c. **Body Built:** Pressure is more in obese persons than in lean persons.
d. **Diurnal Variation:** In early morning, the pressure is slightly low. It gradually increases and reaches the maximum at noon. It becomes low in evening.
e. **After Meals:** Blood pressure is increased for few hours after meals due to increase in cardiac output.
f. **During Sleep:** Usually, the pressure is reduced up to 15 to 20 mmHg during deep sleep. However, it increases slightly during sleep associated with dreams.
g. **Emotional Conditions:** During excitement or anxiety, the blood pressure is increased due to release of adrenaline.
h. **After Exercise:** After moderate exercise, systolic pressure increases by 20 to 30 mmHg and diastolic pressure is not affected by moderate exercise.

Factors Maintaining Blood Pressure

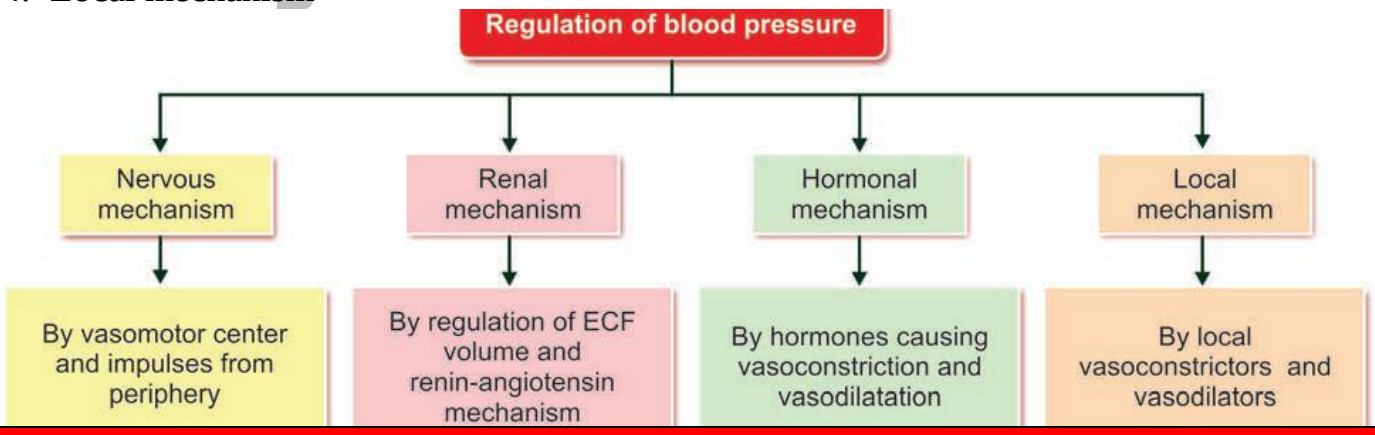
Some factors are necessary to maintain normal blood pressure.

- Cardiac output
- Heart rate
- Peripheral resistance
- Blood volume
- Venous return
- Elasticity of blood vessels
- Velocity of blood flow
- Diameter of blood vessels
- Viscosity of blood

Regulation of Blood pressure

The blood pressure is regulated in following ways:

1. Nervous mechanism or short term mechanism
2. Renal (kidney) mechanism or Long term mechanism
3. Hormonal mechanism
4. Local mechanism



CIRCULATORY SYSTEM