# CIRCULATORY SYSTEM

- The blood vascular system is a mechanism by which various materials are conveyed from one part of the body to another where they are either utilised or removed.
- The conveying medium is the blood. It is transported through specialised vessels called blood vessels (namely, arteries and veins).
- Blood circulation is being maintained by the central pumping organ, the heart.

**STRUCTURE OF HEART:**

- Heart is the central pumping organ of the blood vascular system.
- It is a thick walled, muscular, pulsating organ, situated in the thoracic cavity in between the two pleural bags enclosing lungs, slightly towards the left side in a space called **mediastinum.**
- It is pear shaped, broad anteriorly and the pointed apex is directed posteriorly.
- Heart is covered by a double layered pericardial membrane, formed by an outer fibrous pericardium and inner serous pericardium. Serous pericardium is divided into parietal layer and visceral layer.
- The two layers are separated by a narrow pericardial cavity, which is filled with pericardial fluid. This fluid protects the heart from external shocks, injuries and allows its free movement.
- The wall of the heart consists of three layers, namely, an outer epicardium {formed by a layer of mesothelial cells), middle myocardium (formed by cardiac muscles) and inner endocardium (formed by squamous epithelium).

**1. External structure:**

- Heart of rabbit is four chambered and consists of two auricles and two ventricles. Sinus venosus and truncus arteriosus are absent.
- Auricles and ventricles are separated by a groove called auriculo ventricular groove.
- Each auricle extends posteriorly as a flap which covers the anterior margin of the corresponding ventricle. This flap is called **auricular appendix.**
- The two ventricles are separated by an oblique inter ventricular groove.

**2. Internal Structure:**

- A vertical section of the heart shows the details of the internal structure as described below :

**A. Auricles:**

- The two auricles (left and right) present in the anterior part of the heart. They are separated from each other by a thin **inter auricular septum**.
- In the embryonic stage, this septum has a small pore called **foramen ovalis**.
- At birth, when lungs become functional, the foramen ovalis is gradually closed leaving an oval patch known as **fossa ovalis**.
- The walls of auricles are thin.
- The right auricle is larger than the left and receives deoxygenated blood from different parts of the body (except lungs) through three major veins, viz., the two precaval veins (left and right) and a postcaval vein, [precaval veins (anterior vena cavae) collect blood from different parts of head and fore limbs. Postcaval vein (posterior vena cava) collects blood from other parts of the body].
- The opening of postcaval vein is guarded by a membranous fold, which is a remnant of embryonic **valve of Eustachian**.
- It is non functional in adult. In embryonic stage, it directs the blood from postcaval vein into the left auricle through foramen ovalis.
- Blood from the wall of heart is returned into the right auricle through a coronary sinus. It opens into the left precaval vein.
- This opening is bound by a crescentic fold, the **valve of Thebesius**.
- In the wall of right auricle near the eustachian valve is a small node of specialised tissue, the **sinu auricular node** (S.A. node), the pacemaker.
- Left auricle receives oxygenated blood from lungs through a pair of pulmonary veins, which opens into the left auricle through a common pore. (There are four pulmonary veins in man).
- Right auricle opens into the right ventricle through right auriculo ventricular aperture. It is guarded by a tricuspid valve, which allows the blood to flow from right auricle into the right ventricle.
- Left auricle opens into the left ventricle through left auriculo ventricular aperture. It is guarded by a **bicuspid valve or mitral valve,** which allows the blood to flow from left auricle into left ventricle.

**B. Ventricles:**

- There are two ventricles (left and right) which form the posterior part of the heart. They are separated from each other by **inter ventricular** septum.
- Left ventricle is larger than the right. Wall of ventricles are thick and are highly muscular. Auricles and ventricles are separated by an **auriculo-ventricular septum,** which possesses left and right auriculo ventricular apertures.

- The inner surface of ventricles is raised into muscular ridges called **columnae carnea.**
- Besides there are large conical projections called **papillary muscles.**
- Extending between auriculo-ventricular valves and papillary muscles are connective tissue strands, called **chordae tendinae**.
- In the posterior right border of inter auricular septum, is an **auriculo-ventricular node,** from which, a bundle of specialised muscle fibres arise. It is called **bundle of His.**
- It extends into the inter ventricular septum, divides into two main branches and then spreads into the walls of ventricles as a net of fibres, called **Purkinje fibres.**

**C. Aortic arches**

**i. A pulmonary arch** arises from the left anterior angle of the right ventricle. It proceeds to the lungs. At the base of the pulmonary arch, three semi lunar valves are present.

- They allow the blood to flow into the pulmonary arch from right ventricle.

**ii. A systemic arch** arises from the left ventricle, turns to left, and transports oxygenated blood to different parts of the body through various arteries.

- At the base of systemic arch, are three semilunar valves. They allow the blood to flow into the systemic arch from the left ventricle.
- A fibrous strand, known as **ligamentum arteriosum** is present at the point of contact of the systemic arch and pulmonary arch [In embryonic stage, the two aortic arches are connected by a blood vessel called ductus arteriosus (ductus Botalli) which is modified into ligamentum arteriosum in adult].

**FUNCTIONING OF HEART:**

- As long as the animal is alive, heart pulsates rhythmcially by alternate contraction (systole) and relaxation (diastole).
- Auricles and ventricles never contract simultaneously.
- Auricles contract first and are followed by the contraction of ventricles.
- A systole is always followed by a diastole and together they constitute the heart beat.

**1. Origin and conduction of heart beat:**

- In the heart of rabbit, contraction **(i.e., systole)** originates in a special region called **pace maker.**
- The heart of rabbit has **two pace makers**, namely, **sinu-auricular node** (SA-node) and **A.V. node**
- It is present in the wall of right auricle. Pace maker is formed by modified cardiac muscle. Hence it is called **myogenic pace maker** and such heart is called **myogenic heart.**
- Systole originates in S.A. node and spreads over the auricles as a wave. The auricles then contract.
- This wave of excitation reaches the A.V. node, which conducts it into the walls of ventricles through bundle of His and Purkinje fibres.
- As a result, the ventricles contract.

**2. Cardiac cycle:**

- The cyclical systole and diastole (i.e., contraction and relaxation) of heart chambers is called cardiac cycle. Duration of cardiac cycle is 0.8 sec when heart beats at 75 time per minute.
- Cardiac cycle may be divided into three phases: A. Auricular systole, B. Ventricular systole and C. Ventricular diastole.

**A. Auricular systole:**

- The right auricle receives deoxygenated blood from different parts of the body through a pair of precaval veins and a postcaval vein. Duration of atrial systole is 0.1 sec
- At the same time left auricle receives oxygenated blood from lungs through pulmonary veins.
- When the two auricles are filled with blood, a wave of contraction originates in S.A. node and spreads over the auricles resulting in the contraction of auricles.
- Deoxygenated blood flows into right ventricle and oxygenated blood flows into left ventricle through respective auriculo ventricular apertures.

**B. Ventricular systole:**

- The wave of contraction passes through A.V. node, bundle of His and Purkinje fibres into the walls of ventricles. The ventricles then contract. Duration of ventricular systole 0.3 sec
- End systolic volume is 50ml of blood
- To prevent backward flow of blood, tricuspid valve and bicuspid valve close due to pressure and causing the first heart sound, **lubb.**

- At the same time, the semi lunar valves present at the bases of systemic arch and pulmonary arch open.
- Thus oxygenated blood from left ventricle flows into the systemic arch and deoxygenated blood from right ventricle flows into the pulmonary arch.

**C. Ventricular diastole:**

- Complete Duration of cardiac diastole is 0.4 sec
- End diastolic volume is 120 ml
- Ventricular systole is followed by their diastole. As a result, pressure in ventricles decreases.
- The semi lunar valves of systemic arch and pulmonary arch are closed by causing second heart sound, **dup.**
- Simultaneously the auricles also enter into a diastolic phase. Hence ventricular diastole is also known as auriculo-ventricular diastole.

**3. Double circulation**:

- It is clear that in the heart of rabbit, oxygenated and deoxygenated blood remains separate.
- Right side of heart contains deoxygenated blood and left side contains oxygenated blood.
- In one complete circuit in the body, the blood passes twice through the heart, once through right side and the other time through left side.
- This type of circulation is known as **double circulation.**
- This includes systemic circulation and pulmonary circulation. Oxygenated blood from lungs is collected into the left auricle through pulmonary veins and goes into the left ventricle.
- From there it goes to the various organs through left systemic artery. This circulation is called **systemic circulation.**
- From the organs impure blood is collected into the right auricle through vena cava.
- Impure blood flows into the right ventricle and goes to the lungs through the pulmonary artery.
- This circulation is called **pulmonary circulation**.

**4. Cardiac output**:

- The volume of blood pumped out by each ventricle for each beat is known as **stroke volume.** The volume of blood pumped out by heart per minute is termed as cardiac output.
- It may be calculated by using the following formula:

  Cardia output = Stroke volume $\times$ No.of beats per minute
- In man, stroke volume is 70 ml; number of beats per minute (variable) is about 72. Hence, in man, cardiac output = 70 x 72 = 5040 ml/minute.