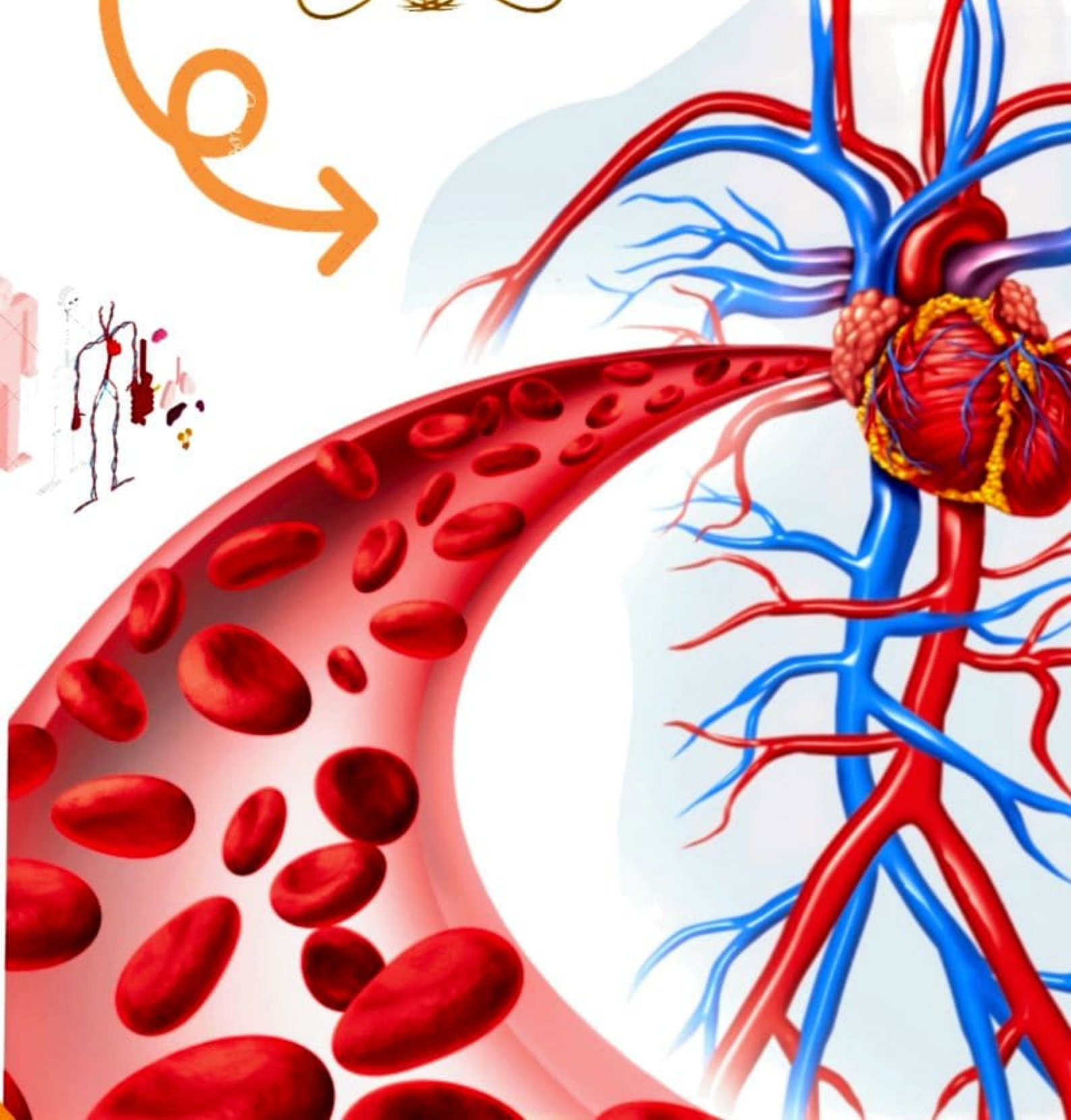


The circulatory system of human beings consists of **heart**, three kinds of **blood vessels**—arteries, veins, capillaries, and **blood**.

We studied the structure and functions of blood in the previous Chapter. In this Chapter, we will study about blood vessels and heart.

BLOOD VESSELS

Blood vessels are branched tubes which form a continuous network in the human body. Blood flows through these tubes and circulates throughout the body. There are three kinds of blood vessels in the human body—**arteries**, veins and **capillaries**.

Arteries

Arteries are the blood vessels which normally carry oxygenated blood *away from the heart* to various organs of the body.

- The wall of an artery consists of an outer **fibrous** connective tissue layer, a thick **elastic** middle layer of smooth muscles, and a thin inner **epithelial** layer called **endothelium** (Fig. 8B.1).
- The walls are *thick and highly muscular with narrow lumen.*
- The thick musculature provides elasticity and contractility to the arteries. As a result, arteries can alter their diameter and regulate the amount of blood flow through them.
- They are **situated deep** in the skin and do not collapse when empty.

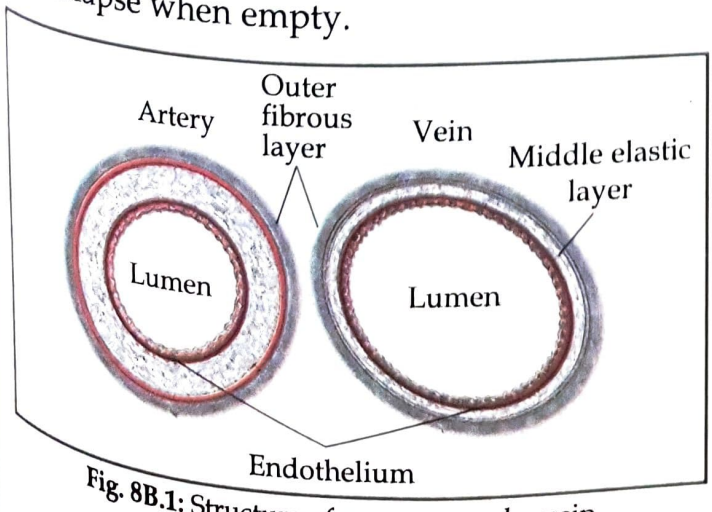


Fig. 8B.1: Structure of an artery and a vein

- In arteries the blood is under high pressure and, therefore, *flows very fast with jerks.*

Veins

Veins are the blood vessels which normally carry deoxygenated blood *away from the tissues towards the heart.*

- Veins also consist of three layers like those of arteries.
- However, in contrast to the arteries, veins have *thin and less muscular walls with a wide lumen.*
- The pressure of blood in the veins is lower as compared to the arteries. Therefore, in the veins, blood *flows slowly and without any jerks.*
- Veins are **situated superficially** within the skin and are visible as bluish-green lines.
- The veins are provided with muscular flaps called **valves** which allow the blood to flow to the heart.

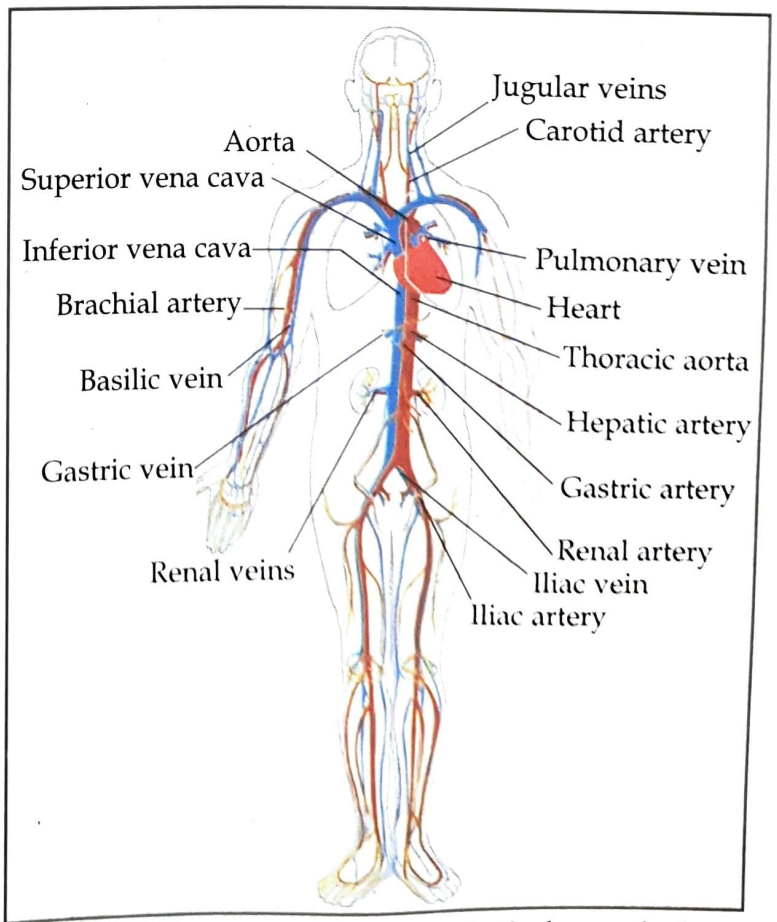


Fig. 8B.2: Major arteries and veins in the human body

Valves

The valves are made up of **muscular flaps**. These flaps resemble swing doors in action. The blood flowing through the veins push these valves in the direction of blood flow and open them up. As a result, the valves swing apart and allow the blood to flow through them. However, if the blood flows in the opposite direction, the flaps remain closed and block the passage, preventing the backward flow of blood.

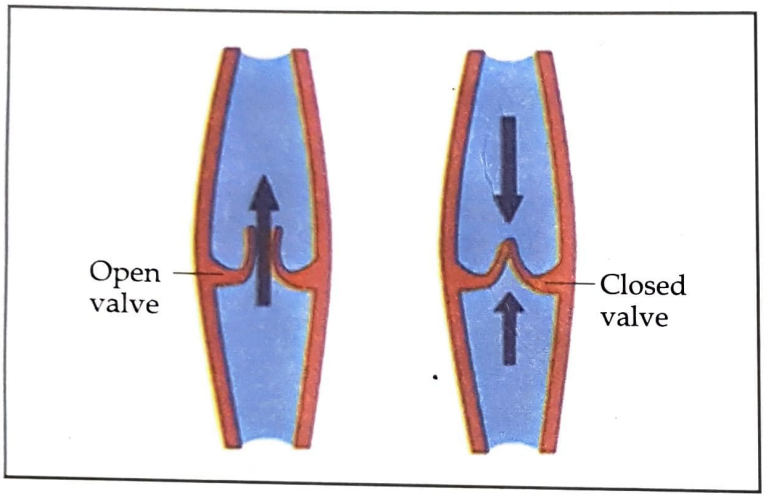


Fig. 8B.3: Valves in a vein

Capillaries

Capillaries are very **narrow** and **thin tubes** which connect the arteries and veins and form a network of vessels within the body.

- Arteries branch into smaller vessels called **arterioles** which repeatedly branch further into capillaries.
- The capillaries join to form the small vessels called **venules** which then unite with each other to form **veins**.
- Capillaries are made up of a single layer of endothelium which is **non-muscular**.
- This layer is *permeable to water* and small-sized solutes such as glucose and amino acids, and *impermeable to proteins* and large molecules.
- Thus, capillaries allow:
  - (*a*) *outward diffusion of oxygen* into the intercellular fluid.
  - (*b*) *inward diffusion of carbon dioxide* from the intercellular fluid.
  - (*c*) *inward and outward diffusion of small-sized solutes* such as glucose and amino acids.
  - (*d*) *squeezing out of WBCs* through the wall by **diapedesis** (amoeboid movement).

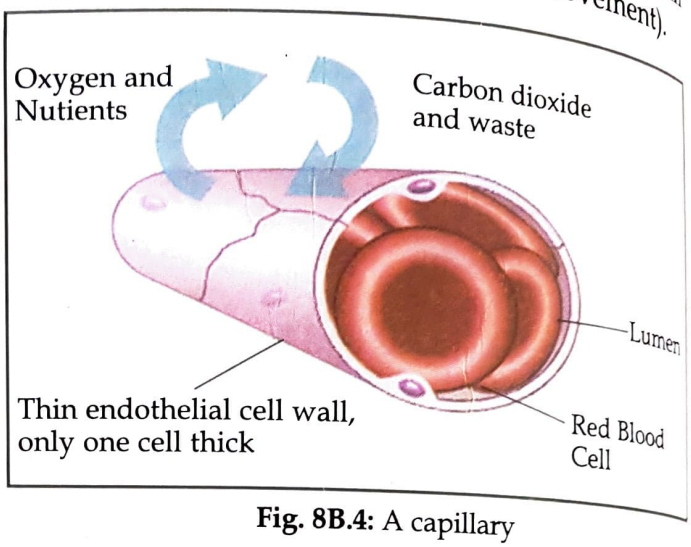


Fig. 8B.4: A capillary

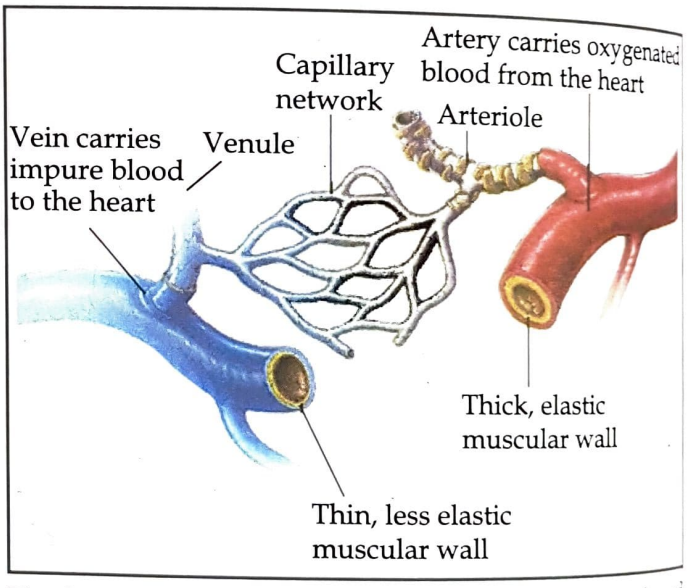


Fig. 8B.5: Structural relationship between an artery, vein and a capillary

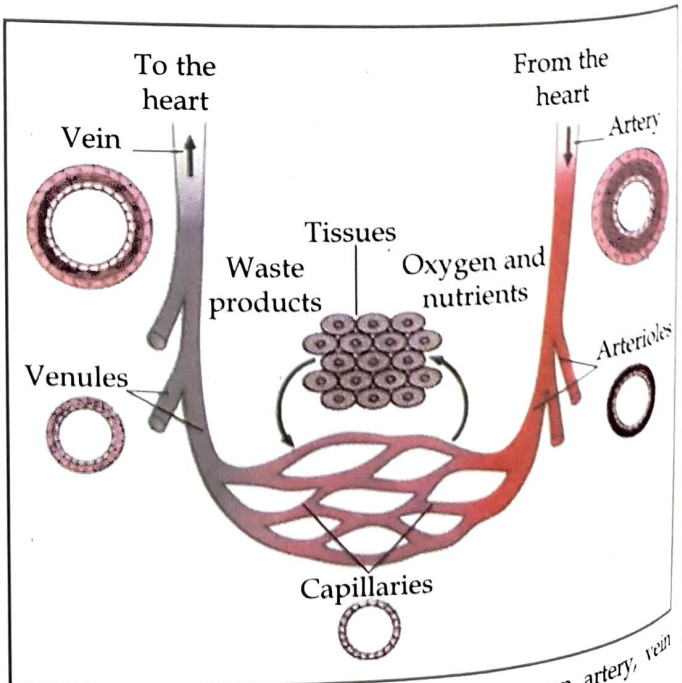


Fig. 8B.6: Functional relationship between an artery, vein and a capillary

Table 8B.1: Differences between an Artery and a Vein

S. No.	*Artery*	*Vein*
1.	Always carries blood away from the heart into an organ.	Always carries blood towards the heart from an organ.
2.	Thick, highly muscular and elastic walls.	Thin, less muscular and less elastic walls.
3.	Lumen is narrow.	Lumen is wide.
4.	Blood flows under high pressure with jerks.	Blood flows under low pressure without jerks.
5.	Deep-seated.	Superficial.
6.	Does not collapse when empty.	Collapses when empty.
7.	Carries oxygenated blood (with the exception of the pulmonary artery).	Carries deoxygenated blood (with the exception of the pulmonary vein).
8.	Valves absent in inner lining.	Valves present in inner lining to check the back flow of blood.

HEART

Heart is a powerful muscular organ which serves as the **pumping organ** of the circulatory system.

Structure of Heart

- **Shape:** The human heart is **pear-shaped** in structure, somewhat triangular in outline.
- **Size:** The heart of an adult human is about the **size of our fist**, 12 cm in length and 9 cm in width.
- **Weight:** The approximate weight of the heart is about **300 grams**.
- **Location:** It is situated in the **centre of the thoracic cavity** between the two lungs and above the diaphragm.
- **Tilted End:** *The narrow lower end of the heart* is slightly tilted towards the left, because of which it is believed that it is located on the left side of the chest.
- **Covering:** Heart is enclosed in a double-walled tough covering called **pericardium**. It is filled with a fluid called **pericardial fluid** which protects the heart from mechanical injuries such as shocks and jerks, and reduces the friction during its pumping action.

Chambers of the Heart

The human heart consists of four chambers.

- The two upper chambers are called **atria** or **auricles**.
- The two lower chambers are known as **ventricles**.

Each longitudinal half of the heart, thus, consists of an auricle which lies above the ventricle. These two longitudinal halves are separated from each other by a **muscular partition** or **septum** to prevent the mixing of blood. *The right half of the heart is filled with deoxygenated blood, whereas left half is filled with the oxygenated blood.*

Auricles

- The auricles are **thin-walled chambers** and receive blood from different organs of the body.
- The *right auricle receives deoxygenated blood* collected from all parts of the body, while the *left auricle receives oxygenated blood* from the lungs.
- The auricles contract simultaneously and deliver blood into the respective ventricles.

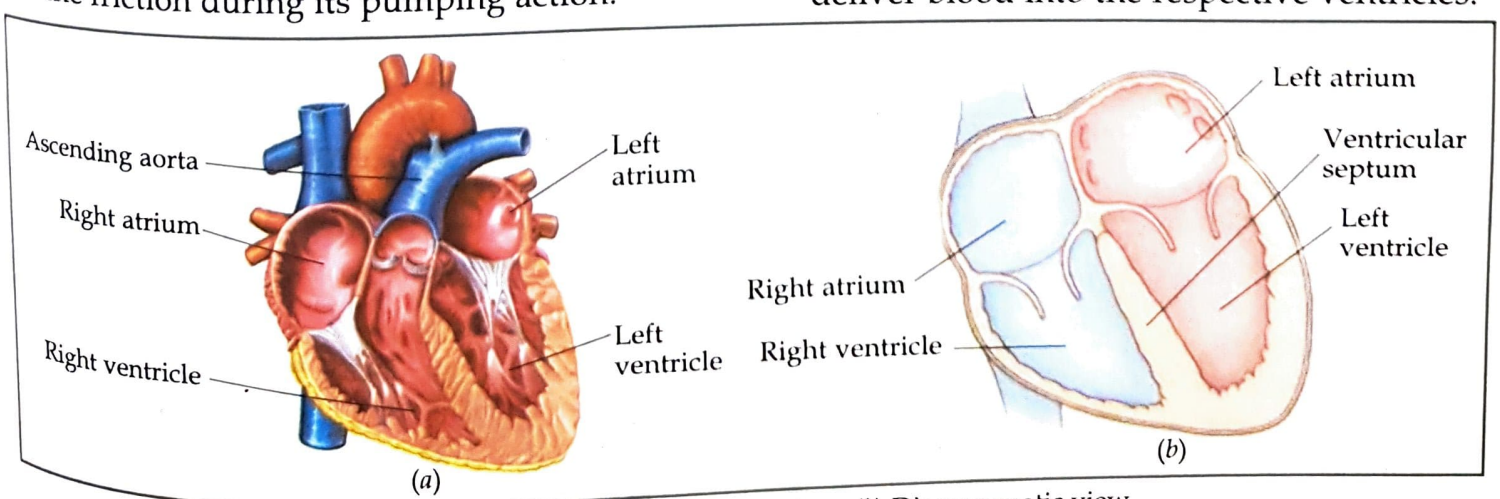


Fig. 8B.7: Human heart: (*a*) Detailed view, (*b*) Diagrammatic view

Ventricles

- The ventricles have **thick muscular walls.**
- The thick walls help them to pump the blood towards body parts with great force.
- The *right ventricle pumps blood to the lungs* for oxygenation and the **left ventricle pumps** the oxygenated *blood to all parts of the body.* The wall of the left ventricle is thicker than that of the right ventricle.

Atrioventricular Apertures

The atrium of each side connects with the ventricle through small apertures. *These apertures through which blood flows from atrium to ventricles are called* ***atrioventricular apertures.*** These are guarded by valves which permit the flow of blood only in one direction, *i.e.,* from atrium to the ventricles.

- The aperture between the left auricle and the left ventricle is guarded by two muscular leaf-like flaps. Therefore, it is called **bicuspid** (*bi*: two; *cusp*: flaps) or **mitral** (left) **valve.**
- The valve in the aperture between the right auricle and the right ventricle is known as **tricuspid valve.** It has three (tri) leaf-like flaps (cusps). Both the valves are held in position by special cords called **chordae tendinae,** arising from the ventricular wall. This arrangement prevents everting of the valves into the atria when the ventricles contract.

BLOOD VESSELS ENTERING AND LEAVING THE HEART

Blood Vessels Entering the Heart

The blood vessels enter the heart through left and right atria/auricles.

Right Auricle

Right auricle receives deoxygenated blood collected from the body through two large **vena cava**—anterior vena cava and posterior vena cava.

- **Anterior vena cava** brings blood from the anterior part of the body including head, chest and arms. It is also termed as **superior vena cava** or **precaval**.
- **Posterior (inferior) vena cava** brings blood to right auricle from the posterior part of the body including abdomen and legs through different veins. A few examples of collecting veins are **hepatic vein** which collects blood from the liver, and **renal vein** which collects blood from the kidney.

Left Auricle

Left auricle receives oxygenated blood from the lungs through four **pulmonary veins**. Two of these arise from the left lung and the other two arise from the right lung.

Blood Vessels Leaving the Heart

The blood vessels leave the heart from the right and left ventricles.

Right Ventricle

Pulmonary arteries arise from the right ventricle and carry deoxygenated blood to the lungs for oxygenation.

Left Ventricle

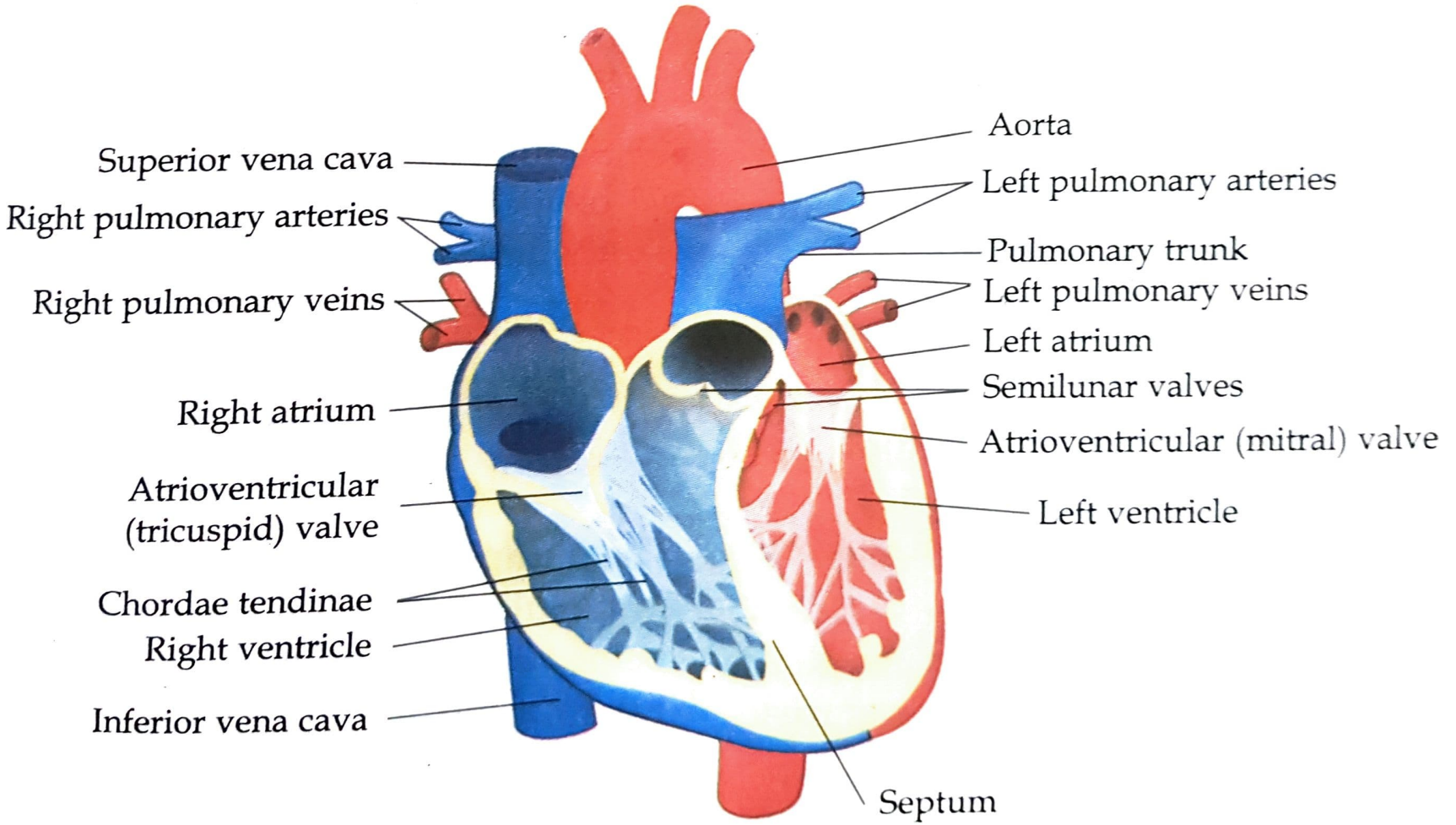
The blood vessel that arises from the left ventricle is termed as **aorta**. It carries oxygenated blood to all the body parts through many small arteries. For example, **hepatic artery** supplies blood to the liver and **renal artery** supplies blood to the kidney.

Two **coronary arteries** arise from the base of the aorta and supply blood to the heart muscles. The blockage of these arteries may lead to heart attack.

Valves Regulating the Blood Flow from Ventricles

The flow of blood from the ventricles into blood vessels is regulated by **semilunar valves** which prevent the back flow of blood into the ventricles when they relax.

- **Pulmonary semilunar valves** are located at the opening of right ventricle into pulmonary artery. These are three in number and pocket-shaped.
- **Aortic semilunar valves** are located at the opening of left ventricle into the aorta. These are also three in number and pocket-shaped.



CIRCULATION OF BLOOD IN HEART

The circulation of blood in the human body is regulated by the pumping action of the heart. The heart is made up of specialised cardiac muscle fibres which contract and relax automatically and rhythmically.

When the auricles relax, they enlarge and receive the blood. During contraction, they pass blood into the ventricles. The ventricular contraction lets the blood flow into the respective blood vessels.

Auricular contraction followed by ventricular contraction constitutes one heartbeat.

The circulation of blood within the heart takes place in the following steps:

- All the four chambers are relaxed for a short period of time. During this period, the two auricles receive blood from the major veins and they get filled up.
- The circulation of blood starts with the contraction of auricles while the ventricles are still in a relaxed state and empty.
- The **contraction of the auricles** pumps the blood into the respective ventricles through atrioventricular apertures.
- The left ventricle gets filled with the oxygenated blood and the right ventricle receives deoxygenated blood.
- Now, both the **ventricles contract** simultaneously and the two **auricles relax**.

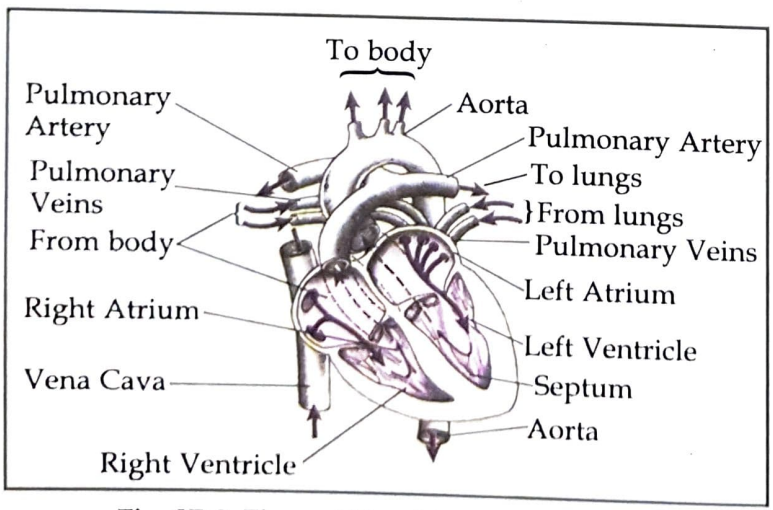


Fig. 8B.9: Flow of blood in heart chambers

- The blood under pressure in the ventricles tends to return to atria but is prevented by the cuspid valves.
- Thus, **semilunar valves open** and the ventricles pump the blood out from the heart because of the force of contraction.
- The right ventricle passes the deoxygenated blood into the pulmonary artery while the oxygenated blood present in the left ventricle is pumped out through the **aorta**.
- Meanwhile, the auricles which are in the relaxed state receive the blood from the respective veins.
- The right ventricle passes the deoxygenated blood collected from different parts of the body by **vena cava**.
- Simultaneously, the left auricle receives oxygen-rich blood from the lungs through the **pulmonary veins**.
- The *auricular relaxation is again followed by their contraction* during which they convey blood to their respective ventricles. This initiates a repeat of the steps for the next heartbeat.

The pumping action of the heart keeps the blood in circulation. The heart of an average human being beats about 72 times a minute. At birth, the rate of heartbeat of an infant is about 140 beats per minute. *Our heart pumps out about 5 litres of blood per minute and an adult human has 5 litres of blood in his body*. What does it mean?

It means that the entire volume of blood present in our body passes through the heart in one minute.

Course of Blood Circulation in One Heartbeat

You have just studied that chambers of the heart contract and relax in a sequential manner. *The contraction of the heart is called* ***systole*** *and the relaxation of the heart is termed as* ***diastole***.

The alternate periods of one systole followed by one diastole constitute one **cardiac cycle**. Different phases of cardiac cycle are as follows:

- **Atrial Systole**: Initially, the auricles contract and enter the systole condition.
- **Ventricular Systole**: Atrial systole is followed by the contraction of ventricles.
- **Joint Diastole**: Now both the ventricles and auricles relax for a short time and this phase is called **joint diastole**. During joint diastole blood continues to flow into the auricles through vena cava and the pulmonary veins. Also, the blood flows gradually from the auricles to the ventricles by the pull of gravity.

- **Atrial Systole and Ventricular Diastole:** The joint diastole is followed by **auricular** or **atrial systole** while the ventricles are still in diastole stage. During this phase, blood is forced into the ventricles.

- **Atrial Diastole and Ventricular Systole:** At the end of atrial systole, the atria enter the diastole phase while the ventricles start contracting (**ventricular systole**). The semilunar valves open and blood is pumped into the respective arteries.

The end of this phase is again followed by joint diastole and the cycle is repeated continuously. Thus, cardiac cycle consists of three phases:

Phase I: Atrial systole and ventricular diastole
Duration = 0.15 seconds.

Phase II: Ventricular systole and atrial diastole
Duration = 0.30 seconds.

Phase III: Ventricular diastole and atrial diastole
Duration = 0.40 seconds.

One complete cycle constitutes one heartbeat, which lasts 0.85 seconds.

During a cardiac cycle, impulses produce electrical currents which can be recorded as an **electrocardiogram (ECG)**. ECG is a basic tool in the hands of a cardiologist (heart specialist) to determine the condition of heart and its valves.

Heart Sounds

During the cardiac cycle, two major heart sounds are produced which can be heard with the help of a stethoscope. These sounds are 'LUBB' and 'DUP'.

First Heart Sound: LUBB

The first heart sound is produced when the atrioventricular valves close at the **onset of ventricular systole**. It is low-pitched, relatively of a longer duration and sounds like 'LUBB'.

Second Heart Sound: DUP (DUB)

The second heart sound 'DUP' is produced because of the closure of semilunar valves. It signifies the **onset of ventricular diastole**. It has a higher pitch, is of a shorter duration and sharper. Thus, one can hear "LUBB-DUP-LUBB-DUP-LUBB-DUP..." by placing a stethoscope on the chest of a person with normal cardiac functioning.

A trained physician can learn a lot about the health of the heart from these sounds.

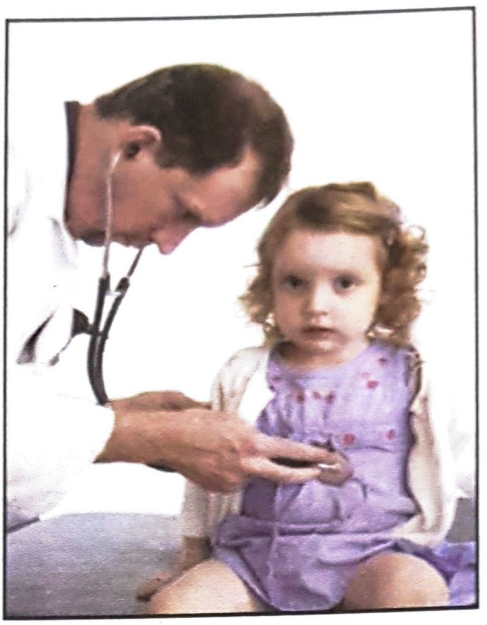


Fig. 8B.10: A doctor listening to heart sounds of a child

Pulse

When the ventricles of the heart contract and pump blood into the arteries with great pressure, the pressure passes along the arteries like a wave. This wave can be felt as a throbbing movement by placing a finger over a superficial artery, for example, one can feel the arterial pressure by pressing the finger on the radial artery of the wrist towards the side of the thumb. This wave of distension is called the **arterial pulse**.

As each heartbeat sends one pulse along the arteries, the pulse rate per minute indicates the heartbeat rate of the person.

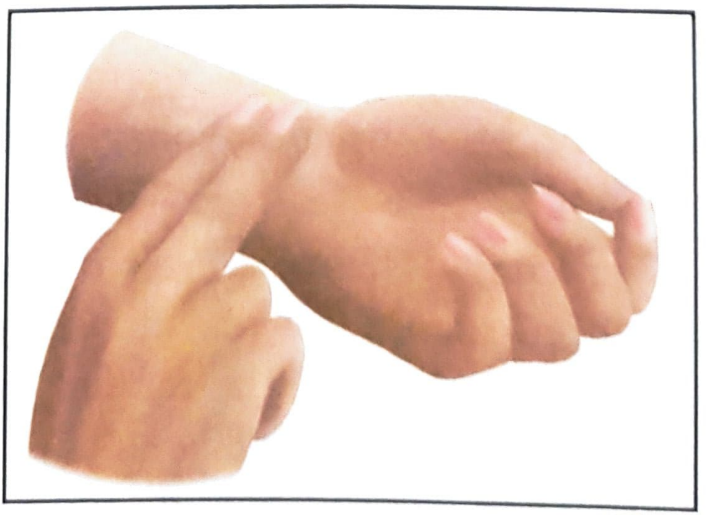


Fig. 8B.11: Counting of pulse by pressing the radial artery

BLOOD PRESSURE

When the blood flows into the arteries, it exerts a pressure on their walls. This pressure is called **blood pressure**. The normal blood pressure has two limits—an upper and a lower.

(*i*) **Upper Limit—Systolic Pressure:** It is the pressure exerted by the blood during **ventricular systole**. The normal systolic pressure of a healthy young person is 120 mm Hg.

(*ii*) **Lower Limit—Diastolic Pressure:** It is the pressure exerted by the blood during **ventricular diastole**. The normal diastolic blood pressure is about 80 mm Hg.

Blood pressure can be measured with an instrument called **sphygmomanometer**.

The normal blood pressure of an adult person is 120/80 mm Hg. The rise in blood pressure above this range is called **hypertension** while decreased blood pressure is termed as **hypotension**.

DOUBLE CIRCULATION—PULMONARY AND SYSTEMIC

In human beings, the blood circulates through the heart twice before completing one full circulation in the body. Each circulation starts from one side

of the heart and ends on the other side. This type of circulation is called **double circulation**.

The two circulatory pathways are as follows:

Pulmonary Circulation (Lung Circulation)

During this circulatory pathway, the blood flows from the heart to the lungs and back to the heart.

- The right ventricle pumps deoxygenated blood into the **pulmonary artery**.
- The pulmonary artery divides into two branches, each entering one lung.
- The blood gets oxygenated in the lung and returns to the left atrium through the **pulmonary vein**.

Systemic Circulation (General Body Circulation)

This circulation gets its name as it deals with the circulation of the blood from the heart to the body and back to the heart.

- The systemic circulation starts from the left ventricle which pumps oxygenated blood into the **aorta**.
- The aorta gives off arterial branches to all the tissues and organs except the lungs.
- **Vena cava** collects the deoxygenated blood through various veins from all the tissues and organs, and brings it back to the right atrium.

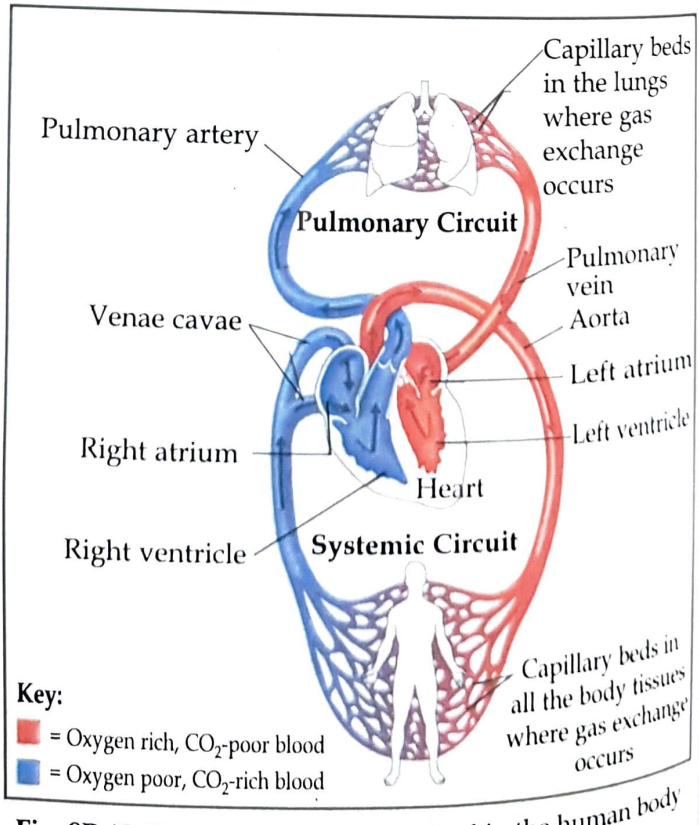


Fig. 8B.12: Double circulation of blood in the human body

PORTAL SYSTEM

You have learnt that an artery begins from the heart and breaks into smaller arteries which finally end into capillaries. The capillaries join to form small veins which fuse with each other and form larger veins as they reach near the heart. In contrast, a vein starts from the capillaries and carries the blood directly to the heart.

However, in some cases, a vein instead of carrying blood directly to the heart divides again into a second capillary system in the tissues. Such a vein is called a **portal vein**. *Thus, a portal vein is one which starts and ends in the capillaries such as hepatic portal vein and hypophyseal portal vein*. The portal vein along with the capillaries constitutes the **portal system**.

Hepatic Portal Vein

The veins from the stomach and the intestine do not open directly into the **posterior vena cava** but open into the liver through **hepatic portal vein**. The nutrients absorbed in the blood from the stomach and the intestine pass to the liver cells. Thereafter, the blood returns to the posterior vena cava again through the **hepatic vein**.

This whole system of collection of the venous blood from the abdominal organs and its supply to the liver is called the **hepatic portal system**.

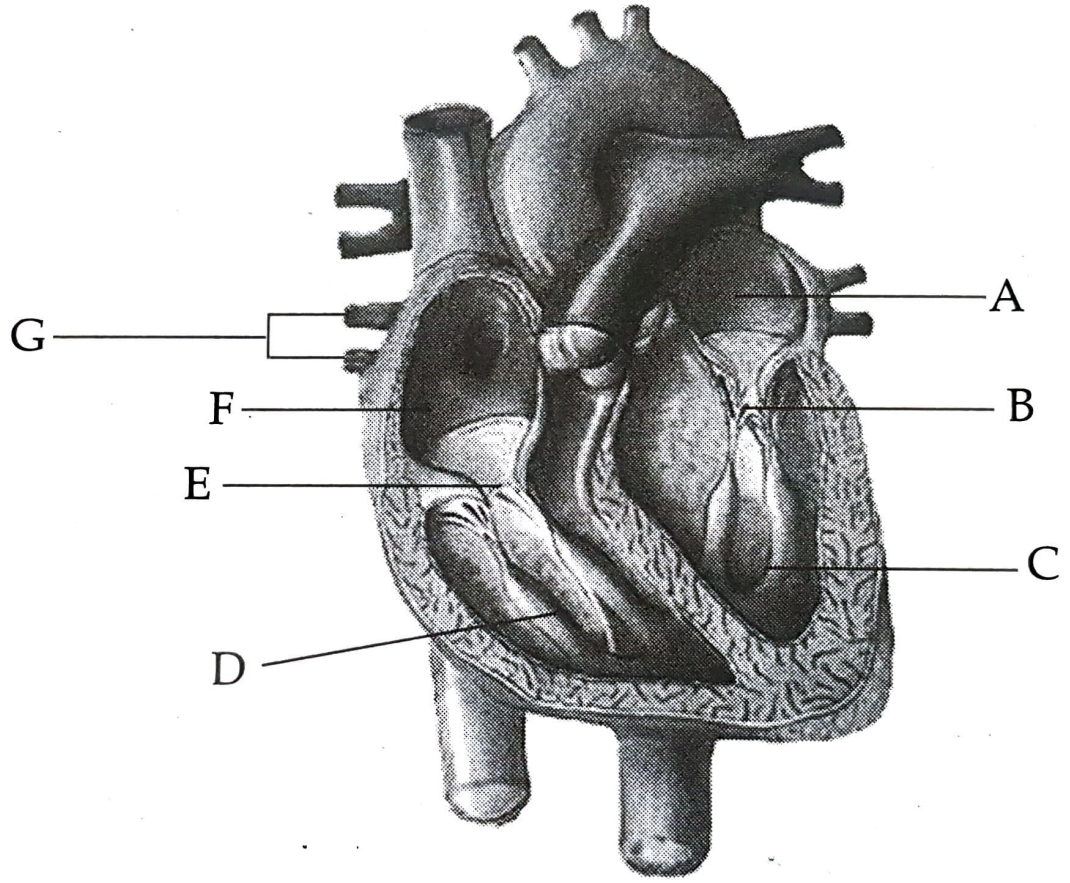
Hypophyseal Portal Vein

Hypophyseal portal vein collects venous blood from the hypothalamus of the brain and breaks into the second capillary system in the anterior part of the pituitary gland. This forms **hypophyseal portal system** which helps the hormones of hypothalamus to reach the anterior pituitary.

1. Categorise the blood vessels based on the thickness of their wall. Draw well-labelled diagrams and give the functions of each.
2. Explain the internal structure of human heart with the help of a diagram.
3. Make a list of the different blood vessels you have studied in this Chapter. Write the parts of the heart from where they arise and the parts of the body where they supply the blood.
4. How does circulation of blood take place in the body? List all the steps in a sequential order.
5. What is a portal system? Explain its importance with the help of an example.

1. Name the valves present in human heart and write their location.
2. What is a cardiac cycle? Why is it called so?
3. What is a portal vein?
4. State the main function of the coronary artery.
5. What is double circulation? Name two circulatory pathways in double circulation.
6. Why do people believe that heart is located on the left side of the thoracic cavity, though it is located in the middle?
7. What are the normal values of blood pressure in a healthy adult human?

3. Following figure represents the structure of the human heart. Study it carefully and answer the questions given below:



(*i*) Name the different parts of the heart labelled from A to F.

(*ii*) Which type of blood flows through the parts labelled B and E?

(*iii*) Name the blood vessel that carries blood to the part labelled F.

(*iv*) Name the circulatory circuit that is formed when the blood flows through the parts C and D.

(*v*) Name the valve present between the parts labelled A and C.