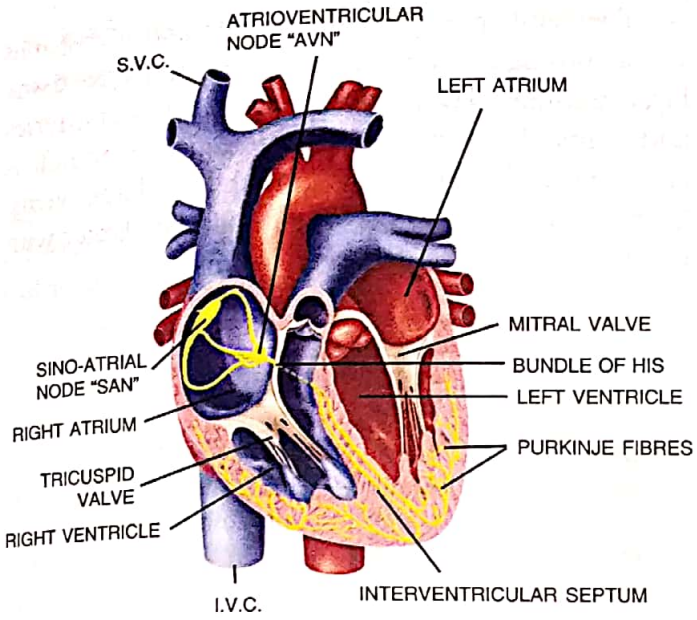


Fig. 8.9 : Internal structure of heart, showing location of "pacemaker" (SAN) and another contraction centre; "AVN" (atrioventricular node).

Sometimes the "pacemaker" becomes faulty causing heart trouble. An artificial "pace-maker" may be fixed in the heart of such a person.

Progress Check

1. Name the following :
   (i) Contraction phase of heart.
   (ii) The structure that holds the heart valves in position.
2. Mention the phase of heart beat in which both the atrio-ventricular valves are closed.

8.8.7 The blood vessels

The blood vessels are branched tubes extending from the heart to all parts of the body. They are of three kinds – arteries, capillaries and veins.

An ARTERY is a vessel which carries blood away from the heart towards any organ.

Characteristics of an artery :

- *thick muscular walls* (Fig. 8.10),
- a *narrow lumen* (the central bore), and
- the *blood in it flows in spurts* which correspond to the ventricular contractions of the heart.

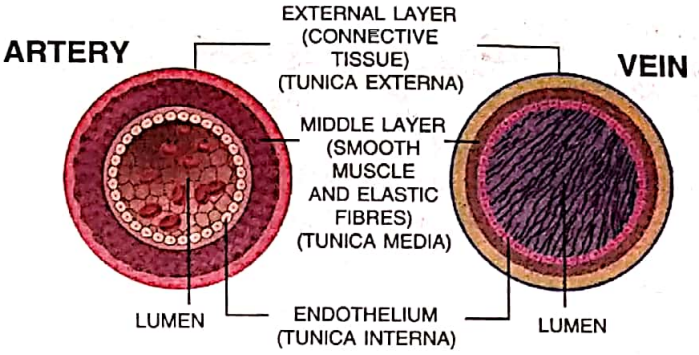


Fig. 8.10 : Structural difference between artery and vein

A VEIN is a vessel which carries the blood away from an organ towards the heart.

Characteristics of a vein :

- *thin muscular walls,*
- a *wider lumen,*
- the *blood in it flows uniformly*, and
- it contains *thin pocket-shaped valves* (Fig. 8.11) whose openings face in the direction of the heart. These valves prevent the backflow of the blood.

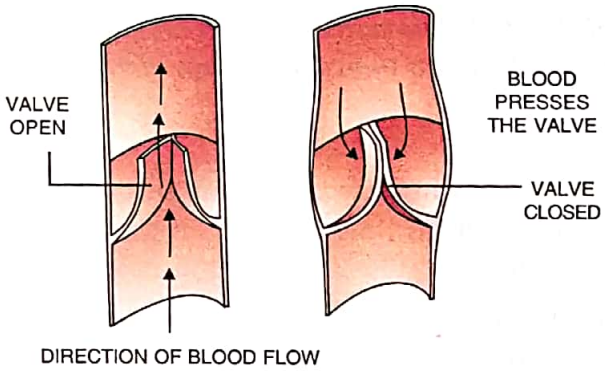


Fig. 8.11 : Valves in a vein regulate the flow of blood in the direction of the heart.

The smallest or the final branch of an artery is called an **arteriole**. Arterioles are highly muscular and can change their diameter manifold. The arteriole breaks up into capillaries (Fig. 8.12A).

A *CAPILLARY* is a very *narrow tube* (about 8 micrometres in diameter);

Characteristics of a capillary :

- its wall consists of a single layer of squamous epithelial cells (endothelium), and
- has *no muscles* (Fig. 8.12B). The total number of blood capillaries present in the whole body is almost inconceivable.

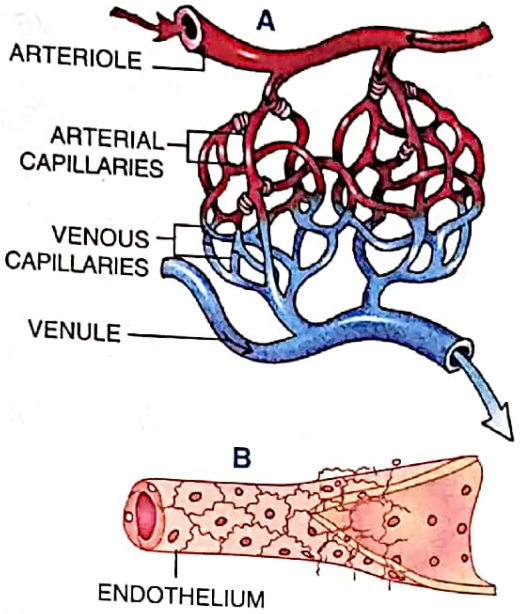


Fig. 8.12 : A. Diagrammatic relationship of artery, capillaries and vein (Blindly ending lymphatic vessels are also usually associated with blood capillaries). B. A capillary, formed of a single layer of epithelial cells.

If all the blood capillaries of the body were placed end to end in a row they could extend to a length of 100,000 kilometres. Their total wall surface would be more than 500 square metres.

Functions of capillaries :

(i) To allow **outward diffusion of oxygen** into the intercellular fluid and from there into the tissue cells.

(ii) To allow **inward diffusion of carbon dioxide** from the intercellular fluid.

(iii) To allow inward and outward **diffusion of substances** like glucose, amino acids, urea, hormones, etc.

(iv) To allow **leukocytes** (WBCs) **to squeeze out** through the capillary walls by means of amoeboid movement.

The capillaries have the power of dilating **(vasodilation)** and contracting **(vasoconstriction)** which respectively increases and decreases the blood supply to the body parts. Evidence of these changes in capillaries is seen in the colour of the skin.

- Walk in the hot sun — Face turns pink (increased blood flow).
- When it is too cold — Face turns bluish (reduced blood flow).

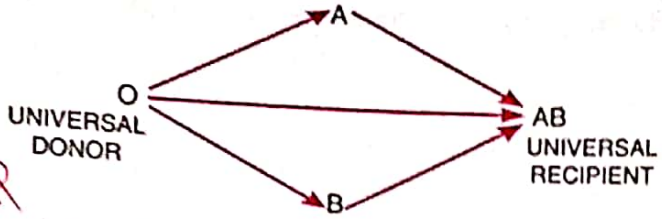
The capillaries gradually reunite and increase in size assuming the same three layers (connective tissue layer, muscular layer and endothelium) as in arteries and veins. The smallest united common branch is called a **venule**. The venules join to form larger veins. Compared with arterioles the venules are larger with much weaker muscular coat.

Table 8.3 Differences between arteries and veins

ARTERIES	VEINS
A. Definition : Blood vessels which carry blood **away from the heart and into an organ.**	**A. Definition :** Blood vessels which carry blood **away from an organ and towards the heart.** (Except hepatic portal vein)
B. Structure :	**B. Structure :**
1. Progressively branched, **decreasing in size.**	1. Progressively unite **increasing in size.**
2. Smallest artery **breaks into arterioles.**	2. Smallest vein **arises from venules.**
3. Have **thick and more muscular walls.**	3. Have **thin and less muscular walls.**
4. Walls are **elastic.**	4. Walls are **non-elastic.**
5. Have **narrower lumen.**	5. Have **wider lumen.**
6. Have **no valves** in their inner lining.	6. **Have valves** in their inner lining to prevent backward flow of blood.
7. Can constrict or dilate to control blood flow.	7. Can not constrict.
8. Usually **deeper** placed.	8. Usually more **superficial** (nearer to skin surface).
9. **Do not collapse** when empty.	9. **Collapse** when empty.
10. Blood flows with **jerks** and under **great pressure.**	10. Blood flows **continuously** and under very little pressure.
11. Carry fully **oxygenated blood** (except pulmonary artery).	11. Carry partially **deoxygenated** and CO_2 **laden blood** (except pulmonary vein).

Progress Check

1. Fill in the blanks
   (i) The ..... have thin and less muscular ....., and have ..... to prevent back flow of .....
   (ii) ..... carry blood to an organ and break up into ..... ending in capillaries.
   (iii) Walls of capillaries consist of a single layer of squamous ..... cells.
   (iv) The substances to and from the tissues diffuse through the walls of .....



Accordingly, O type blood can be given to persons of all types of blood *i.e.* to O, A, B & AB. Hence a person with O type is called **universal donor.** A person with AB type of blood can receive blood from all types, *i.e.*, from AB, A, B & O, and is, therefore, called **universal recipient.** A person with A type can receive blood from A and O types and a person with B type from B and O types only.

The summary of matching (**compatibility**) and mismatching (**incompatibility**) in ABO system is given in the table below :

Table 8.2 Summary of ABO Blood Group matching (Compatibility)

Blood group of Donor	Blood group of Recipient			
	A	B	AB Universal recipient	O
A	✓	×	✓	×
B	×	✓	✓	×
AB	×	×	✓	×
O Universal donor	✓	✓	✓	✓

Rh system : The blood of most people contains a substance called Rh factor. (Rh *stands for Rhesus, our common monkey, in which the factor was first discovered*). When the blood of such an individual (Rh-positive) is transfused into persons lacking it (Rh negative), the blood of the recipient develops an antibody for Rh substance (gets sensitized) within about two weeks of transfusion. Now, if a second transfusion be given to such Rh-negative person, the antibody produced by the first transfusion causes a reaction with the transfused blood, which may even lead to death. This is similar to the development of an allergy.

Rh factor in pregnancy : An Rh-negative woman may become sensitive if she carries an Rh-positive child in her uterus (when the husband is Rh-positive). The first Rh-positive child will be normal, but if it sensitizes the mother, the second positive child if conceived soon, may have a problem, sometimes leading to the death of foetus and abortion.

[**Rh-positive** may be written in short as Rh+ve or as Rh^+ and similarly, the **Rh-negative** may be written as **Rh-ve** or as Rh^-]. People with Rh^+ blood group have D antigens on the surface of RBCs, while people with Rh^- blood group lack these antigens.

Progress Check

1. State which of the following statements are True.
   (i) Process of coagulation starts with the release of a substance from RBCs.
   (ii) Blood fails to clot readily in the case of deficiency of calcium.
   (iii) The solid fibrin and thrombin are one and the same thing.
   (iv) The clear liquid that oozes out after the formation of a clot is serum.
2. Name the following :
   (i) The category of vitamin required for clotting of blood.
   (ii) Any two diseases related with blood clotting.
   (iii) The antibodies present in the plasma of O type blood group.
   (iv) The animal for which Rh stands in the context of blood group.

8.8 BLOOD CIRCULATORY SYSTEM

The circulatory system consists of **heart, blood and blood vessels (arteries, veins** and **capillaries).**

8.8.1 The Heart

Location (not on the left side, but it is felt so.)

The heart is right in the centre between the two lungs and above the diaphragm. The narrow end of the roughly triangular heart is pointed to the left side (Fig. 8.6) and during working, the contraction of the heart is most powerful at this end giving a feeling that the heart is on the left side.

Covering : The heart in adult humans is about the size of our closed fist – 12 cm in length and 9 cm in width. It is protected by a double walled membranous covering called **pericardium.** It contains lubricating pericardial fluid which reduces friction during heart beat and protects it from mechanical injuries.

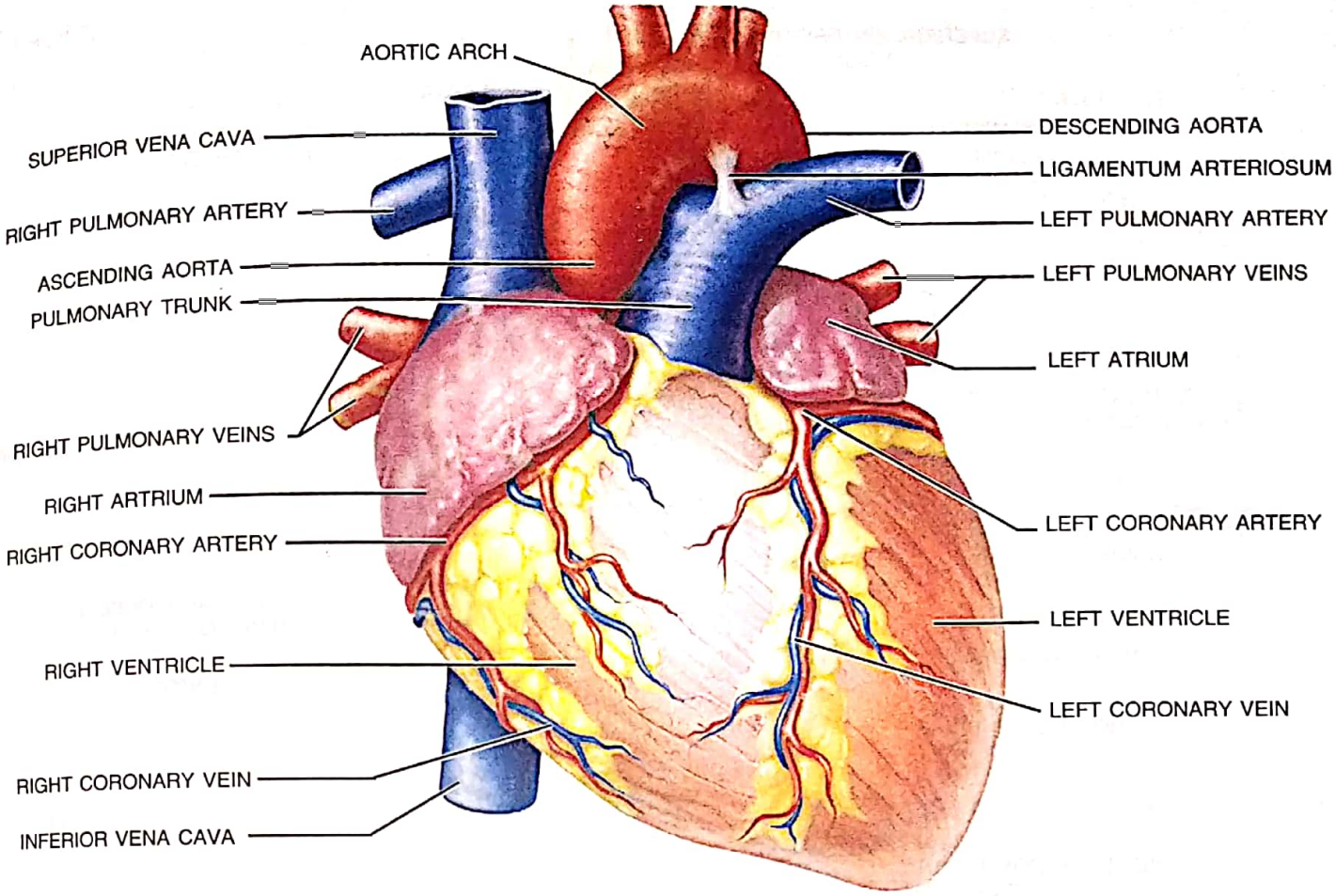


Fig. 8.6 Front view of the human heart

Chambers of the heart (Fig. 8.7)

The heart consists of four chambers – two upper **atria** (sing. *atrium*) and two lower **ventricles**. The **atria** (also called **auricles**) **have thinner walls** because their major function is to receive blood from the body and *pump it into the very next ventricles.*

The **ventricles have thick muscular walls** (Fig. 8.7) because they have to pump blood to long distances. The right ventricle pumps blood only up to the lungs for oxygenation. But the left ventricle pumps it up to the farthest points in the body, such as, up to the toes in the feet or up to the brain against gravity, and so its walls are thicker.

8.8.2 Blood vessels entering and leaving the heart (Figs. 8.6, 8.7 and 8.8)

A. Blood vessels entering the heart

The right atrium receives two large vessels – **anterior vena cava** and **posterior vena cava.**

(1) **Anterior vena cava** (also called superior vena cava or precaval) brings deoxygenated blood from the anterior or upper regions of the body including head, chest and arms.

(2) **Posterior vena cava** (also called inferior vena cava or postcaval) brings blood from the posterior or the lower region of the body including abdomen and legs.

The left atrium receives 4 pulmonary veins (two from each lung). The pulmonary veins bring oxygenated blood.

B. Blood vessels leaving the heart

Arising from the ventricles are two large blood vessels.

1. The **pulmonary artery** arises from the right ventricle and carries deoxygenated blood to the lungs for oxygenation.
2. The **aorta** arises from the left ventricle and carries oxygenated blood to supply it to all parts of the body.

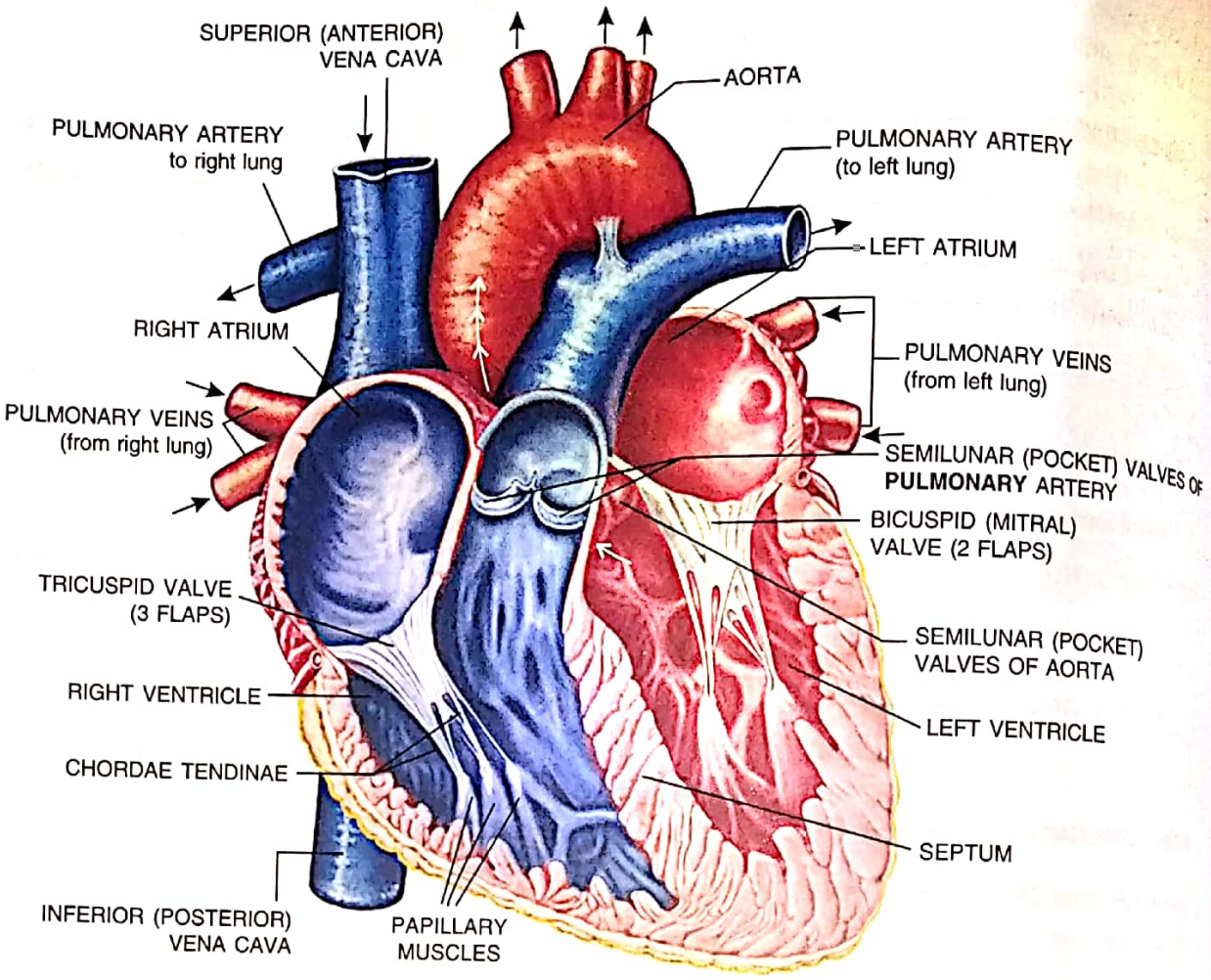


Fig. 8.7 Internal structure of the human heart and the associated blood vessels (diagrammatic)

Coronary arteries : You can also see in Fig. 8.6 two **coronary arteries** (right and left) arising from the base of the aorta. These supply blood to the heart muscles. When there is a blockage in any coronary artery or in any one or more of their branches, there is a **"deadening"** of the corresponding area of the heart muscles leading to **"myocardial infarction"** or a heart attack in popular language. The coronary veins collect blood from heart walls and pour it into the right auricle. **"Angina pectoris"** is the chest pain due to insufficient supply of blood to the heart muscle.

Heart — A bank cashier!

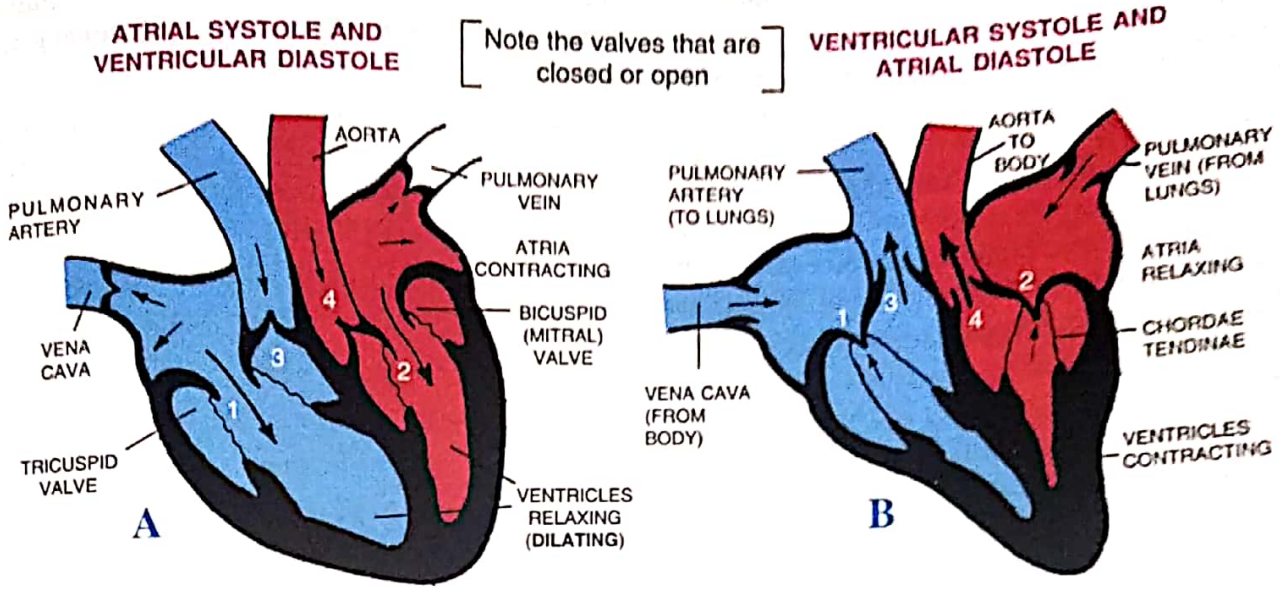
The bank cashier handles so much money everyday, but what he can use for himself is only the salary he gets. Is it not similarly true for the heart? It handles so much blood every minute but it can use only that much which it gets through coronary arteries supplying its muscular walls.

8.8.3 Valves regulate the flow of blood in a single direction

There are four valves in the heart as follows:

1. **Right atrio-ventricular valve** is located at the aperture between the right auricle and the right ventricle. It has **three** thin triangular leaf-like flaps (cusps) and is therefore also called **tricuspid valve**. The apices (pl. of apex) of the flaps are held in position by tendinous cords (**chordae tendinae**) arising from the muscular projections of the ventricle wall known as **papillary muscles.**
2. **Left atrio-ventricular valve** is located in a similar way on the left side of the heart. It has **two** cusps, and is, therefore, called **bicuspid** (also **mitral**) **valve.**
3. **Pulmonary semilunar valves** are located at the opening of the right ventricle into the

Fig. 8.8 Two main phases of heart beat: A – Atrial systole and B – Ventricular systole.



ATRIAL SYSTOLE

- Atrial (auricular) muscles contract
- Openings of vena cava and pulmonary vein close
- Blood enters ventricles by crossing through tricuspid valve (1) and bicuspid valve (2).
- Semilunar valves at the roots of pulmonary artery (3) and aorta (4) are closed producing the sound "DUP", to prevent flow of blood back into ventricles.

VENTRICULAR SYSTOLE

- Ventricular muscles contract.
- Tricuspid valve (1) and bicuspid valve (2) close with a jerk producing the sound "LUBB".
- Blood passes into aorta and pulmonary artery through semilunar valves (3) & (4).
- Atria draw in blood through the openings of vena cava and pulmonary vein.
- Chordae tendinae hold the valves in position preventing their upturning due to pressure exerted by the contracting ventricles

pulmonary artery. These are pocket-shaped and three in number.

4. **Aortic semilunar valves** are located at the point of origin of aorta from the left ventricle. These are also three in number and pocket-shaped.

8.8.4 Circulation of blood in the heart

- It starts with the **contraction of the two atria** (auricles). The ventricles at this time are **relaxing** (or **dilating**) and are empty (Fig. 8.8A). Therefore, the blood from the atria passes into the ventricles easily.
- Next, the **ventricles contract**, and the atria relax. The blood from the ventricles under pressure tends to return to the atria, but the flaps of the two **cuspid** (meaning pointed projection) **valves** get tightened and puffed up, thus closing the passage and preventing the return of blood

Progress Check

1. Fill in the blanks :
   (i) Ventricles have ..... walls when compared with those of auricles.
   (ii) Ventricles give rise to two large blood vessels called ..... and .....
2. Where are the following located ?
   (i) Tricuspid valve (ii) Mitral valve
   (iii) Pulmonary semilunar valves
3. Can you answer why the pulmonary artery shown in Fig. 8.6 is blue in colour ?