UNIT 1 ANATOMY OF THE HEART

Structure

1.0 OBJECTIVES

After reading this unit, you should be able to:

- understand the proper position of a heart inside the thorax;
- know the *various anatomical* structures of various chambers of heart and various valves of heart;
- know the arterial supply, venous drainage and lymphatic drainage of heart; and
- describe the surface marking of heart.

1.1 INTRODUCTION

The human heart is a cone-shaped, four-chambered muscular pump located in the mediastinal cavity of the thorax between the lungs and beneath the sternum, designed to ensure the circulation through the tissues of the body.

The cone-shaped heart lies on its side on the diaphragm, with its base (the widest part) upward and leaning toward the right shoulder, and its apex pointing down and to the left.

Structurally and functionally it consists of two halves–right and left. The right heart circulates blood only through the lungs for the purpose of pulmonary circulation. The left heart sends blood to tissues of entire body/systemic circulation.

The heart is contained in a sac called the pericardium. The four chambers are right and left atria and right and left ventricles. The heart lies obliquely across the thorax and the right side is turned to face the front. Viewed from the front, the sternocostal surface of the heart (Fig. 1.1) mainly consists of the anterior walls of the right atrium, right ventricles and the left ventricle. A small part of the left atrium and left ventricle forms the left border and the apex is formed by the left ventricle. The right atrium and ventricle are separated by the anterior part of the atrioventricular groove, also called the coronary sulcus. The two ventricles are separated by the interventricular groove. The sharp inferior border separates the sternocostal surface from the diaphragmatic surface. The inferior border meets the left border at the apex.

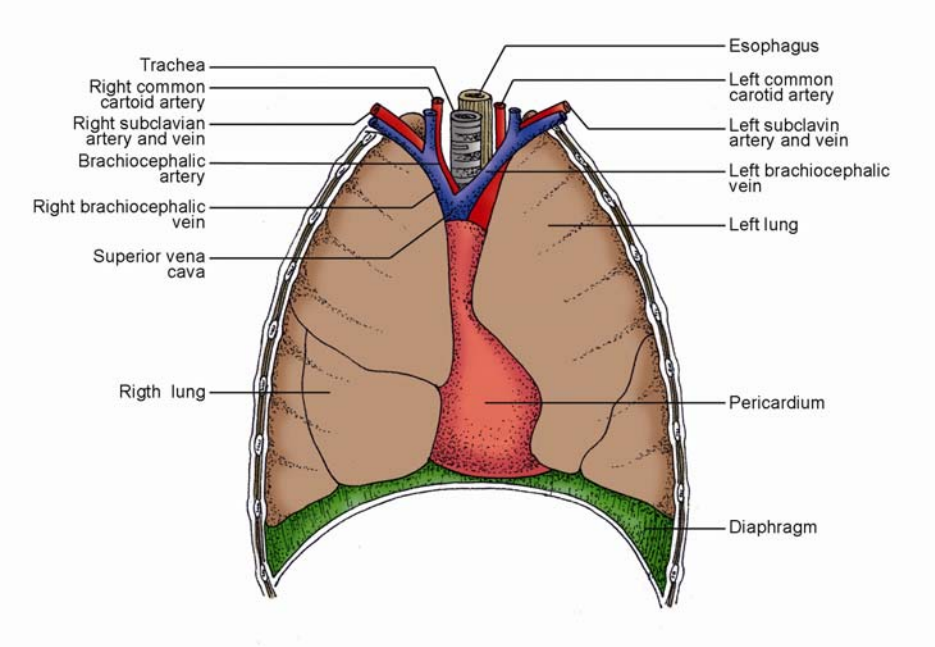

Fig. 1.1: Front view of the heart and lungs

The upper border is formed mainly by the left atrium. The inferior or the diaphragmatic surface (Fig. 1.2) is formed by the left ventricle (two-thirds) and one third by the right ventricle. The two ventricles are separated by the posterior interventricular groove. The posterior surface or base of the heart (Fig. 1.3) is formed mainly by the left atrium and a small part by the posterior part of the right atrium.

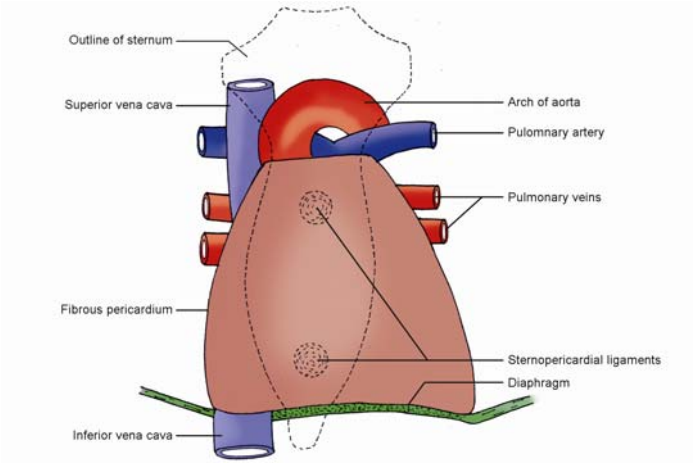

Fig. 1.2: Sternocostal surface of the heart

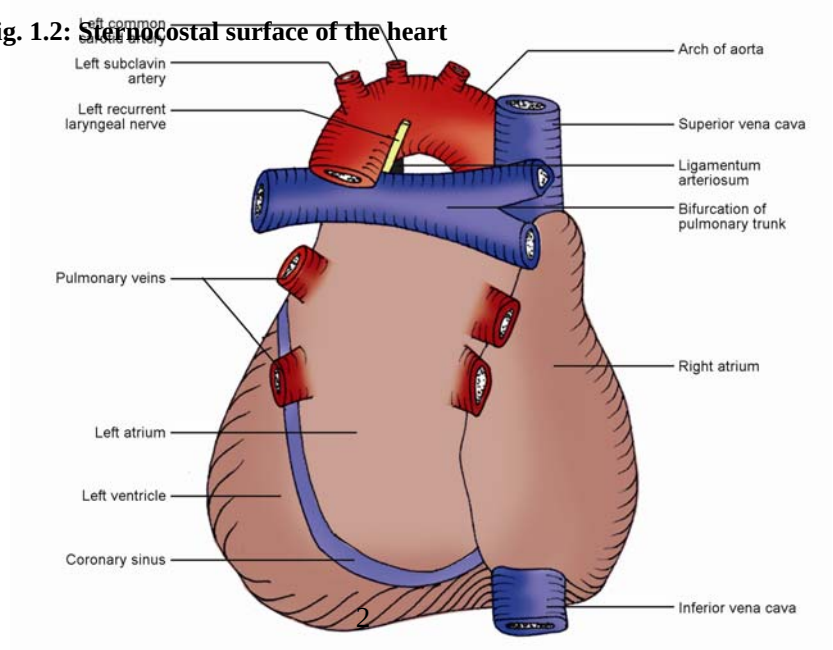

Fig. 1.3: Base of the heart

1.2 CHAMBERS OF HEART

Interior of the Heart

The ventricles are separated from each other by the interventricular septum and the atria are separated from each other by the interatrial septum. The interior of the right atrium (Fig. 1.4) has a rough anterior part, the atrium proper and a smooth part called the ***sinus venarum***. Also it has an appendage called the ***auricle***. All the large veins open into the smooth part. The opening of the superior vena cava is situated in its upper and posterior part and that of inferior vena cava into its lower part, close to the interatrial septum. The opening of the inferior vena cava is bounded by a fold called the valve of the inferior vena cava. Just to the left of this is the opening of the coronary sinus. Besides these there are small openings called ***venae cordis minimae*** for small veins of the heart.

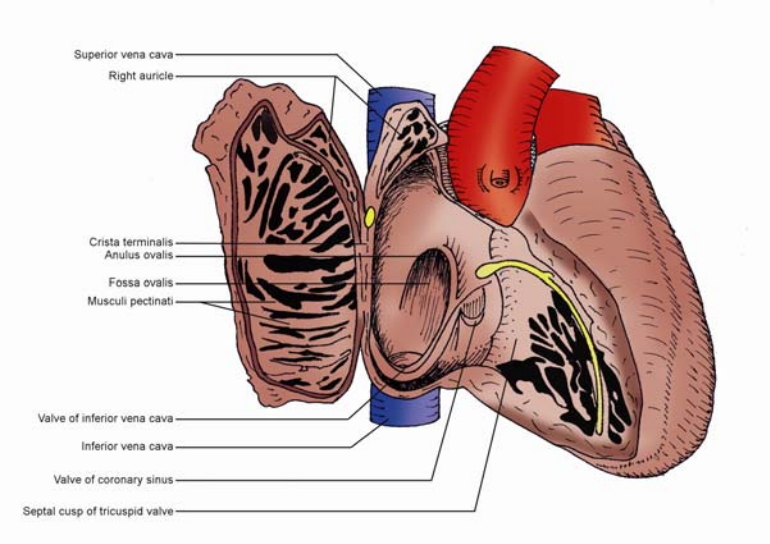

Fig. 1.4: Interior of right side of heart

The sinus venarum and the atrium proper meet at a muscular ridge called the ***crista terminalis*** which corresponds to a groove externally called the ***sulcus terminalis***. ***Musculi pectinati*** are the ridges found in the atrium proper. The interatrial septum shows an oval depression called the ***fossa ovalis*** in its lower part, the upper margin of which forms a curved ridge called the ***limbus fossa ovalis***. The wall of the fossa ovalis is thin and represents the embryonic septum primum. The limbus fossa ovalis represents the lower curved edge of the septum secundum. The right atrium opens into the right ventricle through the right atrioventricular orifice, which is guarded by the tricuspid valve.

Interior of the Left Atrium

The left atrium is a thin walled cavity. Most of the wall is smooth. Musculi pectinati are present only in the auricle of the atrium. The interatrial septum separates the cavity of the right atrium from the left atrium. There may be a depression corresponding to the fossa ovalis in the septum. The four pulmonary veins, two rights and two left from the lungs open into the upper lateral part of the left atrium. The left atrioventricular orifice is situated anteroinferiorly and is guarded by the mitral orifice.

Interior of the Ventricles (Fig. 1.5)

Each ventricle has an inflow part beginning just in front of the corresponding atrioventricular orifice and running forwards to the left towards the apex of the heart. The cavity turns upwards to form the outflow part. The inflow part of each ventricle has a

rough inner surface because of trabaculae carneae which are bundles of muscle fibers. The wall also has fingerlike processes attached to the ventricular wall at one end and free at the other. These are called ***papillary muscles***. These are functionally related to the atrioventricular valves.

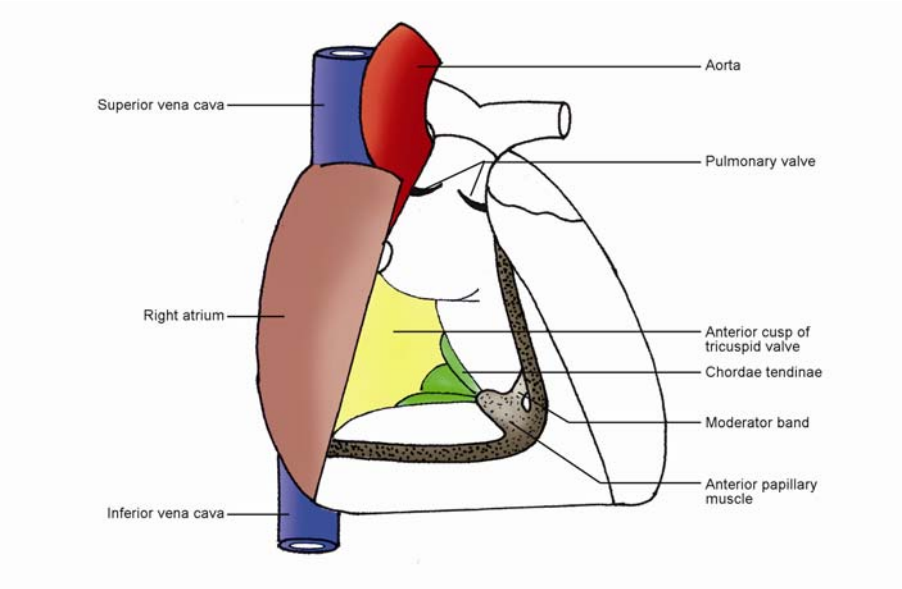

Fig. 1.5: Interior of ventricles

In contrast to the rough wall of the inflow parts, the outflow part of the two ventricles are smooth. The out flow part of the right ventricle is called the infundibulum. It leads to the pulmonary trunk separated by the pulmonary valve. The inflow and outflow parts make an angle of about 90 degrees with each other. The upper part of their junction is marked by a prominent bulging of the myocardium called the supraventricular crest. The outflow part of the left ventricle is called the aortic vestibule. It leads to the ascending aorta separated by the aortic valve. The aortic vestibule forms an acute angle with the inflow path, running sharply upwards and to the right to reach the aortic orifice. It crosses behind the infundibulum from left to right. This explains how the aortic orifice comes to lie to the right of the pulmonary orifice. A large part of the left ventricle is overlapped in front by the right ventricle.

The wall of the left ventricle is much thicker than the wall of the right ventricle. The outline of the left ventricle is roughly circular. In contrast the cavity of the right ventricle is crescentic in outline. This is because of the fact that the interventricular septum bulges into the right ventricle so its right surface is convex, and its left surface is concave.

Check Your Progress 1

Describe the interior anatomical structure of right atrium.

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1.3 ORIFICES OF HEART

Atrio-ventricular Orifices

The right and left atrio-ventricular orifices are oval apertures. The openings lie in a plane that is almost vertical with a slight downward inclination. Each opening is directed forwards then left and slightly downwards. Each orifice is strengthened by a variable amount of fibrous tissue around it. It is guarded by a valve which allows flow of blood, only from atrium to ventricle but not in the reverse direction. The valves are made up of cusps which are thin leaflets of tissue. Each cusp consists of a double fold of endocardium within which is some fibrous tissue. It has two surfaces, ventricular and atrial. It has a

base which is attached to the ring of fibrous tissue around the Atrio-ventricular orifice. It has an apex and free margins. The margins of adjoining cusps are fused to each other for some distance so that the cups form a continuous membrane. The apex and the margins give attachment to tendinous strands called the ***chordae tendinae***. The chordae tendinae are also attached to the ventricular surfaces of the cusps which are therefore, rough in contrast to the atrial surface which are smooth. At their other end the chordae tendinae are attached to the apices of the ***papillary muscles***. Each papillary muscle through the chordae tendinae is attached to the adjoining part of the two cusps. As a result the adjoining margins of the two cusps are drawn together when the papillary muscle contracts.

The features peculiar to each orifice are: the right orifice is larger than the left; it admits the tips of three fingers. In contrast the left orifice is smaller and admits the tips of two fingers. The arrangements of cusps and papillary muscles also differ.

The Tricuspid Valve (Fig. 1.6)

It is made up of three cusps, anterior, posterior and septal. The septal cusp is attached to the medial margin. The anterior cusp is attached to the superior-lateral part of the margin. The posterior cusp is attached to the inferio-lateral part of the margin. The anterior cusp separates the inflow part of the right ventricle from the infundibulum.

The chordae tendinae attached to these cusps arise from a large anterior papillary muscle, a large posterior papillary muscle and directly from the interventricular septum or from small papillary muscles attached to the septum. The chordae tendinae arising from the anterior papillary muscle are attached to the anterior and posterior cusps, those from the posterior muscle to the posterior and septal cusps and those from the septal muscles to the anterior and septal cusps.

The base of the anterior muscle is attached to the sternocostal wall of the right ventricle. The base of the posterior muscle is attached near the angle between the diaphragmatic wall and the interventricular septum. The base of the anterior papillary muscle is connected to the interventricular septum by a special band called the ***septo-marginal trabecula or the moderator band***.

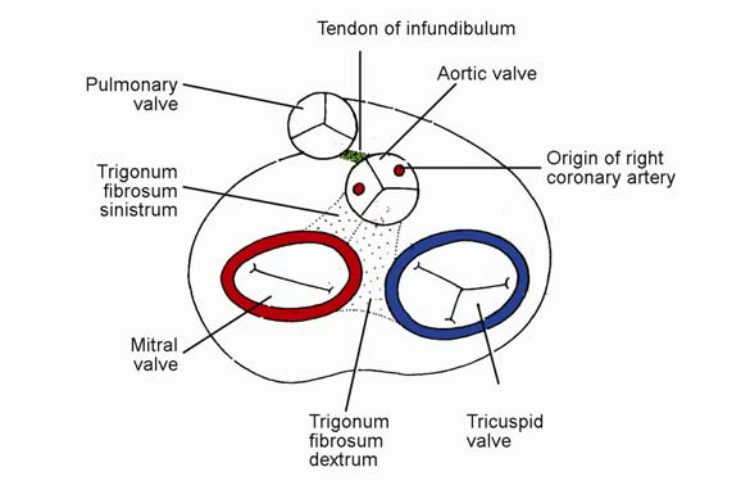

Fig. 1.6: Base of ventricles exposed by removal of the atria

The Mitral Valve

This valve has the same basic features as of the Tricuspid Valve. It has an anterior and a posterior cusp. The anterior cusp is larger and is attached on the upper right part of the margin of the left AV orifice. The posterior cusp is attached to the lower left part. The anterior cusp intervenes between the Mitral and Aortic orifices. There is, therefore, a forceful blood flow on both surfaces of this cusp. The papillary muscles connected to the cusp of the mitral valve are also called the anterior and posterior. These terms are misleading. The anterior papillary muscle arises from the sterno-costal wall of the ventricle near the lower end. The posterior papillary muscle arises from the diaphragmatic

wall near its anterior end. The two muscles run backwards almost parallel to each other and their origins are close together. The chordae tendinae arising from these papillary muscles pass to the adjoining part of the two cusps of the mitral valve.

The Aortic and Pulmonary Orifices (Fig. 1.7)

These circular orifices are located at the upper ends of the outflow parts of the left and right ventricles respectively. The pulmonary orifice which is 3 cms, is 0.5 cm larger than the aortic orifice. The aortic orifice is placed in front and to the right of the mitral orifice. The pulmonary orifice is placed above and to the left of the tricuspid orifice and the aortic orifice intervening between them. The pulmonary orifice is guarded by the pulmonary valve and the aortic orifice by the aortic valve. Each valve consists of three semilunar cusps. Each cusp is triangular. It has a convex edge which is attached to the part of the margin of the orifice. It has two free margins that meet at the apex of the cusp. Each cusp consists of a double fold of endocardium with some fibrous tissue in it. The region of the apex is thickened to form a nodule while crescentric parts near the free edges are called ***lunules***.

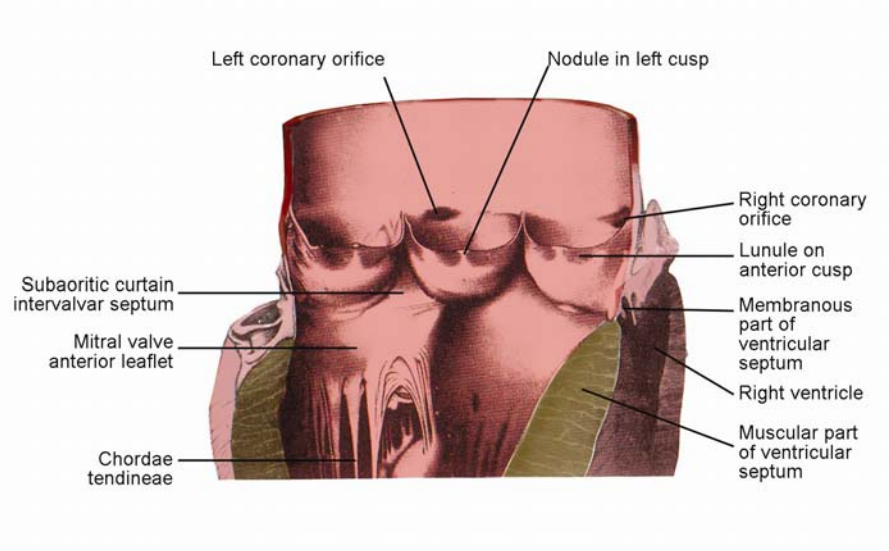

Fig. 1.7: Aorta laid open to show the semilunar valves

The Interventricular Septum (Fig. 1.8)

It corresponds to the anterior and inferior interventricular grooves. Its right side is convex and bulges to the right ventricle. The septum has a posterior border which separates the right and left AV orifices and is continuous with the interatrial septum. The greater part of the septum is thick and muscular but a small area near the posterior margin is membranous. The septal cusp of the tricuspid valve is attached vertically on this part of the septum and divides it into an anterior part that separates the right and left ventricles and a posterior part which separates the left ventricle from the right atrium. The latter part is therefore, referred to as the atrioventricular septum.

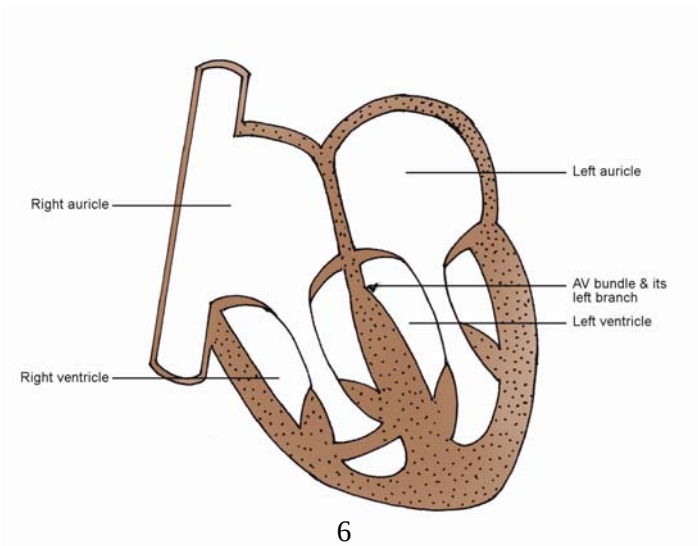

Fig. 1.8: Section of the heart showing the ventricular septum

Check Your Progress 2

Describe the sructure and functions of mitral value.

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1.4 THE CONDUCTING SYSTEM OF THE HEART

The fibrous rings of the four valves of the heart are continuous with each other. They not only form the basis for the attachment of the corresponding valve cusps but also form an electrical barrier between the atrial and ventricular muscle of the heart. This fibrous network surrounding the valve openings is called the “fibrous skeleton” of the heart.

Electrical impulses can spread through the heart muscle but not through the fibrous skeleton of the heart. Each beat of the heart is initiated in the right atrium at the upper end of the crista. The area where this occurs is called the sinoatrial node (SA node). From the SA node rhythmic impulses pass through the atrial musculature, causing them to contract and discharge blood into the ventricles. It is likely that impulses spread through the right atrial wall in several specialized bundles, both through to the left atrium and towards the fibrous skeleton of the heart. However this is not universally accepted. The impulses do not pass directly through the skeleton of the heart so the ventricles are relaxed while atrial contraction occurs. Impulses eventually reach the interatrial septal region near the opening of the coronary sinus. Here, just above this opening, close to the septal leaflet of the tricuspid valve, is another specialized group of myocytes called the atrioventricular node (AV node).

Impulses from the AV node travel onwards though the atrioventricular bundle of HIS. This short bundle pierces the fibrous skeleton and arrives in the region of the thinner membranous part of the interventricular septum. In the interventricular septum the bundle divides into right and left plura or bundle branches, which pass to the respective ventricles. The left crus supply the papillary muscles in the left ventricle and then spreads out as a network in the ventricular wall. The right crus take impulses to the septal and posterior papillary muscles of the right ventricle. It then proceeds in the septo marginal trabecula to the anterior papillary muscle. Eventually it terminates and sends out many branches to form the Purkinje network.

Impulses reaching the AV node from the atria are delayed a little as they pass through the trunk and crura. The impulses first reach the papillary muscles and their contraction closes both atrioventricular valves. Further rapid spreading of the impulses causes simultaneous contraction of both ventricles and blood is ejected in to the pulmonary trunk and aorta. Although the heart can beat by itself each stroke is initiated at the SA node, inherent activity is influenced by the autonomic nervous system. Sympathetic fibers to the heart carry impulses that produce an increase in the rate of impulses generated at the SA

node. The heart beats faster. Para sympathetic activity on the other hand slows down the rate.

There is in fact a three-tier system of rhythmic activity in the heart. First, the muscle fibers themselves have a built-in capacity for contracting rhythmically. If the SA node is destroyed the muscle still contracts, although at a slower rate. The second tier of control is the SA node which under normal circumstances dictates the frequency of contraction. Finally the autonomic nervous system influences the rate according to the particular requirements of the body for blood. One must not of course forget the direct effects of noradrenalin from the adrenal gland.

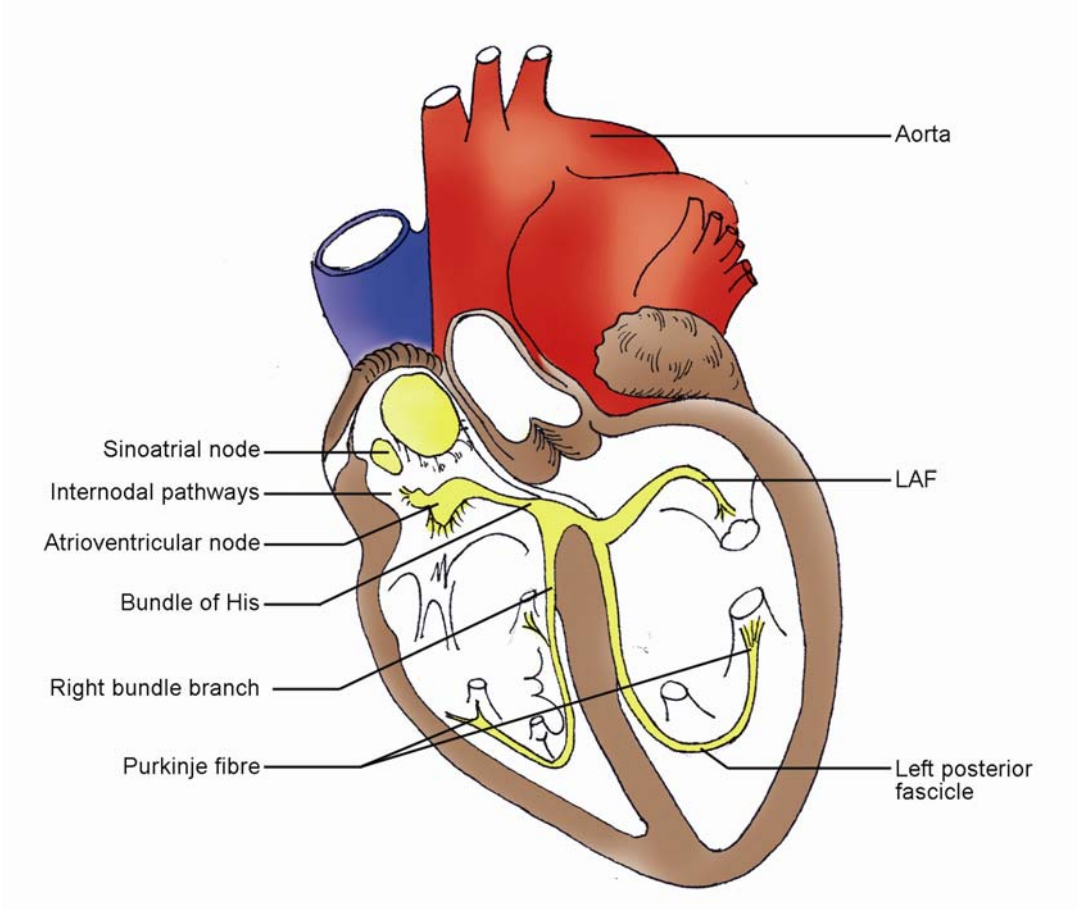

Fig. 1.9: Conducting system of the heart

Cardiac Branches and Cardiac Plexuses

The vagus gives of one superior cervical cardiac branch and an inferior cervical cardiac branch in the neck. These branches descend into the thorax and take part in performing the cardiac plexuses described below. Additional cardiac branches arise in the superior mediastinum and also from the recurrent laryngeal branches. The superficial cardiac plexus is located just below the arch of the aorta, close to the ligamentum arteriosum. It is formed by the inferior cervical branch of the left vagus nerve and the superior cervical branch of the left sympathetic trunk. The deep cardiac plexus is situated in front of the bifurcation of the trachea. It receives several branches from the right and left vagus nerves. They are right superior and inferior cervical cardiac branches, left superior cervical cardiac branch, branches from the right and left vagi arising in the thorax and branches from the right and left recurrent laryngeal nerves. The plexus also receives numerous cardiac branches from the right and left sympathetic trunks. Branches from the superficial and deep cardiac plexuses supply the heart.

1.5 BLOOD SUPPLY OF THE HEART

The heart is supplied exclusively by the right and left coronary arteries. The coronary arteries are functional end arteries. There is no effective anastamosis between right and

left coronary arteries. Therefore, in the event of sudden block of one artery the area of myocardium supplied by that artery undergoes infarction.

Right Coronary Artery

Right coronary artery arises from the anterior aortic sinus. It runs down along the anterior part of the coronary sulcus, reaches the lower border of heart turns round the lower border and lies in the posterior part of the atrioventricular groove. It ends by anastomosing with the circumflex branch of the left coronary artery. Just before its termination it gives off the posterior interventricular branch that runs downwards, forwards and to the left in the posterior interventricular groove. The branches of the right coronary artery are, branches to SA node, branches to right atrium and right ventricle, right marginal artery, posterior interventricular branches and branches to AV node. It is to be noted that the right coronary artery supplies the right atrium, right ventricle and conducting system of the heart.

Left Coronary Artery

The left coronary artery arises from the left posterior aortic sinus. It runs to the left behind the pulmonary trunk and appears between left auricle and pulmonary trunk. In that position the artery divides into anterior interventricular branch and circumflex artery. Circumflex artery turns round the left border of the heart runs through the coronary sulcus between left atrium and left ventricle on the posterior surface of the heart in the posterior part of the atrioventricular groove. It ends by anastomosing with the terminal part of the right coronary artery. The left coronary artery is larger in size than the right coronary artery. The average diameter of left coronary artery is 4 mm. The left coronary artery supplies left ventricle, left atrium, anterior two third of the IV septum and adjacent part of the right ventricle.

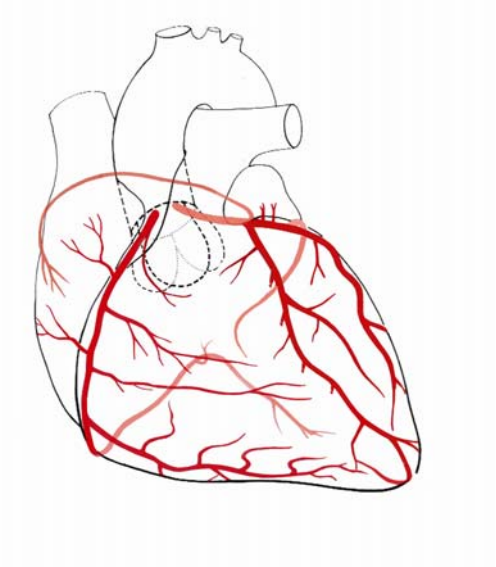

Fig. 1.10: Arteral supply of the heart

The branches of the left coronary artery are anterio interventricular artery (AIV artery) and circumflex artery which is considered to be the continuation of the left coronary artery. It gives rise to the left marginal artery and also few branches for the supply of the posterior surface of the left atrium and left ventricle. Anterior interventricular branch of the left coronary artery supplies the left anterior surface of the left ventricle including the apex, adjoining part of the left ventricle and anterior two-third of the IV septum. The anterior interventricular artery runs along the anterior interventricular sulcus, turns around the inferior border of the heart and anastamoses with the posterior interventricular branch of the right coronary artery. The AIV artery sends a few branches to the anterior surface of the left ventricle. The largest among these is called the diagonal artery. All these arteries arise at an acute angle so that they can are most susceptible to blockage by emboli.

Venous Drainage of the Heart (Fig. 1.11)

The coronary sinus is the main vein of the heart and is about 3 cm. long. It lies in the coronary sulcus at the posterior surface of the heart in the posterior atrio-ventricular groove. The coronary sinus opens into the right atrium. Its tributaries are the great cardiac vein, the middle cardiac vein, the small cardiac vein, the posterior vein of the left ventricle and the oblique vein of the left atrium. In addition to the above some anterior cardiac veins lying on the left ventricle open into the right atrium. A number of ***venae cordis minimae*** drain directly into the chambers of the heart.

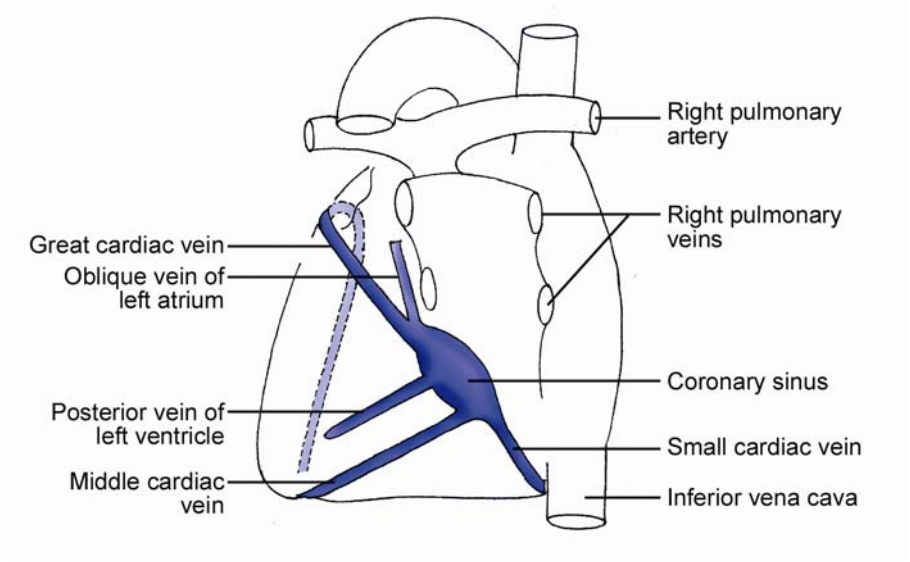

Fig. 1.11: Venous drainage of the heart

Pericardium

The heart is enclosed in a membranous sac called the pericardium. It has ***two*** layers- the ***fibrous*** pericardium which is the outer layer and the ***serous*** pericardium that lies inside the fibrous pericardium. The ***serous pericardium has two layers*** – the outer parietal and the inner visceral layer. The parietal layer lines the fibrous pericardium and the visceral layer the surfaces of the heart. This visceral layer is also called the epicardium.

The pericardium is conical in shape, the base being directed downwards and is partly fused with the tendon of the diaphragm. The apex is the upper end and is fused with the great blood vessels.

The Lymphatic Drainage of the Heart

The heart is drained by vessels that travel in the interventricular and atrioventricular grooves. One set runs in the anterior part of the atrio-ventricular groove. The vessels of this set cross the aorta and reach the brachio-cephalic nodes. Another set of vessels runs along the anterior interventricular groove and ends in the inferio tracheo-bronchial nodes.

Check Your Progress 3

1) Describe the arterial supply of heart.

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2) What is Pericardium? Describe its layer and functions.

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1.6 SURFACE MARKINGS OF THE HEART

The Upper Border of the Heart

A: Mark a point on the lower border of the left second costal cartilage 1.2 cm away from the sternal margin.

B: Mark a point on the upper border of the right third costal cartilage 1.2 cm away from the sternal margin.

Join these two points with a straight line. The line marks the upper border of the heart which is formed by the atria. Right atrium forms the right one-third and the left atrium forms the left two third of the upper border.

Right Border of the Heart

C: Mark a point on the right sixth costal cartilage 2.5 cm away from the sternal margin.

Connect points **B** and **C** a lie which is slightly convex to the right and this line will mark the right border. The right border is formed by the right atrium.

Lower Border of the Heart

D: Mark a point in the left fifth intercostal space 9 cm. from the median plane.

Join points **C** and **D** by a line which passing through the xiphisternal joint. The right two-thirds of the lower border is formed by the right ventricle and the left one third is formed by the left ventricle.

Left Border of the Heart

Connect point **A** and **D** by line which is convex to the left. The left border is formed by the left ventricle except at its upper end which is formed by the left auricle where there is a slight concavity.

The left atrium is not visible at the anterior surface of the heart.

Valves of the Heart

Pulmonary valve is surface marked at the sternal end of the left 3rd costal cartilage.

Aortic valve is surface marked at the sternal margin of the left 3rd intercostal space.

Mitral valve is surface marked at the sternal margin of the 4rd left costal cartilage.

Tricuspid valve is surface marked at the midsternum opposite the 4th intercostal space, however, it is to be noted that the actual position of the valves does not coincide with the auscultatory areas.

The auscultatory areas are as follows:

Pulmonary valve is best heard at the left second intercostal space near the sternum.

Aortic auscultatory area is at the right second intercostal space near the sternum.

Mitral auscultatory area is just over the apex of the heart.

Tricuspid auscultatory area is at the lower end of the body of the sternum.

The auscultatory areas are the sites where the closure of valves are best heard.

Check Your Progress 4

How you will mark the left border of a heart?

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1.7 LET US SUM UP

In this unit, you have learnt that heart is a muscular organ situated in thorax covering with pericardium and consist of four chambers i.e. right atrium, left atrium, right ventricle and left ventricle. These atrium and ventricles are separated by interatrial septum and interventricular septum respectively. Left atrium and left ventricle as well as right atrium and right ventricle are connected with atrioventricular orifices where Mitral valve and tricuspid valve are situated respectively. Heart has its own special conduction system.
It also has coronary arteries for its blood supply. The border of the heart as well as valve of the heart can also be identified by surface marking of the heart.

1.8 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

The interior of the right atrium has a rough anterior part, the atrium proper and a smooth part called the ***sinus venarum***. Also it has an appendage called the ***auricle.*** All the large veins open into the smooth part. The opening of the superior vena cava is situated in its upper and posterior part and that of inferior vena cava into its lower part, close to the interatrial septum. The opening of the inferior vena cava is bounded by a fold called the valve of the inferior vena cava. Just to the left of this is the opening of the coronary sinus.

Check Your Progress 2

The mitral valve has an anterior and a posterior cusp. The anterior cusp is larger and is attached on the upper right part of the margin of the left AV orifice. The posterior cusp is attached to the lower left part. The anterior cusp intervenes between the Mitral and Aortic orifices. There is, therefore, a forceful blood flow on both surfaces of this cusp. The papillary muscles connected to the cusp of the mitral valve are also called the anterior and posterior. These terms are misleading. The anterior papillary muscle arises from the sterno-costal wall of the ventricle near the lower end. The posterior papillary muscle arises from the diaphragmatic wall near its anterior end. The two muscles run backwards almost parallel to each other and their origins are close together. The chordae tendinae arising from these papillary muscles pass to the adjoining part of the two cusps of the mitral valve.

The mitral valve closes during ventricular contraction (systole) and thus prevents blood from flowing back into the left atrium.The papillary muscles and chordae prevent the valve cusps from prolapsing into the left atrium during systole.All components of the valve apparatus are essential for the proper functioning of the mitral valve.In disease

states there can be mitral regurgitation (leaking) or mitral stenosis(narrowing) or a combination of the two.

Check Your Progress 3

1) The arterial supply is by the right and left coronary arteries. In the event of sudden block of one artery the area of myocardium supplied by that artery undergoes infarction.

   Right coronary artery

   Right coronary artery arises from the anterior aortic sinus. Just before its termination it gives off the posterior interventricular branch that runs downwards, forwards and to the left in the posterior interventricular groove. The branches of the right coronary artery are, branches to SA node, branches to right atrium and right ventricle, right marginal artery, posterior interventricular branches and branches to AV node. It is to be noted that the right coronary artery supplies the right atrium, right ventricle and conducting system of the heart.

   Left coronary artery

   The left coronary artery arises from the left posterior aortic sinus. It divides into anterior interventricular branch (left anterior descending -LAD) and circumflex artery. The left coronary artery supplies left ventricle, left atrium, anterior two third of the I.V. septum and adjacent part of the right ventricle.

   The branches of the left coronary artery: Anterio interventricular artery (LAD) and Circumflex artery which is considered to be the continuation of the left coronary artery. It gives rise to the left obtuse marginal arteries and also few branches for the supply of the posterior surface of the left atrium and left ventricle. Anterior interventricular branch of the left coronary artery(LAD) has septal branches and diagonal branches and supplies the left anterior surface of the left ventricle including the apex, adjoining part of the left ventricle and anterior two-third of the IV septum. The LAD runs along the anterior interventricular sulcus, turns around the inferior border of the heart and anastamoses with the posterior interventricular branch of the right coronary artery.

2) The heart is enclosed in a membranous sac called the pericardium. It has ***two*** layers- the ***fibrous*** pericardium which is the outer layer and the ***serous*** pericardium that lies inside the fibrous pericardium. The ***serous pericardium has two layers*** – the outer parietal and the inner visceral layer. The parietal layer lines the fibrous pericardium and the visceral layer the surfaces of the heart. This visceral layer is also called the epicardium.

Check Your Progress 4

A: Mark a point on the lower border of the left second costal cartilage 1.2 cm away from the sternal margin.

D: Mark a point in the left fifth intercostal space 9 cm. from the median plane

Connect point **A** and **D** by line which is convex to the left. The left border is formed by the left ventricle except at its upper end which is formed by the left auricle where there is a slight concavity.