THE HEART

General Description and Function

The heart is a hollow muscular organ that consists of four chambers; right and left atria separated by the interatrial septum, and right and left ventricles separated by the interventricular septum. Each **atrium** pumps blood to the **ventricle** on the same side via the **atrioventricular orifice** guarded by an **atrioventricular valve**. Each ventricle pumps blood to a major artery. Blood flow always occurs in one direction, from the atria to the ventricles and from the ventricles to the arteries. Retrograde blood flow is prevented by the presence of heart valves at the atrioventricular orifices and at the roots of the major arteries.

The function of the heart is to pump blood and maintain blood circulation **[Figure 1]**.The blood circulation begins with the return of venous blood to the right atrium via the superior and inferior venae cavae and the coronary sinus. Blood from the right atrium is pumped through the right atrioventricular orifice to the right ventricle. From the right ventricle, the venous blood passes through the pulmonary trunk to the lungs to be oxygenated. The oxygenated blood returns from the lungs to the left atrium via the four pulmonary veins. The left atrium pumps this blood to the left ventricle through the left atrioventricular orifice. From the left ventricle, blood is ejected into the aorta to be distributed to all body tissues. After gaseous and nutrient exchange at the tissues, the venous blood is returned to the right atrium and the cycle completes.

The passage of blood from the right ventricle to the lungs and its return to the left atrium is the **pulmonary circulation**. The pumping of blood from the left ventricle to the body tissues and its return to the right atrium is the **systemic circulation**.

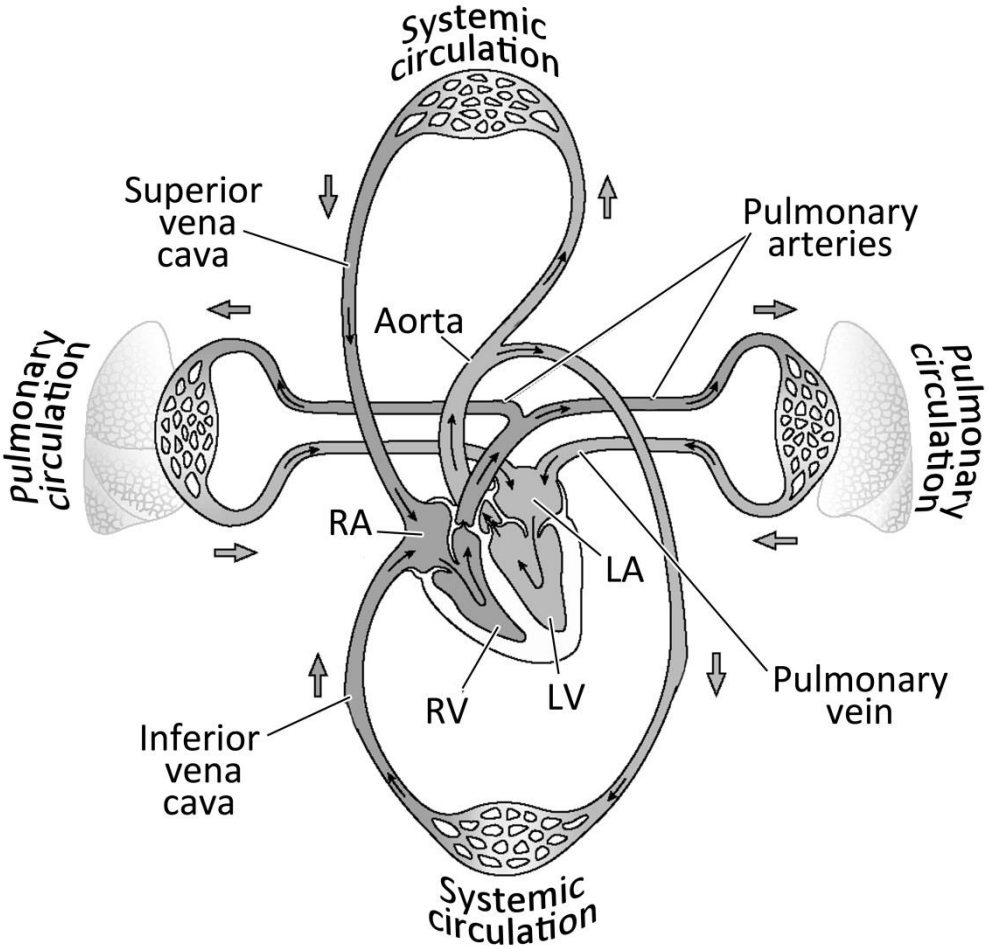

Figure 1. The blood circulation (RA/LA: right/ left atrium, RV/LV: right/ left ventricle)

Whenever a cardiac chamber fills with blood it is in a state of relaxation or **diastole** and when it contracts to pump the blood it is said to be in **systole**. The cardiac cycle is organized so that the atria contract together while the ventricles are relaxed and the ventricles contract together when the atria are relaxed.

Size, Position and Orientation

The heart is frequently described as having the size of the person's clenched fist. Its average weight in the adult is variable but is around 300-350 g. The position of the heart in the thoracic cavity depends on body posture, the position of the diaphragm and the state of respiration. In the erect position the heart lies at the level of T7-T10 vertebrae at the end of inspiration, but rises to the level of T5-T8 vertebrae at the end of expiration. The general shape and orientation of the heart is that of a four-sided pyramid that has fallen over and is resting on one of its sides so that the apex of the pyramid projects anteroinferiorly and to the left whereas the base faces posteriorly. The four sides of the pyramid are anterior, inferior, right and left.

The heart, like this pyramid, has an **apex**, **base**, **anterior** (sternocostal) **surface** and **inferior** (diaphragmatic) **surface**. The right and left (pulmonary) surfaces are narrow and represent the right and left borders of the heart. The anterior surface of the heart is quadrilateral and has four borders; superior, inferior, right and left.

Because the great vessels attach to the base of the heart, the base is fixed posteriorly to the pericardial sac. From the base the heart projects along its longitudinal axis forward, downward, and to the left, ending in the apex. The **apex of the heart** is formed by the inferolateral part of the left ventricle and is positioned at the left 5th intercostal space just medial to the midclavicular line, which is about 8-9 cm from the midline. This orientation of the heart brings the atria, which form the base of the heart, posterior to the ventricles. At the same time, the right chambers contribute more to the front of the heart while the left chambers contribute to the back. The planes of the atrioventricular orifices are more vertical than horizontal; hence the blood flows almost horizontally forward from the atria to the ventricles.

The Cardiac Borders

The cardiac borders represent the four borders of its anterior surface that can be seen on a chest X-ray and can also be traced on the surface of the thoracic cage **[Figure 2]**.

- The **superior border** is slightly oblique from left to right. It begins in the upper part of the left 2nd intercostal space; 1-2 cm from the sternal margin, and ends in the lower part of the right 2nd intercostal space; 1-2 cm from the sternal margin. It is formed by the right and left atria under cover of the pulmonary trunk and ascending aorta.
- The **right border** passes from the right 2nd intercostal space to the right 5th intercostal space; 1-2 cm from the sternal margin. It is slightly convex to the right and is formed by the superior vena cava, right atrium and inferior vena cava, in that order from above downwards.
- The **inferior border** passes from the right 5th intercostal space to a point in the left 5th intercostal space just medial to the midclavicular line i.e. the point of the cardiac apex. It is slightly convex upwards and is formed by the right ventricle and a small part of the left ventricle.
- The **left border** extends obliquely from the cardiac apex to the left 2nd intercostal space; 1-2 cm from the sternal margin. It is formed by the left ventricle and the left auricle above.

*This roughly quadrangular area demarcated by these borders is dull to percussion and clinicians refer to it as the **precordium**.*

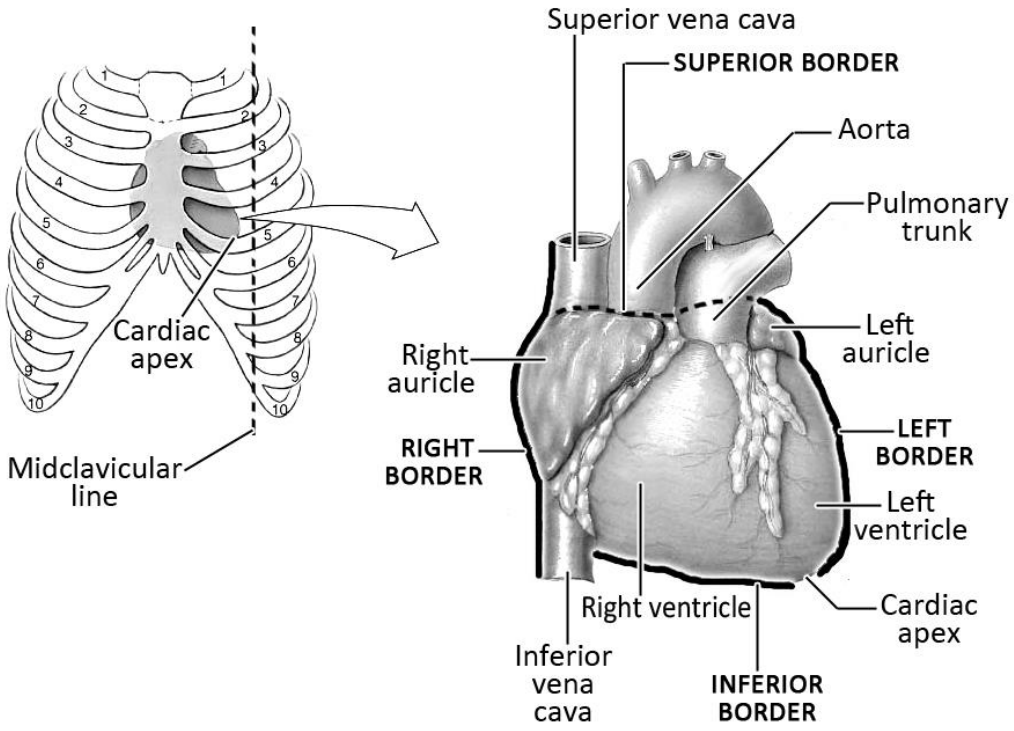

Figure 2. The borders of the heart, anterior view.

The Surface Sulci

The partitions that divide the heart into chambers are the interatrial and interventricular septa and the fibrous margins of the atrioventricular orifices. The fibrous margins of the atrioventricular orifices and the interventricular septum produce external grooves on the surface of the heart called sulci.

- The **coronary (atrioventricular) sulcus** is produced by the fibrous tissue of the atrioventricular orifices. It encircles the heart, separating the atria from the ventricles. Because of the orientation of the heart, it runs almost vertically on the anterior surface but becomes more horizontal posteriorly. The horizontal part of the coronary sulcus separates the base of the heart from the inferior surface.
- The **anterior and posterior interventricular sulci** are produced by the interventricular septum. The anterior interventricular sulcus separates the two ventricles on the anterior surface of the heart. The posterior interventricular sulcus separates the two ventricles on the inferior (diaphragmatic) surface of the heart. The two sulci are continuous with each other below the cardiac apex.

The cardiac sulci contain the coronary arteries and their branches; and the cardiac veins and their tributaries. These blood vessels are normally buried in collections of fatty tissue.

The Cardiac Surfaces **[Figure 3]**

- The **anterior** or **sternocostal surface** is formed mainly by the right ventricle with small part of the right atrium on the right and small part of the left ventricle on the left. The right atrium is separated from the right ventricle by the anterior (vertical) part of the coronary sulcus containing the right coronary artery. The right ventricle is separated from the left ventricle by the anterior interventricular sulcus which contains the anterior interventricular artery and the great cardiac vein.

- The **inferior** or **diaphragmatic surface** is the surface on which the heart rests on the central tendon of the diaphragm. It is formed mainly by the left ventricle with small part of the right ventricle to the right. The two ventricles are separated from each other by the posterior interventricular sulcus which contains the posterior interventricular artery and the middle cardiac vein.
- The **base** of the heart represents its **posterior** or **vertebral surface**. It is formed mainly by the left atrium with small part of the right atrium. The atria in the base are separated from the ventricles in the inferior surface by the posterior (horizontal) part of the coronary sulcus which contains the circumflex and right coronary arteries, the coronary sinus and the continuations of the small and great cardiac veins.

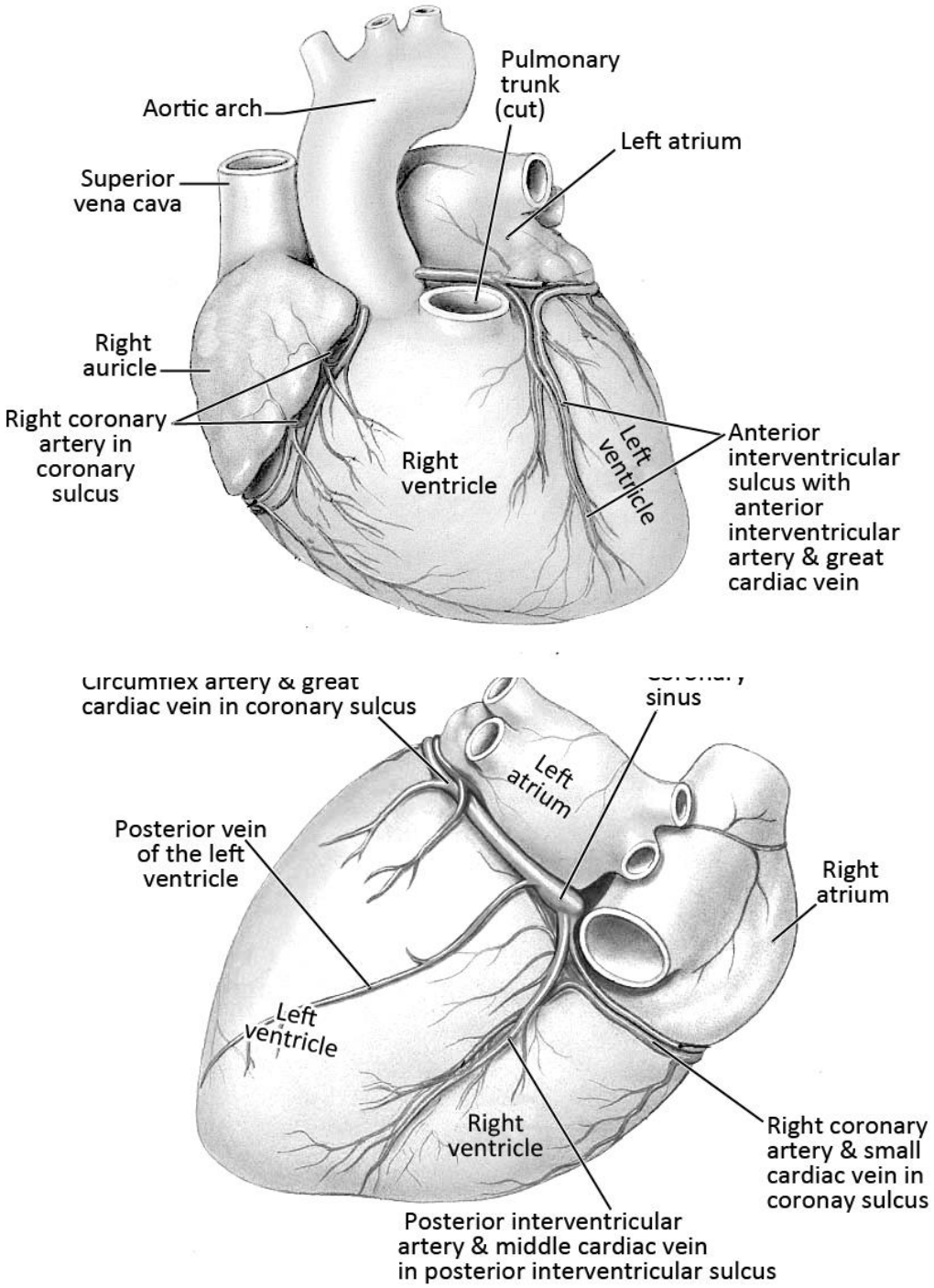

Figure 3. The surfaces of the heart in anterior (above) and posteroinferior views (below).

The Cardiac Chambers and Septa

The right atrium

Three veins drain blood into the right atrium. The **superior vena cava** drains venous blood from the head, neck, upper limbs and thoracic wall. The **inferior vena cava** drains the rest of the body. The **coronary sinus** drains blood from the heart itself. The superior vena cava enters the upper posterior portion of the right atrium, and the inferior vena cava and coronary sinus enter the lower posterior portion of the right atrium. From the right atrium, blood passes into the right ventricle through the **right atrioventricular orifice**. This opening faces forward and is guarded by the **tricuspid valve**.

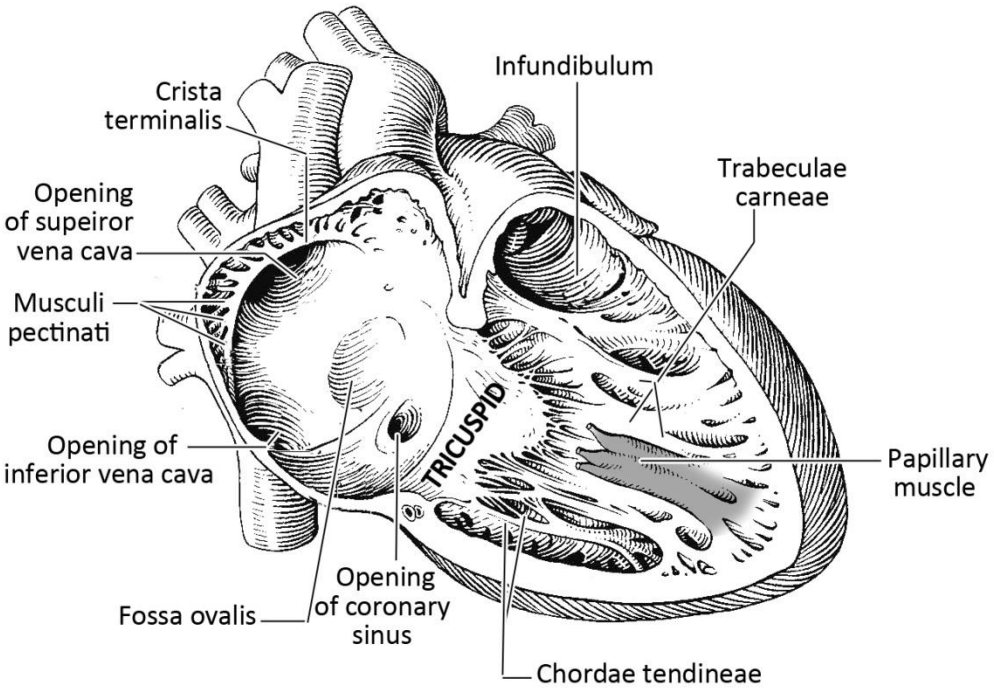

Figure 4. The internal features of the right atrium and right ventricle.

Externally, the right atrium is composed of two parts; the **auricle** and the **venous part**. The auricle is the small earlike, conical muscular pouch that extends anteriorly from the right atrium and overlaps the ascending aorta. The venous part is directed posteriorly and receives the veins that drain into the right atrium. The two parts are separated from each other by a groove called the **sulcus terminalis**.

On the internal surface **[Figure 4]**, the sulcus terminalis produces an elevated ridge called the **crista terminalis**. The crista begins on the roof of the atrium just in front of the opening of the superior vena cava and extends down the interatrial septum to end between the opening of the inferior vena cava and coronary sinus. The part of the atrial cavity posterior to the crista is called the **sinus venarum**. It has smooth, thin walls and both venae cavae empty into it.

The part of the atrial cavity anterior to the crista, including the right auricle, is sometimes referred to as the **atrium proper**. Its walls are covered by muscular ridges called the **musculi pectinati** (pectinate muscles), which fan out from the crista like the teeth of a comb.

The fetal circulation

During fetal life, the interatrial septum develops from two incompletely overlapping septa called the ***septum primum*** *and* ***septum secundum*** *[**Figure 5**]. The* ***foramen ovale*** *represents an oval defect between the two septa. The fetal blood returning to the right atrium from the placenta is rich with oxygen and has to pass to the left side of the heart without passing to the fetal lungs; which are not functional. The foramen ovale allows passage of most of the right atrial blood to the left atrium. The remaining amount of blood that passes to the right ventricle is pumped through the pulmonary trunk and from there it passes via the* ***ductus arteriosus*** *to the aorta. As a result, all the oxygenated blood that returns to the fetal right atrium is transferred to the arterial side of the circulation.*

After birth and due to initiation of breathing, the blood pressure on the left side of the heart exceeds the pressure in the right side causing the septum primum and septum secundum to adhere closely to each other and fuse; so that the foramen ovale is closed. The remnant of the foramen ovale and septum primum form an oval depression called the ***fossa ovalis****. The sharp lower margin of the septum secundum forms the margin of this fossa; the* ***limbus****. At the same time, the ductus arteriosus obliterates and the remnant fibrous band forms the* ***ligamentum arteriosum****. Failure of closure of the fossa ovalis results in an* ***atrial septal defect****. Failure of obliteration of the ductus arteriosus results in a condition known as* ***patent ductus arteriosus****.*

The interatrial septum

This septum separates the right atrium from the left atrium. It faces forward and to the right because the left atrium lies posteriorly and to the left of the right atrium. A depression with a sharp margin is clearly visible in the septum just above the orifice of the inferior vena cava. This is the **fossa ovalis** (oval fossa), with its prominent margin, the **limbus fossa ovalis**. The fossa ovalis marks the location of the embryonic **foramen ovale**, which is an important part of the fetal circulation.

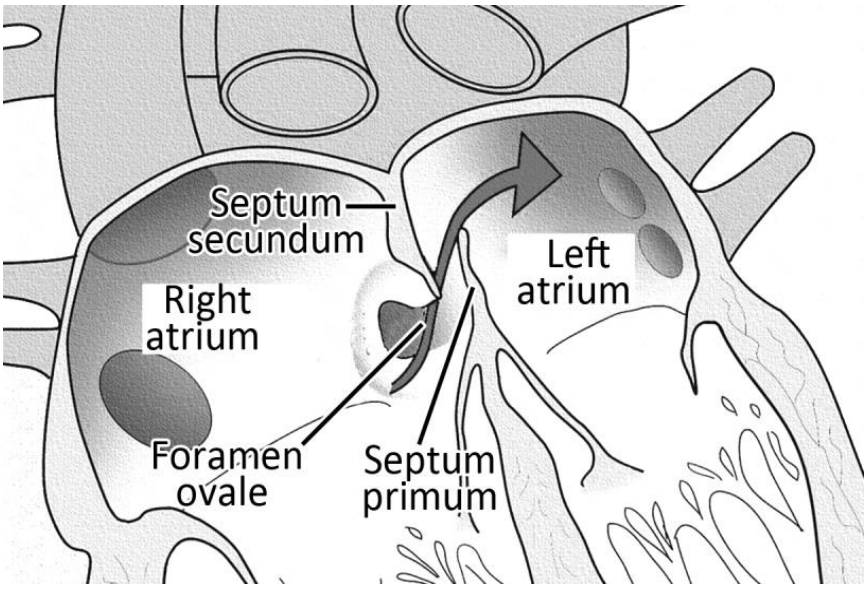

Figure 5. The foramen ovale in the fetal heart.

The right ventricle

The right ventricle is located anterior to the right atrioventricular orifice. It appears triangular in a longitudinal section **[Figure 4]** with an upper funnel-shaped outflow tract that leads to the pulmonary trunk. This outflow tract is called the **infundibulum**. The walls of the right ventricle are smooth in the infundibulum and near the right atrioventricular

orifice. Elsewhere, the walls have numerous irregular muscular ridges called the **trabeculae carneae**. The trabeculae carneae of the right ventricle exist in either of three forms:

- Most trabeculae are either attached to the ventricular walls throughout their length, forming **ridges**, or attached at both ends across the ventricular cavity, forming **bridges**.
- A few trabeculae carneae form the **papillary muscles** which have only one end attached to the ventricular surface, while the other end serves as the point of attachment for tendon-like fibrous cords called the **chordae tendineae**. The chordae tendineae connect to the free edges of the cusps of the tricuspid valve. The papillary muscles; through the chordae tendineae, prevent the cusps of the tricuspid valve from flipping backwards into the right atrium during ventricular systole. That way they prevent retrograde flow of blood from the ventricle into the atrium. There are **three papillary muscles** in the right ventricle. Named relative to their point of origin on the ventricular surface, they are the **anterior**, **posterior**, and **septal** papillary muscles.
- A single specialized trabeculum forms a bridge between the lower portion of the interventricular septum and the base of the anterior papillary muscle. This **septomarginal trabeculum** or **moderator band** carries a portion of the cardiac conduction system, the **right bundle of the atrioventricular bundle**, to the anterior wall of the right ventricle.

The interventricular septum

This septum separates the two ventricles and forms part of the wall of each. Due to heart rotation, the right surface of the interventricular septum faces anteriorly and to the right while the left surface faces posteriorly and to the left. The septum develops from two parts. The upper small part is thin and **membranous**. The lower part forms the majority of the septum. It is thick and **muscular**. Failure of union of the membranous and muscular parts results in a **ventricular septal defect**. Because left ventricular pressure is greater than the right ventricular pressure, the septum bulges to the right so that on a cross section the right ventricle appears crescent-shaped while the left ventricle appears circular.

The left atrium

Most of the left atrium is smooth walled. This part lies posteriorly and contains the openings of the four pulmonary veins. The **left auricle** is a small anterior part of the left atrium. It overlaps the root of the pulmonary trunk and its walls are rough due to presence of **musculi pectinati**. Unlike the right atrium, there is no clear sulcus or crista between the two parts of the left atrium. The **left atrioventricular orifice** leads from the left atrium to the left ventricle and is guarded by the **mitral (bicuspid) valve**.

The left ventricle

The left ventricle lies anterior to the left atrium. Its anterior rounded end forms the cardiac apex. The interventricular septum forms the anterior wall of the left ventricle and separates it from the right ventricle. The walls of the left ventricle are normally three times thicker than the walls of the right ventricle. The longitudinal section of the left ventricle is conical in shape with its outflow tract; the **aortic vestibule**, passing towards the ascending aorta. The walls of the left ventricle are smooth in the aortic vestibule and near the left atrioventricular orifice. Elsewhere, the walls are rough due to presence of the **trabeculae carneae**. The trabeculae carneae in the left ventricle are fine and delicate in contrast to those in the right ventricle. The general appearance of the trabeculae with muscular ridges and bridges is similar to that of the right ventricle. Papillary muscles, together with chordae tendineae, are also observed and their structure is as described for the right ventricle. However, only **two papillary muscles** are found in the left ventricle; the **anterior** and **posterior** papillary muscles. The anterior papillary muscle is large and passes to the anterior cusp of the mitral valve. The posterior one is smaller and passes to the posterior cusp.

The Cardiac Valves

The tricuspid and mitral valves

The tricuspid and mitral valves (the **atrioventricular valves**) consist of cusps that are fixed by their bases to the fibrous rings of the atrioventricular orifices. The free edges of the cusps are held by the chordae tendineae of the papillary

muscles **[Figure 6]**. During emptying of the atria, the cusps are open to allow flow of blood into the ventricles. During contraction of the ventricles, the cusps close the atrioventricular orifice while the papillary muscles and the chordae tendineae prevent separation of the valvular cusps.

The **tricuspid valve** consists of three cusps named **anterior**, **posterior** and **septal**. The **mitral** or **bicuspid valve** is composed of two cusps named **anterior** and **posterior**. The naming of the cusps is according to the wall of the ventricle to which they are attached. The anterior cusps of both valves are usually the largest cusps.

The pulmonary and aortic valves

The pulmonary and aortic valves lie at the distal end of the outflow tracts of the right and left ventricles, respectively. The **pulmonary valve** lies between the **infundibulum** of the right ventricle and the root of the **pulmonary trunk**. The **aortic valve** lies between the **aortic vestibule** and the root of the **ascending aorta**. These valves are called **semilunar valves** because each consists of three semilunar cusps **[Figure 32]**. Each cusp forms a pocket-like **sinus** or a dilatation in the wall of the root of the pulmonary trunk or aorta. The cusps of the pulmonary valve are named **left**, **right** and **anterior.** The cusps of the aortic valve are named **right**, **left**, and **posterior**. The right and left coronary arteries originate from the right and left aortic sinuses. Because of this, the **posterior aortic sinus** and cusp are sometimes referred to as the **noncoronary** sinus and cusp.

The semilunar cusps are not secured by chordae tendineae or papillary muscles. Instead, the integrity of the semilunar valves depends on the recoil of blood at the end of ventricular systole. Each semilunar cusp has a free edge projecting upward into the lumen of the pulmonary trunk or aorta. The free superior edge of each cusp has a middle, thickened portion called the **nodule** of the semilunar cusp; and a thin lateral portion called the **lunule** of the semilunar cusp. After ventricular contraction, the recoil of blood fills these sinuses and forces the cusps closed in a Y-shaped pattern so that the three nodules contact each other at the center.

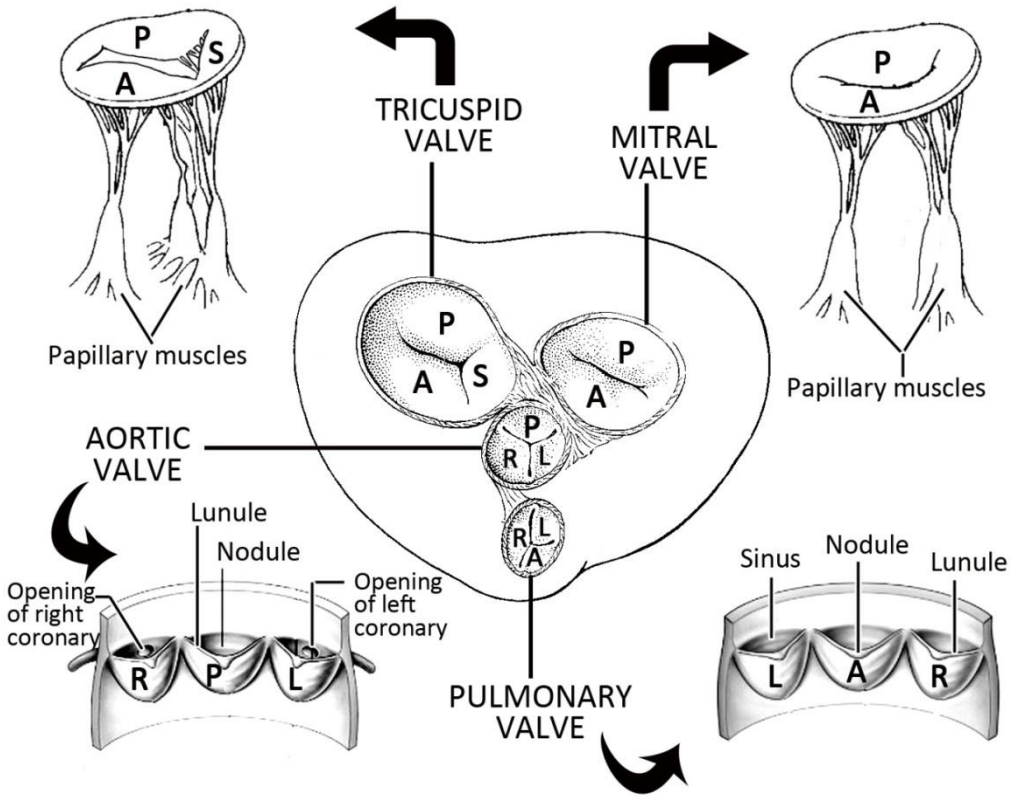

Figure 6. Superior view of the heart valves in situ. The four corner insets show the features of each valve. Letters indicate the name of the cusps of each valve (A: anterior, P: posterior, S: septal, R: right, L: left)

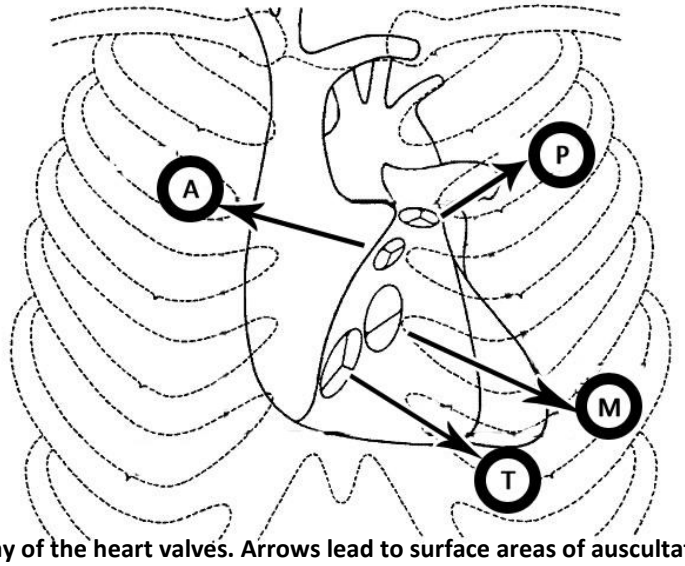

Figure 7. Surface anatomy of the heart valves. Arrows lead to surface areas of auscultation for each valve. (A: aortic, P: pulmonary,T: tricuspid,M: mitral).

Chest auscultation for heart sounds

Auscultation for heart sounds enables the clinician to listen to the heart valves as they close, giving an idea about the cardiac cycle and heart rate and rhythm. Each heart valve sound is heard with maximum clarity at an area that corresponds to the direction of blood flow through that valve ***[Figure 7]****.Blood flows upwards and to the right through the aortic valve, upwards and to the left through the pulmonary valve and forwards downwards and to the left through the tricuspid and mitral valves. Therefore;*

- *The* ***aortic valve*** *is heard over the medial end of the right second intercostal space.*
- *The* ***pulmonary valve*** *is heard over the medial end of the left second intercostal space.*
- *The* ***tricuspid valve*** *is heard just to the left of the lower part of the sternum at the fifth intercostal space.*
- *The* ***mitral valve*** *is heard over the apex of the heart in the left fifth intercostal space at the midclavicular line.*

These areas are where the stethoscope is placed for examination of heart sounds. They do not represent the actual anatomical position of the valves.

Structural Layers of the Heart

The wall of each heart chamber consists of three layers;

- The **endocardium**; is the thin internal layer composed of endothelium and subendothelial connective tissue that lines the heart and covers its valves.
- The **myocardium** is the thickest layer. It is composed of myocardial fibers arranged into superficial transverse and deep arch-shaped layers. In the ventricles, an additional middle layer of oblique fibers is present. The myocardium is thicker in the ventricles than in the atria. It is also thicker in the left chambers than in the corresponding right chambers.
- The **epicardium**; is the thin external layer formed by the visceral layer of serous pericardium.

The Fibrous Skeleton of the Heart

The cardiac skeleton is a composed of dense fibrous connective tissue in the form of four rings (**anulus fibrosus**) with interconnecting areas in a plane between the atria and the ventricles. The four rings of the cardiac skeleton surround the two atrioventricular orifices, the aortic orifice and opening of the pulmonary trunk **[Figure 8]**. The interconnecting areas include two trigones. The **right fibrous trigone** is a thickened area of connective tissue between the aortic ring and right atrioventricular ring. The **left fibrous trigone** is a thickened area of connective tissue between the aortic ring

and the left atrioventricular ring. The **membranous part of the interventricular septum** descends as a small projection from the lower margin of the skeleton.

The cardiac skeleton serves three main **functions**. It maintains the integrity of the openings it surrounds and provides points of attachment for the valvular cusps. It also acts as a dense connective tissue partition that electrically isolates the atria from the ventricles. The atrial myocardium is attached to the upper border of the rings, whereas the ventricular myocardium is attached to the lower border of the rings.

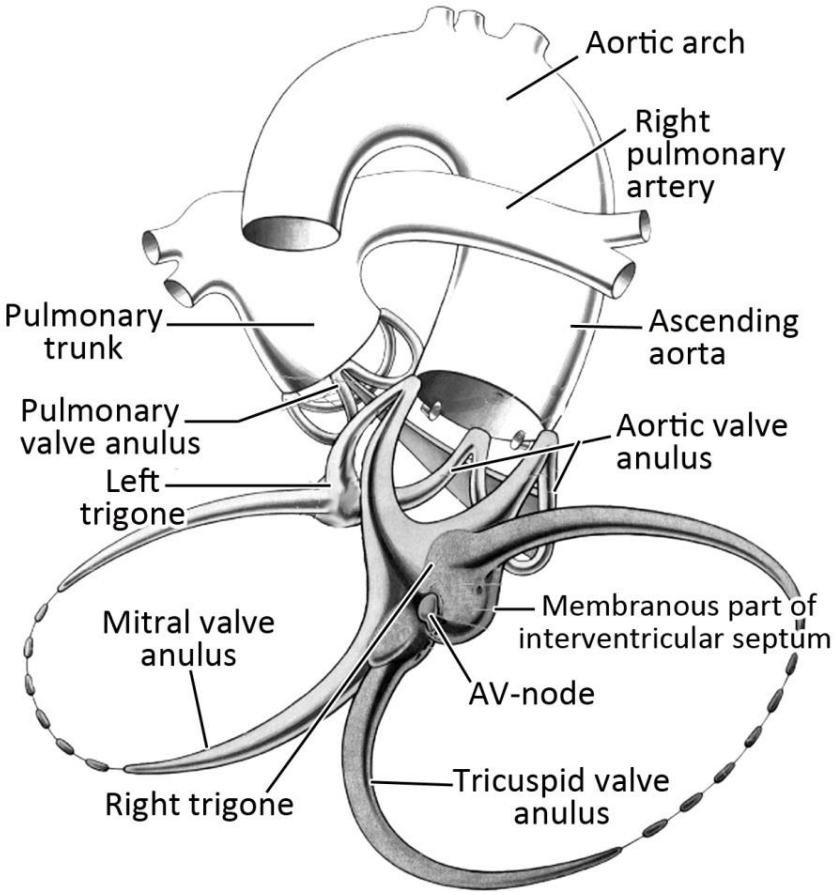

Figure 8. The fibrous skeleton of the heart, posterior view.

The Conducting System of the Heart

The heart is an **autonomous** muscle that can contract at a **spontaneous rhythm** in the absence of external nerve stimuli. The spontaneous rhythm is generated and conducted within the heart itself by the **conduction system**. This system consists of specialized myocardial fibers that have the ability to generate and propagate stimuli that cause myocardial contraction. These modified myocardial fibers can only be identified under the microscope; macroscopically they are indistinguishable from the rest of the myocardial fibers. The conducting system of the heart consists of nodes and networks organized into four basic components **[Figure 9]**; the **sinuatrial node (SA node)** , the **atrioventricular node (AV node)**, the **atrioventricular bundle (of His)** with its right and left bundle branches and the subendocardial plexus of conduction cells called **Purkinje fibers**.

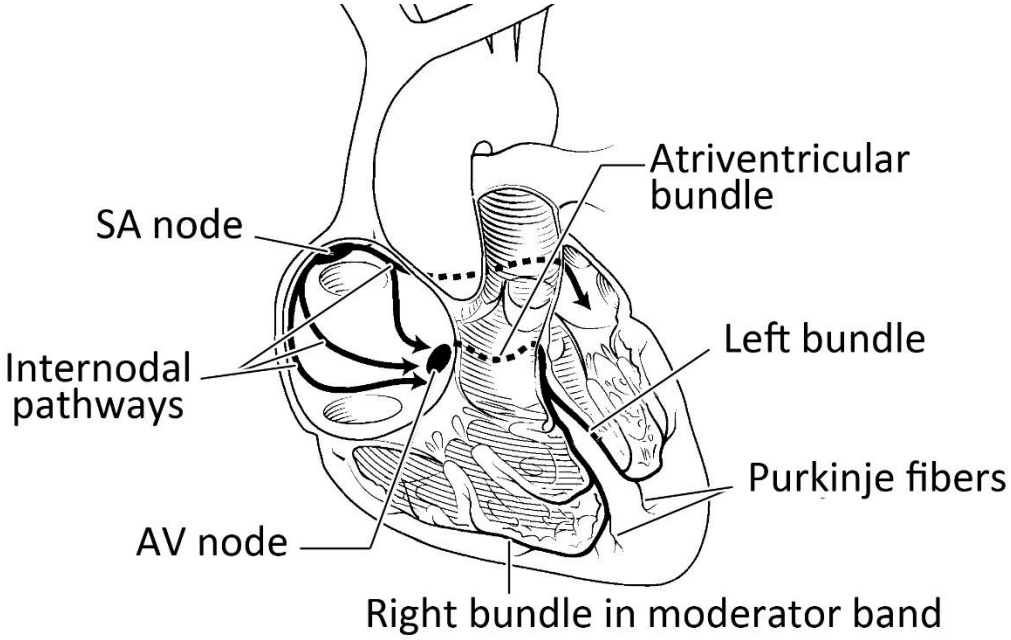

Figure 9. The conducting system of the heart.

The sinuatrial node

The SA node is responsible for generating the action potentials that **start atrial contraction** and is therefore called the **pacemaker** of the heart. It is **subepicardial** in position. It is located at the superior end of the crista terminalis at the junction of the superior vena cava and the right atrium. Impulses from this node spread though the atrial walls causing their contraction and reach the atrioventricular node. It is believed that there are three main pathways for the spread of the impulses in the atria called the anterior, intermediate and posterior **internodal pathways**.

The atrioventricular node

Atrial wall stimulation cannot spread directly to the ventricles because of the presence of the isolating fibrous skeleton. It has to pass exclusively through the atrioventricular node. The AV node acts as a **check-point** that **delays** the conduction of the stimulus to the ventricles until atrial contraction is over. It lies in the lower part of the interatrial septum to the left of the opening of the coronary sinus just above the attachment of the septal cusp of the tricuspid valve.

The atrioventricular bundle, the bundle branches and Purkinje fibers

The **atrioventricular bundle** is a direct continuation of the atrioventricular node. It extends from the AV node to the level of the junction of the membranous and muscular parts of the interventricular septum. Here, it divides into right and left bundle branches.

The **right bundle branch** continues on the right side of the interventricular septum toward the apex of the right ventricle. From the septum it enters the moderator band to reach the base of the anterior papillary muscle. At this point, it breaks up into the **subendocardial plexus** of ventricular conduction cells or **Purkinje fibers**. This network of specialized cells spreads throughout the ventricle to supply ventricular musculature.

The **left bundle branch** passes to the left side of the interventricular septum and descends to the apex of the left ventricle. Here, it usually divides into **anterior and posterior fasciculi** to the anterior and posterior papillary muscles of the left ventricle. At the bases of the papillary muscles, the fasciculi break up into **Purkinje fibers**.

Innervation of the Heart

Although the heart is an autonomous muscle, its function requires modification in response to internal and external environmental changes. This modification is influenced by the autonomic nerves that supply the heart via the cardiac

plexus. Autonomic nerve impulses affect heart rate and rhythm, cardiac output and power of contractility. They also alter the diameter of coronary arteries that supply the heart in response to increased or decreased cardiac action.

The cardiac plexus

This is a complex mesh of sympathetic and parasympathetic fibers and small ganglia that is divided into superficial and deep parts. The **superficial part** lies between the aortic arch above and the pulmonary trunk below. The **deep part** lies between the aortic arch in front and the tracheal bifurcation behind.

- The preganglionic **parasympathetic fibers** reach the heart as cardiac branches from the right and left vagus nerves. They enter the cardiac plexus and synapse in ganglia located either within the plexus or in the walls of the atria. Parasympathetic stimulation decreases the heart rate; reduces the force of myocardial contraction and constricts the coronary arteries.
- **Sympathetic fibers** reach the heart through the cardiac nerves from the sympathetic trunk. Preganglionic sympathetic fibers from the upper four or five segments of the thoracic spinal cord enter the sympathetic trunk. They synapse in cervical and upper thoracic sympathetic ganglia, and postganglionic fibers proceed as bilateral branches from the sympathetic trunk to the cardiac plexus. Sympathetic stimulation increases the heart rate; increases the force of myocardial contraction and dilates the coronary arteries.
- **Visceral afferent fibers** from the heart pass through the cardiac plexus and return to the central nervous system in the cardiac branches of the sympathetic trunk and vagus nerves. The afferents associated with the **vagus nerve** carry information about alterations in blood pressure and blood chemistry and are concerned with **cardiac reflexes**. The afferents associated with the cardiac **sympathetic nerves** return to the upper four or five thoracic spinal cord segments. They conduct **pain** sensation from the heart which is often referred to the neck and left upper limb.

Arterial Supply of the Heart

The heart is supplied by the **right** and **left coronary arteries** which circle the heart in the coronary sulcus. They give branches that run along the margins of the heart and in the interventricular sulci and converge toward the cardiac apex **[Figure 10]**.

The branches of the coronary arteries anastomose with each other at subepicardial and myocardial levels but the anastomotic channels are too small to maintain viability of the tissue should occlusion occur. Therefore, the coronary arteries are generally considered to be **functional end arteries**. Anastomoses exist between the terminal parts of the right and the left coronary arteries in the coronary sulcus and between the interventricular branches around the apex in approximately 10% of apparently normal hearts.

The right coronary artery

The right coronary artery arises from the **right aortic sinus** of the ascending aorta. It passes anteriorly and to the right between the right auricle and the pulmonary trunk and then descends vertically in the anterior part of the coronary sulcus, between the right atrium and right ventricle. On reaching the inferior border of the heart, it gives the marginal branch and turns posteriorly to continue in the posterior part of the coronary sulcus. As it reaches the posterior interventricular groove it continues down the groove as the posterior interventricular artery.

- **Branches**
  - Several **atrial branches** pass to the right atrium anteriorly and to the left atrium posteriorly. One of the atrial branches gives off the **sinu-atrial nodal branch**, which passes posteriorly and forms a vascular ring around the opening of the superior vena cava to supply the SA node.
  - The **right conus artery** supplies the infundibulum and the upper part of the anterior wall of the right ventricle.
  - **Anterior ventricular branches** supply the lower part of the anterior wall of the right ventricle. The lowest and largest one is the marginal artery.
  - The **marginal artery** runs towards the apex along the inferior border of the heart.

- The **atrioventricular nodal branch** passes through the upper part of the interventricular septum to supply the AV node.
- The **posterior interventricular artery** is the continuation of the right coronary in the posterior interventricular sulcus. It gives posterior ventricular branches that supply the diaphragmatic surfaces of the ventricles and the posterior part of the interventricular septum.

The distribution pattern of the right coronary artery enables it to supply the right atrium and right ventricle, the sinu-atrial and atrioventricular nodes, the interatrial septum, a portion of the left atrium, the posteroinferior one-third of the interventricular septum, and a portion of the posterior part of the left ventricle. Damage to the right coronary artery will have greater effect on the heart rate and rhythm rather than myocardial contractility. Such damage will also have a greater effect the pulmonary circulation than on the systemic circulation.

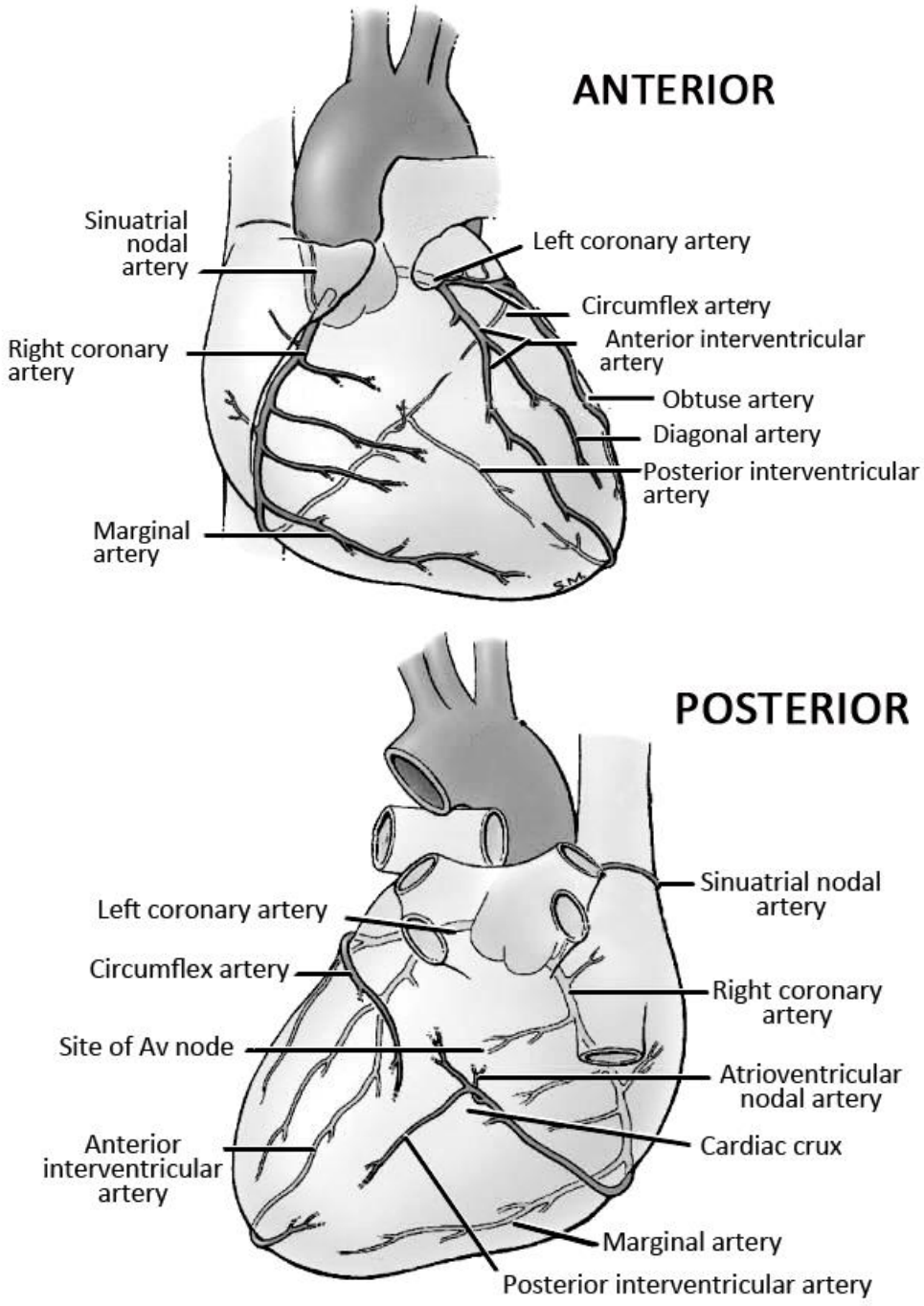

Figure 10. The common distribution of the coronary arteries.

The left coronary artery

The left coronary artery arises from the **left aortic sinus** of the ascending aorta. It passes between the pulmonary trunk and the left auricle before entering the coronary sulcus. While still posterior to the pulmonary trunk, the artery divides into its two terminal branches; the **anterior interventricular** and the **circumflex arteries**.

- The **anterior interventricular artery** (left anterior descending artery) descends obliquely toward the cardiac apex in the anterior interventricular sulcus. In most people (65%) it curves below the cardiac apex and anastomoses with the posterior interventricular branch of the right coronary artery. The anterior interventricular artery is the most common coronary branch affected by ischemic heart disease. It gives the following **branches**:
  - The **left conus artery** supplies the aortic vestibule.
  - **Anterior ventricular branches** supply the anterior walls of the left ventricle and the anterior part of the interventricular septum.
  - The **diagonal artery** runs towards the cardiac apex and anastomoses with the obtuse branch of the circumflex artery.
- The **circumflex artery** winds around the left margin of the heart and runs in the posterior part of the coronary sulcus to anastomose with the terminal part of the right coronary. It gives the following **branches**:

Variations in the distribution patterns of the coronary arteries

Several variations in the basic distribution patterns of the coronary arteries occur:

- *The distribution pattern described above for both right and left coronary arteries is the most common and consists of a **right dominant coronary artery**. This means that the posterior interventricular branch arises from the right coronary artery. The right coronary artery therefore supplies a considerable portion of the posterior wall of the left ventricle and the circumflex branch of the left coronary artery is relatively small.*
- *In contrast, in hearts with a **left dominant coronary artery**, the posterior interventricular branch arises from an enlarged circumflex branch and supplies most of the posterior wall of the left ventricle.*
- *Another point of variation relates to the arterial supply to the sinu-atrial and atrioventricular nodes. In most cases, these two structures are supplied by the right coronary artery. However, vessels from the circumflex branch of the left coronary artery occasionally supply one or both nodes.*

  - The **obtuse (left marginal) artery** runs along the left border of the heart to supply the cardiac apex.
  - **Anterior and posterior ventricular branches** supply the left ventricle.
  - **Atrial branches** supply the left atrium.

The distribution pattern of the left coronary artery enables it to supply most of the left atrium and left ventricle, and most of the interventricular septum, including the atrioventricular bundle and its branches. Damage to the left coronary artery will have great effect on the heart myocardial contractility and the systemic circulation.

Venous Drainage of the Heart

The venous blood of the heart is drained by three pathways; the coronary sinus, the anterior cardiac veins and the minimal cardiac veins **[Figure 11]**.

The Coronary Sinus

This thin-walled, large-calibered vein drains most of the heart. It runs in the posterior part of the coronary sulcus, usually under a thin cover of myocardium. It is formed at its left end by the union of the great and middle cardiac

veins. At its right end, it opens into the posterior wall of the right atrium to the left of the inferior vena caval opening and anterior to crista terminalis. It receives five tributaries:

- The **great cardiac vein** runs in the anterior interventricular sulcus with the descending interventricular artery and ascends to run with the circumflex artery to the base of the heart where it joins the middle cardiac vein at the left end of the coronary sinus. The **left marginal vein** accompanies the obtuse artery and drains to the left end of the great cardiac veins.
- The **middle cardiac vein** runs in the posterior interventricular sulcus with the posterior interventricular artery and joins the great cardiac vein to form the coronary sinus.
- The **small cardiac vein** begins as the right marginal vein which runs with the marginal artery and then continues as the small cardiac vein in the posterior part of the coronary sulcus. It drains into the coronary sinus near its right end.
- The **posterior vein of the left ventricle** opens into the sinus to the left of the middle cardiac vein.
- The **oblique vein of the left atrium** opens into the upper part of the coronary sinus opposite the middle cardiac vein or posterior vein of the left ventricle.

The Anterior Cardiac Veins

These vessels form a series of parallel veins on the anterior surface of the right ventricle and cross the coronary sulcus to open directly into the right atrium.

The minimal cardiac veins

The minimal cardiac veins **(venae cordis minimae)** are very small veins that open directly into the walls of all chambers. They are most numerous in the right atrium.

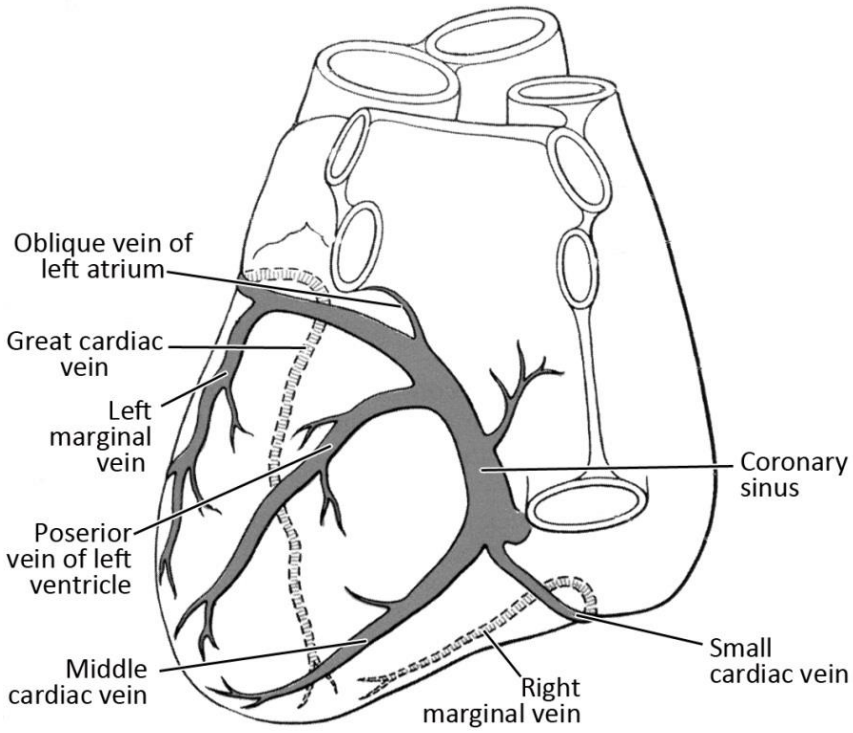

Figure 11. The coronary sinus and cardiac veins, posterior view.