

## The Heart - Anatomy

[mere rearrangement of Dr. Amjad Shatarat's slides]

### General Information

The heart is a double, self-adjusting suction and pressure pump, slightly larger than one's loosely clenched fist. It's a pair of valved muscular pumps combined in a single organ in the shape of a pyramid that's fallen over and resting on one of its sides.

The Heart is composed of a base, an apex and 4 surfaces: **left and right pulmonary, inferior [diaphragmatic] and anterior [sternocostal] surfaces**.

### THE HEART'S STRUCTURE

Part	Formed by:	Location	Notes
The apex	The inferolateral part of the left ventricle	Directed downward, forward and to the left, <u>posterior to the left 5th intercostal space</u> , 9cm from the median plane	It's where the sound of the <b>mitral valve</b> closure are maximal, the apex underlies the site where the heartbeat may be auscultated
The base	Mainly by the left atrium and a little contribution from the right atrium	Posteriorly facing T6-T9 vertebrae	separated from the vertebrae by the <u>pericardium</u> , <u>oblique pericardial sinus</u> , <u>oesophagus</u> and <u>aorta</u>
The sternocostal [anterior] surface	Mainly by the right atrium and right ventricle		
The diaphragmatic [inferior] surface	Mainly by the right and left ventricles [separated by the interventricular groove]  And the inferior surface of the right atrium [where the IVC opens]		Related mainly to the central tendon of the diaphragm
The left pulmonary surface	The left ventricle and a portion of the left atrium	faces the left lung	Board and conex Forms the cardiac impression in the left lung
The right pulmonary surface	The right atrium		Broad and convex

### ON THE HEART'S SURFACE

Structure	Location	Contents
The coronary sulcus	circles the heart, separating the atria from the ventricles	1. The right coronary artery 2. The small cardiac vein 3. The coronary sinus 4. The circumflex branch of the left coronary artery
The anterior interventricular sinus	on the anterior surface of the heart	1. The anterior interventricular artery 2. The great cardiac vein
The posterior interventricular sinus	on the diaphragmatic surface of the heart	1. The posterior interventricular artery 2. The middle cardiac vein

- The wall of the heart is composed of cardiac muscle:
  1. Myocardium -> covered externally by serous pericardium
  2. Epicardium -> lined internally with endothelium
  3. Endocardium
- The fibrous skeleton of the heart is a complex framework of dense collagen forming:
  - Four fibrous rings [L. annuli fibrosi] surround the orifices of the valves
  - The right and left fibrous trigone formed by the connection between the rings
  - The membranous parts of interatrial and interventricular septa.
- Importance of the fibrous skeleton:
  - Keeps the orifices patent and prevents them from being overly distended by the increased volume pressure from pumping blood
  - Provides attachment for the leaflets and cusps of the valves
  - Provides attachment for the myocardium
  - Form an electrical insulator by separating the atria and the ventricles and the conducted impulses ensuring that they contract independently and by surrounding and providing passage for the initial part of the AV bundle of the conducting system of the heart.

**CHAMBERS OF THE HEART:** Right and left atria [sing. atrium], and right and left ventricles.

Chamber	Cavities	Structure/Parts	Openings	Notes
The right atrium	<p>A main cavity and a small outpouching auricle*</p> <p>- The right auricle is a triangular-shaped superior portion of the rt. atrium that is like an add-on room that <u>increases the- capacity of the rt. atrium</u> as it <u>overlaps with the ascending aorta</u>. It's not usually well-demarcated from the rest of the atrium. It's a <u>point of entry for the cardiac surgeon</u>.</p>	<p>1. Posterior smooth-walled -&gt; derived from the embryonic sinus venosus in which enter the SVC and IVC</p> <p>2. Thin-walled anterior trabeculated part the constitutes the original embryonic right atrium</p> <p>3. Pectinate muscles on the <u>lateral aspect of crista terminalis</u>, <u>run laterally</u> and generally parallel to each other along the free wall of the atrium</p>	<p>1. The superior vena cava -&gt; returns blood from the head, neck and upper limbs and receives blood from the chest wall via the azygos system. Opens into the <u>upper part</u> of the atrium.</p> <p>2. The inferior vena cava -&gt; drains blood from all the structures below, and including, the diaphragm. Opens into the <u>lower part</u> of the atrium, <u>anterior to its orifice</u> is a flap-like valve: <u>Eustachian valve</u> [valve of IVC]</p> <p>3. The coronary sinus -&gt; drains most of the blood from the heart wall and <u>opens into the venous atrial component between the orifice of IVC, the fossa ovale and the vestibule of atrioventricular opening</u>. Guarded by a <u>semicircular valve</u> that covers the lower part of the orifice called <u>Thebesius' or Thebesian valve</u>.</p> <p>4. Several small venous ostia draining the minimal atrial veins are scattered on the atrial [mainly <b>septal aspect</b>] wall. <u>The anterior cardiac veins and the right marginal vein</u> may enter the atrium through larger ostia.</p>	<p>The two parts of the rt. atrium are separated by the ridges of the <b>Crista Terminalis</b> muscle: most prominent <u>superiorly next to the SVC orifice</u> then fades out to the right of the IVC ostium in <u>position that corresponds with the sulcus terminalis</u> externally.</p> <p>The Eustachian valve is large during fetal life as it serves to <u>direct oxygenated blood from the placenta through the foramen ovale of the atrial septum into the left atrium</u>.</p> <p>The fossa ovalis is fetal remnants in the right atrium that is a shallow depression which was the site of foramen ovale in the fetus.</p> <p>The annulus ovalis forms the upper margin of the fissa.</p> <p>Both located on the atrial septum.</p>

\*Auricle: is a term used improperly instead of the atrium. It's called atrial appendage *not* auricular appendage. The term auricular fibrillation is clinically incorrect, it should be atrial fibrillation

The right ventricle		<p>1. Inflow portion that contains the tricuspid valve and structure called "Trabeculae Carneae"</p> <ul style="list-style-type: none"> <li>- prominent ridges attached to the ventricular wall</li> <li>- when attached on both ends they form bridges</li> <li>- papillary muscle:                             <ul style="list-style-type: none"> <li>a. anterior papillary muscle -&gt; <u>largest and most constant</u> and arises from the ant. wall</li> <li>b. posterior papillary muscle -&gt; <u>may consist of one, two or three structures</u> with some chordae tendineae arising directly from the ventricular wall</li> <li>c. septal papillary muscle -&gt; <u>most inconsistent</u> [small or absent] with chordae tendineae arising from the septal wall</li> </ul> </li> </ul> <p>*The septomarginal [moderator] band forms a bridge between the ant. papillary muscle and lower part of the interventricular septum.</p> <p>2. The <u>smooth-walled</u> outflow tract that leads to the pulmonary trunk and is called "Conus arteriosus"</p>	<p>1. The right atrioventricular orifice -&gt; communication with the rt. atrium, <b>guarded by the Tricuspid valve</b> that consists of three cusps formed by a fold of endocardium with some C.T.</p> <p>2. The pulmonary orifice -&gt; communication with the pulmonary trunk</p>	<p>*The <b>septomarginal</b> [moderator] band carries a portion of the cardiac conduction system, the <u>right bundle branch to the anterior wall of the right ventricle</u>. Facilitates conduction time allowing coordinated contraction of the ant. papillary muscle.</p> <p>*The atrium contracts when the ventricle relaxes. Blood <u>enters [inflow] to the posterior part</u> and when the ventricle contracts it's pushed to the outflow portion into the pulmonary tract <u>superiorly and to the left</u>. With the help of the <b>supraventricular crest</b>, which deflects the <u>incoming flow</u> into the main cavity of the ventricle and the <u>outgoing flow</u> into the conus arteriosus towards the pulmonary orifice, the blood flow takes a <u>U-shaped path</u>, changing direction about 140 degrees.</p>
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		<p>[infundibulum]. It's derived from the <b>embryonic bulbus cordis</b></p> <p>These two parts are <u>separated by prominent muscular bands</u> [parietal band and supraventricular crest [crista supraventricularis], the septal band and the moderator [septomarginal] band.</p>		
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<b>The left atrium</b>	A main cavity and a left auricle	<ol style="list-style-type: none"> <li>1. Small rough part -&gt; the left auricle which represents the remains of the left part of the primordial atrium and therefore its wall is trabeculated with pectinate muscle</li> <li>2. Large smooth part -&gt; the walls of the four pulmonary veins are incorporated into the wall of the left atrium [<i>in the embryo, it's only one common pulmonary vein with four tributaries</i>]</li> </ol>	<ol style="list-style-type: none"> <li>1. The <i>valveless</i> pairs of right and left pulmonary veins enter the smooth-walled atrium</li> <li>2. AV orifice through which the left atrium discharges the oxygenated blood it receives from the pulmonary veins into the left ventricle</li> </ol>	<p>Roughly cuboidal and lies behind the right atrium separated by the obliquely positioned septum [<u>the rt. atrium is in front and anterolateral to the left atrium</u>]</p> <p>Behind it lies the fibrous pericardium that separates it from the <b>oesophagus</b> [it has a close relation with the left atrium]</p> <p>Forms most of the heart's base</p> <p>Smaller in volume than the right atrium but has thicker walls</p> <p>A semilunar depression if the interatrial septum indicates the floor of the oval fossa and the surrounding ridge is the valve of the oval fossa</p>
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<b>The left ventricle</b>	<ol style="list-style-type: none"> <li>1. An inlet region guarded by the mitral valve [ostium venosum]</li> <li>2. An outlet region, guarded by the aortic valve [ostium arteriosum]</li> <li>3. An apical trabecular component</li> </ol>	<ol style="list-style-type: none"> <li>1. The interior of the left ventricle is a mesh of trabeculae carneae that are <u>finer and more numerous</u> than those in the right ventricle</li> <li>2. Anterior and posterior papillary muscles that are <u>larger</u> than those in the right ventricle</li> <li>3. A double leaflet mitral valve that guards the left AV orifice</li> <li>4. A <u>smooth-walled, non-muscular</u>, supero-anterior outflow part called <b>The aortic vestibule</b> leading to the aortic orifice and aortic valve.</li> <li>5. An aortic orifice is surrounded by fibrous ring</li> </ol>	<ol style="list-style-type: none"> <li>1. The left atrioventricular orifice between the left atrium and left ventricle guarded by the Mitral valve</li> <li>2. The aortic orifice guarded by semilunar valve, opens to the ascending aorta</li> </ol>	<p>It's a conical cavity that is <u>longer</u> than the right ventricle</p> <p>The wall of the left ventricle is three times thicker than the right</p> <p>Forms the apex of the heart and nearly all the left pulmonary surface and most of the diaphragmatic surface</p> <p>The left AV orifice [guarded by the mitral valve] admits atrial blood during <u>diastole</u>, <i>flow being towards the apex</i> then, during <u>systole</u>, blood is <i>expelled from the apex through the aortic valve</i> and the blood undergoes two right angle turns [180 degrees] <b>around the anterior cusp of the mitral valve.</b></p> <p>The orifices of the left ventricles are in close contact [unlike those in the right ventricle] the fibrous membrane of the susps in the mitral valve are continuous with those in the aortic valve forming the <b>subaortic curtain</b> [fibrous vurtain]</p>
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- **The interventricular / ventricular septum** -> is a strong, obliquely placed partition between the right and left ventricles and forms part of the walls of each. It's formed by muscular and membranous parts.
  - The muscular part has the thickness of the remainder of the wall of the left ventricles [which is thicker than the right ventricle's wall because of the much higher pressure in the left one]. The IVS bulges into the cavity of the rt. ventricle.
  - The membranous part is formed superiorly and posteriorly by a thin membrane from the fibrous skeleton of the heart. The septal cusp of the tricuspid valve is attached to the middle of this membranous wall. Inferiorly to this we have the interventricular septum and superiorly we have the atrioventricular septum separating the right atrium and left ventricle.

**THE VALVES OF THE HEART:** function to **maintain unidirectional flow of blood**

1. **Atrioventricular** -> right/tricuspid and left/mitral/bicuspid
2. **Semilunar** -> aortic and pulmonary

The atrioventricular valvular complex consists of:

1. The orifice and its associated annulus [ring]
2. The cusps, the supporting chordae tendineae and the papillary muscles

Histology of heart valves: **The cusps are composed of connective tissue with over-lying endocardium**. Avascular structures. [3 layers]

1. **Spongia** -> loose connective tissue located on the atrial or blood vessel [aorta or pulmonary] side of each valve.
2. **Fibrosa** -> forms the core of the valve and contains fibrous extensions from the dense irregular c.t of the skeletal rings or the heart
3. **Ventricularis** -> immediately adjacent to the ventricular surface of each valve and is covered with endothelium. It contains dense c.t with many layers of elastic fibers and, in AV valves, it's continuous with chordae tendinae.

- Valves are **avascular** -> small blood vessels and smooth muscle are only found *near the base of the cusp*. They are exposed to blood on both surfaces and **thin enough to allow exchange of nutrients by diffusion**.
- Valvulitis -> inflammation of the heart valves caused by rheumatic fever. This inflammation induces angiogenesis and vascularisation of the valves [mainly the mitral valve (65-70%) and then the aortic (20-25%)]. It can lead to progressive **replacement of the valve's elastic tissue [in ventricularis] by irregular masses of collagen** fibers causing the valve to thicken. They become rigid and inflexible which affects their ability to open and close.

Structure of atrioventricular valves:

1. The extreme edges of the cusps are thin and delicate with a sawtooth appearance from the insertion of chordae tendineae.
2. Away from the edge, the atrial surface contains nodules [mainly present in children] called **The noduli Albin**.
  - The noduli albini -> minute fibrous nodules on the margins of the mitral and tricuspid valves.

The papillary muscles and chordae tendineae.

- The bases of the cusps are attached to the fibrous ring of the skeleton of the heart whereas their free edges and ventricular surfaces are attached to the chordae tendineae.
- The papillary muscles -> contract when the ventricles contract and prevent the cusps from being forced into the atrium and turning inside out as the intraventricular pressure rises.
- Chordae tendineae -> are fibrous collagenous structures supporting the cusps of AV valves. The tendinous cords that arise from the apices of the papillary muscles attach to the free edges and ventricular surfaces of the cusps [connects the cusps to the papillary muscles].
- During the contraction -> the chordae tendineae of the papillary muscles are connected to the adjacent parts of two cusps. On the closure of an AV valve, the narrow border between the row of **Albini nodules** and **the free edge** of each cusp presses against that of the next resulting in a secure, **watertight** closure.
- The papillary muscle begins to contract before contraction of the ventricles, tightening the tendinous cords and drawing the cusps together. The chords prevent separation of the cusps because they're attached to *adjacent sides of two cusps* and prevent prolapsing as ventricular pressure rises. Thus, blocking **regurgitation of blood** during ventricular systole. The papillary muscle insures competence of the valve.

**Atrioventricular valves**

Valve	Location	Structure	Notes
Tricuspid [right AV] valve	guards the right atrioventricular orifice between the right atrium and right ventricle	Consists of three cusps [anterior, septal and inferior] or leaflets, the bases are attached to a fibrous ring around the orifice [annulus fibrosus] -> to keep the caliber of the orifice constant.  Measures on average 11.4 cm.  The <u>atrial surface is smooth</u> , the <u>ventricular surface is irregular</u> because of the insertion of chordae tendineae.	The orifice best seen from atrial aspect  It's almost vertical [45 degrees on the sagittal plane]

Mitral [Bicuspid or left AV] valve	guards the left atrioventricular orifice between the left atrium and left ventricle	Consists of two cusps The subaortic curtain [mentioned above]	The left AV orifice admits atrial blood during diastole and the flow is towards the apex. After closure of the mitral cusps, and throughout the ejection phase of systole, blood is expelled from the apex through the aortic orifice. And takes a 180 degrees turn <b>around the anterior cusp of the mitral valve</b> [mentioned above somewhere as well].
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The orifices and cusps of both AV valves undergo considerable change in position, form and area during a cardiac cycle. **Both valves move anteriorly and to the left during systole and reverse their motion during diastole.** The mitral valve reduces its official [anular] area by as much as 40% during systole.

### Semilunar valves

- No chordae tendineae or papillary muscles.
- No distinct circular ring of fibrous tissue at the base of the arteries from which these valves arise
- The arterial wall expands into three dilated pouches, the sinuses of valsalva.
- Consist of three pocket-like cusps of approximately equal size.

Structure of semilunar valve:

1. Largely smooth and thin
2. At the centre of the free margin of each cusp is a small *fibrous nodule* called **The nodulus Arantii.**
3. On each side of the nodule along the entire free edge of the cusp, there's a thin, halfmoon-shaped area called Lunula that has fine striations parallel to the edge.
4. The cusps are named according to their position in the fetus before the heart rotates to the left.
5. The official nomenclature refers to an anterior, a posterior and a septal cusps according to their position in the fetus. The position changes with development and in adults we have anterior, right and left semilunar cusps.

- The edge of each cusp is thickened in the region of contact forming Lunule, the apex of each angulated free edge is thickened further.

Valve	Location	Structure	Notes
Aortic valve	opening of the aorta	Consists of three cusps [posterior, left and right]  Superior to the right and left cusps in the Sinus of Valsalva are the openings of the right and left coronary arteries	
Pulmonary valve	At the apex of the infundibulum, the outflow tract of the right ventricle, the opening into the pulmonary trunk	Consists of three cusps [anterior, left and right] with free edges projecting upwards into the lumen of the pulmonary trunk.	During the diastole, the valve is closed and all three cusps are tightly apposed, then it opens passively during systole and then closes rapidly at the end of systole..

### HEART BLOOD SUPPLY

The endocardium and subendocardial tissue receive nutrients and oxygen directly by diffusion or microvasculature from the heart chambers.

The rest of the heart: from the coronary arteries [right and left].

- Two arteries form an oblique inverted crown, in which an anastomotic circle in the atrioventricular groove is connected by marginal and interventricular loops intersecting at the cardiac apex
- The arteries originate from the ascending aorta in the Sinus of Valsalva, superior to the right and left semilunar cusps. [no arteries arise from the posterior cusp]

Artery	Origin	Course	Branches	Supply to	Notes
Left coronary artery [LCA]	Left sinus valsalva, superior to the left cusp from the ascending aorta	Between the left auricle and the left side of the pulmonary trunk	1. Anterior interventricular [left anterior descending LAD] 2. Circumflex artery  *Left diagonal artery may arise directly from LCA trunk	1. Most of the left ventricle 2. A small area of the right ventricle to the right interventricular groove 3. The anterior 2/3 of the ventricular septum	Has short [0.5-2cm] common stem

				4. RBB and LBB	
Anterior interventricular [left anterior descending LAD]	a branch of the LCA	Runs downward in the anterior interventricular groove to the apex of the heart  -In most individuals it passes around the apex and enters the posterior interventricular groove to form anastomosis with the terminal branches of the RCA -In one third of people it terminates at the apex of the heart		1. Anterior left ventricle wall 2. Anterior two thirds of the interventricular septum 3. Bundle of His 4. The apex	In MI, LAD is obstructed in 50% of the cases, RCA in 30% and the circumflex in 20%
The circumflex artery	a branch of LCA	winds around the left margin of the heart in the atrioventricular groove	1. Left marginal artery to the left margin of the ventricle down to the apex 2. Anterior and posterior ventricular branches supply the left ventricle 3. Atrial branches supply the left atrium		About the same size as LAD
The right coronary artery RCA	arises from the right anterior sinus of Valsalva superior to the right cusp from the ascending aorta	runs along the right AV sulcus embedded in fat	1. Sinoratrial nodal artery -> one of the <u>first branches</u> of the RCA to the SA node  2. Atrioventricular nodal artery -> arises <u>from the distal end</u> of the RCA and penetrates the interatrial septum to supply the AV node  3. Posterior interventricular artery -> the <u>terminal distribution of RCA</u> and courses in the posterior interventricular sulcus to supply parts of the right and left ventricle and the <u>posterior third of the interventricular septum</u>	1. In most individuals it supplies all the right ventricle except for a small area to the right of the anterior interventricular groove 2. the variable part of the diaphragmatic surface of the left ventricle 3. the posteroinferior third of the ventricular septum 4. the right atrium and part of the left atrium 5. the SA and AV nodes 5. LBB	

The branches of the coronary arteries are generally considered Functional End arteries -> the supplied areas lack sufficient anastomosis from other large branches to maintain viability in cases of occlusion [ think hypoxia and ischemia!!] , however, anastomosis does exist.

The caliber of coronary arteries based on measurements of arterial casts or angiograms ranges between 1.5 - 5.5 mm at their origin. The left exceeds [larger] the right in 60% of hearts, the right being larger in 17% and both being approximately equal in 23%. The diameters may increase up to the 30th year.

LAD, RCA and the circumflex branch of LCA account for 85% of occlusions.

Normal, common variation in the coronary arteries. The most common one affects the supply of diaphragmatic surface of both ventricles because of variation in the origin, size and distribution of the posterior interventricular artery.

1. Right dominance [90%] -> it's a branch of the RCA
2. Left dominance [10%] -> branch of the circumflex branch of the LCA ]
  - Dominant refers to the artery that gave off the posterior interventricular artery
  - Balanced pattern -> branches of both arteries run in or near the posterior interventricular groove.

**Supply to the conduction system:**

Part	Supply	Notes
SA node	1. Mainly by the RCA [ sinoatrial nodal artery in 60%] 2. Sometimes by the LCA [circumflex branch in 40%]	There's a common variation in the origin of the sinoatrial nodal artery
AV node and AV bundle	The right coronary artery	
Right bundle branch RBB	the LCA	
Left bundle branch LBB	the RCA and LCA	

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**VENOUS DRAINAGE OF THE HEART**

1. Coronary sinus -> lies in posterior coronary sulcus [post. atrioventricular groove] drains most blood of the heart into the right atrium.
2. Tributaries of the coronary sinus:
  - a. Great cardiac vein -> the main tributary, lies in the anterior interventricular sulcus with LAD
  - b. Middle cardiac vein -> lies in the posterior interventricular sulcus with the posterior interventricular artery
  - c. Small cardiac vein
3. Venae cordis minimae [thebesian veins] and anterior cardiac veins -> open directly to the chambers of the heart.