The HEART ANATOMY

By:

Dr. Nabil A Khouri MD, MsC, Ph.D
• Lies within the pericardium in middle mediastinum
• Behind the body of sternum and the 2nd to 6th costal cartilages
• In front of the 5th to 8th thoracic vertebrae
• One third of the heart lies to the right of median plane and 2/3 to the left
  – Anterior to the vertebral column, posterior to the sternum
EXTERNAL CHARACTERISTICS

- Conical in shape
- Located in the meddle Mediastinum
- A hollow muscular organ, pyramidal in shape, somewhat larger than a closed fist; consists of four chambers (right and left atria, right and left ventricles)
- **Cardiac Apex** is formed by left ventricle and is directed downwards and forwards to the left.
- It lies at the level of the fifth left intercostal space, 1~2cm medial to the left midclavicular line (9cm from the midline)
External morphology

one apex,
one base,
two surfaces
three borders
three grooves
Two surfaces

- **Sternocostal surface (Right surface):** It is formed mainly by the right atrium and right ventricle, and a lesser portion of its left is formed by the left auricle and ventricle.

- **Diaphragmatic surface (Left surface):** It is formed by both ventricles—chiefly the left ventricle, directed backwards and downwards, and rests upon the central tendon of the diaphragm.

Three borders

- **Right border**—vertical, is formed entirely by right atrium

- **Left border**—round, is mainly formed by the left ventricle and partly by the left auricle

- **Inferior border**—horizontal, is formed by the right ventricle and cardiac apex

- **Cardiac base (posterior surface)** is formed by the left atrium and to a small extent by the right atrium. It faces backward and to the right.
3. Right surface:
- It is formed by right atrium only.

4. Left surface:
- It is formed by left ventricle and left atrium.

- The apex of the heart:
  - It is formed by the left ventricle only.

- The base (posterior surface):
  - It consists of two atria mainly left atrium.
Base of the Heart (posterior surface)

- It is formed by the 2 atria, mainly left atrium, into which open the 4 pulmonary veins.

- It is directed backwards.

- Lies opposite middle thoracic vertebrae (5-7).

- Is separated from the vertebral column by descending aorta, esophagus and oblique sinus of pericardium.

- Bounded inferiorly by post. part of coronary sulcus, which lodges the coronary sinus.
The heart has sulci on the external surfaces:

1. Coronary sulcus (atrio-ventricular):
   - It separates the 2 atria from the 2 ventricles and lodges the 2 coronary arteries and coronary sinus.

2. Anterior and posterior interventricular sulci.
   - It separates the two ventricles anteriorly and posteriorly and lodges the corresponding interventricular arteries.
• **Interatrial groove** — separates the two atria and is hidden by pulmonary trunk and aorta in front.

The posterior interventricular groove extend from the base of the ventricular portion to a notch called:

**The cardiac apical incisure**
COVERING OF THE HEART

- Pericardium – a double-walled sac around the heart
  - Protects and anchors the heart
  - Prevents overfilling of the heart with blood
  - Allows for the heart to work in a relatively friction-free environment

Heart Covering: Pericardium

- Pericardium (3 layers)
  - fibrous pericardium (outer layer) made of dense CT, holds heart in place, prevents overfilling
  - serous pericardium (2 layers)
    - parietal layer sticks to fibrous pericardium
    - visceral layer (= epicardium) is the outermost layer of the heart wall

- Between parietal and visceral layers is the pericardial cavity, which contains serous fluid (which reduces friction)
Fibrous Pericardium

Fibrous pericardium is strong fibrous part of the sac. It is firmly attached below to central tendon of the diaphragm. It fuses with outer coats of great blood vessels passing through it (aorta, pulmonary trunk, superior and inferior venae cavae, and pulmonary veins). Fibrous pericardium is attached in front to sternum by sternopericardial ligaments.
Pericardial sinuses

Transverse sinus
Oblique sinus

Reflections of visceral layer of peritoneum around great vessels of the heart
Oblique Sinus:

- Formed by reflections of pericardium onto pulm veins of heart

- Cul-de-sac/cardiac bursa

- Ant: by the Lt Atrium
- Post: by Parietal Pericardium

- Below it opens into the P cavity
Transverse Sinus

Horizontal gap between the arterial ends of heart tubes in front and venous ends behind

Ant: Ascending aorta and Pulmonary trunk
Post: SVC

On each side it opens into P cavity
Phrenic nerve innervations
LAYERS OF THE HEART WALL

- Epicardium – visceral pericardium
- Myocardium – cardiac muscle layer forming the bulk of the heart
- Endocardium – endothelial layer of the inner myocardial surface
the Heart
ANTERIOR SURFACE

- Arch of aorta
- Descending aorta
- Ligamentum arteriosum
- Left pulmonary artery
- Superior vena cava
- Auricle of right atrium
- Pericardium
- Pulmonary trunk
- Auricle of left atrium
- Coronary sulcus
- Right ventricle
- Fat in coronary sulcus
- Fat in anterior interventricular sulcus
- Anterior interventricular sulcus
- Pericardium fused to diaphragm
- LEFT VENTRICLE
- RIGHT VENTRICLE

(a) Anterior (sternocostal) surface
the Heart,
POSTERIOR SURFACE
Chambers of The Heart

• Contains four chambers
  – Right Atrium – receives blood from the systemic circuit (from the body) and passes it to the right ventricle.
  – Right Ventricle – pumps blood into the pulmonary circuit (to the lungs).
  – Left Atrium – collects the blood from the pulmonary circuit (lungs) and passes it to the left ventricle.
  – Left Ventricle – pumps the blood out to the systemic circuit (body).
  – The atria contract FIRST and then the ventricles contract.
HEART ANATOMY (CROSSECTION VIEW)

FRONTAL SECTION

- Superior vena cava
- Right pulmonary artery
- Pulmonary trunk
- Right atrium
- Right pulmonary veins
- Fossa ovalis
- Pectinate muscles
- Tricuspid valve
- Right ventricle
- Chordae tendineae
- Trabeculae carneae
- Inferior vena cava
- Aorta
- Left pulmonary artery
- Left atrium
- Left pulmonary veins
- Mitral (bicuspid) valve
- Aortic semilunar valve
- Pulmonary semilunar valve
- Left ventricle
- Papillary muscle
- Interventricular septum
- Myocardium
- Visceral pericardium

Lecture on Anatomy of the Heart (drnnamanisamuel@gmail.com)
Internal Anatomy and Organization

- Atria – separated by the interatrial septum
- Ventrices – separated by the interventricular septum
- Atrioventricular valves extend into the openings between the atria and ventricles permitting the blood to flow in one direction only.
- Contraction of the papillary muscles prevent the atrioventricular valves from folding back into the atria.
The right atrium

- Ascending aorta
- Superior vena cava
- Right pulmonary artery
- Pericardial reflection
- Right superior pulmonary vein
- Left atrium
- Right inferior pulmonary vein
- Interatrial septum
- Limbus of fossa ovalis
- Fossa ovalis
- Valve (Eustachian) of inferior vena cava
- Inferior vena cava
- Pulmonary trunk
- Right auricle
- Conus arteriosus
- Crista terminalis
- Atrioventricular part of membranous septum
- Septal cusp of tricuspid valve
- Pectinate muscles
- Opening of coronary sinus
- Valve (Thebesian) of coronary sinus

Opened right atrium: right lateral view

https://www.studyblue.com/notes/note/n/an2-03-the-heart/deck/8068324
Two ways into heart: superior and inferior vena cava

Superior Vena Cava

Interatrial septum
divides right and left atrium

Auricle

Crista Terminalis

Fossa ovalis

Pectinate Muscle
* probe-patent in 20-25% of population
** highly variable in size
Right Ventricle

- Blood flows from the right atrium to the right ventricle through the cusps of the *right atrioventricular valve* known as the *tricuspid valve*.
- The tricuspid valve is attached by long tendons called *chordae tendineae* to the *papillary muscles*.
- The papillary muscles of the *heart* serve to limit the movements of the *mitral* and *tricuspid valves*. These muscles contract to tighten the *chordae tendineae*, which in turn prevent inversion.
- This occurs in response to *pressure* gradients. Instead they brace the valves against the high pressure, preventing regurgitation of ventricular blood back into the atrial cavities.
- When the right ventricle contracts, the tricuspid closes *preventing* blood from entering the right atrium. The chordae tendineae keep the tricuspid from *folding back* into the right atrium.
- Blood exits the right ventricle through the *conus anteriosus* as the *pulmonary semilunar valve* opens into the pulmonary trunk dividing into the *right and left pulmonary arteries* leading to the lungs.
The Sectional Anatomy of the Heart
The anterosuperior side of a plastinated human right ventricle. The human heart has one well defined anterior papillary muscle and one to three septal papillary muscles. The septal papillary muscle and the chordae tendineae connecting it to the tricuspid valve’s septal leaflet.
An internal image of the human right ventricle. Visible are the anterior papillary muscle, its chardae tendineae connecting it to the tricuspid valve, the trabeculae carneae and the moderator band. The moderator band of humans arises apically on the septal wall and originates at the base of the anterior papillary muscle.
Left Heart Anatomy

- Left Atrium
- Left Ventricle
- Pulmonary Veins
- Aorta
Left Atrium

- Smaller than right atrium
- Thicker walls than right atrium
- 2 left & 2 right pulmonary veins
- Oval impression – *Fossa Ovalis*
- Atrial Appendage (longer & narrower)

- Receives oxygen rich blood from the two right and two *left* pulmonary veins.
- Blood passes from the left atrium to the left ventricle through the left atroventricular valve or bicuspid.
The Sectional Anatomy of the Heart
Contractions causes the bicuspid to close keeping the blood from backing up in the left atrium; distance between the apex and base increases; diameter of the ventricle chambers decrease.

- Blood exits through the semilunar valve into the ascending aorta.
- Right and left coronary arteries originate at the aortic sinuses and deliver blood to the heart.
- Blood passes into the descending aorta and into the systemic circuit.

Left Ventricle

- Oval shaped
- Larger than right
- Walls 3 X thicker than right
- Smooth walls
- Papillary muscles
- Cordae tendinae
The right ventricle as compared to the left ventricle:

– Has a thicker wall
– Produces more powerful contractions
– Is round in cross-section
– Develops a higher pressure when it contracts
– Produces six to seven times the force when it contracts
Structural Differences between the Left and Right Ventricles

(a) Fat in anterior interventricular sulcus

(b) Superior view

(c) Dilated vs. Contracted
**Structure of the Heart**

**Skeleton of the heart:** consists of fibrous rings that surround **atrioventricular, pulmonary, and aortic orifices** and are continuous with **membranous upper part of ventricular septum**. Fibrous rings around atrioventricular orifices separate muscular walls of atria from those of ventricles but provide attachment for muscle fibers. Fibrous rings support bases of valve cusps and prevent valves from stretching and becoming incompetent. Skeleton of heart forms basis of electrical discontinuity between atria and ventricles.
The Fibrous Skeleton of the Heart.

Located at the AV boundary. Function:

Serves as an attachment point for valves and keeps them patent.

Attachment point for cardiac myocytes

Acts as an electrical insulator: Keeping the Atrial electrical activity separated from the Ventricular electrical activity

Anterior Pul. Valve

Pul. Valve

Aortic Valve

Tricosp. Valve

Mitral Valve

Left Fibrous trigone

Rt Fibrous trigone

Tendon of the conus

Location of AV bundle
Arch of aorta
Pulmonary trunk
Fibrous coronet of aortic valve
Membranous part of interventricular septum
Tunnel for AV bundle
Membranous interatrial septum
Right fibrous trigone
Left fibrous ring (of mitral valve)
Right fibrous ring (of tricuspid valve)
Left fibrous coronet of pulmonary valve
Left fibrous trigone
Posteroinferior view
Valves of the Heart

Posterior

- Fibrous skeleton
- Left AV (bicuspid) valve (open)
- Aortic valve (closed)
- Right AV (tricuspid) valve (open)
- Pulmonary valve (closed)

Anterior

- Pulmonary veins
- Left AV (bicuspid) valve (open)
- Chordae tendineae (loose)
- Papillary muscles (relaxed)
- Left ventricle (dilated)

(a) Relaxed ventricles

TRANSVERSE SECTION, SUPERIOR VIEW, ATRIA AND VESSELS REMOVED

FRONTAL SECTION THROUGH LEFT ATRIUM AND VENTRICLE
Mitral (Tricospidic) Valve

• The right tricuspid valve complex is made of the 3 valve leaflets, the annulus, the supporting chordae tendineae, and the papillary muscles.

• The atrial and ventricular masses, *conduction system* tissue, and support structure of the fibroelastic cardiac skeleton allow coordinated actions of the tricuspid valve.

Mitral (Bicospidic) Valve

• 2 triangular leaflets
• Larger, thicker, stronger than tricuspid
• Anterior leaflet (aortic or septal)
• Posterior leaflet (ventricular)
• Papillary muscle – contraction occurs during systole to shorten Cordae Tendinae and prevent MR during ventricular systole
The semilunar valves

- Are pocketlike structures attached at the point at which the pulmonary artery and the aorta leave the ventricles.
- The pulmonary valve guards the orifice between the right ventricle and the pulmonary artery.
- The aortic valve protects the orifice between the left ventricle and the aorta.
- Three leaflets of the aortic semilunar and two leaflets of the pulmonary valves are thinner than those of the atrioventricular valves, but they are of the same general construction with the exception that they possess no chordae tendineae.
The (PULMONIC) Pulmonary valve

- 3 semi-lunar cusps
- Attached to wall of pulmonary trunk
- 2 cusps sit Anterior (right & left)
- 1 cusp sits Posterior

The cusps of the pulmonic valve are defined by their relationship to the aortic valve and are thus termed anterior or nonseptal, right and left cusps. They can also be defined by their relationship to a commissure found in the pulmonic and aortic valves and hence termed right adjacent (right facing), left adjacent (left facing), and opposite (nonfacing).

The pulmonic valve, like the other 3 cardiac valves, is formed by endocardial folds that are supported by internal plates of dense collagenous and elastic connective tissue and are continuous with the cardiac skeleton.
Aortic valve

- Similar to pulmonary
- Leaflets - 3 semicircular scallops
- Like 3 pronged coronet
- Names
  - Right coronary cusp (anterior)
  - Left coronary cusp (left posterior)
  - Non-coronary cusp (right posterior)
  - The normal aortic valve is trifoliate. The 3 aortic valve cusps are aptly named for the sinuses that they overlie.
The aortic valve annulus

- Is a collagenous structure lying at the level of the junction of the aortic valve and the ventricular septum, usually a semilunar crownlike structure demarcated by the hinges of the leaflets.
  - This serves to provide structural support to the aortic valve complex as it attaches to the aortic media distally and the membranous and muscular ventricular septum proximally and anteriorly.
- The right and left cusps are usually equal in size, with the posterior cusp being slightly larger in two thirds of individuals with no clinical significance.
- Each cusp has 2 free edges, both shared with the adjacent cusps. At the center of each free edge is a small fibrous bulge named the nodule of Arantius.
- These nodules are located at the contact site of valve cusp closure.
- The rim of each valve cusp is slightly thicker than the cusp body and is known as the lunula. The lunulae of adjacent cusps slightly overlap each other at the time of valve closure, serving a role of increased valve support.
Heart valves can malfunction in several ways, including:

- **Regurgitation is leakage of the valve.** This means the valve doesn't close completely, causing the blood to flow backward through the valve. This results in leakage of blood back into the atria from the ventricles (in the case of the mitral and tricuspid valves) or leakage of blood back into the ventricles (in the case of the aortic and pulmonary valves).

- **Stenosis is narrowing of the valve.** With stenosis, the valve opening is narrowed and the valve doesn't open properly, inhibiting the ability of the heart to pump blood across the narrowed valve due to the increased force required to pump blood through the stiff (stenotic) valve(s).

- **Atresia.** This means the valve opening doesn't develop normally as a child, preventing blood from passing from an atria to a ventricle, or from a ventricle to the pulmonary artery or aorta. Blood must find an alternate route, usually through another existing congenital (present at birth) defect, such as an atrial septal defect or a ventricular septal defect.
**Mitral Valve**

- 2 triangular leaflets
- Larger, thicker, stronger than tricuspid
- Anterior leaflet (aortic or septal)
- Posterior leaflet (ventricular)
- Papillary muscle – contraction occurs during systole to shorten Cordae Tendinae
  - prevent MR during ventricular systole

**Tricuspid valve**

- 3 triangular shaped leaflets
- Names
  - Anterior
  - Septal
  - Posterior
- Papillary muscles & chordae tendinae are present but play a more important role in the high pressure chamber of LV
Pulmonary valve

- 3 semi-lunar cusps
- Attached to wall of pulmonary trunk

Aortic valve

- Similar to pulmonary
- Leaflets - 3
- Semi lunar shape
- Attached to wall of aortic artery
The Conducting System

- The conducting system includes:
  - **Sinoatrial (SA) node**
  - **Atrioventricular (AV) node**
  - **Conducting cells**
    - Atrial conducting cells are found in internodal pathways (distributes the contractile signal to the atrial muscles)
    - Ventricular conducting cells consist of the AV bundle, bundle branches, and Purkinje fibers
1. The sinoatrial (SA) node (pacemaker) generates impulses.
2. The impulses pause (0.1 sec) at the atrioventricular (AV) node.
3. The atrioventricular (AV) bundle connects the atria to the ventricles.
4. The bundle branches conduct the impulses through the interventricular septum.
5. The Purkinje fibers stimulate the contractile cells of both ventricles.
Impulse Conduction through the heart

- SA node begins the action potential
- Stimulus spreads to the AV node
- Impulse is delayed at AV node
- Impulse then travels through ventricular conducting cells
- Then distributed by Purkinje fibers
- Sinoatrial (SA) node – Fires at 60–100 beats/minute
- Intranodal pathway
- Atrioventricular (AV) node – Fires at 40-60 beats/minute
- Atrioventricular bundle of His
  – Ventricular tissue fires at 20-40 beats/minute and can occur at this point and down
- Right and left bundle branches
- Purkinje fibers
**Impulse Conduction through the Heart**

**STEP 1:**
SA node activity and atrial activation begin.
Time = 0

**STEP 2:**
Stimulus spreads across the atrial surfaces and reaches the AV node.
Elapsed time = 50 msec

**STEP 3:**
There is a 100-msec delay at the AV node. Atrial contraction begins.
Elapsed time = 150 msec

**STEP 4:**
The impulse travels along the interventricular septum within the AV bundle and the bundle branches to the Purkinje fibers and, via the moderator band, to the papillary muscles of the right ventricle.
Elapsed time = 175 msec

**STEP 5:**
The impulse is distributed by Purkinje fibers and relayed throughout the ventricular myocardium. Atrial contraction is completed, and ventricular contraction begins.
Elapsed time = 225 msec
Autonomic regulation

- Originates in cardiovascular center of medulla oblongata
- Increases or decreases frequency of nerve impulses in both sympathetic and parasympathetic branches of ANS
- Norepinephrine has 2 separate effects
  - In SA and AV node speeds rate of spontaneous depolarization
  - In contractile fibers enhances Ca$^{2+}$ entry increasing contractility
- Parasympathetic nerves release acetylcholine which decreases heart rate by slowing rate of spontaneous depolarization
Autonomic Cardiovascular Control

- Hypothalamic autonomic centre
- Brainstem Solitary Tract Nucleus
- Sympathetic outflow
  - Vagus nerve
  - Preganglionic neuron
  - Sympathetic postganglionic neuron
  - $\alpha_2$
- Carotid sinus
- Arterial baroreceptors
- Aorta
- Sinus node
- Cardiac baroreceptors
- Arteriolar constriction $\alpha_1$-receptors

Fig. 6-4
Nervous System Control of the Heart

INPUT TO CARDIOVASCULAR CENTER
- From higher brain centers: cerebral cortex, limbic system, and hypothalamus
- From sensory receptors:
  - Proprioceptors—monitor movements
  - Chemoreceptors—monitor blood chemistry
  - Baroreceptors—monitor blood pressure

OUTPUT TO HEART
- Increased rate of spontaneous depolarization in SA node (and AV node) increases heart rate
- Increased contractility of atria and ventricles increases stroke volume
- Decreased rate of spontaneous depolarization in SA node (and AV node) decreases heart rate

Cardiovascular (CV) center
Cardiac accelerator nerves (sympathetic)
Vagus nerves (cranial nerve X, parasympathetic)
Conduction System of the Heart

(a)
- SA node
- Bachmann's bundle
- Internodal fiber
- AV node
- Bundle of His
- Bundle branches
- Purkinje fibers

(b)
- P
- Q
- S
- T
- U

Time (s)