# Cardiovascular System (C.V.S)

**Primary function** of the cardiovascular system is to supply body cells with O2 and nutrients and carry away CO2 and waste products.

Cardiovascular system is a closed circuit system, composed:

- **Heart**
- **Arteries**
- **Capillaries**
- **Veins**
- **Blood**

We can divide the primary function of CVS into two major divisions

- **Pulmonary circulation:** 1). carries blood to the lungs 2). Eliminates CO2 via the lungs and 3). returns blood to the heart

- **Systemic circulation:** 1). Supplies blood to the rest of the body 2). Delivers O2 to all the body 3). And carries away wastes.

## The Heart

The heart is a cone-shaped, hollow, muscular pump.

**Size:** the adult heart has a mass of between 250- 350 gram and is about the size of a clenched fist, around 14 cm long and 9 cm wide.

**Location:** the heart lies in the mediastinal area of thoracic cavity between the lungs.

**Surrounding structures:**

- Posterior to sternum
- Medial to lungs
- Anterior to vertebral column
- On the top of diaphragm
- About 2/3 of heart lies left to midline.

## Base, Apex, and Surfaces of the heart

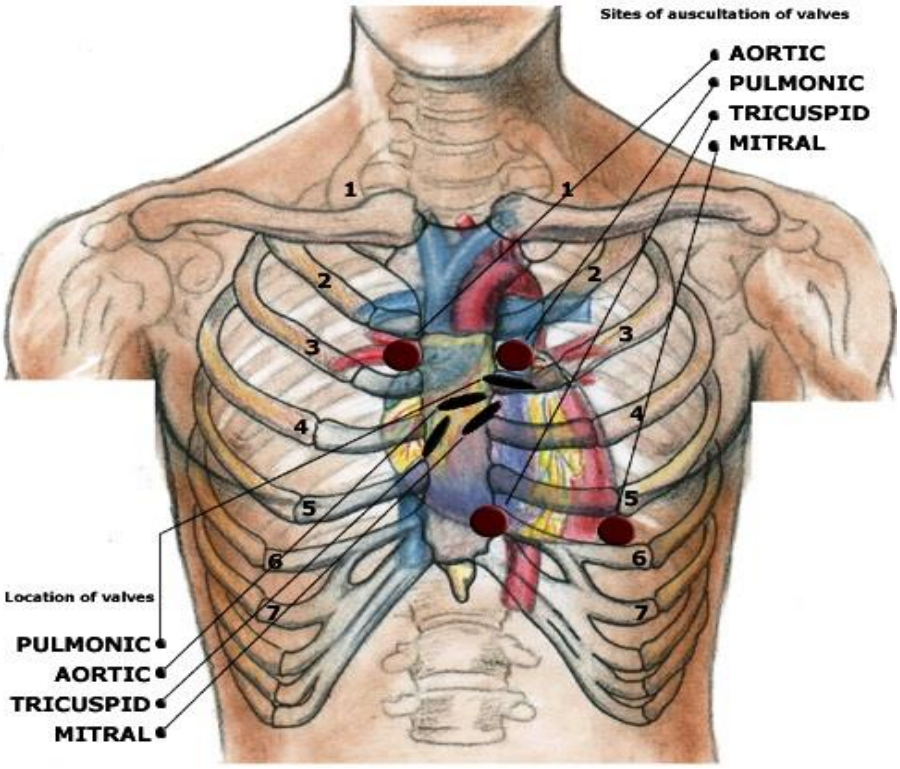
**Base:** is formed by left and right atria. Mostly the left atrium found beneath the 2nd rib.

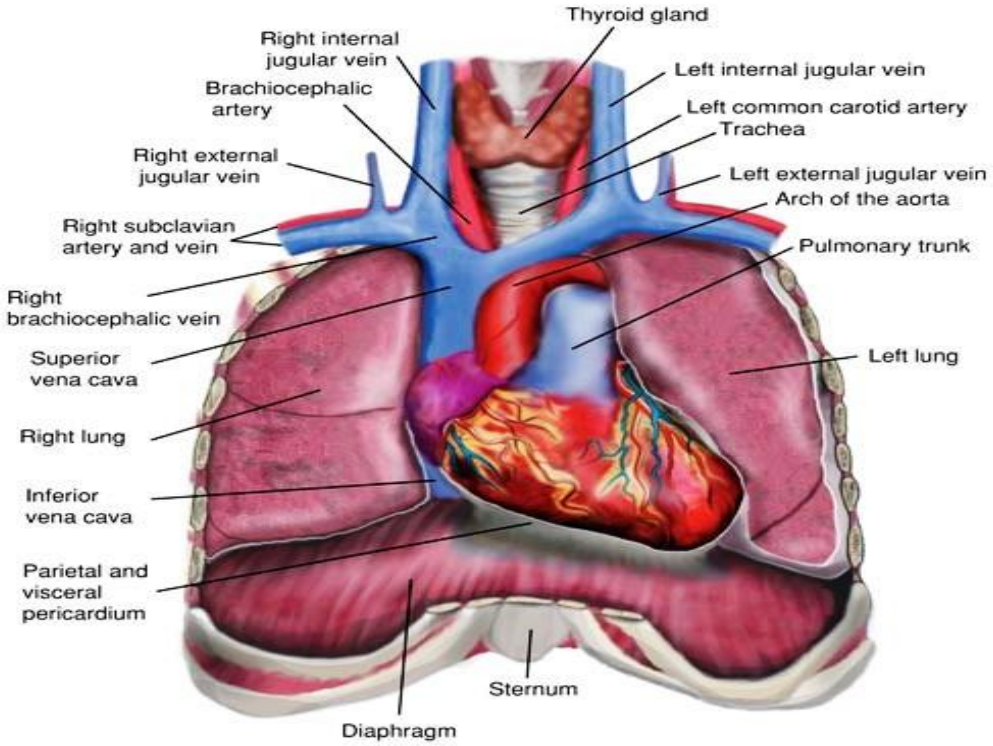
**Apex:** lies in the left 5th intercostal space, Formed by the left ventricle.

**Inferior/ diaphragmatic:** liens on underside. It formed by left and right ventricles.

**Anterior/ Sternocostal:** lies just behind the sternum and the ribs. Formed mostly by the right ventricle.

**Left/ pulmonary:** formed mostly by left ventricle.






## Pericardium

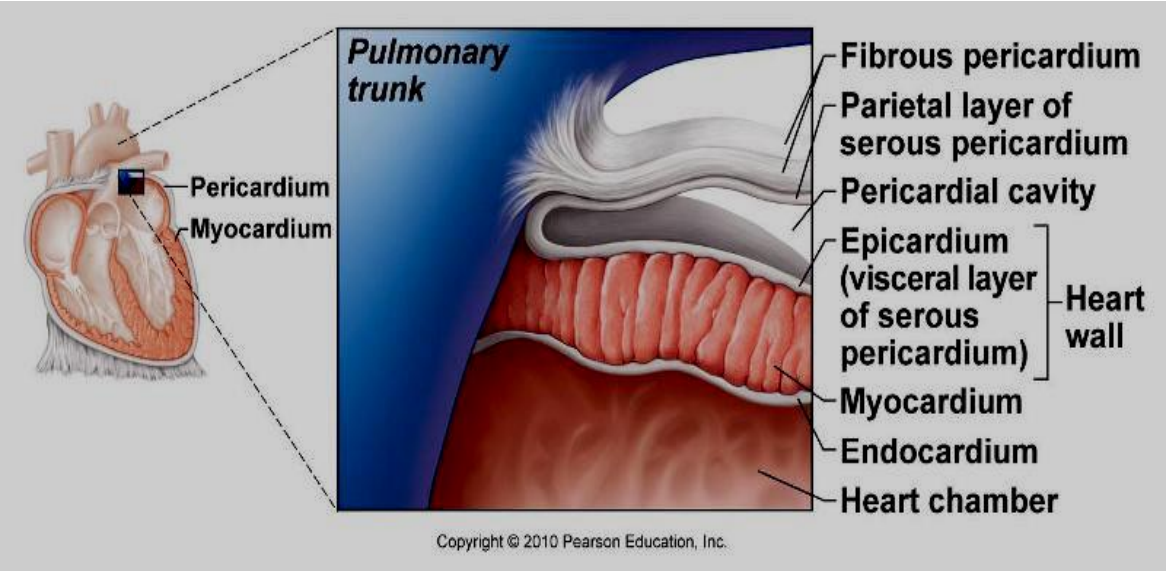
A sac called pericardium covers the heart. The pericardium restricts heart movements in the thoracic cavity and prevents overfilling with blood.

The pericardium is composed of 2 parts:

1. Fibrous pericardium: is the outer part of pericardium and it composed of tough dense connective tissue.
2. Serous pericardium: is the inner part of pericardium and it composed of 2 subdivisions **a). a parietal layer**: that lines the inner surface of the fibrous pericardium.

   **b). visceral layer <u>(epicardium)</u>:** that covers the outside of the heart.

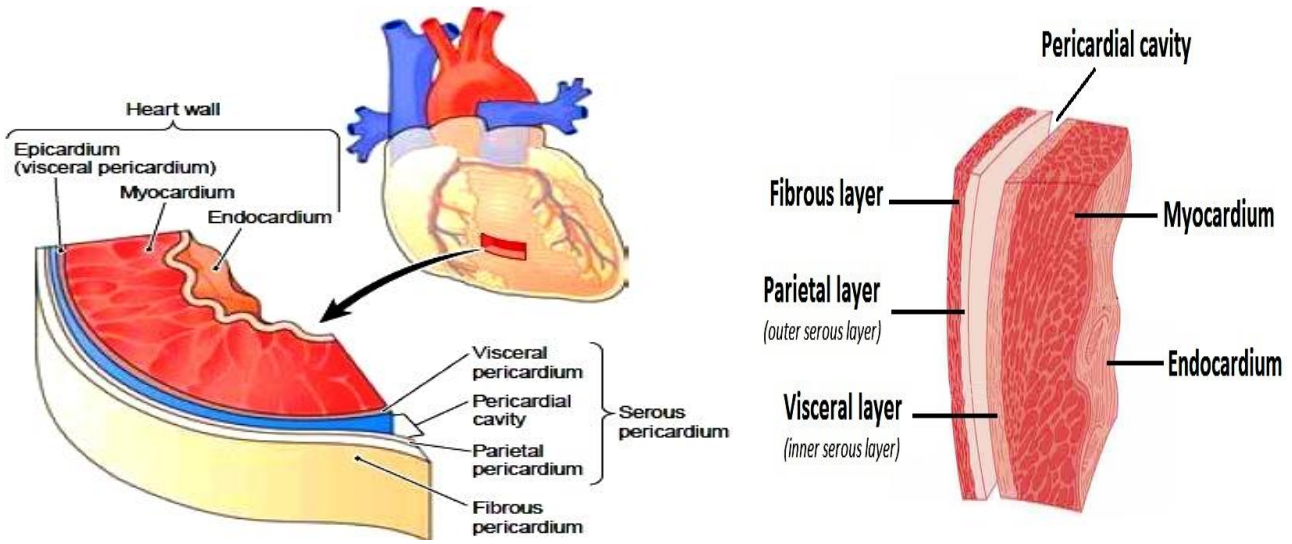
   **c). pericardial cavity**: a thin space between the parietal and visceral layers of pericardium which contains a **serous fluid**. The serous fluid lubricates the membranes and reduce prevents the friction during heartbeat.




## Heart wall Structure

The heart wall consists of three layers:

1. **The epicardium** (epi = upon or above): is the outer layer of the heart, composed mainly of simple squamous epithelium and areolar connective tissue.
2. **The myocardium** (myo= muscle): Is the middle layer of the heart wall .and, is composed of cardiac muscle tissue. The myocardium is the thickest of the three heart wall layers.
3. **The endocardium** (endon= within): is the inner layer of the heart wall and it composed of simple squamous epithelium and a layer of areolar connective tissue. The endocardium also covers the surface of valves and continues as the endothelium of blood vessels.




**Pericardium & cardiac wall structure 1**

# Chambers of the Heart

Heart consists 4 chambers, the 2 superior chambers are known as **atria** (**right atrium** and **left atrium**). The 2 inferior chambers are known as **ventricles** (**right ventricle** and **left ventricle**).

**Right Atrium**: it receives deoxygenated blood and passes it the right ventricle.

Opening into the right atrium:

1. **Superior vena cava** (blood comes from head neck, upper limbs and superior regions of the trunk and enters into right atrium)
2. **Inferior vena cava** (blood comes from lower limbs, and trunk and enters into right atrium.
3. **Coronary sinus** (blood comes from the heart wall and enters into right atrium).
4. **Right atrioventricular opening** (blood leaves right atrium and enters into right ventricle). This opening is guarded by tricuspid valve.

**Interatrial septum** forms a thin wall between the right and left atria.

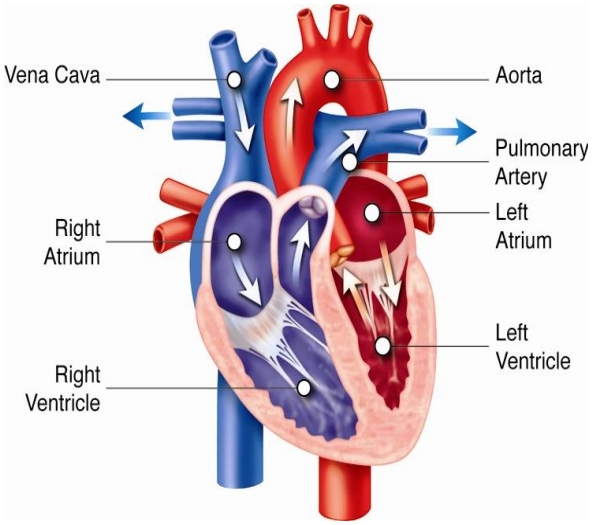
Fossa ovalis: is an oval depression in the interatrial septum. It represents a remnant of fetal foramen ovale.

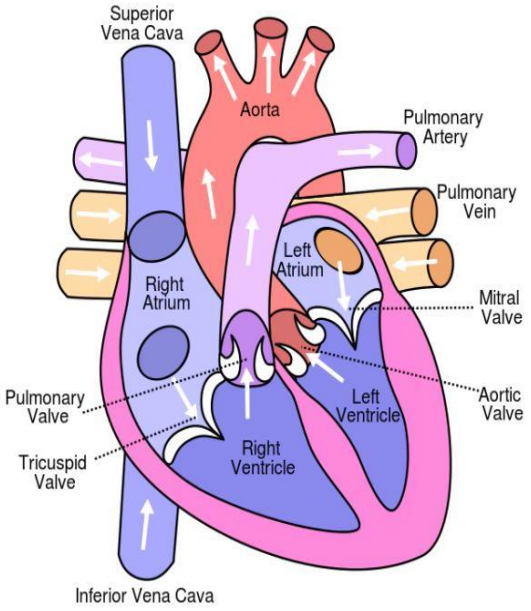
**Right Ventricle**: The right ventricle forms most of the anterior surface of the heart. Deoxygenated blood flows into the right ventricle from the right atrium.

Opening of the right ventricle:

1. Right aterioventricular opening (via tricuspid valve) blood enters ventricle
2. Pulmonary trunk (blood leaves the right ventricle and enters into pulmonary artery.

An interventricular septum forms a thick wall between the right and left ventricles




**Left Atrium:** oxygenated blood enters the left atrium from the pulmonary veins.

Opening of the left atrium:

1. Pulmonary veins (blood comes from lungs and enters left atrium).
2. Left atrioventricular opening: blood leaves left atrium and enter the left ventricle.this opening is guarded by mitral (bicuspid) valve.

**Left Ventricle:** oxygenated blood flows into the left ventricle from the left atrium. The wall of left ventricle is 2-3 times as thick as right ventricle.

Opening in the left ventricle:

1. Left atrioventicular opening (blood comes from the left atrium).
2. Aortic (blood leaves left ventricle to flows into aortic artery). It is guarded by aortic valve.

**The valves:** are connective tissue flaps that lined by epithelial tissue. Their function is to permit the passage of the blood in one direction and prevent backflow.

In the heart, there are 4 valves; two as atriovanticular and two as semilunar.

**Atrioventricular valves:**

1. Right atriovantricular valve (tricuspid) is made of three cusps.
2. Left atriovantricular valve (mitral or bicuspid) is made of two cusps.

The free edges of the cusps are attached to *papillary muscles* through the cord like structures called **cordae tendineae**.

**Papillary muscles:** these muscles are cone shaped which originated from the ventricular wall. There apex are connected to cordae tendineae.

**Cordae tendineae:** are fine tendinous cords which are attached from papillary muscles to the border of cusps.

This attachment is to prevent the bulging of the valves into the atria during ventricles contract.

**Semilunar Valves**:

1. Aortic valve: present at the opening the aorta in left ventricle. (has 3 cusps).
2. Pulmonary valve: present at the opening of pulmonary trunk. (has 3 cusps).

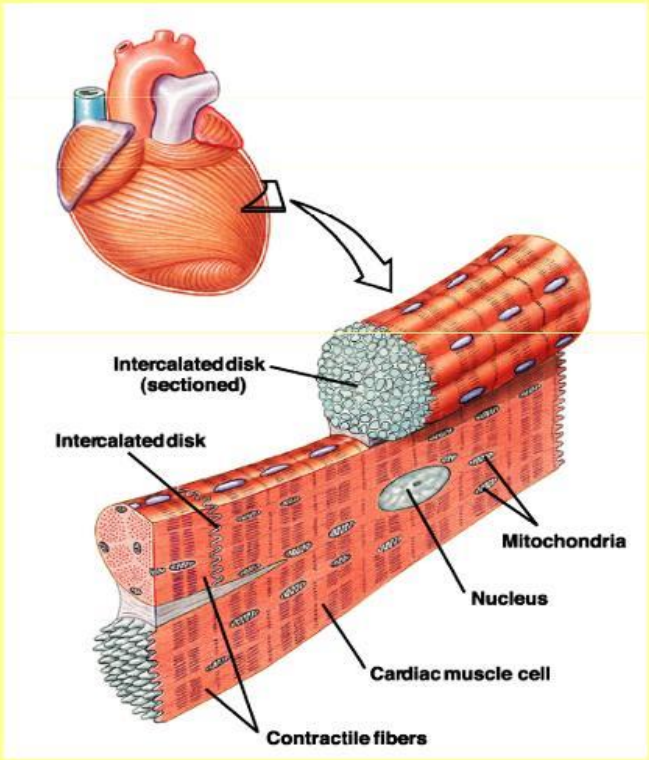
These valves open when ventricles contract to allow the blood to flow from right ventricle to pulmonary artery and from left ventricle to aorta.

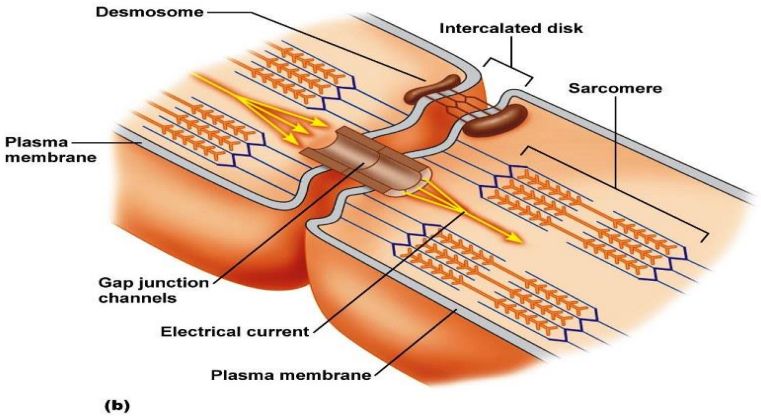
They close when ventricle relax.

## Cardiac Muscle

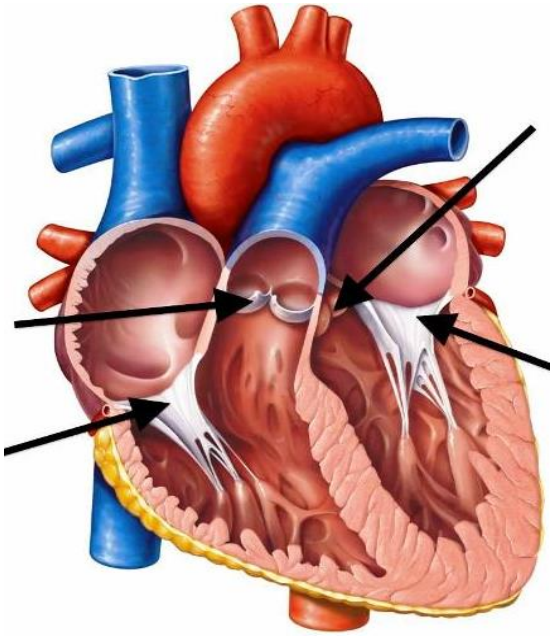
### Cardiac Muscle and Heart Function

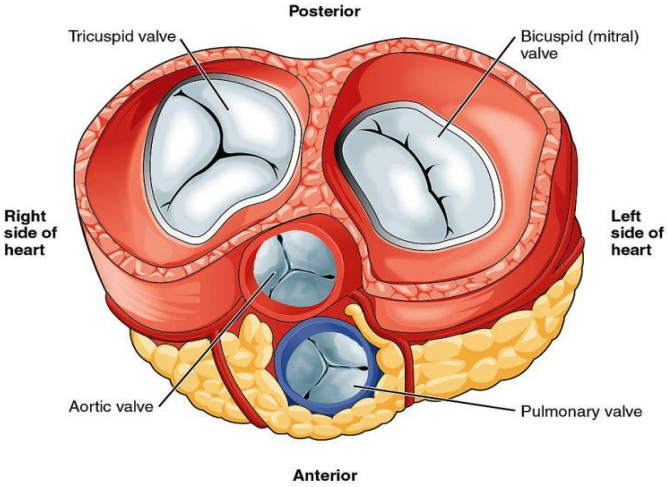
- Cardiac muscle fibers are striated – sarcomere is the functional unit
- Fibers are branched; connect to one another at intercalated discs. The discs contain several gap junctions
- Nuclei are centrally located
- Abundant mitochondria
- SR is less abundant than in skeletal muscle, but greater in density than smooth muscle
- Sarcolemma has specialized ion channels that skeletal muscle does not – voltage-gated Ca2+ channels
- Fibers are not anchored at ends; allows for greater sarcomere shortening and lengthening

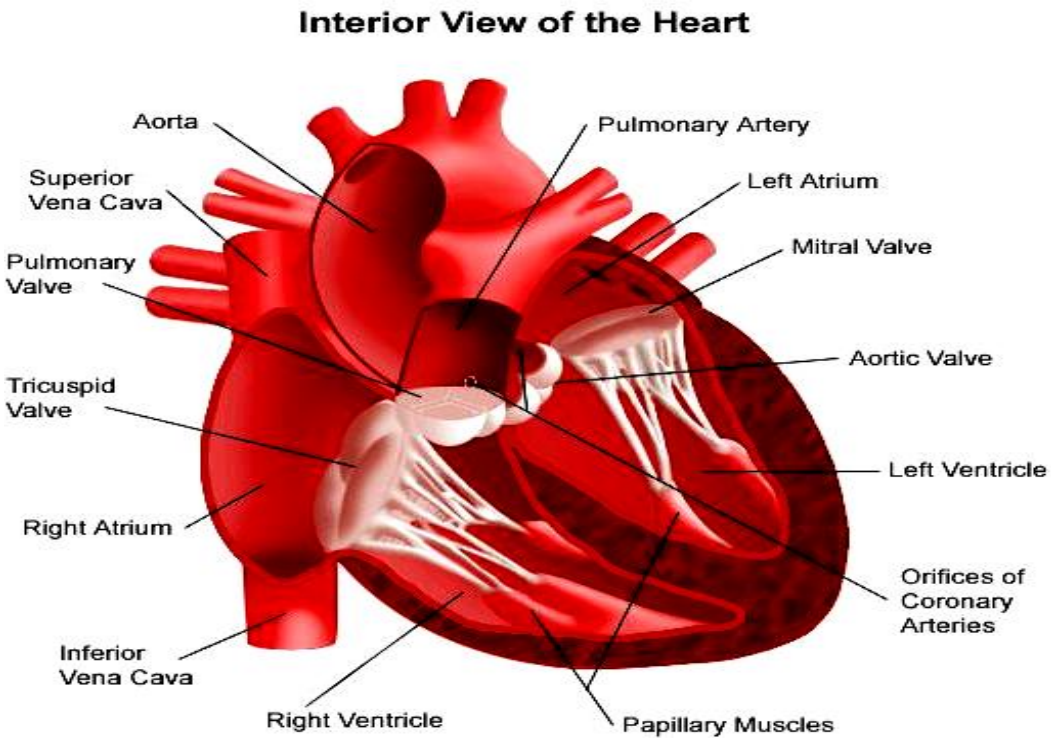













## Externally:

### Sulci of the Heart

1. **Coronary sulcus = ateriovantricular sulcus**: is a relatively deep groove that extends around the heart and separates atria and ventricles.
2. **Anterior interventricular sulcus**
3. **Posterior interventricular sulcus** located between the left and right ventricles.

### Fibrous skeleton of the Heart:

Is located between the atria and ventricles.

**Functions:**

1. Separate atria and ventricles.
2. Anchors heart valves.

3. Provides electrical insulation between atria and ventricles. (so prevent contraction of all chambers at the same time).

## Blood supply to the heart

### Arteries

**Left** and **right** **coronary arteries**: their origin is ascending aorta.

- **Right coronary artery** it gives two branches:

1. *Right marginal artery*: it supplies the right border of the heart.
2. *Posterior interventricular artery*: it supplies the right and left ventricles.

- **Left coronary artery** it gives the following branches:

1. *Anterior interventricular artery* (left anterior descending artery): it supplies the anterior surface of both ventricles.
2. *Circumflex artery*: supplies the left atrium and ventricle.

**Veins**

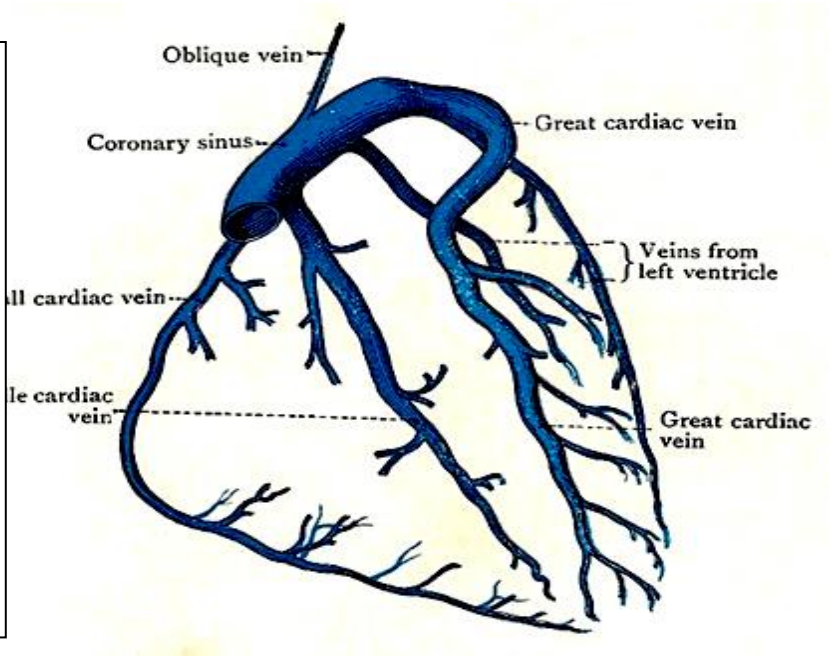
**Coronary sinus:** receive blood from:

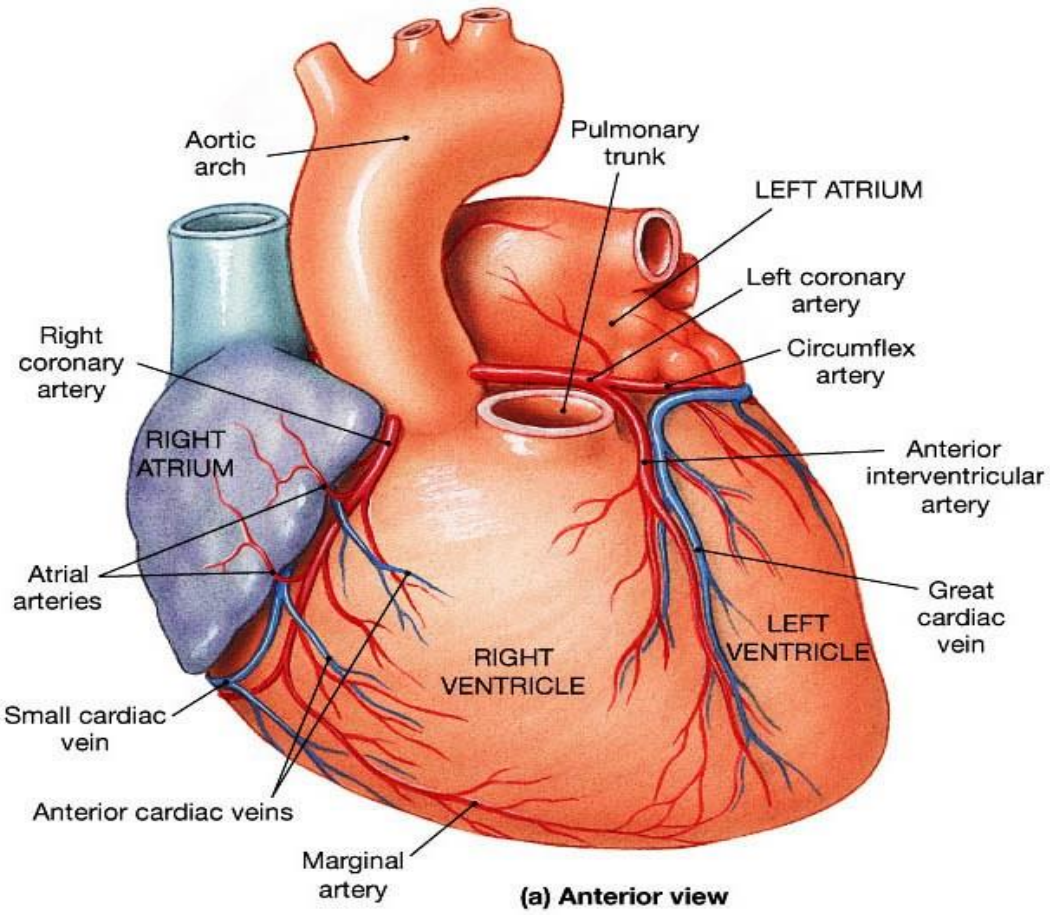
1.great cardiac vein

2. middle cardiac vein

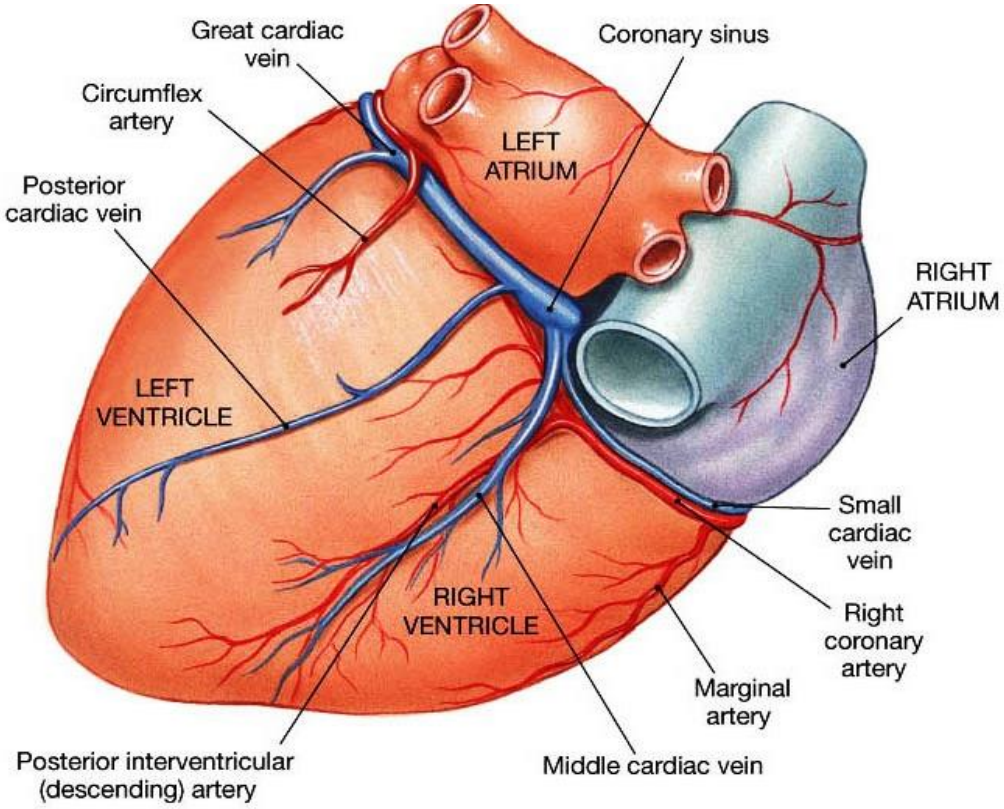
3. small cardiac vein

**The coronary sinus opens directly into the right atrium**

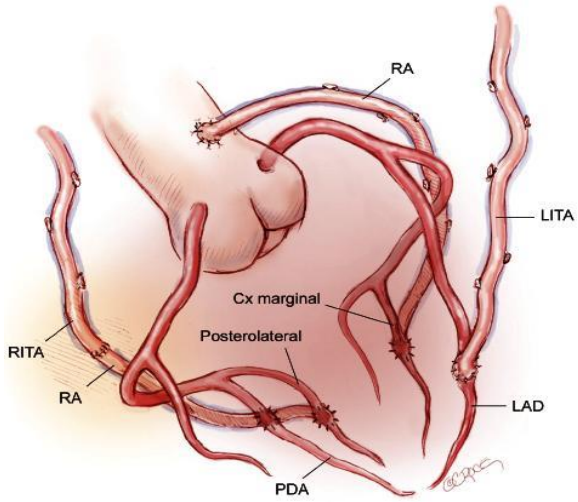


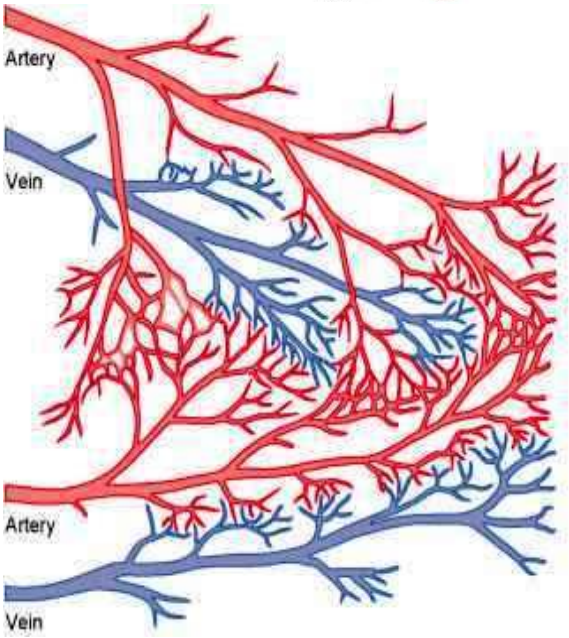



**(a) Anterior view**




**(b) Posterior view**




- *Connections among smaller arteries are called anastomoses.*

*Anastomoses may delay appearance of ischemic heart symptoms***.**

## Nerve Supply to the heart

**Sympathetic:** derived from thoracic spinal cord T1-T2.

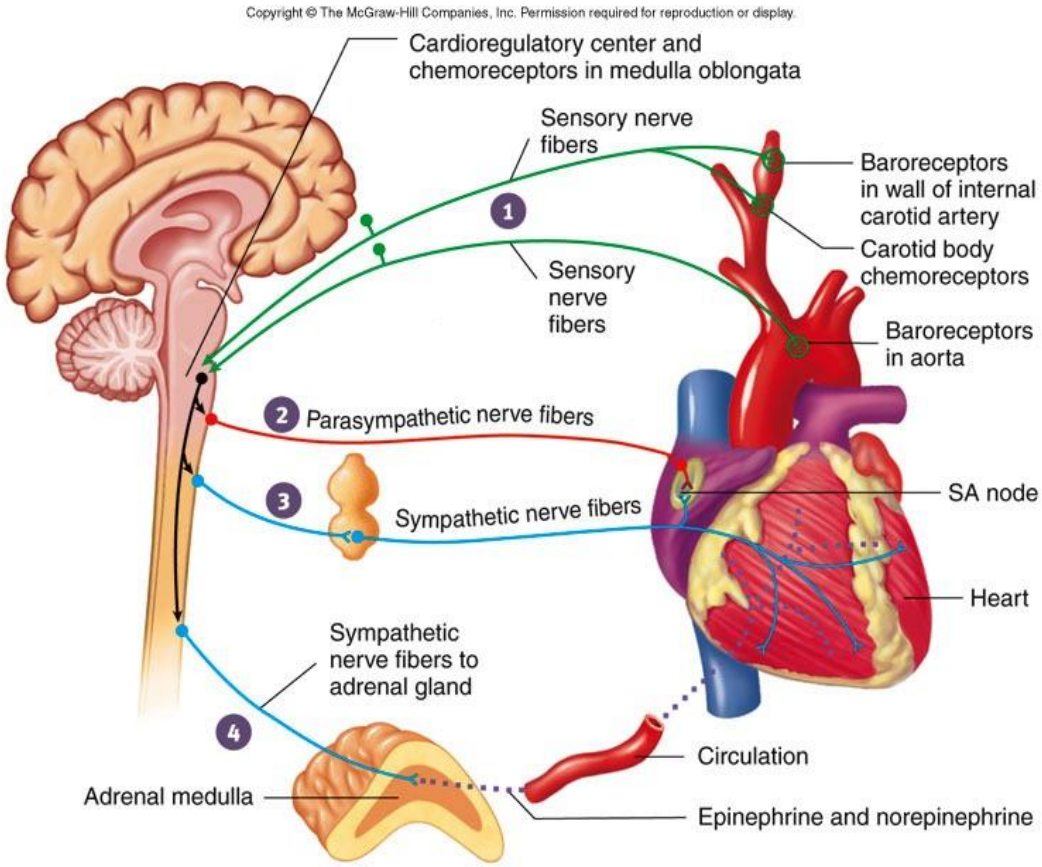
Stimulation of the heart by sympathetic nervous system leads to

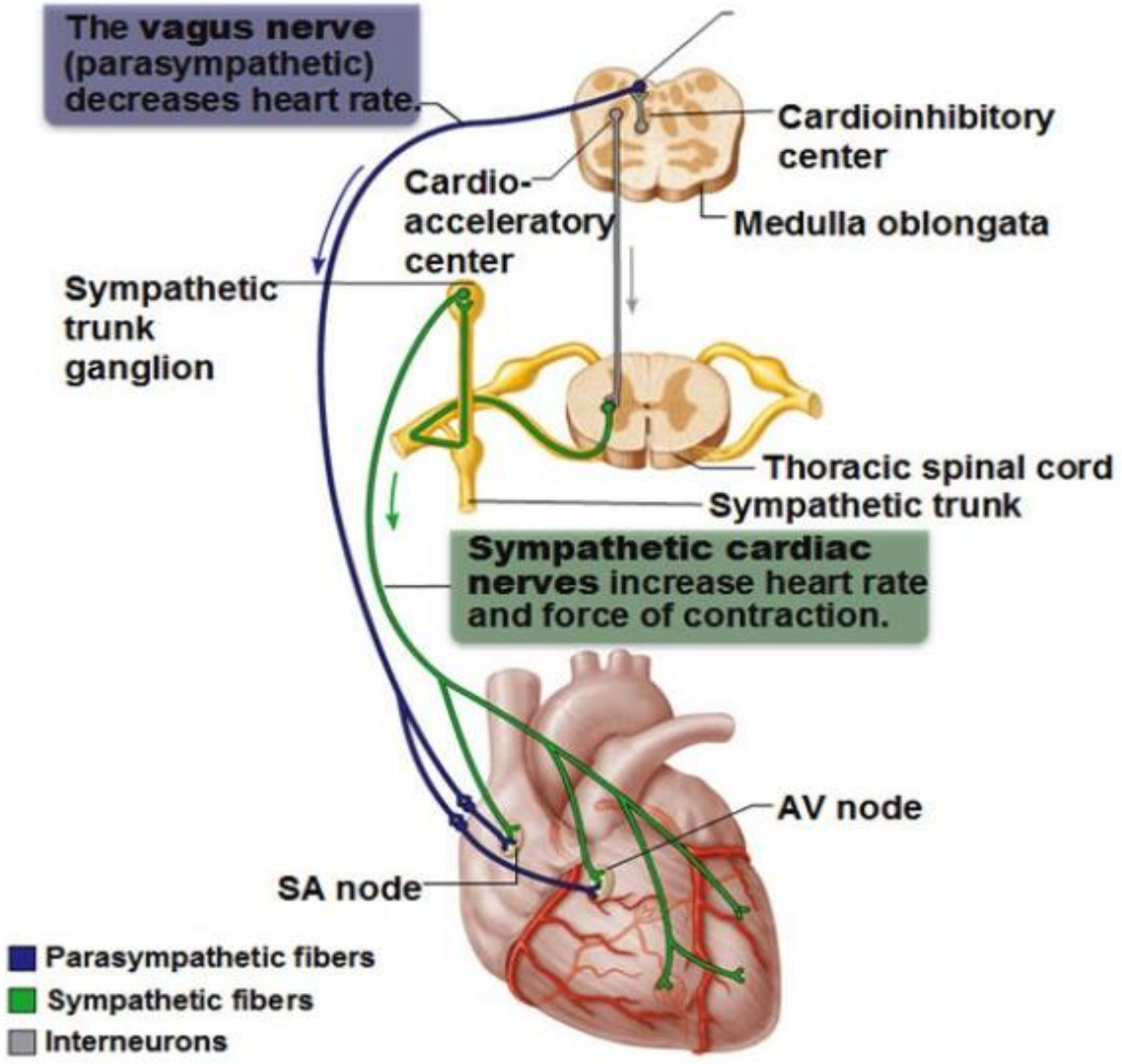
**increase heart rate (tachycardia), increase force of contraction,** and **dilation of coronary arteries.**

**Parasympathetic:** branches of vagus nerve (cranial nerve X)

Stimulation of the heart by parasympathetic nervous system leads to:

**<u>Slowing of the heart</u> (bradycardia), <u>reduction in the force of contraction</u>, and <u>constriction of coronary arteries</u>.**




The vagus nerve (parasympathetic) decreases heart rate.
Cardioinhibitory center
Cardio-accelerator center
Medulla oblongata
Sympathetic trunk ganglion
Thoracic spinal cord
Sympathetic trunk
Sympathetic cardiac nerves increase heart rate and force of contraction.
AV node
SA node
Parasympathetic fibers
Sympathetic fibers
Interneurons

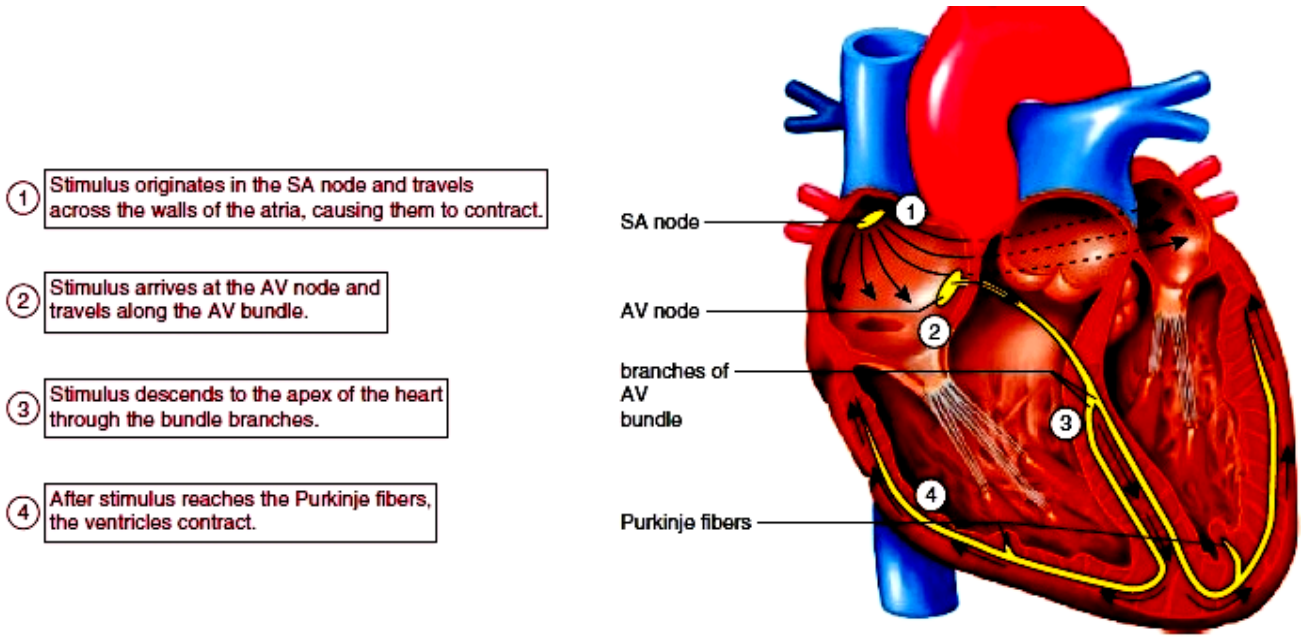
# Conducting System of the Heart

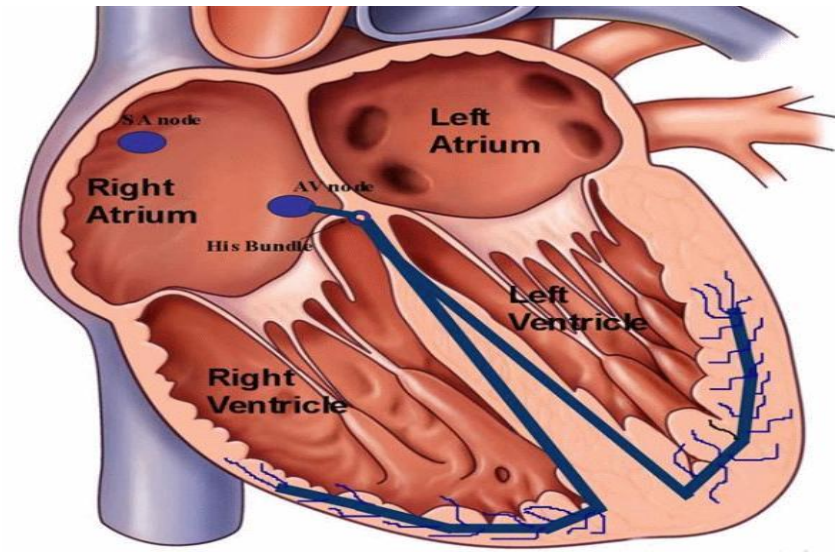
The heartbeat originates in a **specialized cardiac muscle cells (cardiac conducting system)** and spreads via this system to all parts of the myocardium.

Parts of conducting system:

1. **Sinoatrial (SA) node** is located in the **posterior wall of right atrium** (at the junction of the superior vena cava with the right atrium).
2. **Atrioventricular (AV) node** is located in the right posterior portion of interaterial septum
3. **Bundle of His:** located in the interventricular septum and divided into branches right and left.
4. **Purkinje fibers:** begin within the apex of the heart and extend through the walls of the ventricles.

**This system has ability to stimulate cardiac contraction without any innervations.**

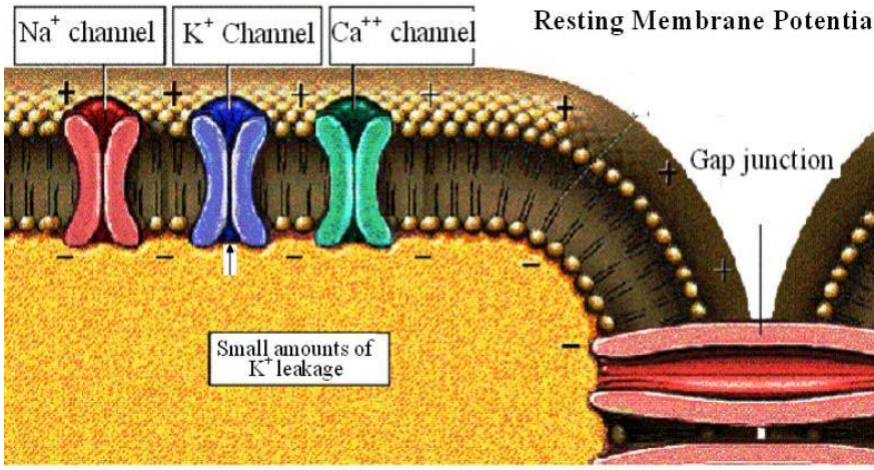





## Electricity and Action potential of the cardiac muscle

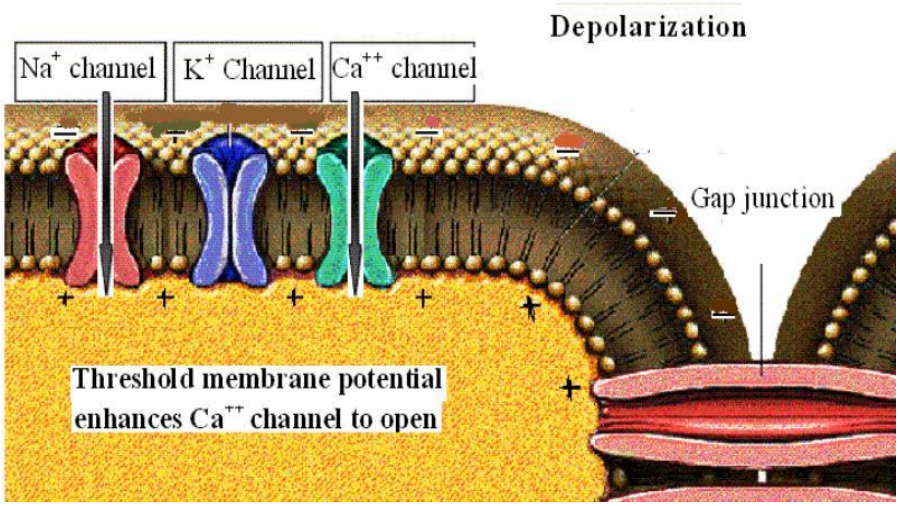
- Myocardial fibers have a resting membrane potential of approximately (-90) mV.

- At resting membrane potential the $Na^+$ channel $Ca^{++}$ channel are closed. While some leakage of $K^+$ through $K^+$ channel.




- The action potential in the stimulated cardiac myocyte is divided into 5 phases:

- Phase 0 : rapid depolarization: occurs due to rapid $Na^+$ influx, so the inner membrane gradually becomes less negative, and when the membrane potential becomes (- 40)mV (reaches the threshold for initiating action potential), the $Ca^{++}$ influxes leads to produce the rapidly rising phase of action potential depolarization. The membrane potential reaches to the +30 mV.

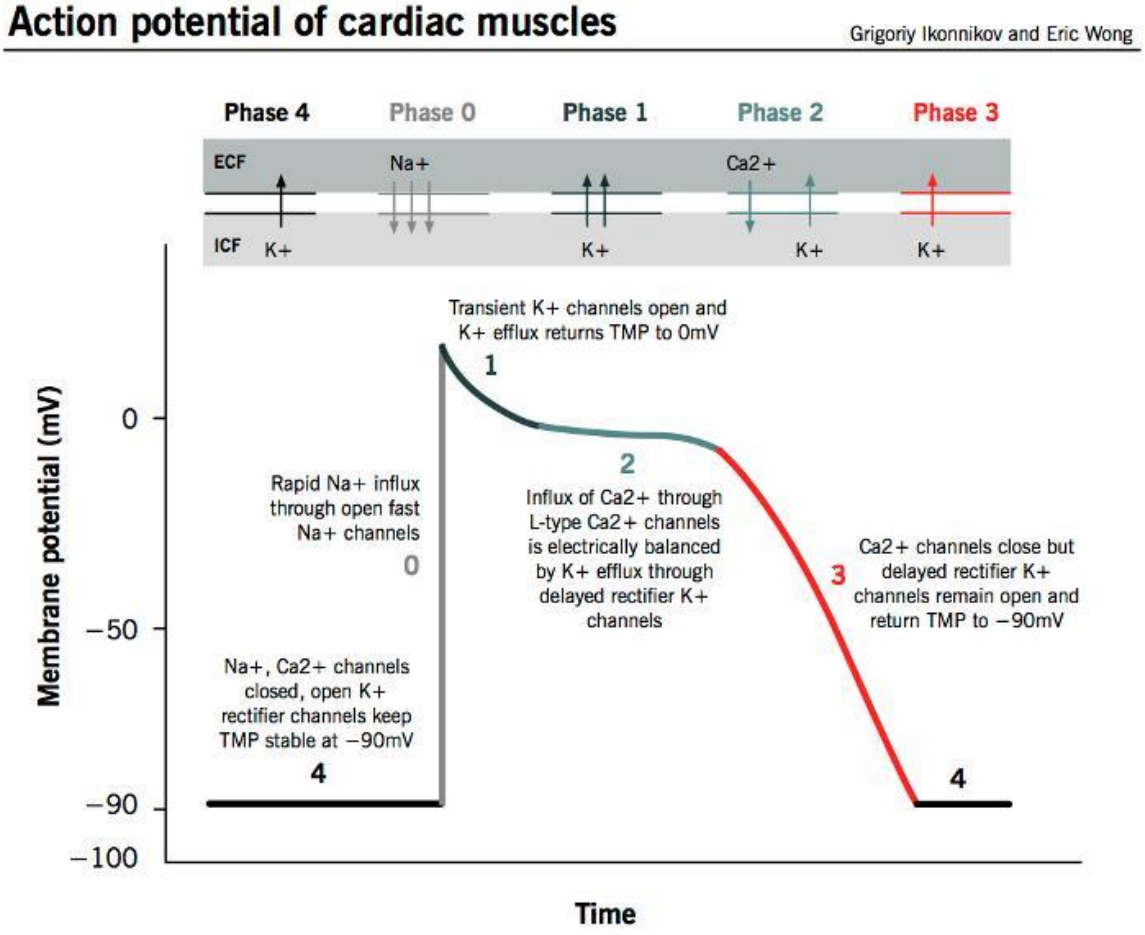



- Phase 1: initial rapid repolarization. It is a short phase. The membrane potential in this phase reaches to (-10) mV. This phase occurs due to closure of $Na^+$ channel and opening of $K^+$ channel.

- Phase 2: plateau. It occurs due to slow influx of $Ca^{++}$.

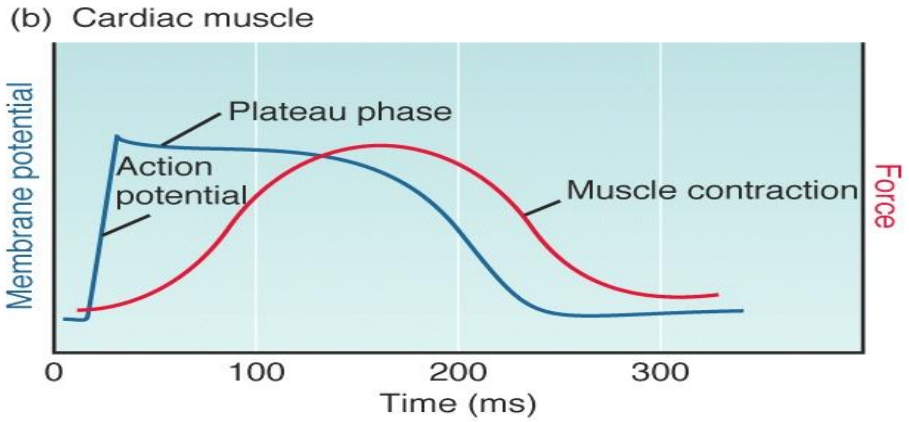
- Phase 3: repolarization. during this phase complete repolarization and the membrane reaches to approximately resting value.

- Phase 4: resting potential. The membrane potential is maintained at (-90)mV.




Action potential causes the release Ca++ into cytoplasm (from sarcoplasm) which causes the muscle contraction.

All heart cells are electrically joint one to another by intercalated disc (gap junction), so one cardiac muscle generate action potential it just spread to the other.



**Duration of action potential:** is about **250 msec.** at a heart rate **75 beats/ minute.** The duration of action potential decrease when heart rate increases.

## Cardiac cycle

It is the inclusive period of time from the start of one heartbeat to the initiation of the next.

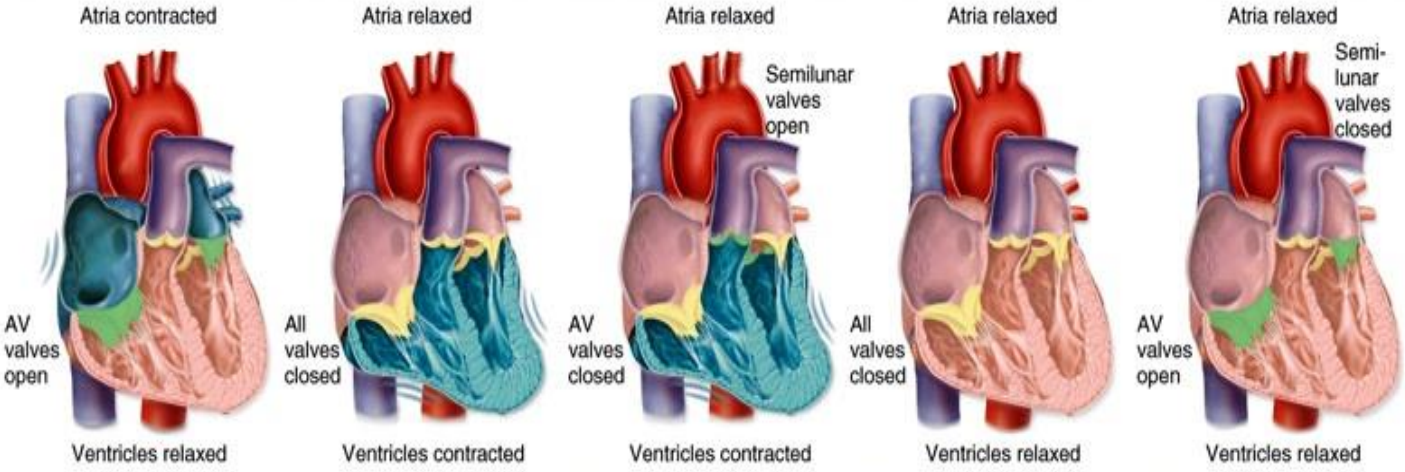
In each cardiac cycle, there are alternate contractions and relaxation of all chambers.

Each contraction is called **systole** and each relaxation is called **diastole.**

The events at single cardiac cycle:

1. **Atrial systole:** contraction of both atria (left and right) simultaneously leads to move blood (20%) from atria to the ventricles (from right atrium to the right ventricle through tricuspid valve. And from left atrium to the left ventricle through mitral valve).
2. **Atrial diastole:**
3. **Ventricular systole:** In this period, the tricuspid and mitral valves are closed, and the blood forced into the blood vessels through semilunar valves (from left ventricle to the pulmonary artery. And from left ventricle to the aorta).
4. **Ventricular diastole:** most of blood (80%) flows passively from relaxing atria into the ventricles through the open aterioventricle valves.

| Structure \ Phase | Atrial systole | Early ventricular systole ⟷ Late ventricular systole | Early ventricular diastole ⟷ Late ventricular diastole |
|---|---|---|---|
| Atria | Contract | Relax | Relax |
| Ventricles | Relax | Contract | Relax |
| AV valves | Open | Closed | Open |
| Semilunar valves | Closed | Open | Closed |



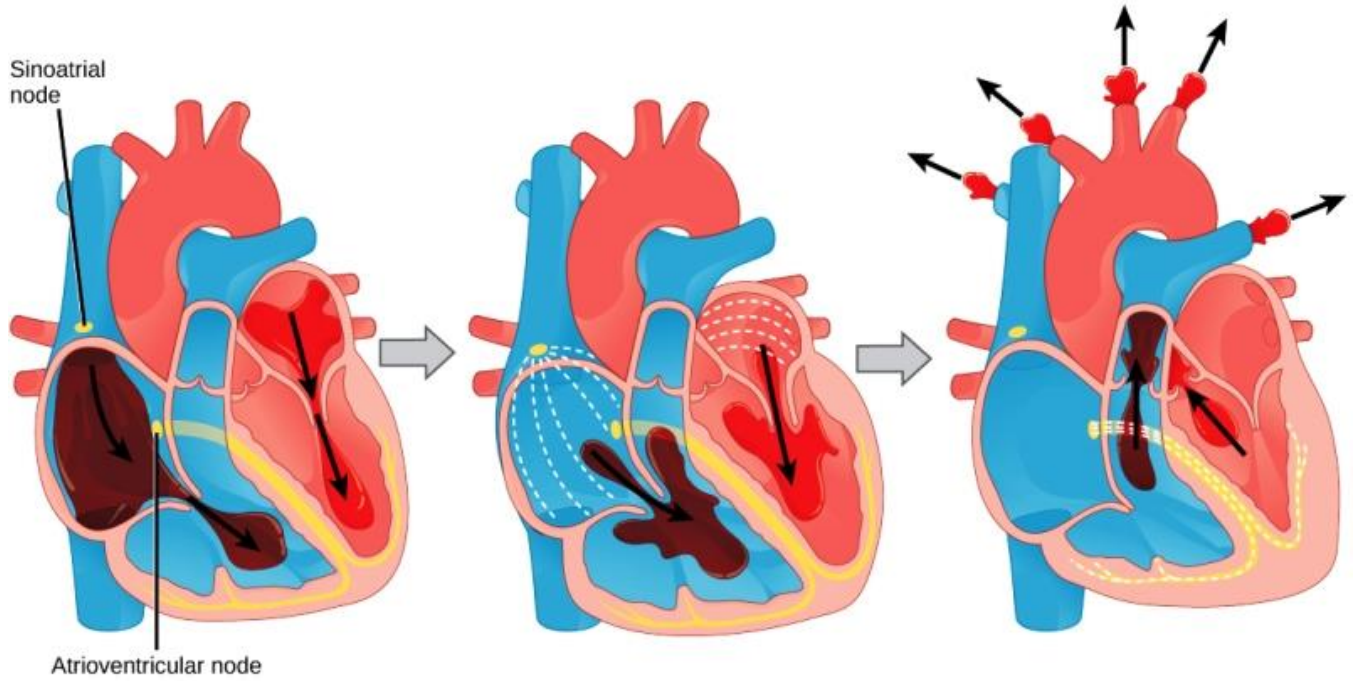

(1) **Atrial systole** Atria contract, AV valves open, semilunar valves closed

(2) **Early ventricular systole** Atria relax, ventricles contract, AV valves forced closed, semilunar valves still closed

(3) **Late ventricular systole** Atria relax, ventricles contract, AV valves remain closed, semilunar valves forced open

(4) **Early ventricular diastole** Atria and ventricles relax, AV valves and semilunar valves closed, atria begin passively filling with blood

(5) **Late ventricular diastole** Atria and ventricles relax, atria passively fill with blood as AV valves open, semilunar valves closed



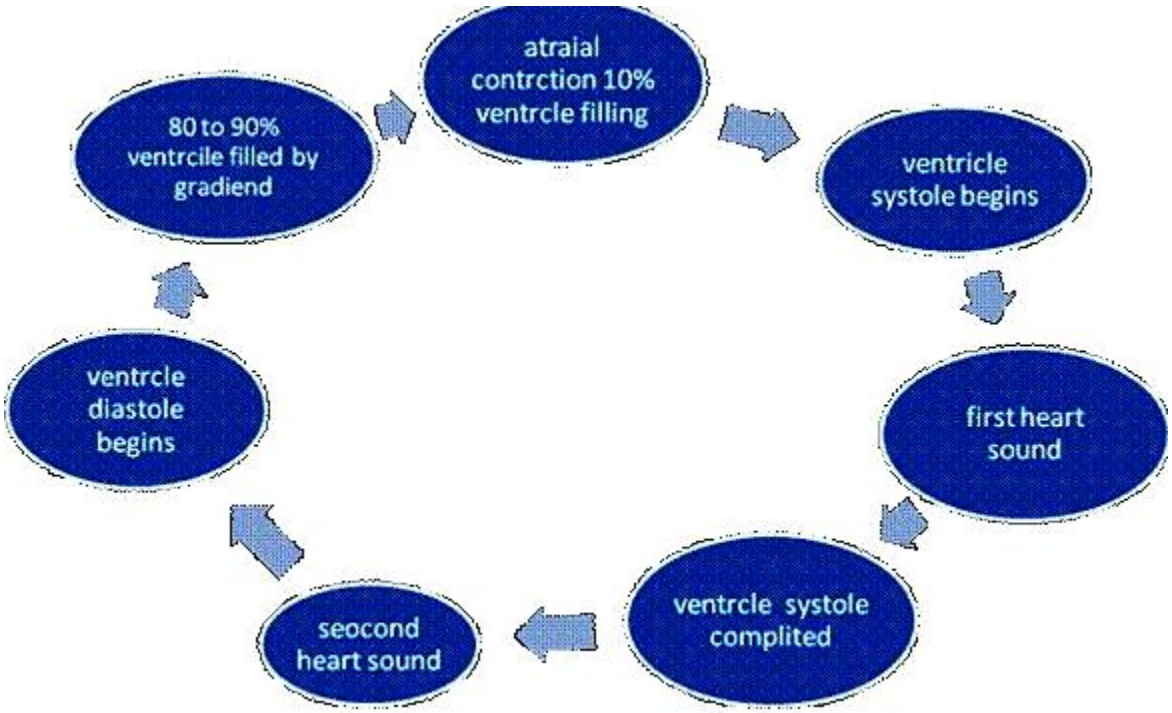

**(a) Cardiac diastole**: all chambers are relaxed, and blood flows into the heart.

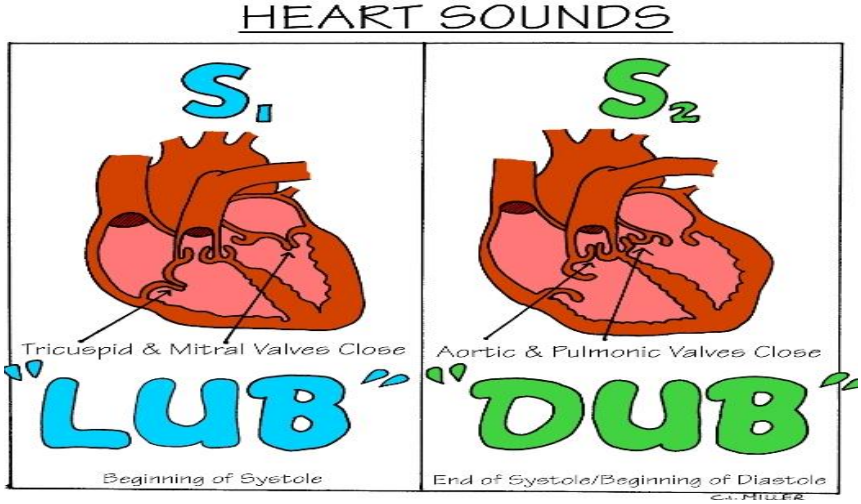
**(b) Atrial systole, ventricular diastole**: atria contract, pushing blood into the ventricles.

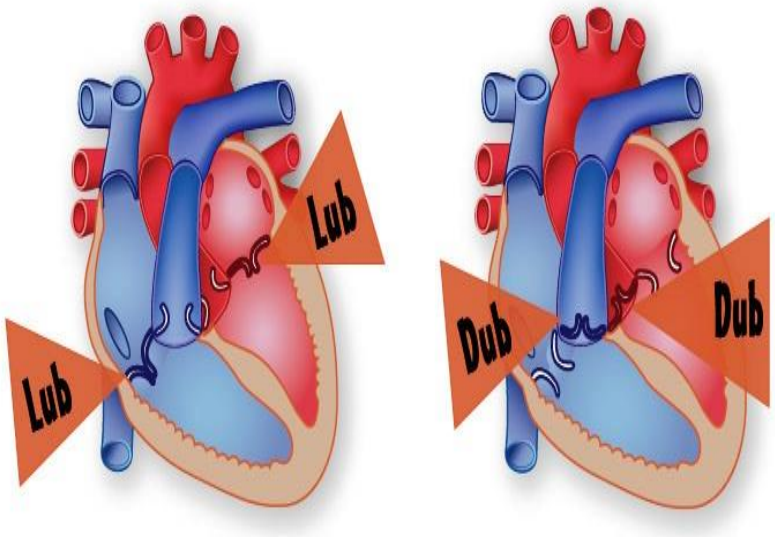
**(c) Atrial diastole, ventricular systole**: after the atria relax, the ventricles contract, pushing blood out of the heart.

## Heart Sounds

1. **Labb Sound**: Made by contraction of ventricles and closure of tricuspid and mitral valves.
2. **Dupp Sound**: Made by closure of pulmonary and aortic valves. When ventricles relax.


atraial contrction 10% ventrcle filling
ventricle systole begins
first heart sound
ventrcle systole complited
seocond heart sound
ventrcle diastole begins
80 to 90% ventrcile filled by gradiend


HEART SOUNDS
S1
S2
Tricuspid & Mitral Valves Close
Aortic & Pulmonic Valves Close
"LUB"
"DUB"
Beginning of Systole
End of Systole/Beginning of Diastole
C. MILLER

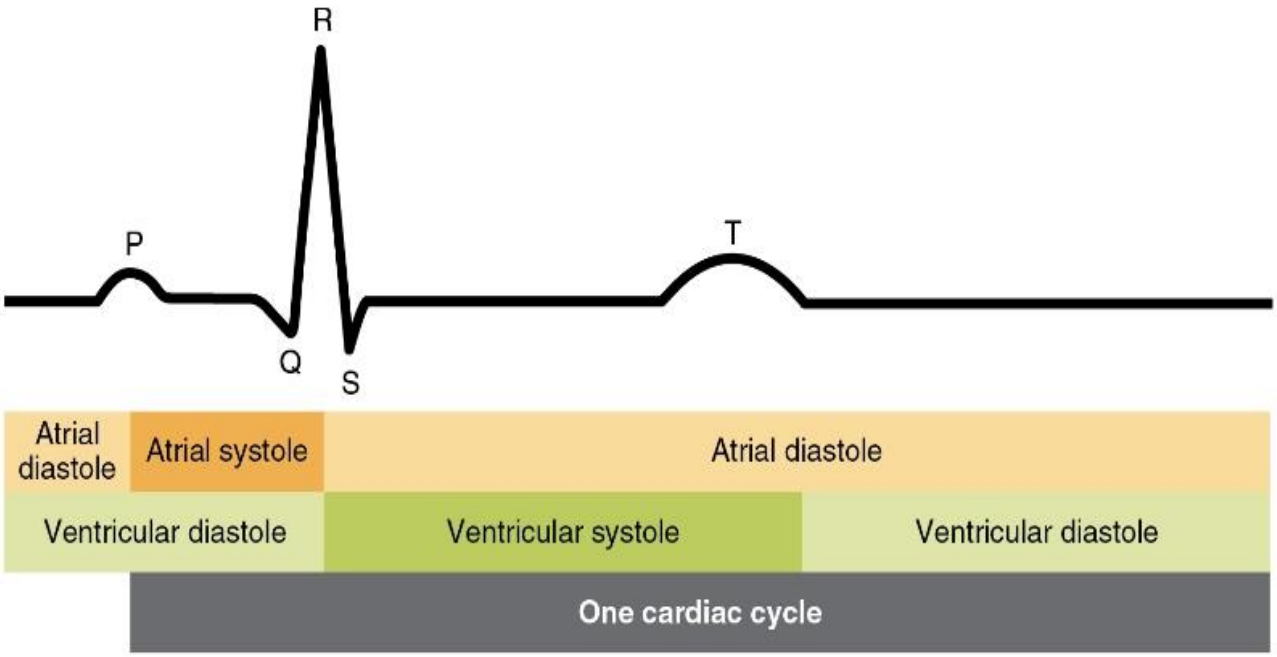

Normal Heart "Lub"
Normal Heart "Dub"
Lub
Lub
Dub
Dub

# Normal Electrocardiogram (ECG or EKG)

It refers to the record of the potential fluctuation during the cardiac cycle. Due to sequential spread of the excitation in the:

1. Atria
2. Interventricular septum.
3. Ventricular wall
4. Repolarization of the myocardium

These events appear in the ECG as a **series of positive and negative waves** (P, Q, R, S, and T).

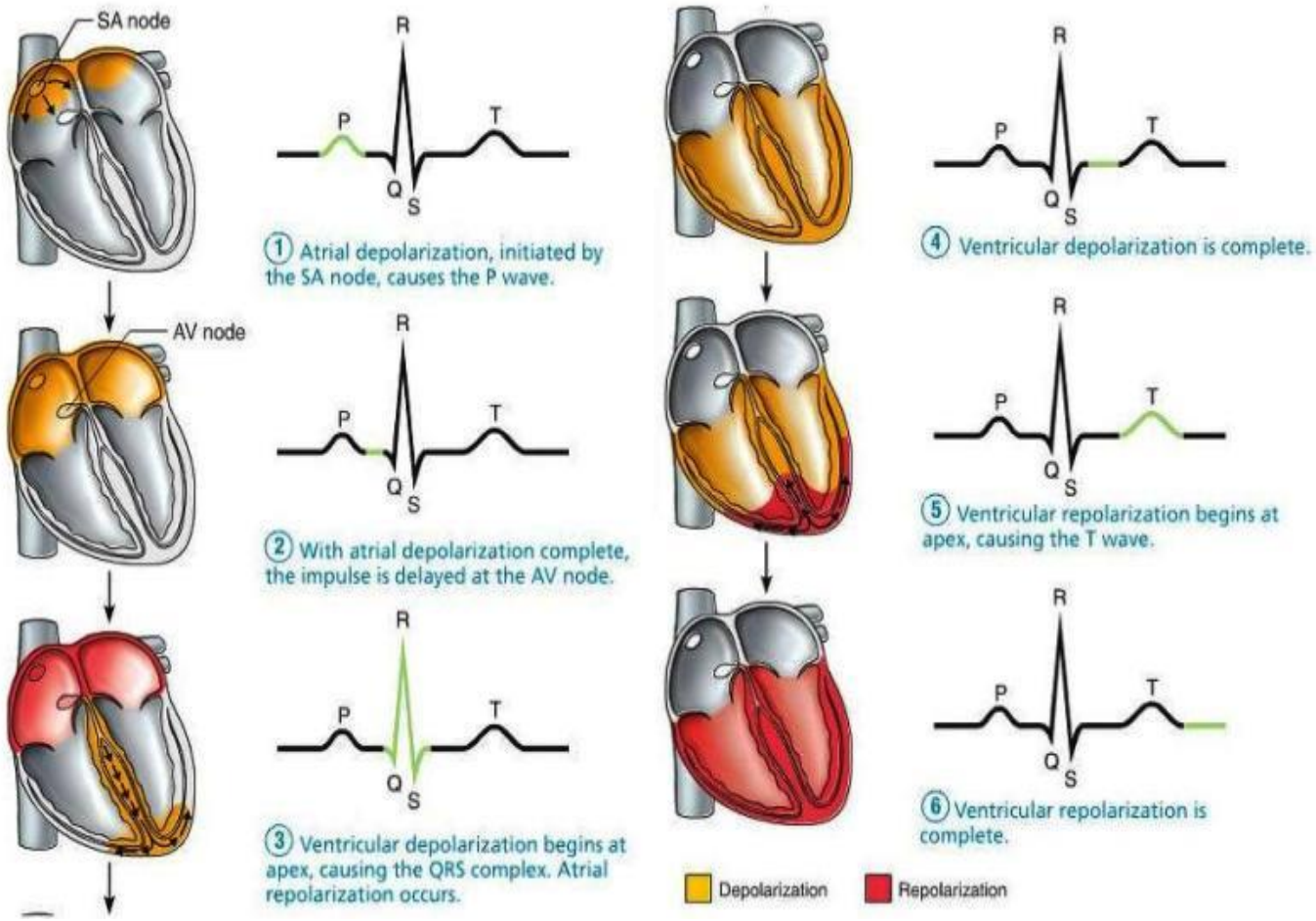



# Waves of ECG

***P wave:*** atrial depolarization

***QRS complex wave:*** ventricular depolarization

***T wave:*** ventricular repolarization.




## Intervals and segments

***P-R interval:*** it measured from the onset of P wave to the onset QRS complex.

It measures the AV conduction time. Its duration varies from 0.12-0.2sec.

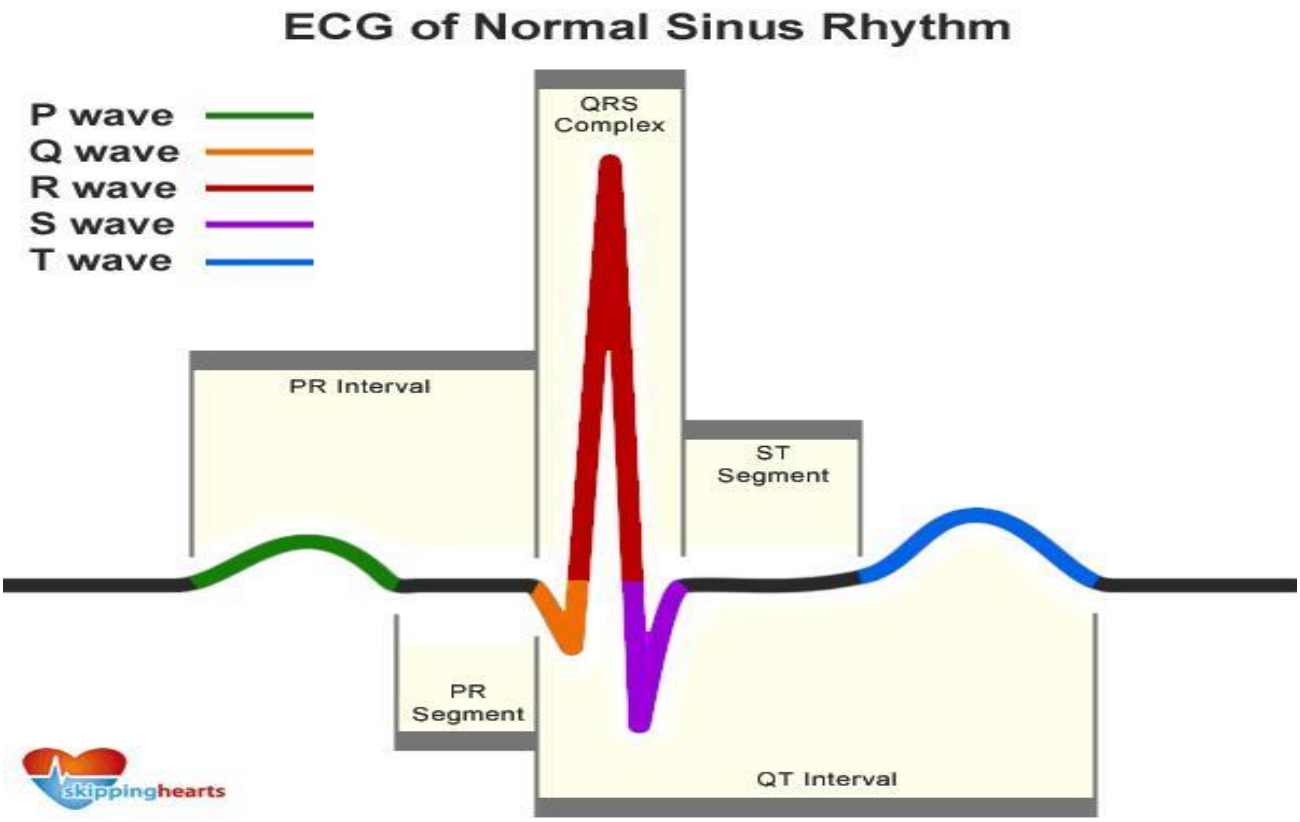
***QT interval:*** it is the time from the start of the QRS complex to the end of T wave.

It indicates total systolic time of ventricle (ventricular depolarization and repolarization).

***PQ segment:***

***ST segment:*** it is an isoelectric period between the end of QRS and beginning of T wave.

Its duration is about 0.32 sec.




## Clinical application of ECG:

It is important in the diagnosis, prognosis, and planning treatment of the cardiac disorders e.g.:

1. Cardiac arrhythmias
2. Myocardial infarction
3. Cardiac hypertrophy
4. Changes in the ionic composition of the heart.

## Cardiac Output

It means the amount of blood ejected by each ventricle per minute.

Stroke volume: is the amount of blood ejected by each ventricle per beat

Cardiac output = *stroke volume* **x** *heart rate*