

Physiology of the cardiovascular system

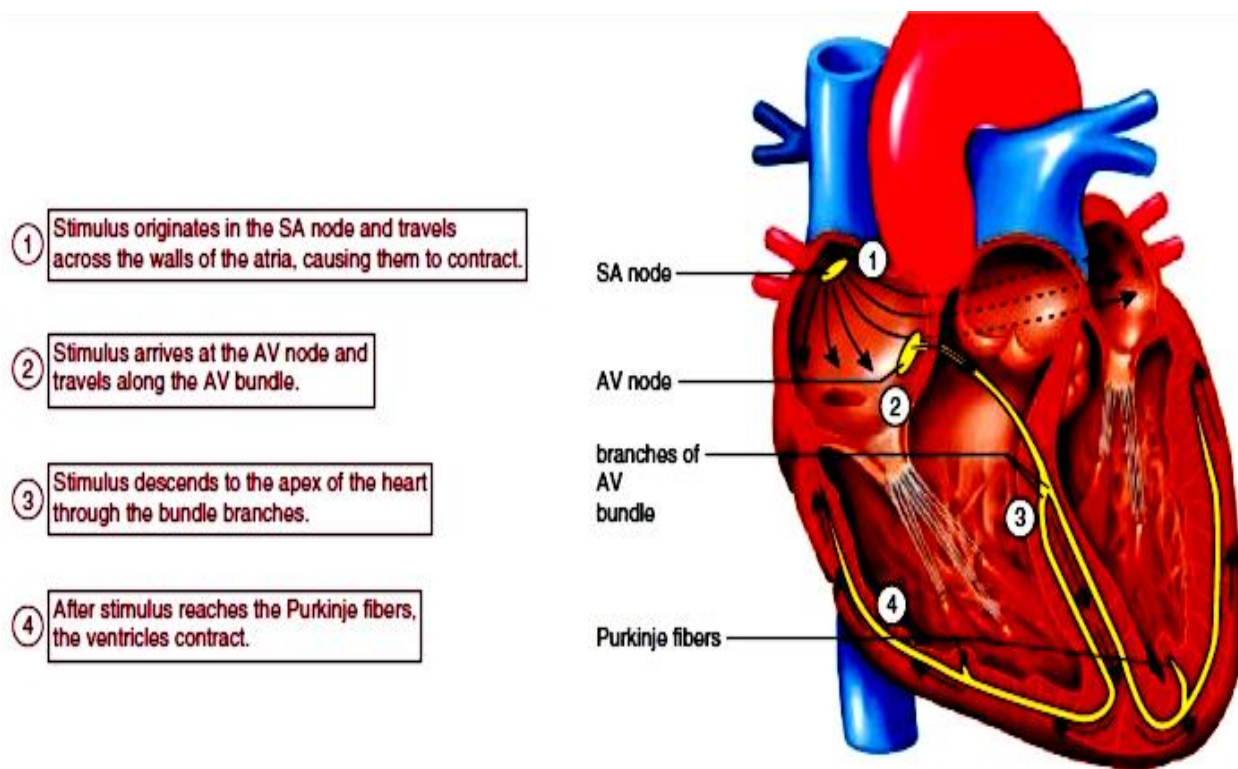
Conducting System of the Heart

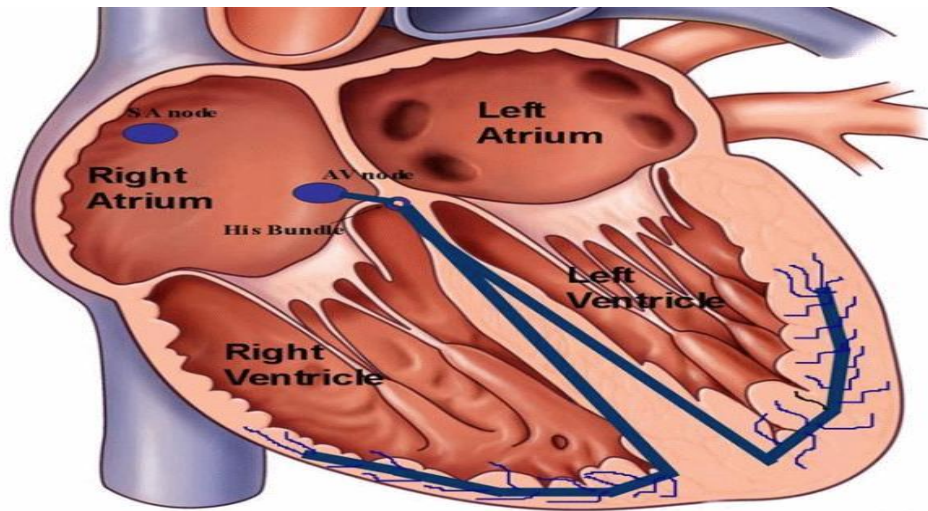
The heartbeat originates in a specialized cardiac muscle cells (cardiac conducting system) and spreads via this system to all parts of the myocardium.

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 interatrial 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.

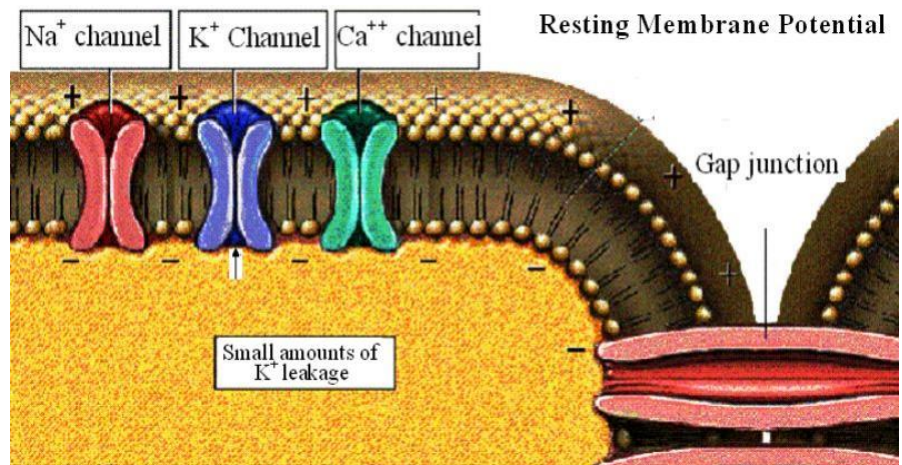




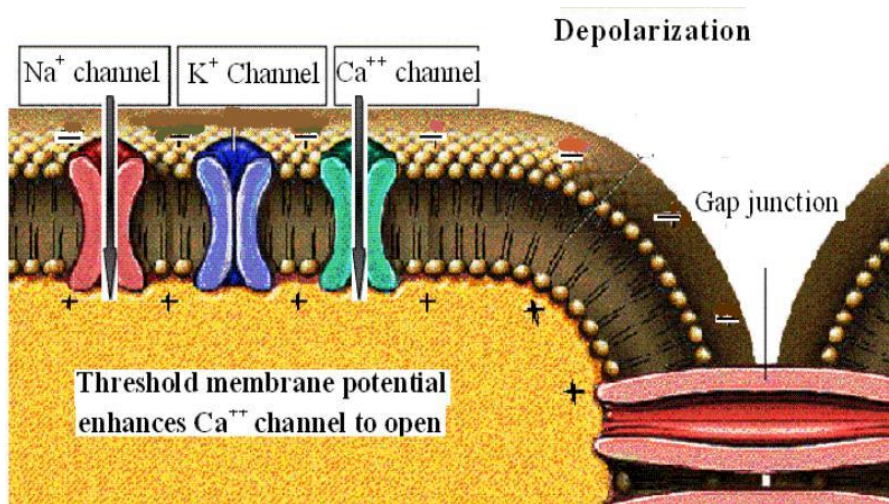
Electricity and Action potential of the cardiac muscle

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

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



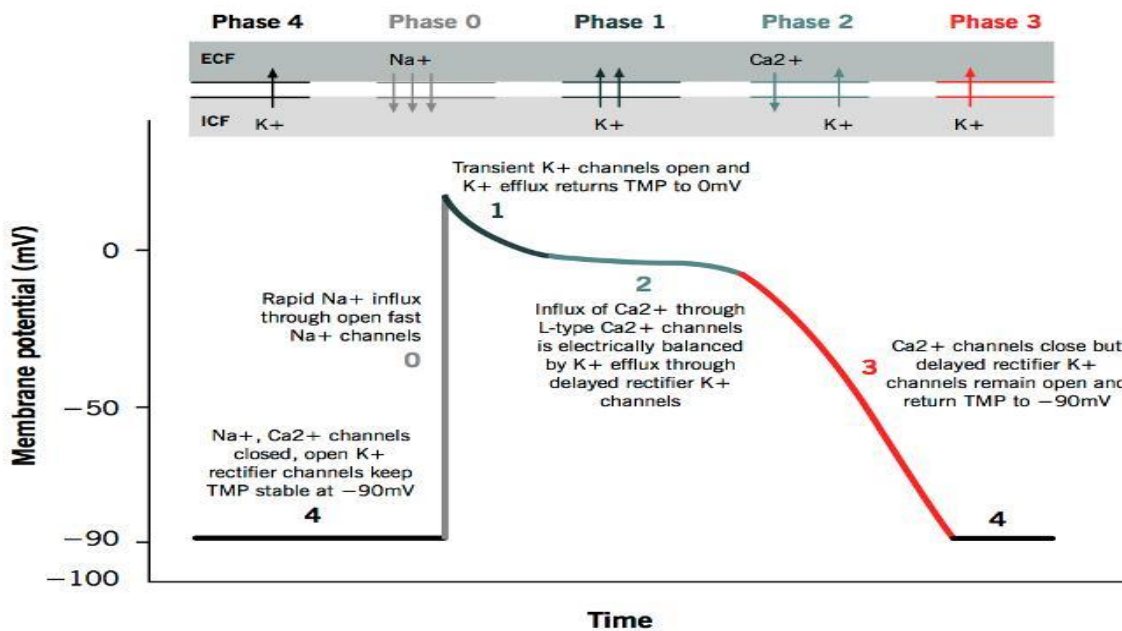
- **The action potential in the stimulated cardiac myocyte is divided into 5 phases:**
- **Phase 0 : rapid depolarization:** occurs due to rapid Na^+ influx, so the inner membrane gradually becomes less negative, and when the membrane potential becomes (- 40)mV (reaches the threshold for initiating action 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.

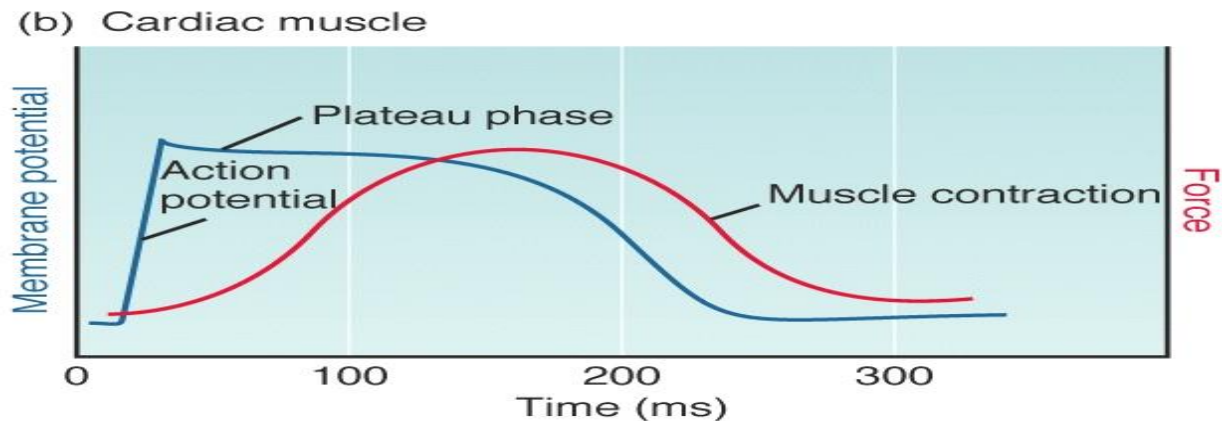
Action potential of cardiac muscles

Grigoriy Ikonnikov and Eric Wong



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.

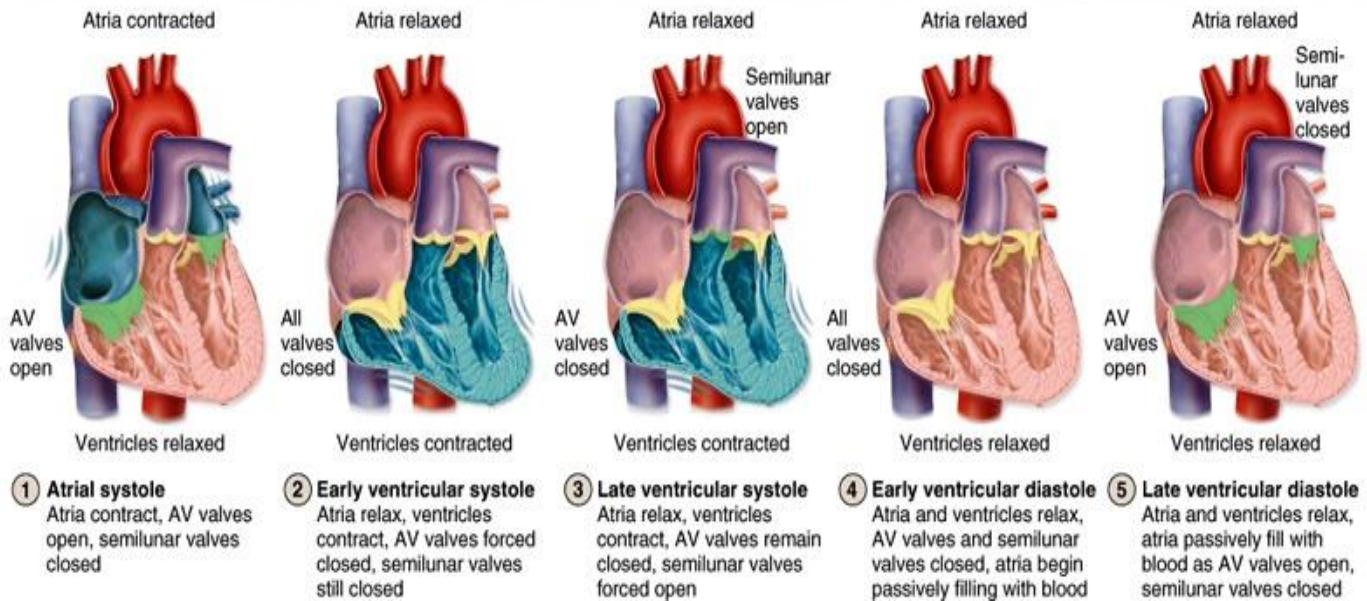
The events at single cardiac cycle:

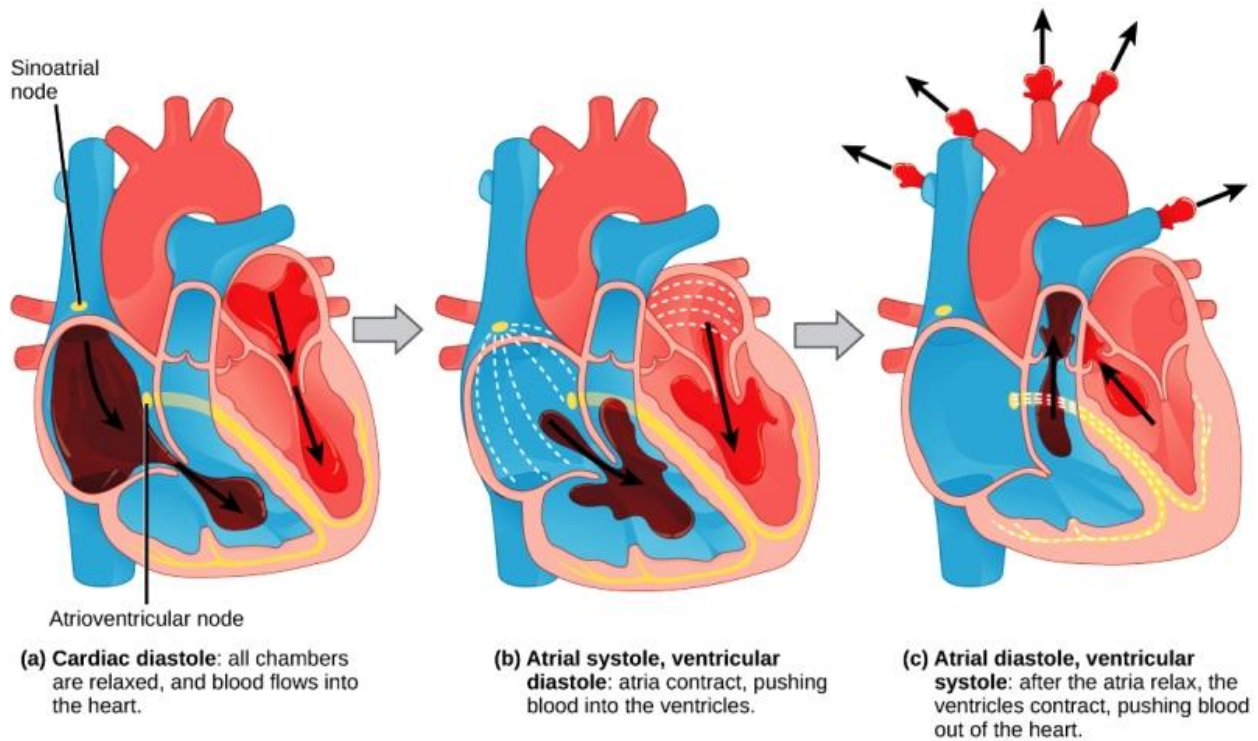
- 1. Atrial systole: contraction of both atria (left and right) simultaneously leads to move blood (20%) from atria to the ventricles (from right atrium to the right ventricle through tricuspid valve. And from left atrium to the left ventricle through mitral valve).**
- 2. Atrial diastole:**
- 3. Ventricular 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 atriocentric valves.

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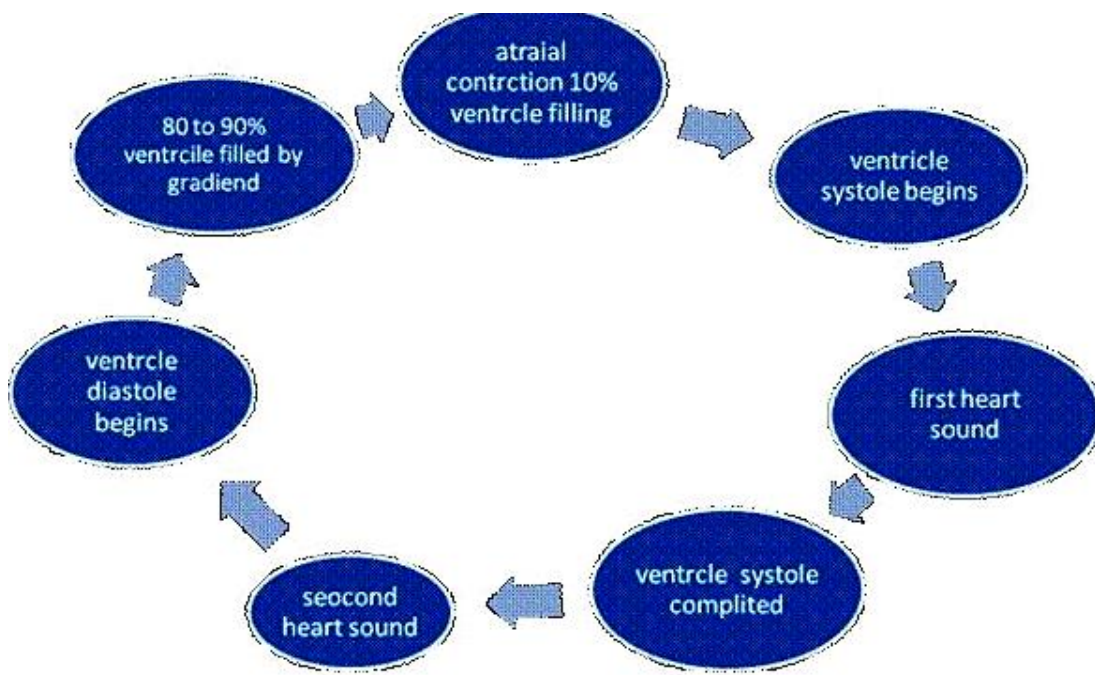
Structure \ Phase	Atrial systole		Early ventricular systole	Late ventricular systole	Early ventricular diastole	Late ventricular diastole	
			↔		↔		
Atria	Contract		Relax				
Ventricles	Relax		Contract				
AV valves	Open		Closed			Open	
Semilunar valves	Closed		Open			Closed	



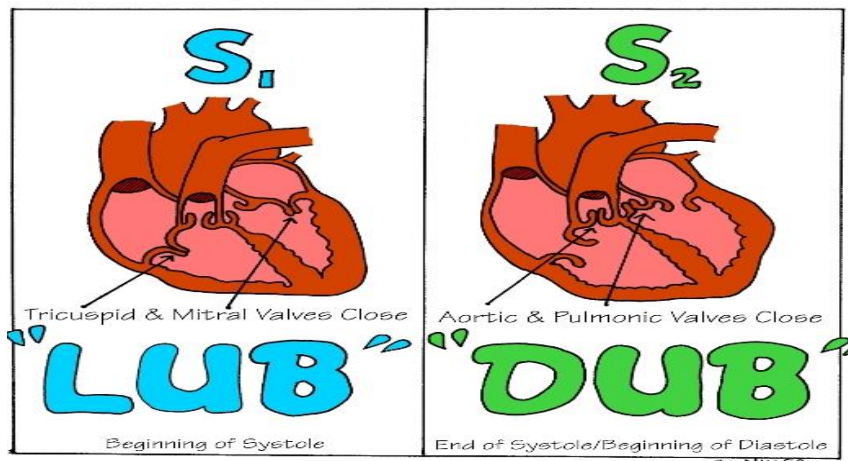


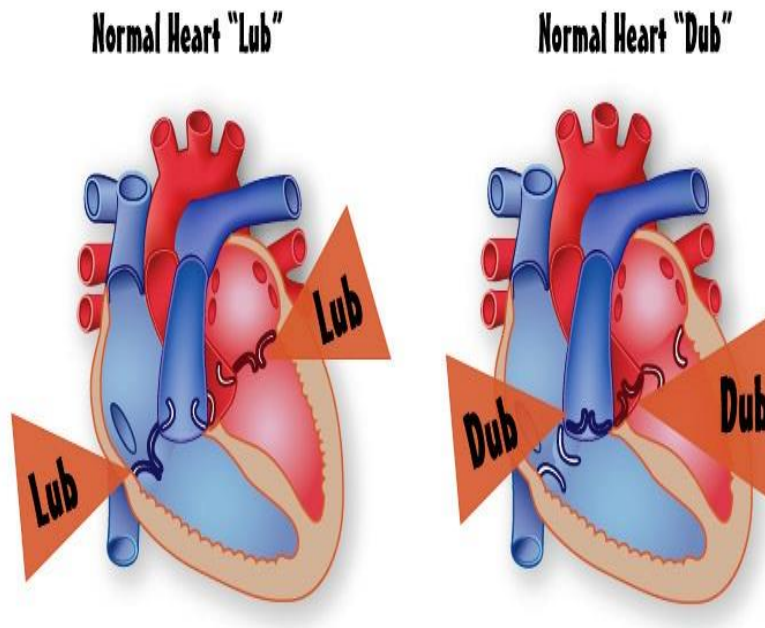
Heart Sounds

- 1. Lubb 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.



HEART SOUNDS



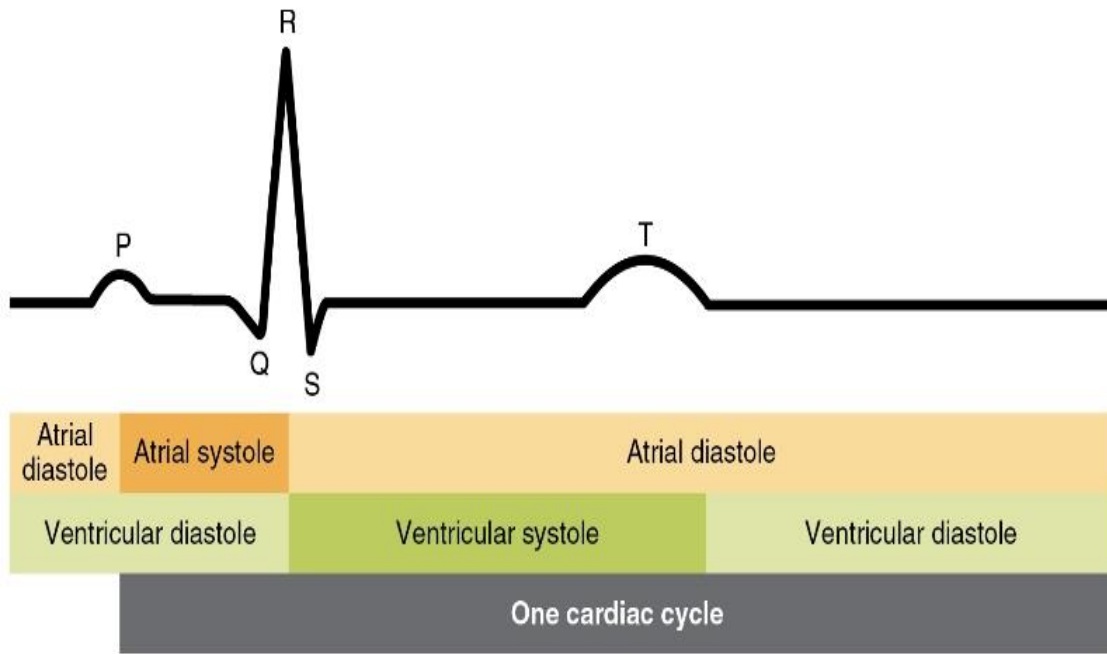


Normal Electrocardiogram (ECG or EKG)

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).

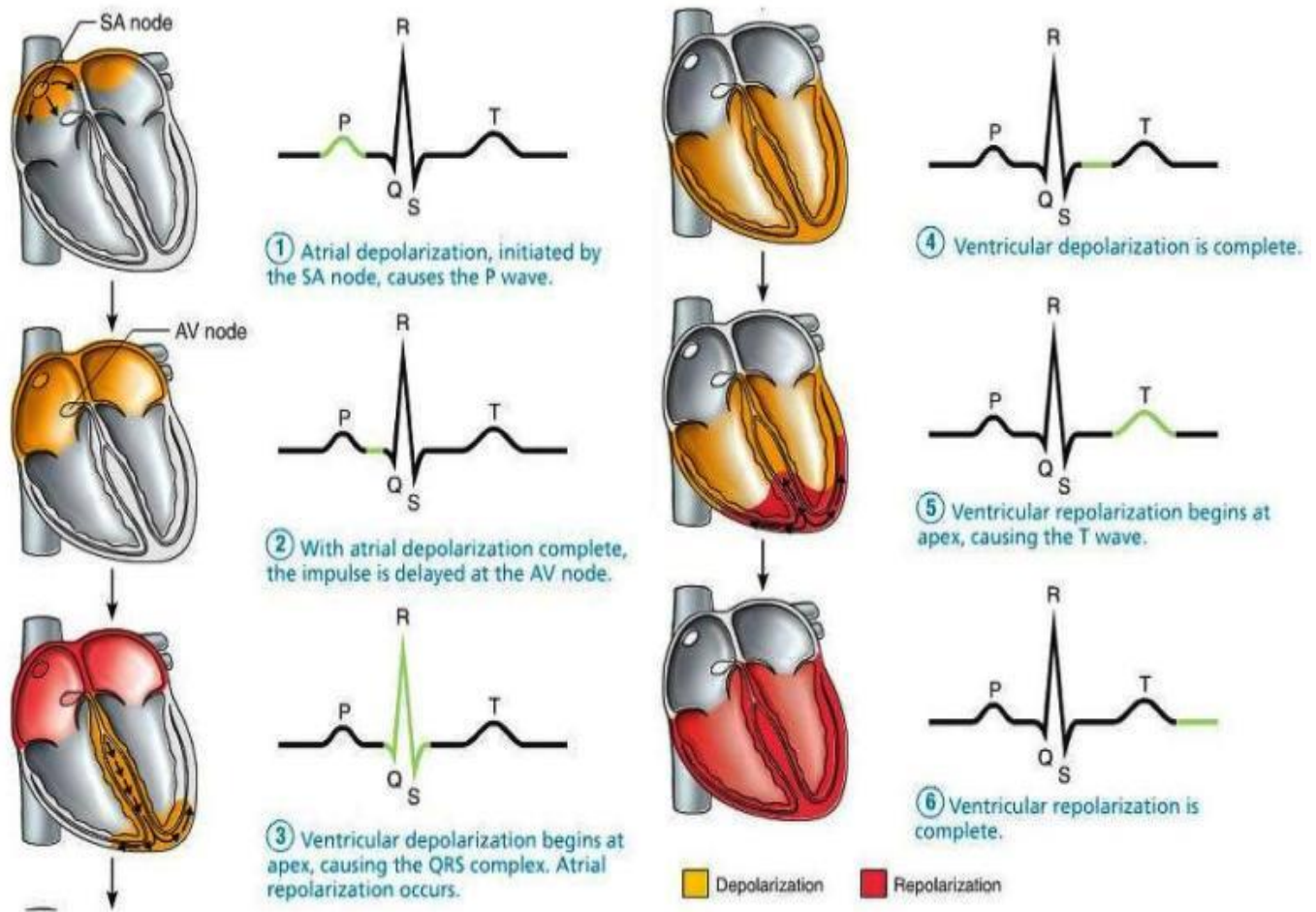


Waves of ECG

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.

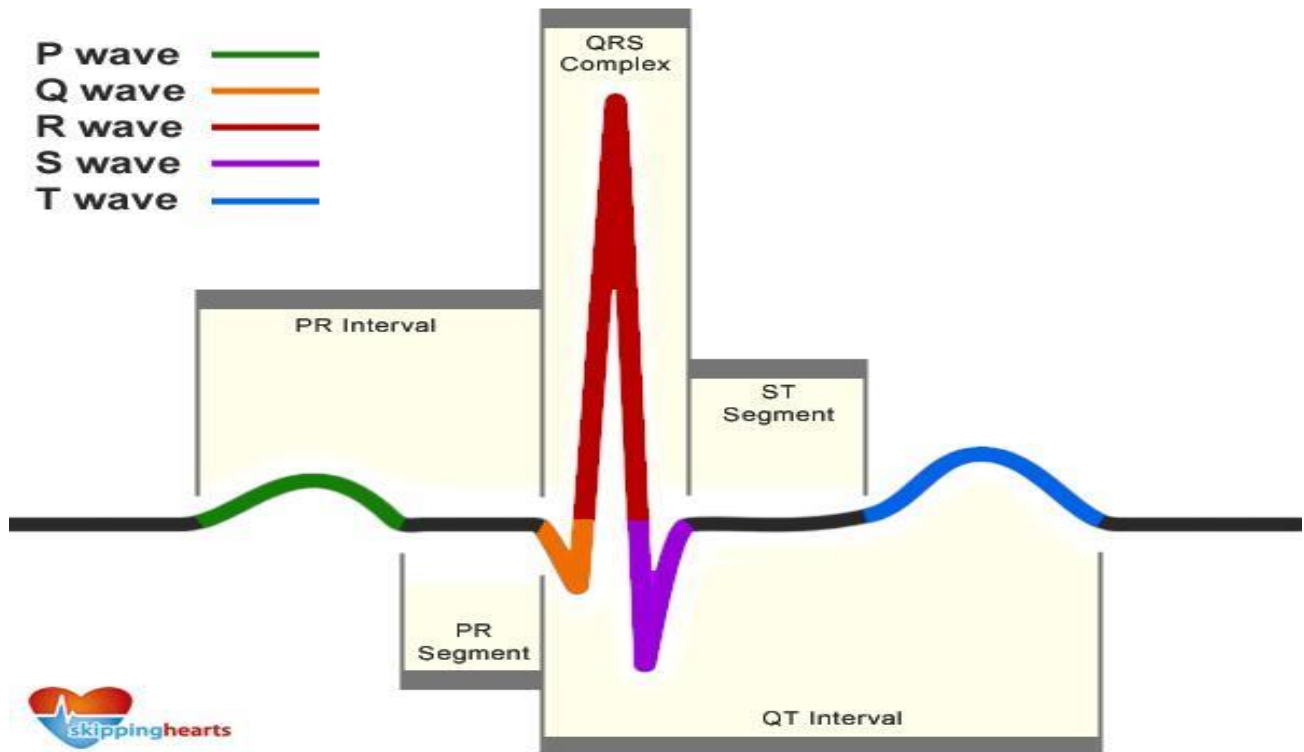
It indicates total systolic time of ventricle (ventricular depolarization and repolarization).

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.

ECG of Normal Sinus Rhythm



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*