# *Physics of Medical Devices*

*Fourth Lecture*

# *Electrocardiograph I,II*

***Fourth Stage***

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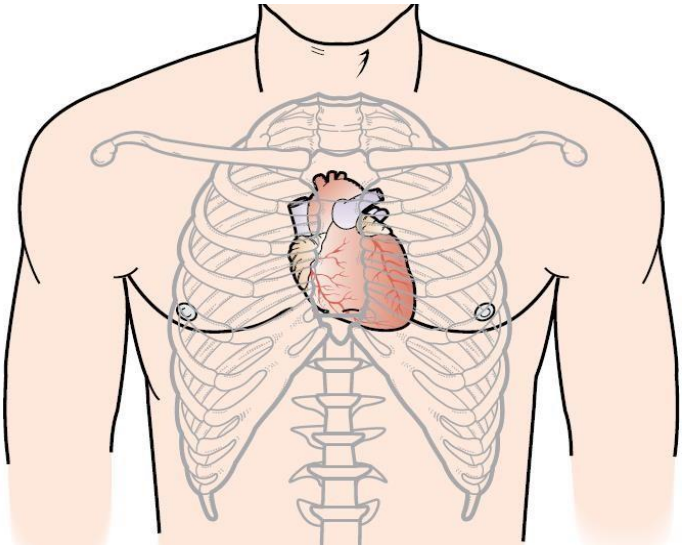
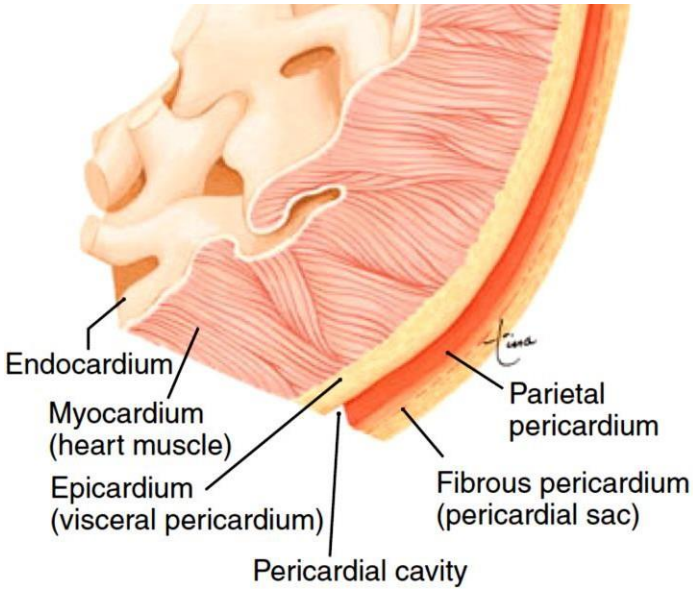
# The heart and potential source

## Anatomy of the Heart

- The heart, a fist-sized muscular organ located in the mediastinum, is the central structure of the cardiovascular system.
- It is protected by the bony structures of the sternum anteriorly, the spinal column posteriorly, and the rib cage.
- The heart is roughly conical, with the base of the cone at the top of the heart and the apex (the pointed part) at the bottom.



*Location of the heart*

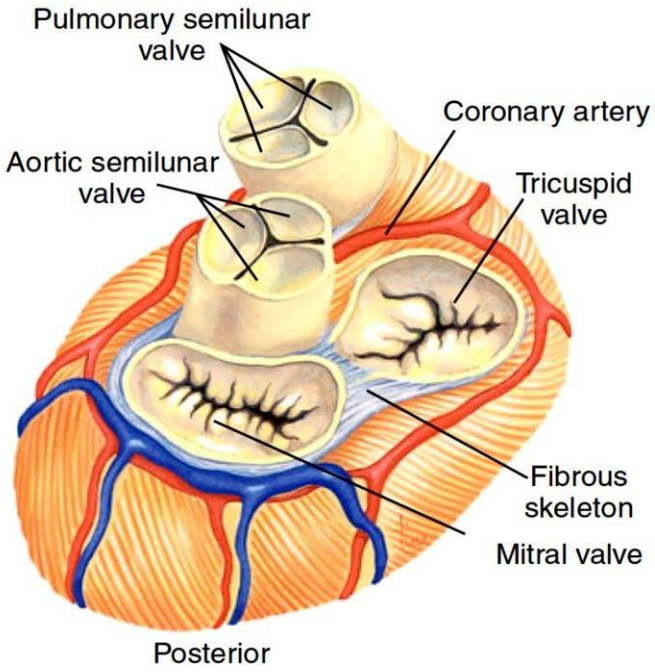



*Layers of the heart*

## *Heart Valves:*

Properties of Heart Valves

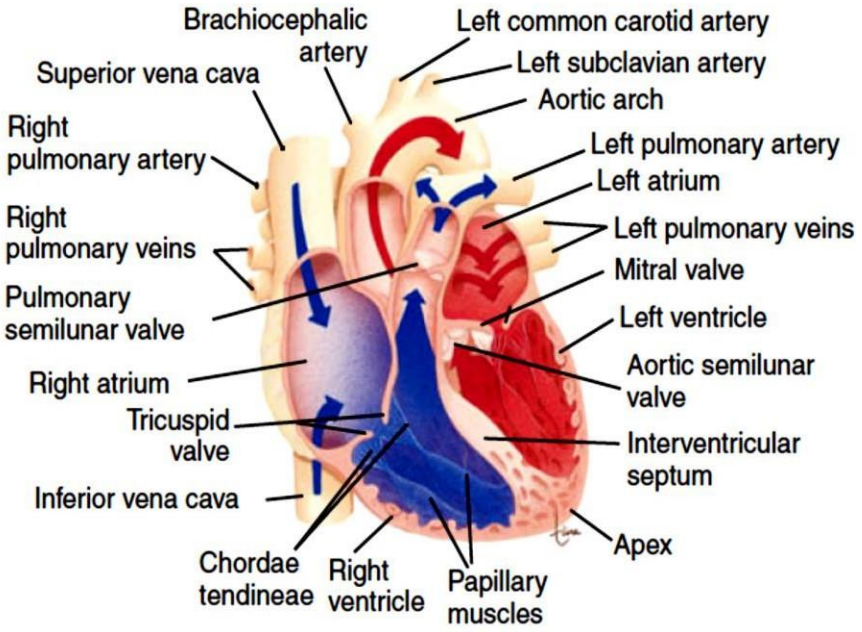
- Fibrous connective tissue prevents enlargement of valve openings and anchors valve flaps.
- Valve closure prevents backflow of blood during and after contraction.




*Superior view with atria removed*

## *Heart Chambers and Great Vessels*

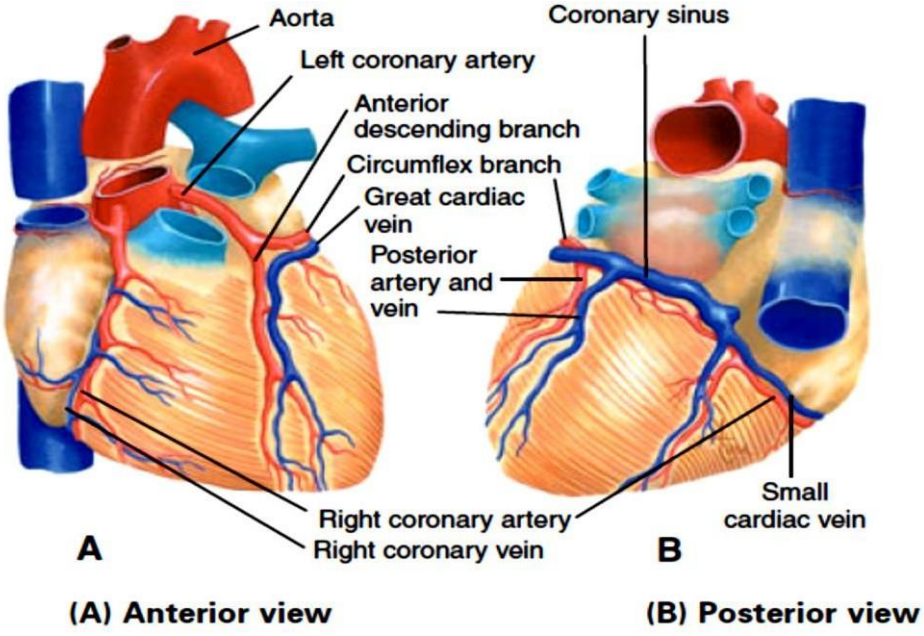
- ✓ The heart is a hollow muscle with an internal skeleton of connective tissue that creates four separate chambers.
- ✓ The superior chambers of the heart are the right and left atria.
- ✓ Their primary function is to collect blood as it enters the heart and to help fill the lower chambers.
- ✓ The more thickly muscled lower chambers of the heart are the ventricles.




*Heart–Anterior section (arrows show direction of blood flow)*

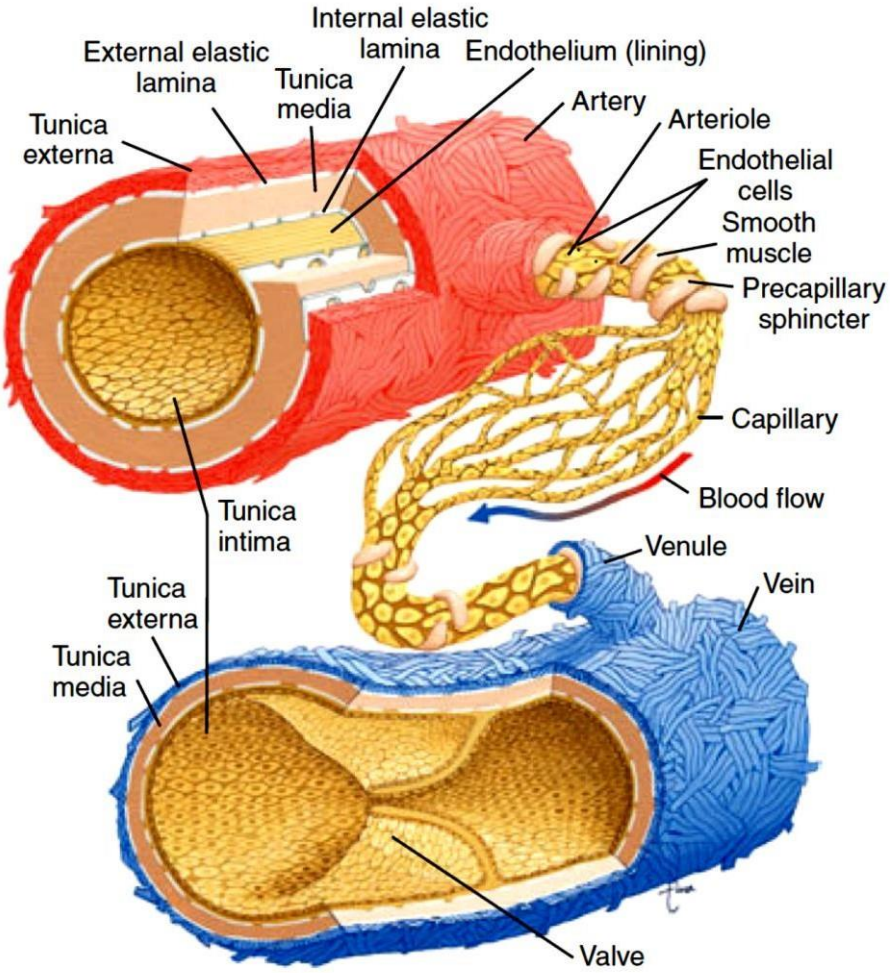
## *Coronary Arteries and Veins*

- ✓ The coronary arteries and veins provide blood to the heart muscle and the electrical conduction system.
- ✓ The left and right coronary arteries are the first to branch off the aorta, just above the leaflets of the aortic valve.



## *Anatomy of the Cardiovascular System*

- The cardiovascular system is a closed system consisting of the heart and all the blood vessels.
- Arteries and veins are connected by smaller structures that transport substances needed for cellular metabolism to body systems and remove the waste products of metabolism from those same tissues.
- Arteries carry blood away from the heart and, with the exception of the pulmonary arteries, transport oxygenated blood.
- Veins move blood toward the heart. With the exception of the pulmonary veins, they carry blood that is low in oxygen and high in carbon dioxide.




**Blood vessels–Cross-section**

## *Physiology of the Heart*

- Normal blood flow through the heart begins at the right atrium, which receives systemic venous blood from the superior and inferior vena cava.
- Blood passes from the right atrium, across the tricuspid valve, to the right ventricle. It is then pumped across the pulmonary valve into the pulmonary arteries.
- Outside the heart, the left and right pulmonary arteries distribute blood to the lungs for gas exchange in the pulmonary capillaries.
- Oxygenated blood returns to the left atrium through the left and right pulmonary veins.
- After passing across the mitral valve, blood enters the left ventricle, where it is pumped across the aortic valve, through the aorta, into the coronary arteries and the peripheral circulation.

**Mechanics of Heart Function**

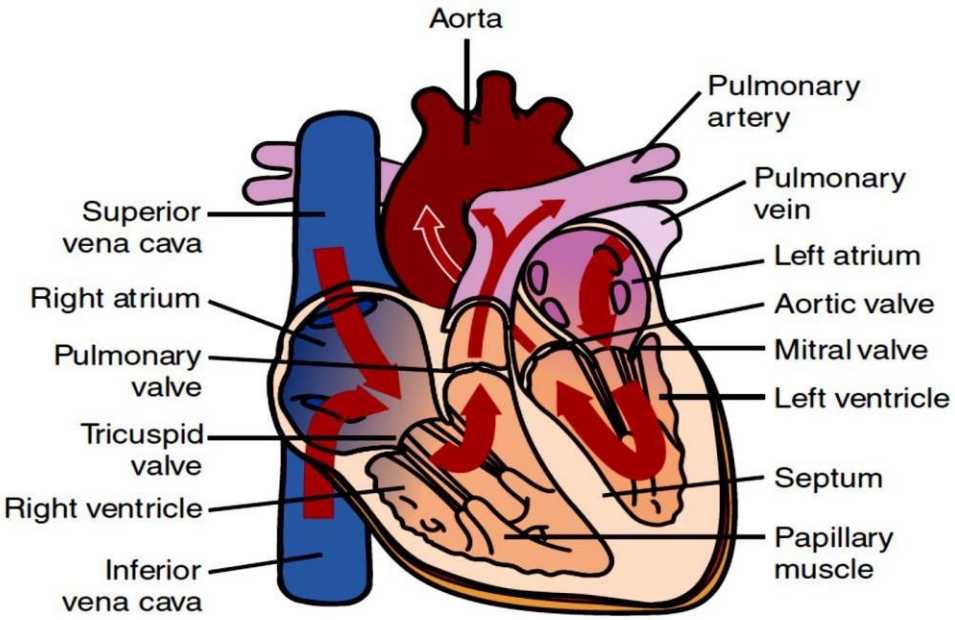
| Process | Action |
|---|---|
| Cardiac cycle | Sequence of events in 1 heartbeat. Blood is pumped through the entire cardiovascular system. |
| Systole | Contraction phase—usually refers to ventricular contraction. |
| Diastole | Relaxation phase—the atria and ventricles are filling. Lasts longer than systole. |
| Stroke volume (SV) | Amount of blood ejected from either ventricle in a single contraction. Starling's Law of the Heart states that the degree of cardiac muscle stretch can increase the force of ejected blood. More blood filling the ventricles increases SV. |
| Cardiac output (CO) | Amount of blood pumped through the cardiovascular system per min. CO = SV x Heart rate (HR) |

**Properties of Cardiac Cells**

| Property | Ability |
|---|---|
| Automaticity | Generates electrical impulse independently, without involving the nervous system. |
| Excitability | Responds to electrical stimulation. |
| Conductivity | Passes or propagates electrical impulses from cell to cell. |
| Contractility | Shortens in response to electrical stimulation. |

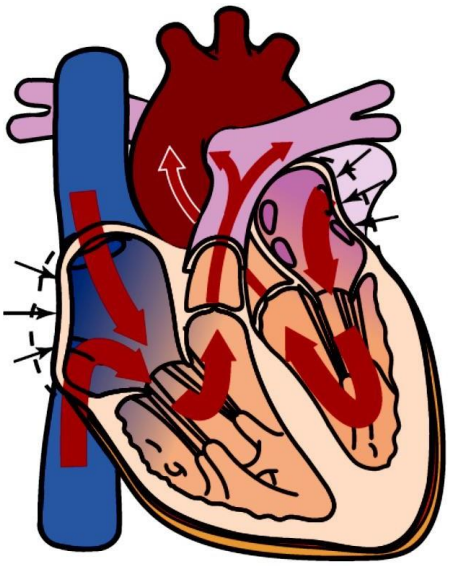
## *Systolic and Diastolic Phases in the Heart*

Diastole: the phase of the heartbeat when the heart muscle relaxes and allows the chambers to fill with blood.

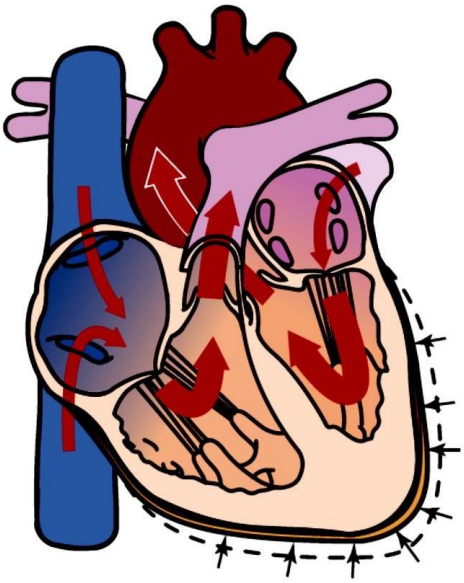



**Diastole**

Systolic: phase relating to the phase of the heartbeat when the heart muscle contracts and pumps blood from the chambers into the arteries.



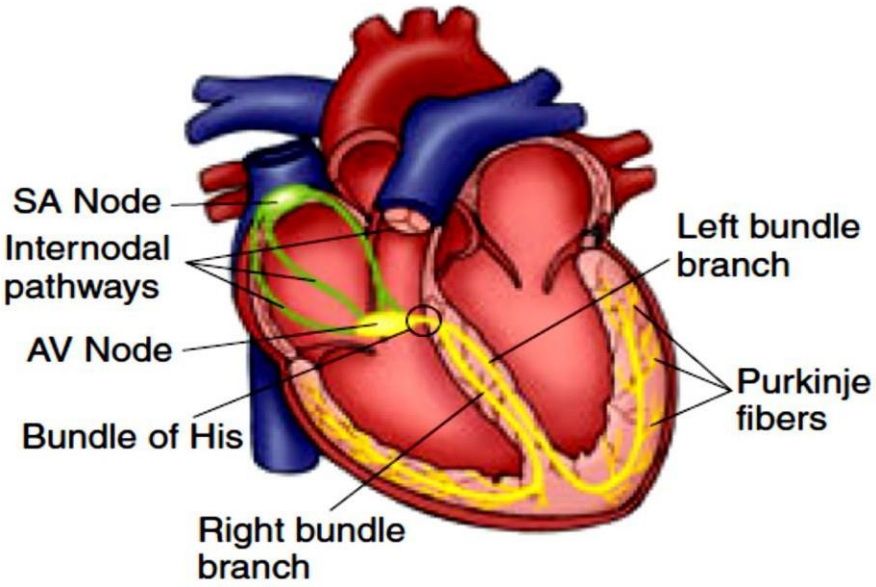
**Atrial systolic phase**



**Ventricular systolic phase**

## *Electrical Conduction System of the Heart*

| Electrophysiology | |
|---|---|
| **Structure** | **Function and Location** |
| Sinoatrial (SA or sinus) node | Dominant pacemaker of the heart, located in upper portion of right atrium. Intrinsic rate 60—100 bpm. |
| Internodal pathways | Direct electrical impulses between the SA and AV nodes and spread them across the atrial muscle. |
| Atrioventricular (AV) node | Part of the AV junctional tissue, which includes some surrounding tissue plus the connected bundle of His. The AV node slows conduction, creating a slight delay before electrical impulses are carried to the ventricles. The intrinsic rate is 40–60 bpm. |
| Bundle of His | At the top of the interventricular septum, this bundle of fibers extends directly from the AV node and transmits impulses to the bundle branches. |
| Left bundle branch | Conducts electrical impulses to the left ventricle. |
| Right bundle branch | Conducts electrical impulses to the right ventricle. |
| Purkinje system | The bundle branches terminate with this network of fibers, which spread electrical impulses rapidly throughout the ventricular walls. The intrinsic rate is 20–40 bpm. |



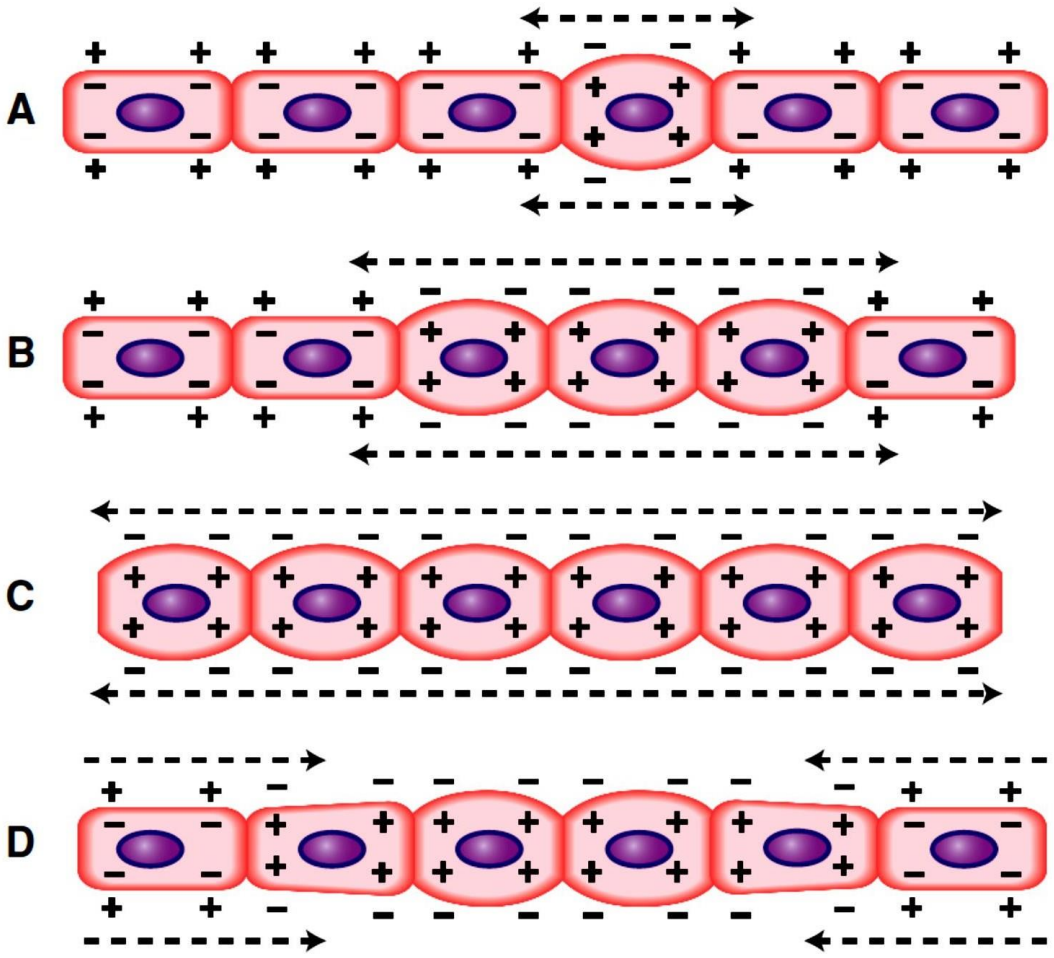

**Conduction system of the heart**

## ***The Depolarization Process***

The electrical charge of a cell is altered by a shift of electrolytes on either side of the cell membrane. This change stimulates muscle fiber to contract.

## ***The Repolarization Process***

Chemical pumps re-establish an internal negative charge as the cells return to their resting state.



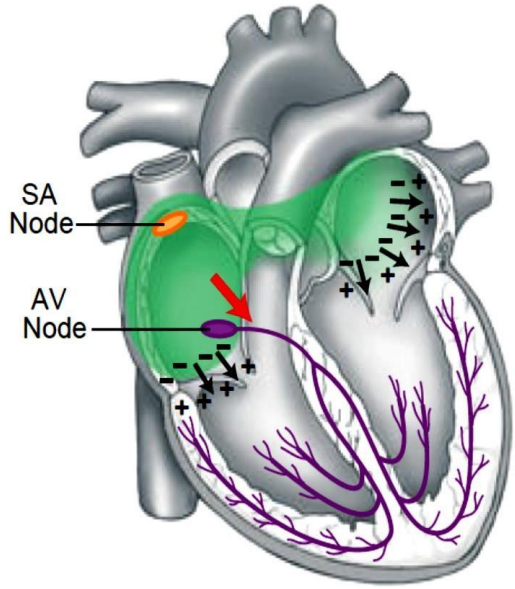

(A) A single cell has depolarized.

(B) A wave propagates from cell to cell.

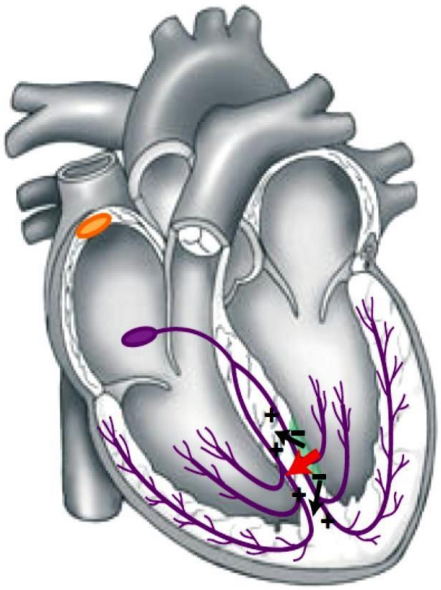
(C)Wave propagation stops when all cells are depolarized.

(D) Repolarization restores each cell's normal polarity.

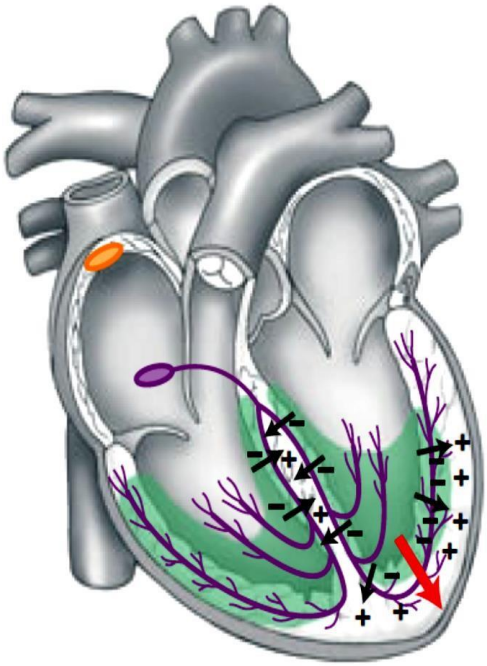
## *Progression of Depolarization through the Heart*



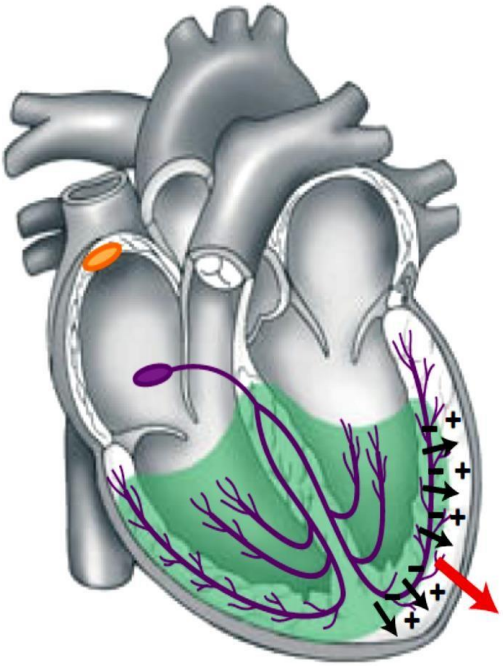

**Atrial depolarization**



**Septal depolarization**



**Apical depolarization**



**Left ventricular depolarization**