

Physics of Medical Devices

First lecture

Electrocardiograph I

Msc. Eman Ahmed

Third Stage

Department of medical physics

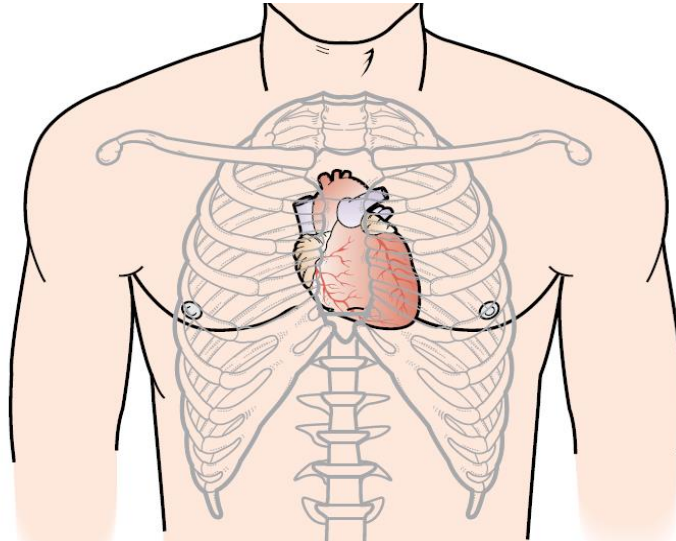
Al-Mustaqbal University-College

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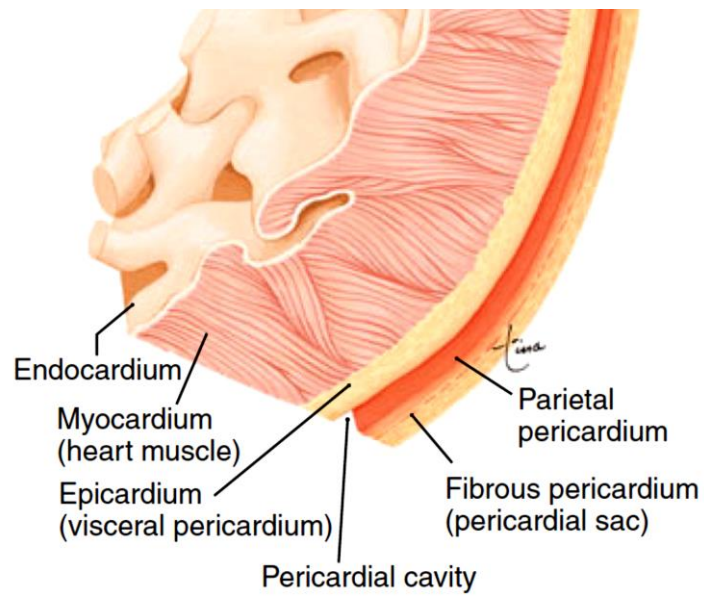
The heart and potential source

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

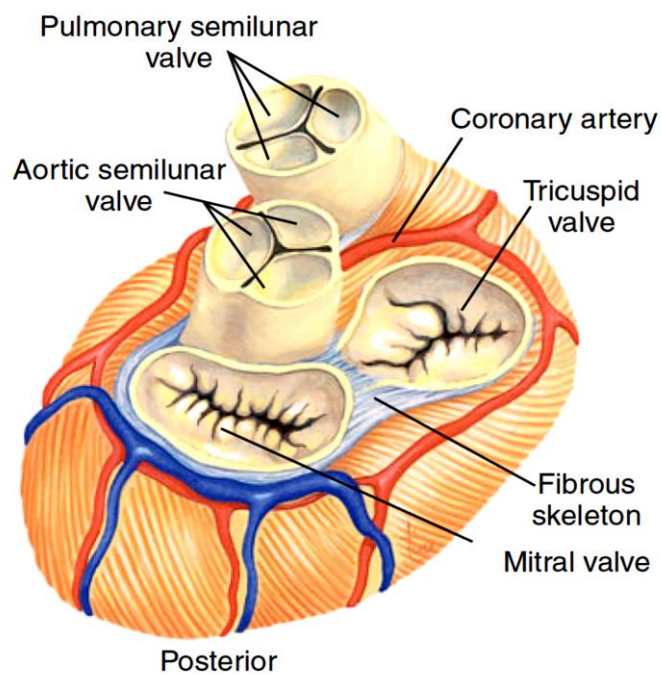


Layers of the heart

Heart Valves:

Properties of Heart Valves

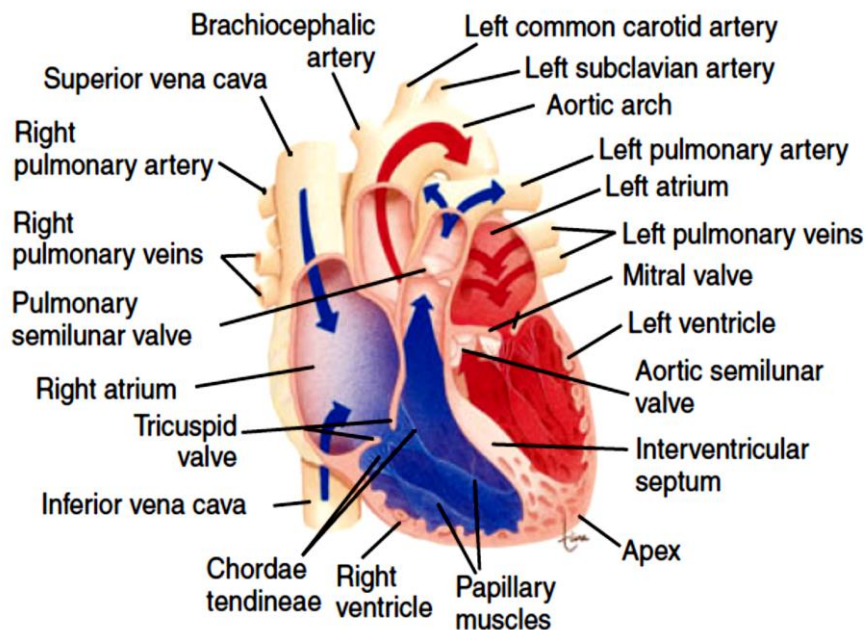
- Fibrous connective tissue prevents enlargement of valve openings and anchors valve flaps.
- Valve closure prevents backflow of blood during and after contraction.



Superior view with atria removed

Heart Chambers and Great Vessels

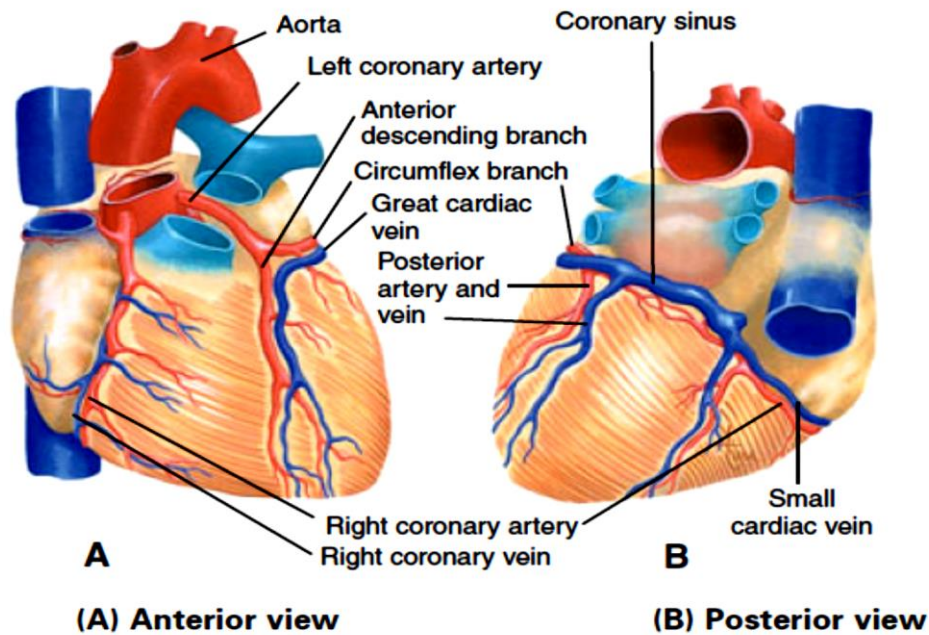
- ✓ The heart is a hollow muscle with an internal skeleton of connective tissue that creates four separate chambers.
- ✓ The superior chambers of the heart are the **right and left atria**.
- ✓ Their primary function is to collect blood as it enters the heart and to help fill the lower chambers.
- ✓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



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

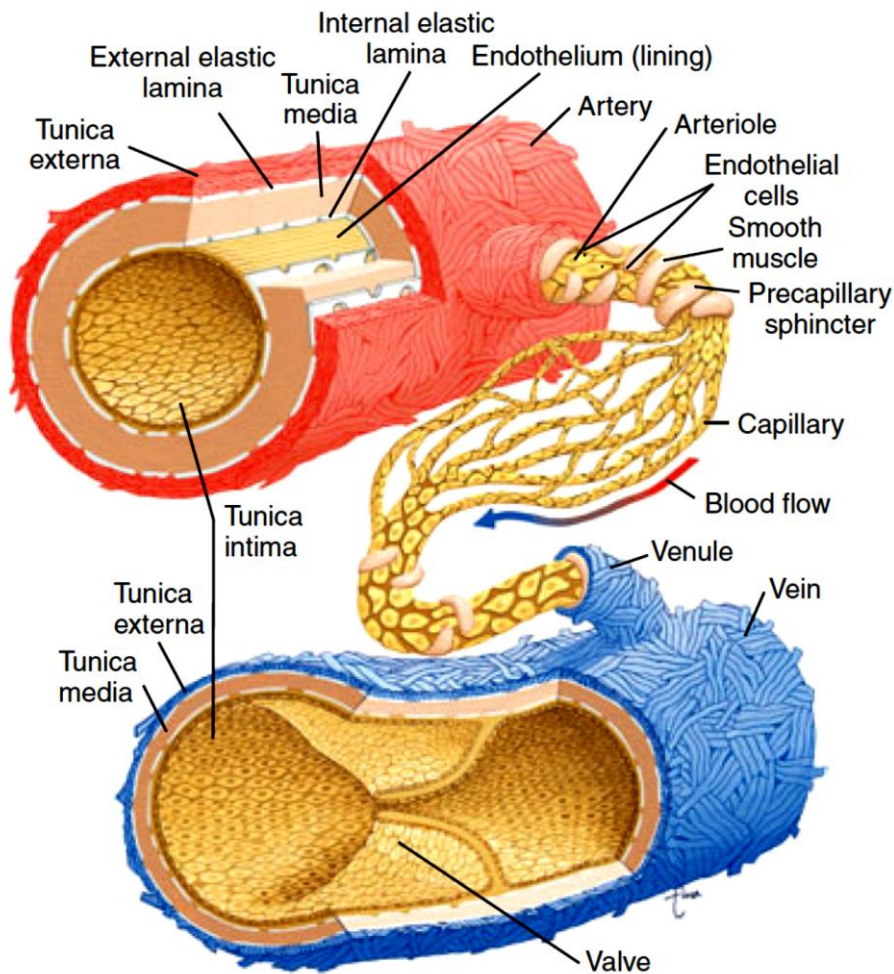
Coronary Arteries and Veins

- ✓ 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.

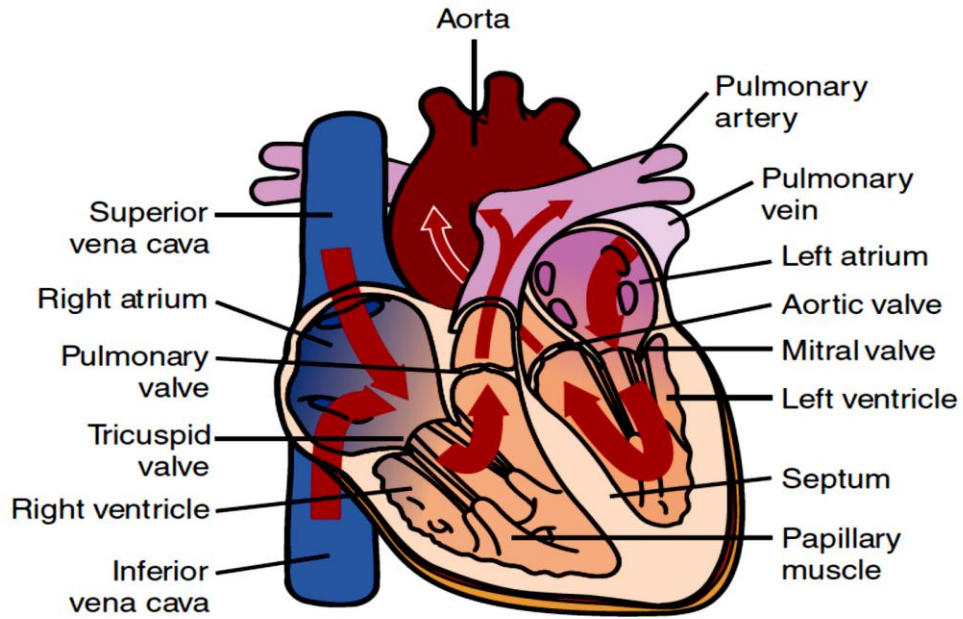
- ✚ After passing across the mitral valve, blood enters the left ventricle, where it is pumped across the aortic valve, through the aorta, into the coronary arteries and the peripheral circulation.

| 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. $CO = SV \times \text{Heart rate (HR)}$ |

| 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. |

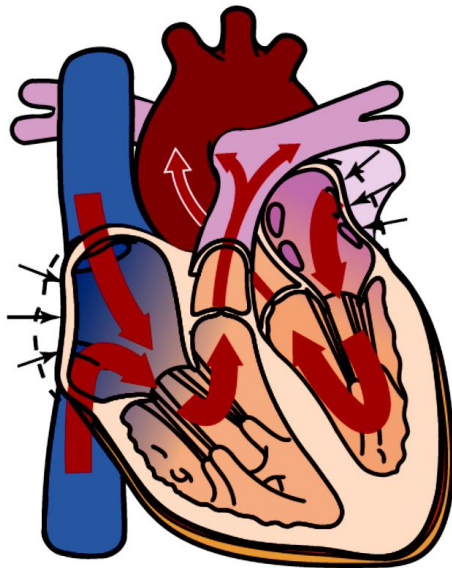
Systolic and Diastolic Phases in the Heart

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

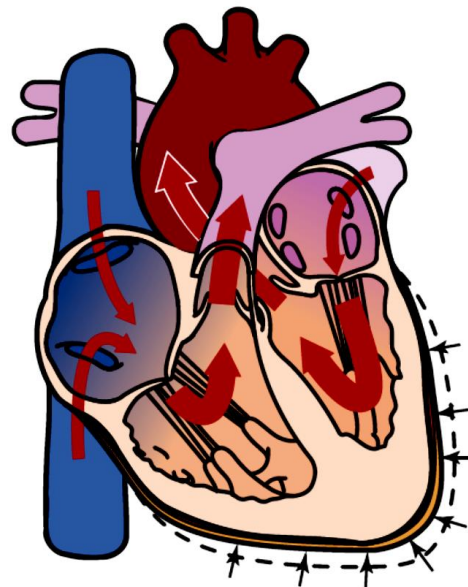


Diastole

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



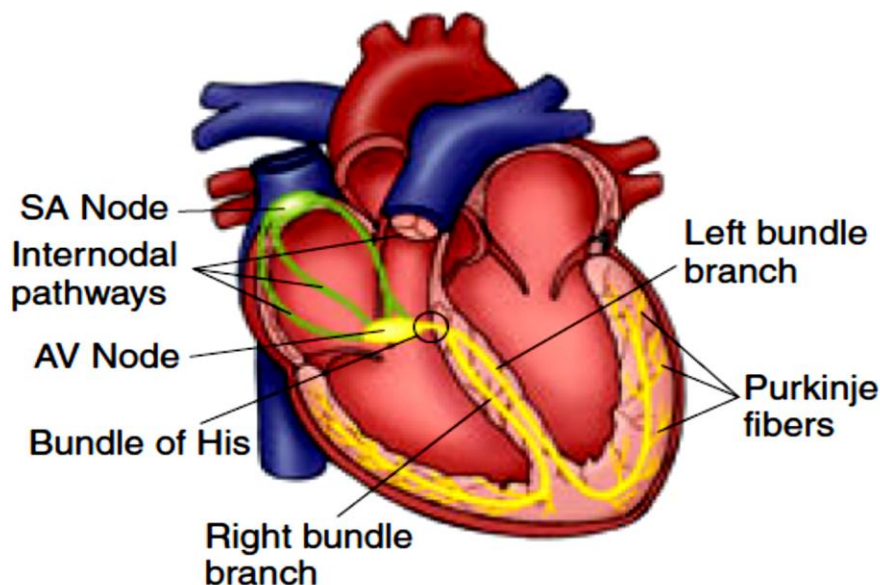
Atrial systolic phase



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. |



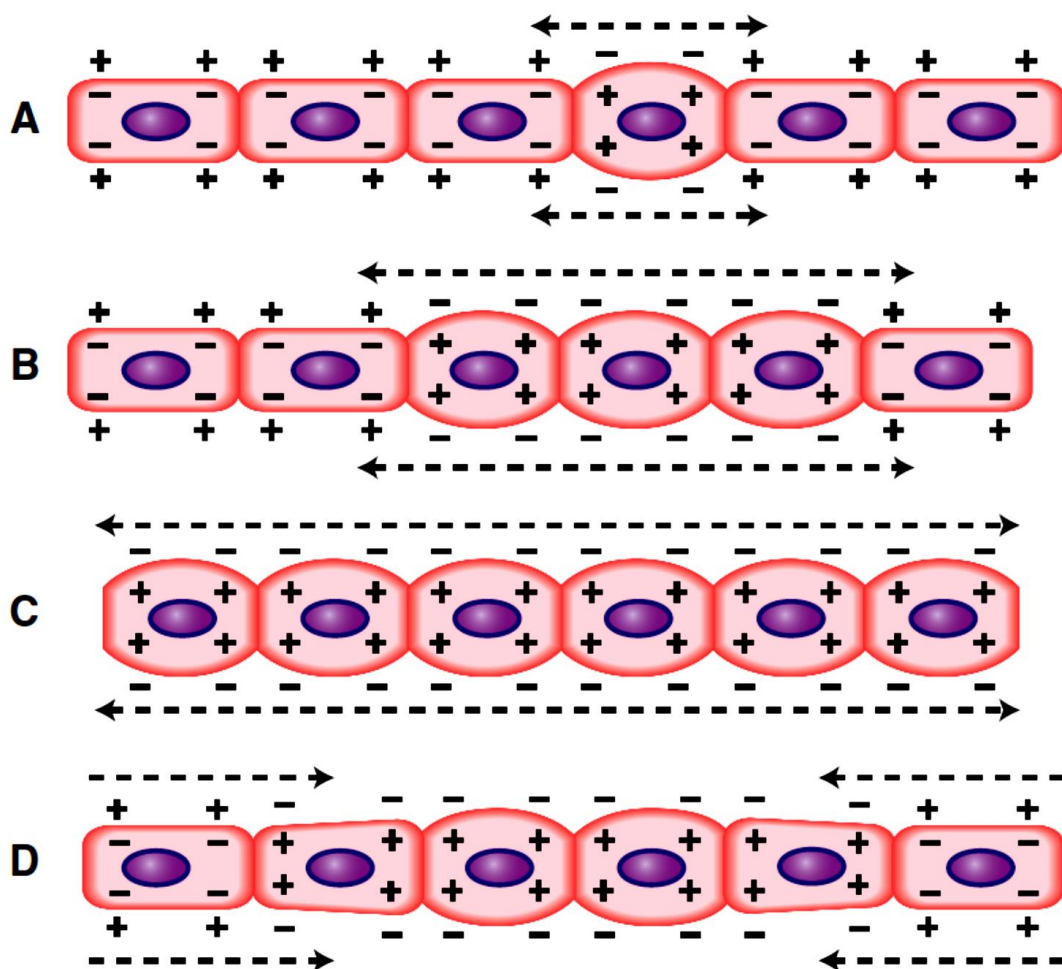
Conduction system of the heart

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.

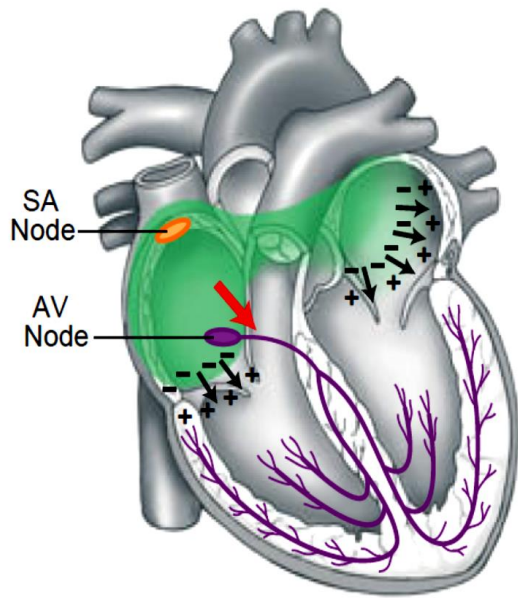
The Repolarization Process

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

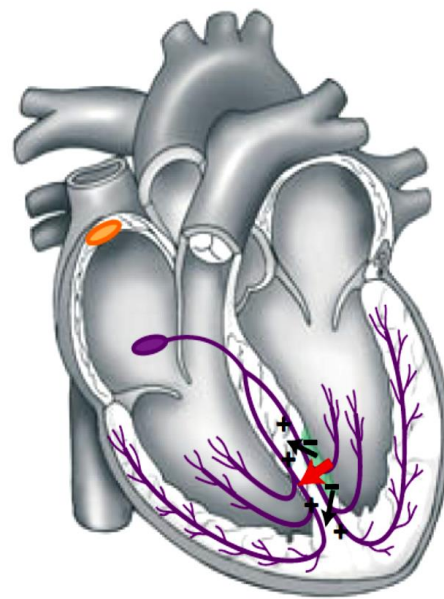


- (A) A single cell has depolarized.
- (B) A wave propagates from cell to cell.
- (C) Wave propagation stops when all cells are depolarized.
- (D) Repolarization restores each cell's normal polarity.

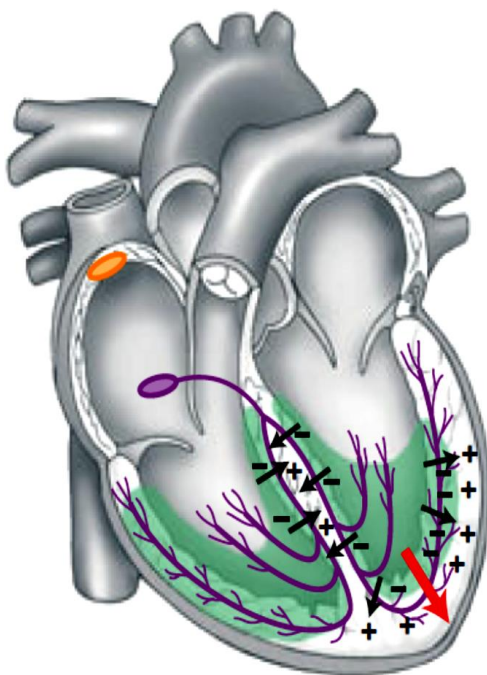
Progression of Depolarization through the Heart



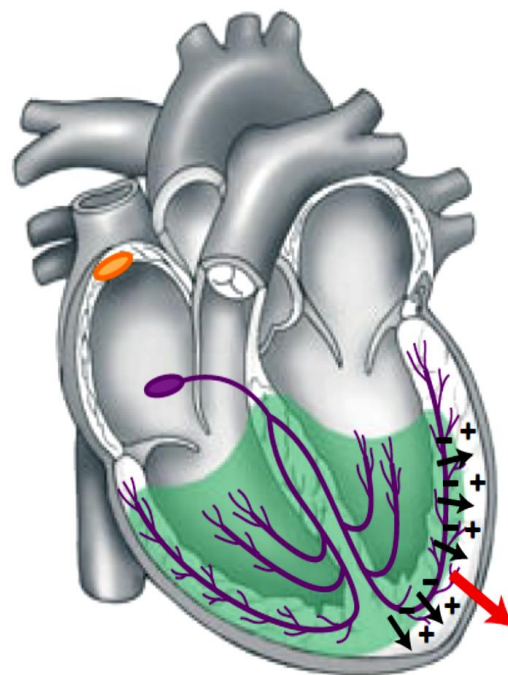
**Atrial
depolarization**



**Septal
depolarization**



**Apical
depolarization**



**Left ventricular
depolarization**