



# Cardiac Electric Activity

Color index

- **Important**
- Further Explanation

**Only in  
Boys' Slides**

**Only in  
Girls' Slides**

Explained in **Guyton  
Chapter 10**

# Objectives

- ✧ Discuss the cardiac conductive system and its function.
- ✧ Describe the action potential of the cardiac muscle and its components.
- ✧ Define the refractory period and the excitation-contraction coupling
- ✧ Discuss the control of excitation and conduction of the heart.

## ✓ Boys'

- ✧ Discuss the genesis of the resting membrane potential in the heart.
- ✧ Compare and contrast the ionic currents during the different phases of the action potential in myocytes.
- ✧ Compare and contrast fast-response and slow-response action potentials in the heart.
- ✧ Describe the physiological significance of the plateau phase and refractory period of a ventricular working muscle cell.
- ✧ Discuss the electrical activity of the pacemaker.
- ✧ Describe the sequence of normal conduction in the heart.
- ✧ Define intrinsic heart rate.
- ✧ Discuss regulation of heart rate under different physiological conditions.

# How The heart perform its function?

✧ Contractions in cardiac muscles are triggered by:

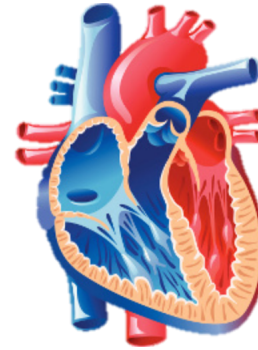
## Action potential :

It's different from skeletal muscle in that:

- ✓ They are self-generating
- ✓ They are conducted directly from cell to cell
- ✓ They have longer duration

✧ Electrical potentials arise from:

- ✓ Differences in the concentrations of ions across the membrane.
- ✓ The presence of selective ion-conducting channels spanning the membrane, namely  $K^+$ ,  $Na^+$ , and  $Ca^{2+}$ .



## Recall!

By:

- ✓ Autorhythmicity
- ✓ Conductivity
- ✓ Excitability
- ✓ Contractility

## Resting Ventricular Muscle

$K^+$ 4 mM/L	←	140 mM/L
$Na^+$ 140 mM/L	→	10 mM/L
$Ca^{++}$ 1.2 mM/L	→	0.0001 mM/L

EC

IC

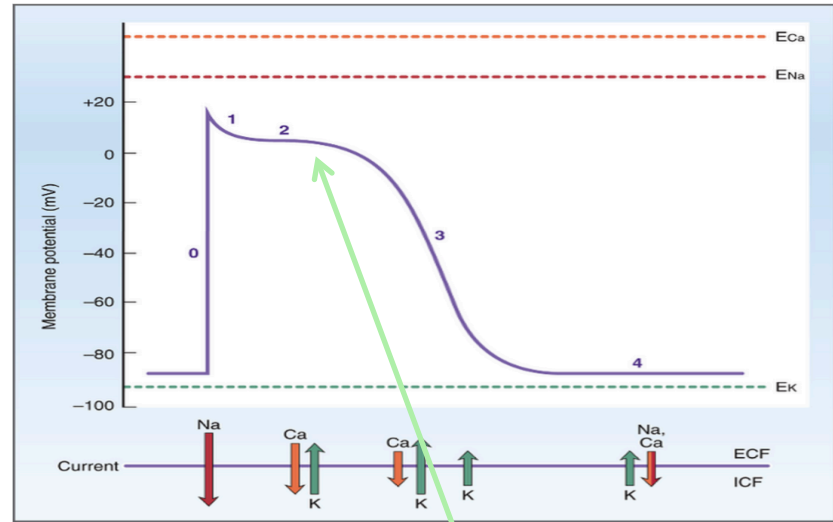
# Action Potential in Cardiac Muscle

Resting membrane potential -85 to -95mV

## Phases of cardiac Action Potential

## Ionic Changes

<b>0- Rapid Depolarization</b> (+20 mV) (When it reach +20 Na channel will close)	<b>Na<sup>+</sup> in</b>
<b>1- Partial Repolarization</b> (5-10mV) (From +20 till 0 K <sup>+</sup> keep going out)	<b>K<sup>+</sup> out</b>
<b>2- Action potential plateau</b> (0 mV) (In this steady state Ca <sup>++</sup> moving in slowly and there is K <sup>+</sup> going out BUT because movement is slow while 1Ca <sup>+</sup> + in slowly 2K <sup>+</sup> out)	<b>Ca<sup>2+</sup> in</b> <b>(slow)</b>
<b>3- Repolarization</b> (back to RMP) ( No stimulation, nor impulse because there is no ion moving)	<b>K<sup>+</sup> out</b>



### What causes the Plateau in the Action Potential?

\*The slow sodium-calcium channels:  
slow to open & remain open

Large quantity of both calcium and sodium ions flows to the interior of the cardiac muscle fiber, Maintains prolonged period of depolarization

# Refractory Period of Cardiac Muscle

- ✧ Further stimulation of cardiac muscle depending on time during the action potential.
- ✧ **The Refractory Period of The Heart:**
  - ✓ Is the interval of time during which a normal cardiac impulse cannot re-excite an already excited area of cardiac muscle

## Absolute Refractory Period

**Cardiac muscle CANNOT be re-excited while it is contracting**

- ✓ To maintain pump blood and supply O2 and nutrient
  - ✓ Long ARP

=Absolute Refractory period

During: **Depolarization and 2/3 Repolarization**

\*Duration: **0.25- 0.3 sec**

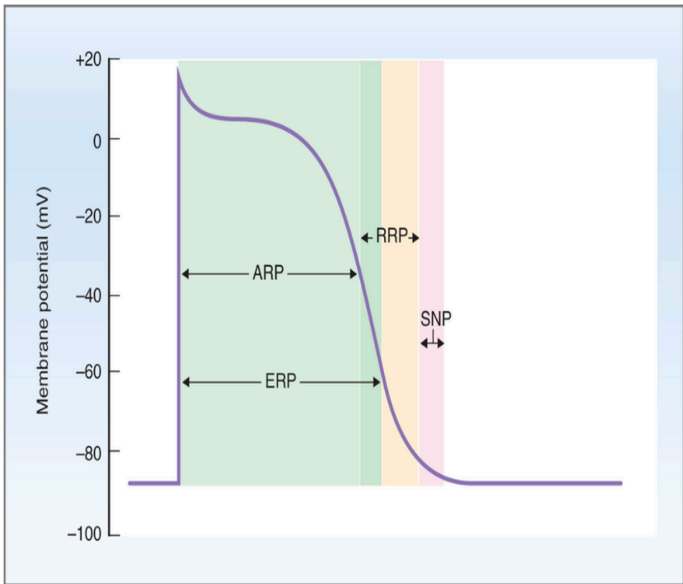


## Relative Refractory Period

**\*Cardiac muscle can be excited by STRONG STIMULUS**

During: **Repolarization**

\*Duration: **0.05 sec**



\*No need to memorize numbers ONLY know ARP is longer than RRP

# Cardiac Electrical Activity

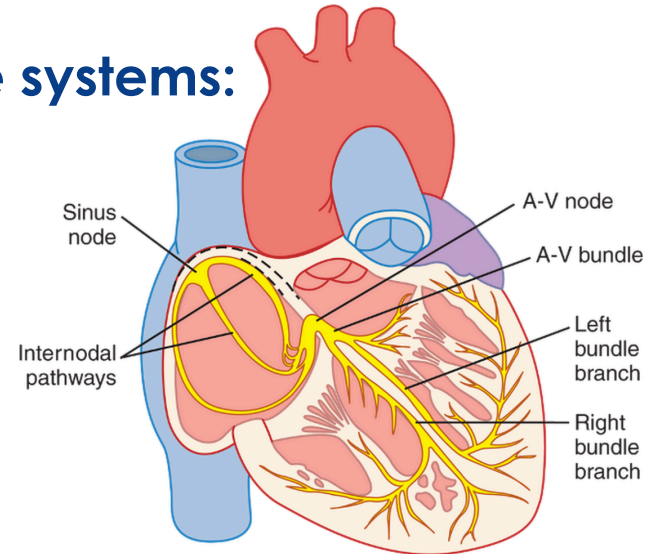
- ✧ **Automaticity of the heart**, the heart is capable of:
- ✓ **Generating** rhythmical electrical impulses.
- ✓ **Conduct** the impulses rapidly through the heart.

✧ When it functions normally The atria contract about one sixth of a second ahead of ventricular contraction. **WHY?**

To allow filling of the ventricles before they pump the blood into the circulation.

## ✧ Specialized excitatory and conductive systems:

- ✓ Sinoatrial node (S-A node)
- ✓ Internodal Pathway
- ✓ Atrioventricular node (A-V node)
- ✓ Atrioventricular bundle (Bundle of His)
- ✓ Purkinje fibers



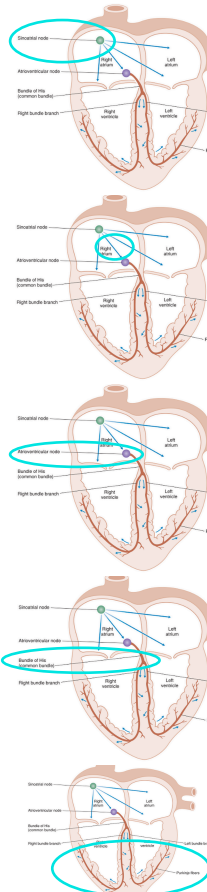
# Conduction of Impulses



A great video done by med433

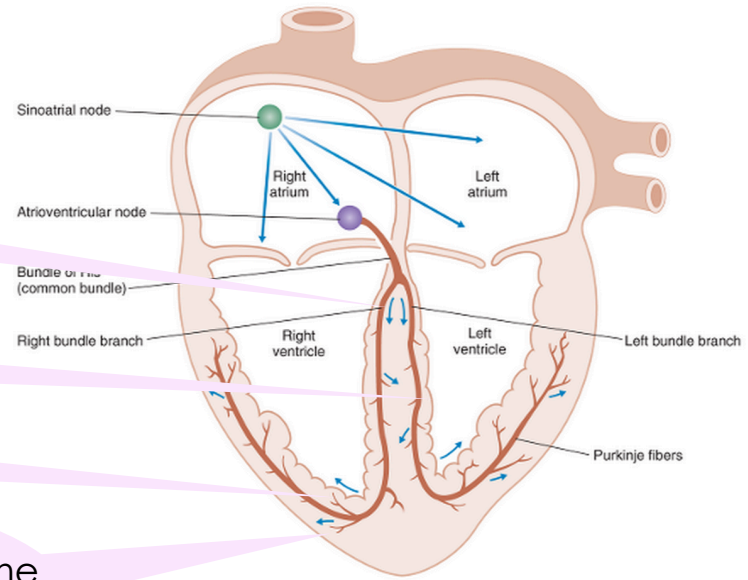
[https://www.youtube.com/watch?v=2ZCbDI2V41Q&ab\\_channel=MojahedOtayf](https://www.youtube.com/watch?v=2ZCbDI2V41Q&ab_channel=MojahedOtayf)

## Location



	Location	
<b>Sinoatrial node</b> (S-A node)	Superior lateral wall of the right atrium	✦ <b>Pacemaker of the heart. Why?</b> Because its rate of rhythmic discharge is <b>greater</b> than any other part in the heart and it has the <b>highest frequency</b> ✦ Originating action potentials by itself.
<b>Internodal pathway</b>	End of sinus nodal fibres	Connects directly with surrounding atrial muscle fibers, Therefore allowing action potentials originated from sinus node to spread through the entire atrial muscles.
<b>Atrioventricular node</b> (A-V node)	Posterior wall of the right atrium	✦ <b>Delay in the conduction of impulses . why?</b> To allows time for the atria to empty the blood into the ventricles before ventricular contraction begin
<b>Atrioventricular bundle</b> (bundle of His)	-	-
<b>Purkinje fibers</b>	Penetrate atrioventricular fibrous tissue	✦ <b>Transmit action potentials at a very high velocity</b> ✦ It has very high permeability of gap junctions so, ions are transmitted easily from one cell to the next that will lead to enhance the velocity of transmission.

# Purkinje System



Divides into right and left bundle branches

Each branch spread toward the apex of the heart

Divide into small branches

Penetrate and become continuous with cardiac muscle fibres

## Control of Excitation and Conduction in the Heart

- ✧ The impulse normally arises in the sinus node
- ✓ The Sinus Node is the Pacemaker of the Heart



# Abnormal Pacemakers

	Ectopic Pacemaker	Blockage Pacemaker
Definition	A pacemaker elsewhere other than the sinus node.	Resulted from blockage of transmission of the cardiac impulse from the sinus node to the other parts of the heart.
Cause	Developing of a rhythmical discharge rate that is more rapid than that of the sinus node at any part or the heart.	-
Examples	<ul style="list-style-type: none"><li>✧ A-V node</li><li>✧ Purkinje fibres</li></ul>	<ul style="list-style-type: none"><li>✧ A-V blockage</li></ul>
Consequences	Abnormal heart beats	Cardiac impulses fails to pass from atria into the ventricles → Atria beats with its normal rhythm (S-A) → New pacemaker developed in purkinje fibres with a new rate.

# Conduction velocity (CV) in heart:

## ✧ Depends on:

- ✓ Current spread
- ✓ Hence
- ✓ Diameter (Larger diameter = faster conduction).
- ✓ Number of gap (more gap junctions = faster conduction).

✧ **Purkinje fibres:** very large diameter.

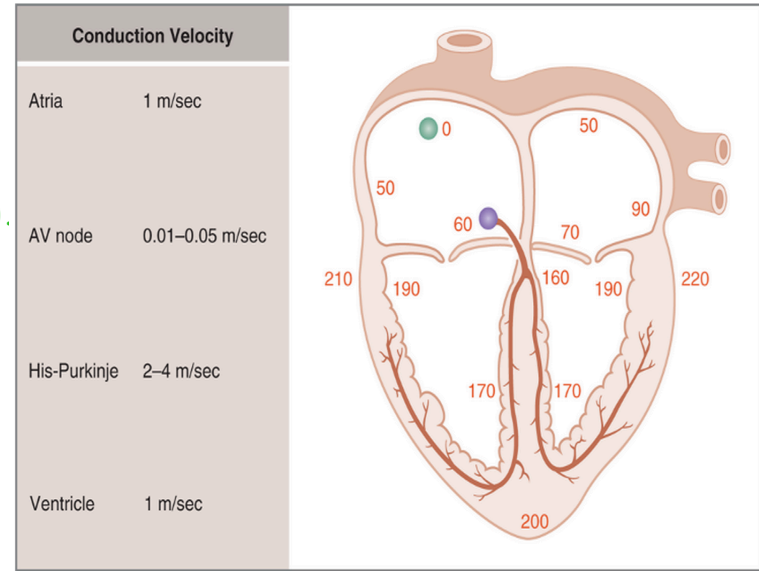
✧ **AV node and bundle (Bundle of His):** small diameter and few gap junctions.

## Cardiac Rhythm:

✧ The regularity of:  
✓ Initiation of cardiac impulses.  
✓ Sequence of excitation of the heart.  
i.e., regularity of the electrical activity of the heart.

✧ The normal cardiac rhythm is called sinus **Rhythm**.

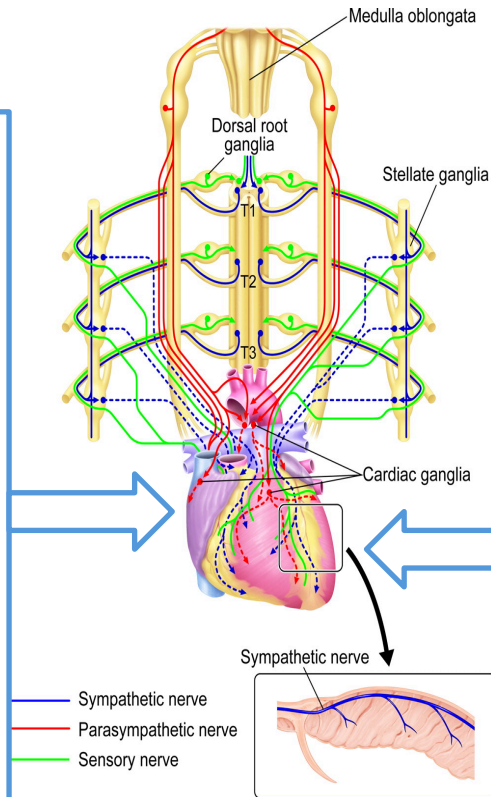
✧ Any variation from the normal rhythm (sinus rhythm) is termed: **Arrhythmia or Dysrhythmia**.



# Cardiac Nerves

## Parasympathetic nerves

- ✧ **Origin :**  
Vagus nerve
- ✧ **Supply :**  
S-A node mainly
- ✧ **Its stimulation :**
  - ✓ Decrease the SA rhythm.
  - ✓ Decrease the transmission of impulses to AV.
- ✧ **Strong stimulation of the vagus nerve:**
  - ✓ Stop completely the the rhythmical excitation (SA)
  - ✓ Complete blocking of the cardiac impulses from the atria to the ventricle
  - ✓ Some point in the purkinje fibers develops a rhythm of its own (ectopic pacemaker)



## Sympathetic nerves

- ✧ **Origin :**  
Sympathetic trunk
- ✧ **Supply :**  
All parts of the heart with strong supply to the ventricles
- ✧ **Its stimulation :**
  - ✓ Increase the rhythm of SA node
  - ✓ Increase the transmission of impulses to AV node.
  - ✓ Increase the force of contraction

- ✧ Parasympathetic stimulation has no effect on the force of contraction because it does not supply the ventricles .
- ✧ The sympathetic stimulation has a crucial effect on the contraction because supply the ventricles

Note:

# MCQs

**1- One of Specialized Excitatory and Conductive System of the Heart is highest conducting velocity:**

- A. The Atrioventricular node
- B. Purkinje fibers
- C. Sinoatrial node
- D. The internodal pathway

**2- Increasing of conduction velocity of A-V node leads**

- A. Increase ventricular filling
- B. Increase stroke volume
- C. Decrease stroke volume
- D. None of the above

**3- The normal pacemaker of the heart is:**

- A. The Atrioventricular node
- B. Purkinje fibers
- C. Sinoatrial node
- D. The internodal pathway

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# BEST OF LUCK