



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

السلام عليكم ورحمة الله وبركاته

Cardiovascular System Block

Cardiac Electrical Activity:

Conducting System

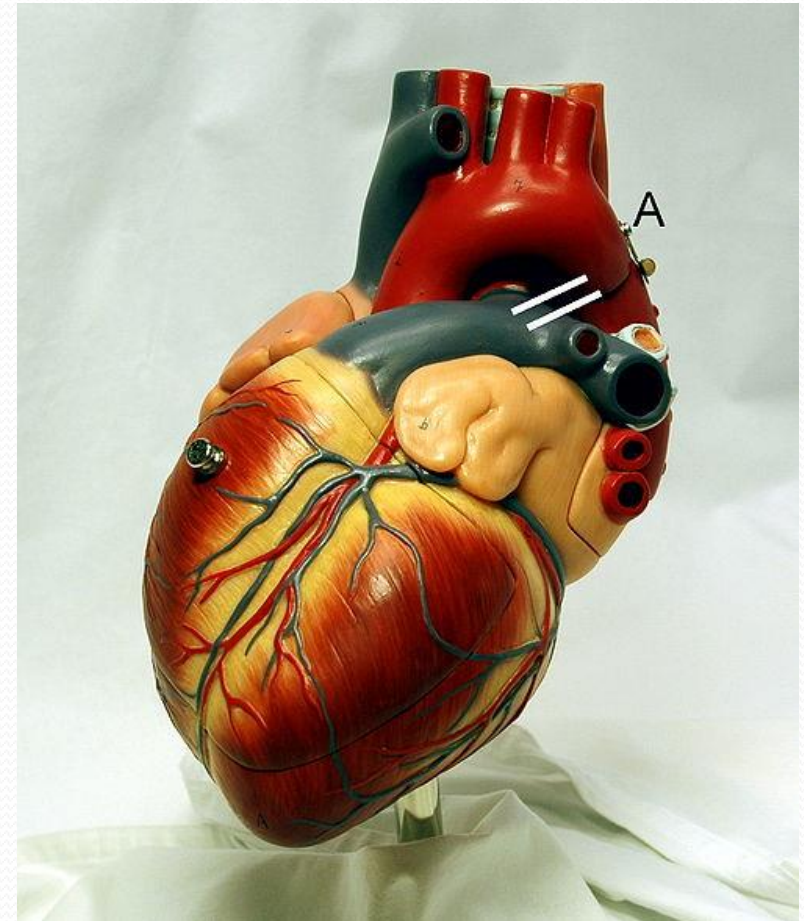
(Physiology)

Dr. Hayam Gad

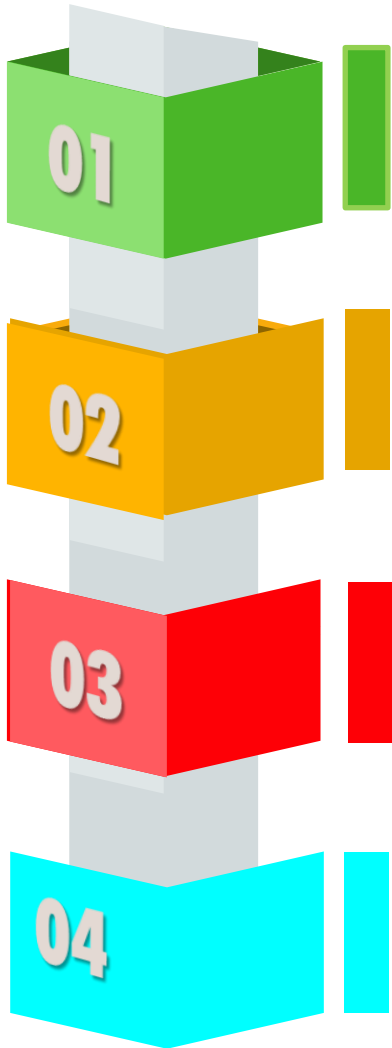
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Learning Objectives



Know The Components of The Conducting System of The Heart, The Conduction Velocities & Spread of The Cardiac Impulse Through The Heart

Understand The Control of Excitation and Conduction in The Heart

Identify The Action Potential of The Pace Maker and The Differences Between Pace Maker Potential & Action Potential of Myocardial Cells

Describe The Control Of Heart Rhythmicity and Impulse Conduction By The Cardiac Nerves, What is Latent and Abnormal Pacemakers

Cardiac Electrical Activity

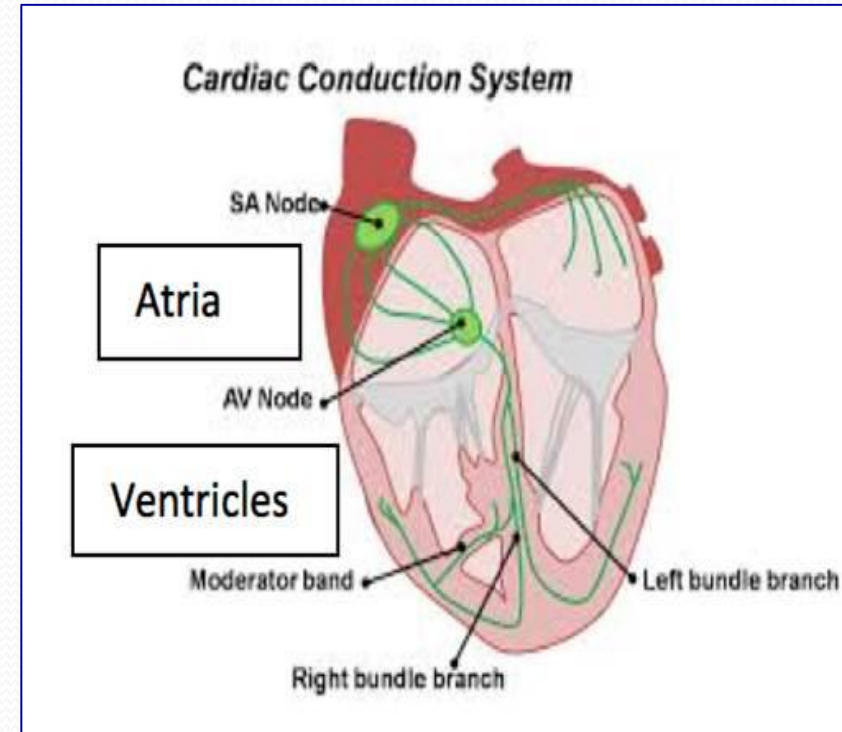
Automaticity of the heart: the heart is capable of:-

- **Generating** rhythmical electrical impulses
- **Conduct** the impulses rapidly through the heart in a specialized conducting system formed of specialized muscle fibers (Not nerve fibers).

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



Components of the Conducting System

S-A node

Internodal pathway

A-V node

A-V bundle (Bundle of His)

Left & right bundle branches

Purkinje fibers

S-A node

A-V node

Right bundle branches

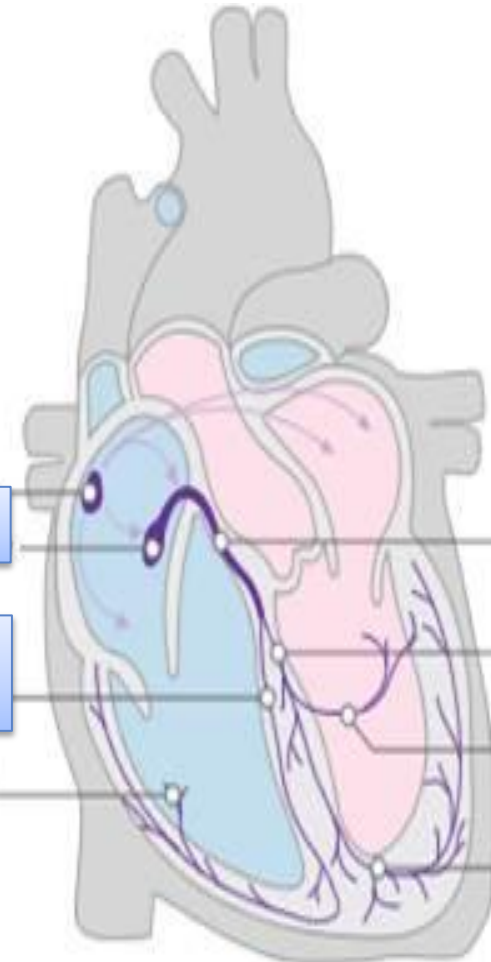
Purkinje fibers

Bundle of His

Left bundle branches

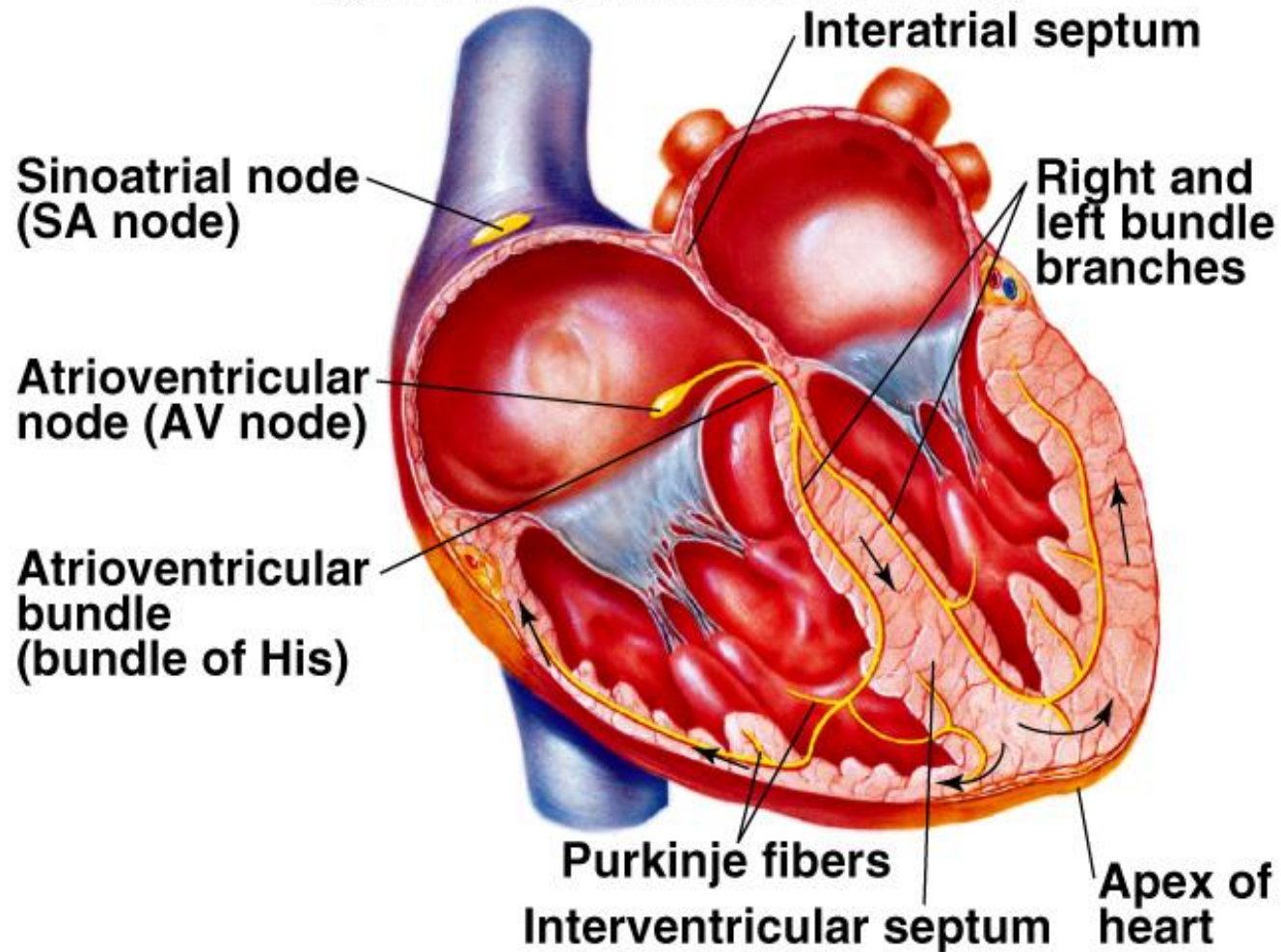
Left anterior division

Left posterior division



The Conducting System of the Heart

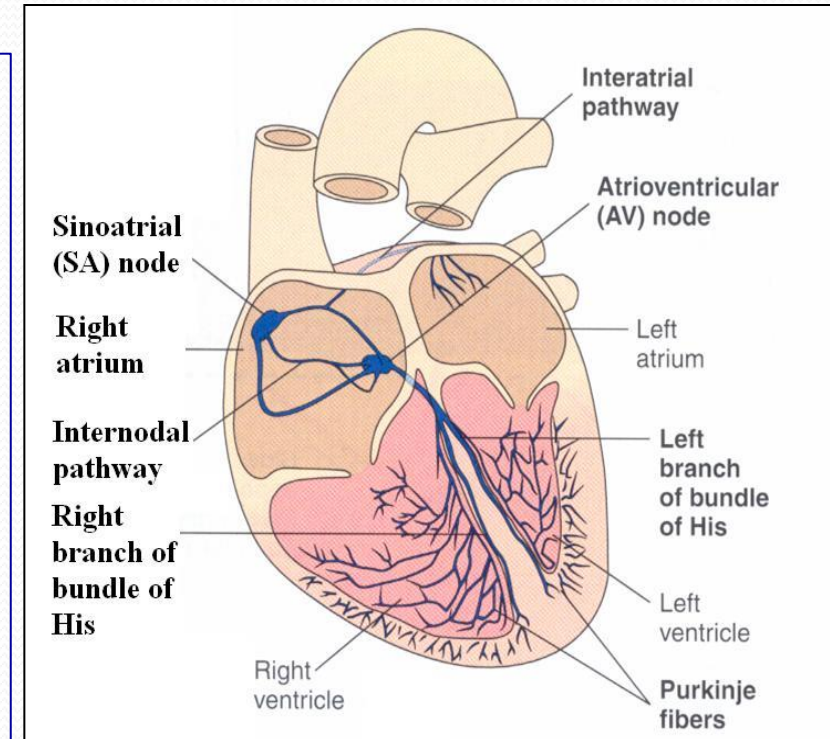
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Heart has a special system for generating rhythmical electrical impulses to cause rhythmical contraction of the heart muscle.

The Sinoatrial Node (S-A node)

- Located in the superior lateral wall of the right atrium. Its fibers are continuous with atrial fibers.
- It is made of modified cardiac muscles.
- Velocity of conduction between its fibers is 0.05 m/s.
- Its membrane potential is unstable, so it is responsible for generating the electrical impulses (action potentials) that bring about the mechanical activity i.e contraction of the heart.
- *It is the normal Pacemaker of the heart*
- SA node has the fastest rate of autorhythmicity.

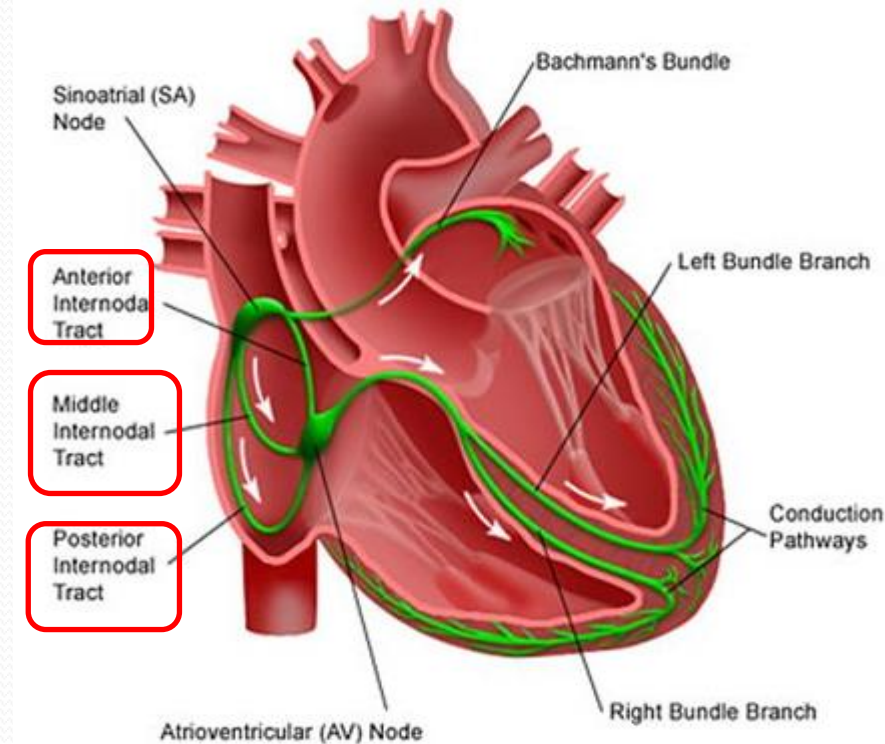


Why?

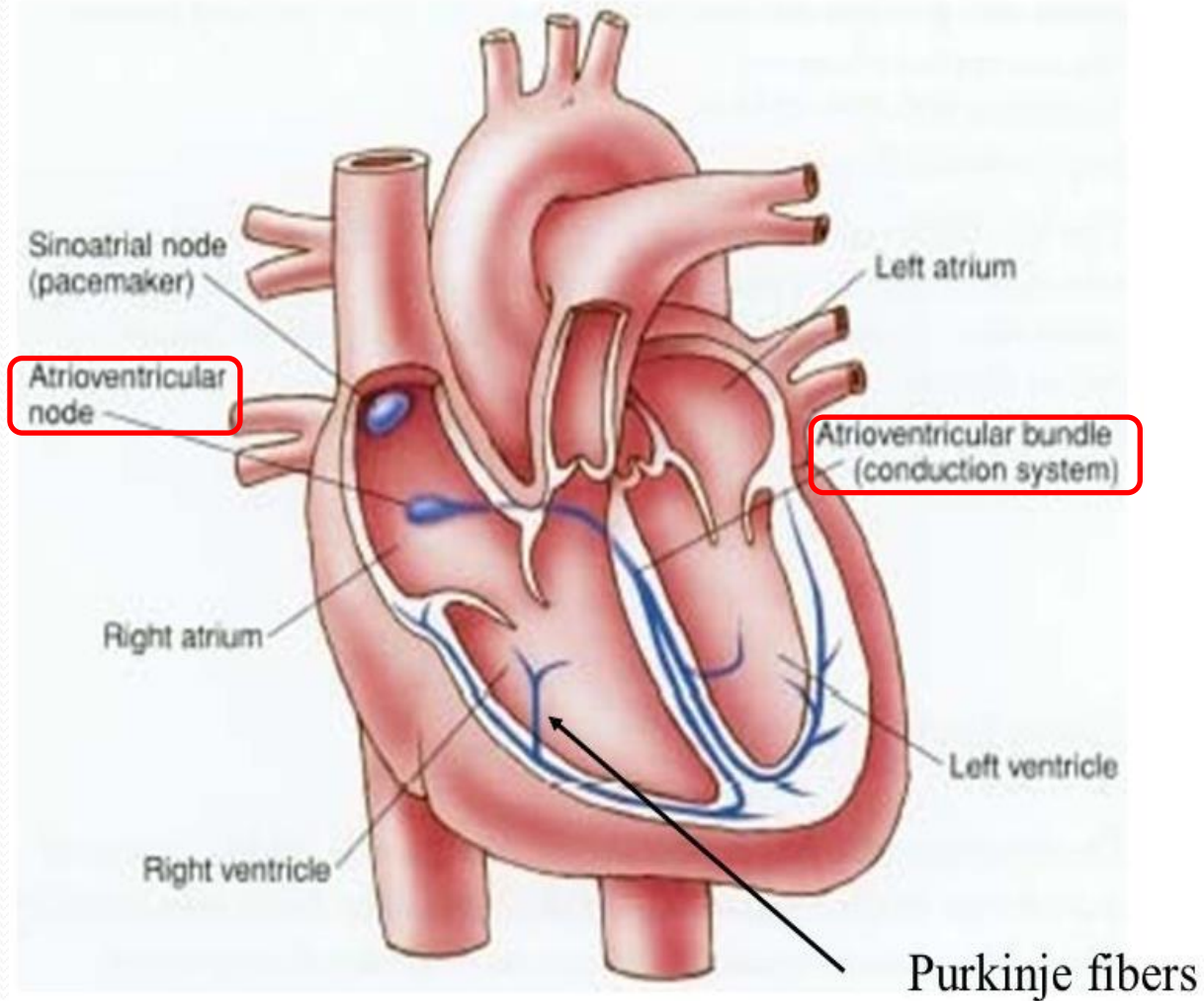
The Internodal Pathway

Action potential can travel from S-A node to spread through out the atrial muscle through two routes:-

- ❑ Ordinary atrial muscle fibers (conduction velocity is 0.3 m/s).
- ❑ Internodal pathway:-
 - Anterior internodal bundle of Bachman
 - Middle internodal bundle of Wenkebach
 - Posterior internodal bundle of Thoral.
(conduction velocity is 1 m/s.)



The A-V node



- The A-V node is located in the posterior wall of the right atrium immediately behind the tricuspid valve.
- The impulse after leaving S-A node takes 0.03 sec to reach the A-V node.
- A-V node receives impulses from S-A node and transmits them to ventricles through A-V bundle.
- Delay in the conduction of impulses occurs at A-V node (0.13 sec)

Significance Of A-V Nodal Delay (0.13 sec)

The cardiac impulse does not travel from the atria to the ventricles too rapidly:-

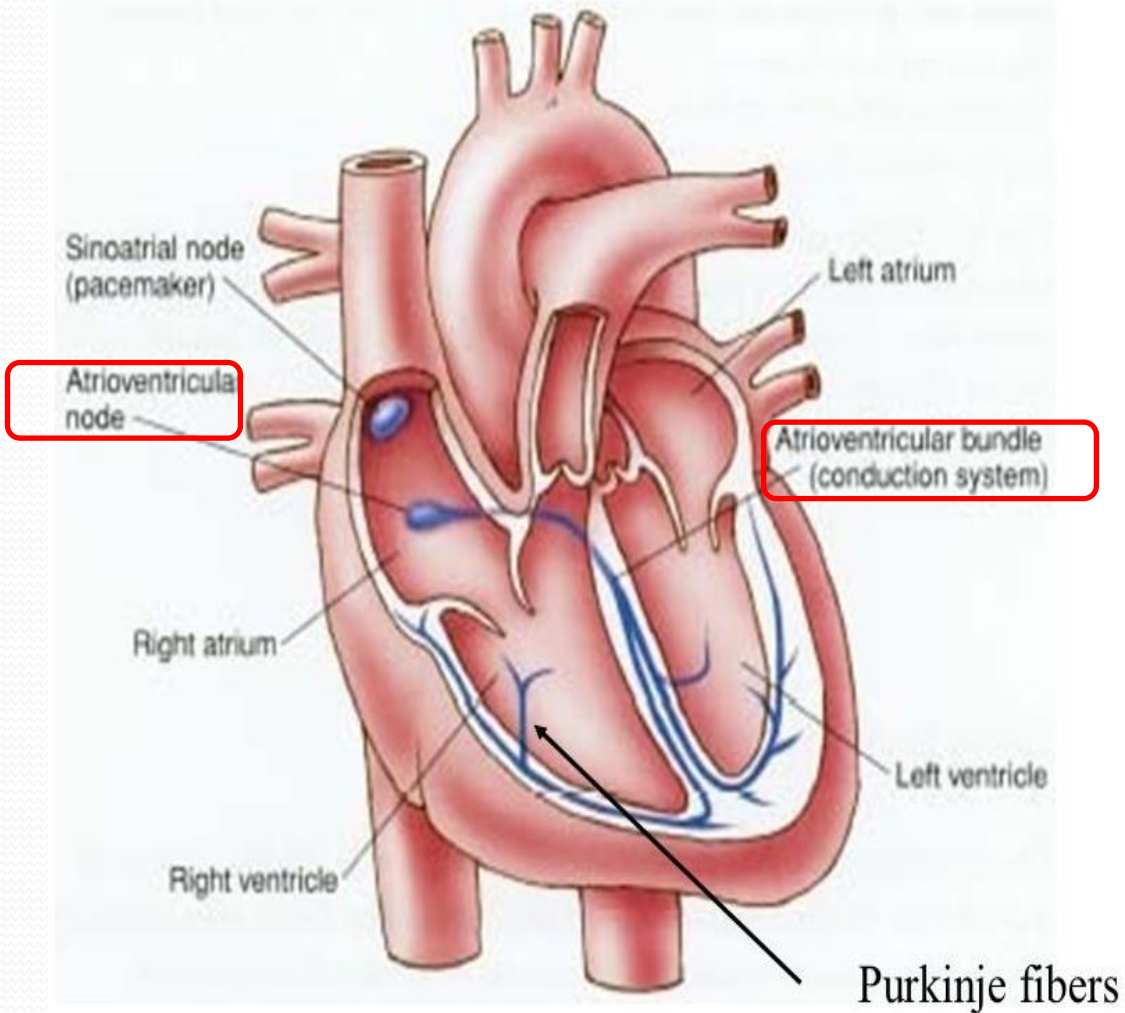
1- To allow time for the atria to empty the blood into the ventricles before ventricular contraction begin and so gives time for ventricular filling with blood and increases the efficiency of the pumping action of the heart.

2- To protects ventricles from pathological high atrial rhythm.

The cause of slow conduction is mainly diminished number of gap junctions between the successive cells

Why
?

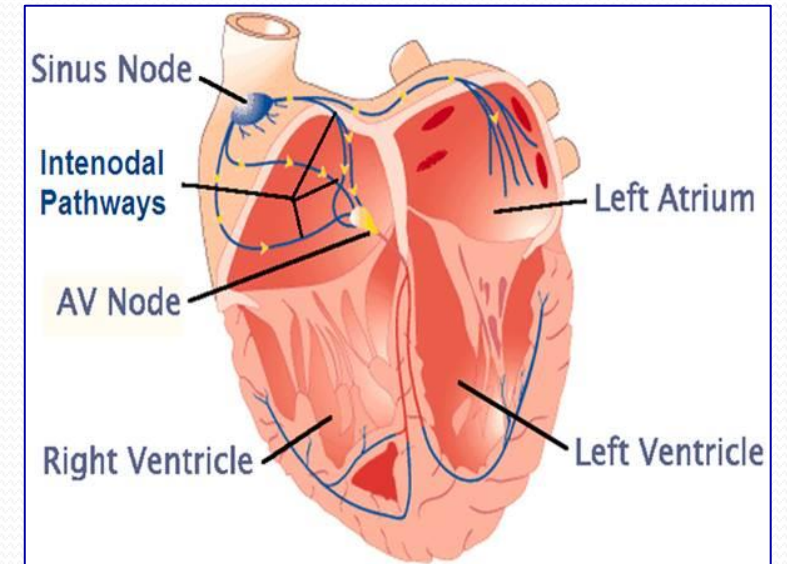
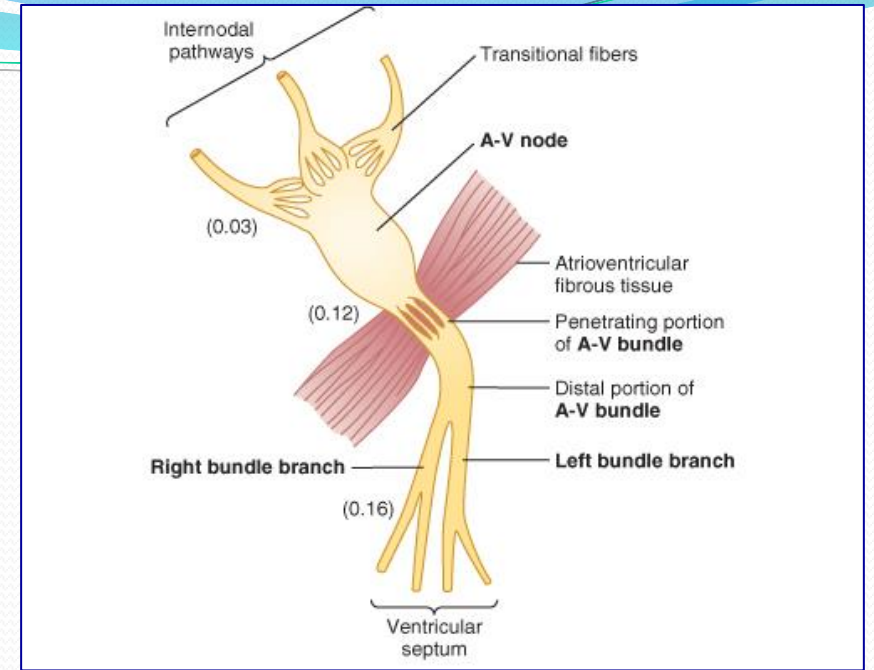
The A-V bundle (Bundle of His) The Right & Left Bundle Branches



- A-V node transmits impulses to ventricles through A-V bundle.
- A-V bundle conducts impulses to A-V bundle branch at velocity of 1 m/s.
- Bundle of His splits into two branches (right and left bundle branches) present on the respective sides of the ventricular septum and spread toward the apex of the heart, then reflect on ventricular wall.

IV- The Purkinje System

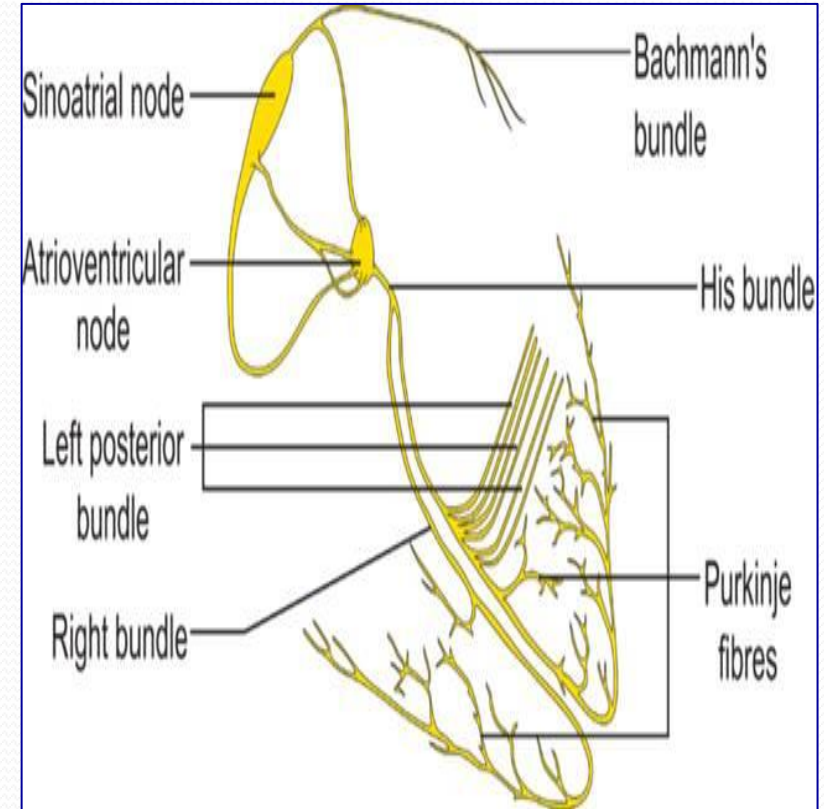
- ❑ After the right and left bundle branches reflect on ventricular wall, they divide into small branches (Purkinje fibers).
- ❑ Purkinje fibers penetrate and become continuous with ventricular cardiac muscle fibers.
- ❑ From the time the cardiac impulse enters the bundle branches until it reaches the terminations of Purkinje fibers, the total time averages only 0.03 sec.



IV- The Purkinje System.....Cont.

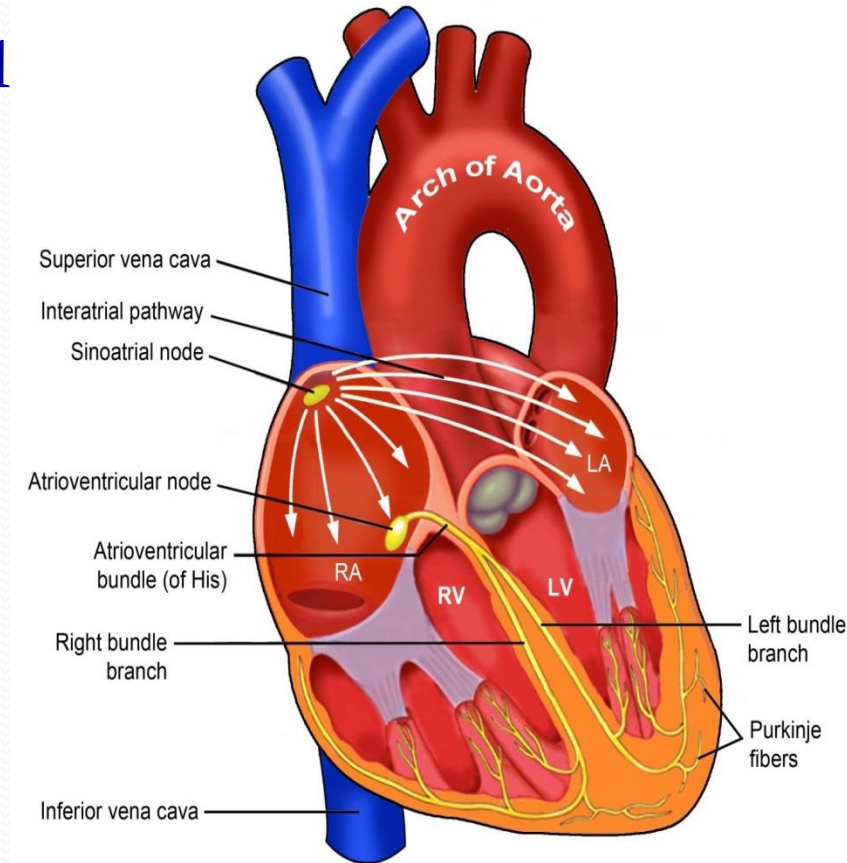
- Purkinje fibers are very large fibers
- Transmit action potentials at a very high velocity (1.5-4.0 m/sec)
 - a very high permeability of gap junctions at the intercalated discs between the successive cells of Purkinje fibers.
 - → ions are transmitted easily from one cell to the next
 - → enhance the velocity of transmission
- Significance: ensures that different parts of ventricles are excited almost simultaneously so all ventricular muscle contract at almost the same time; this greatly increases the efficiency of heart as a pump (**synchronous contraction**).

Why?

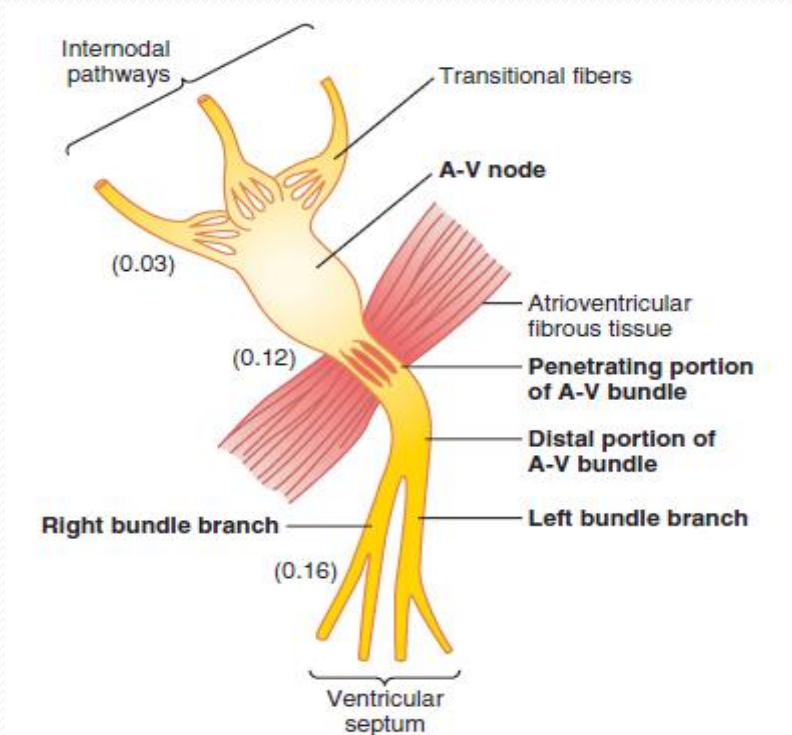


Conduction of Impulse: The One-Way Conduction Through A-V Bundle

- APs spread from S-A node through internodal pathway quickly at velocity of 1.0 m/sec.
- Impulses pass through A-V node at a velocity of 0.01 m/sec.). Time delay occurs (0.13 sec).
- Impulse conduction increases as spread to Purkinje fibers at a velocity of 4.0 m/sec.
- Ventricular contraction begins 0.1–0.2 sec. after contraction of the atria.
- A special characteristic of the A-V bundle is inability of action potentials to travel backward from the ventricles to the atria.
- The atrial muscle is separated from the ventricular muscle (except at the A-V bundle) by a continuous fibrous barrier which acts as an insulator to prevent re-entry of cardiac impulse by this route from the ventricles to the atria.



Conduction Velocities & Spread of the Cardiac Impulse Through The Heart

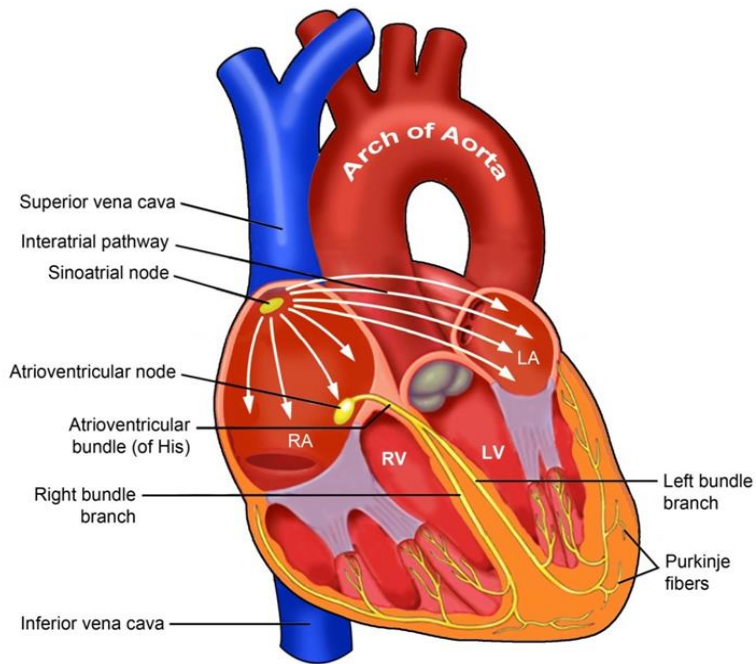


S-A node
 Internodal pathway
 A-V node
 Bundle of His
 Purkinje system
 Atrial & Ventricular
 muscles

0.05 m/sec.
 1.00 m/sec.
 0.01 m/sec. (slowest)
 1.00 m/sec.
 4.00 m/sec. (Fastest)
 0.3-0.5 m/sec.

Organization of the A-V node. The numbers represent the interval of time from the origin of the impulse in the S-A node.

Sequence of Excitation



**Sinoatrial
node**

**Atrial
syncytium**

**Atrio-
ventricular
node**

A-V bundle

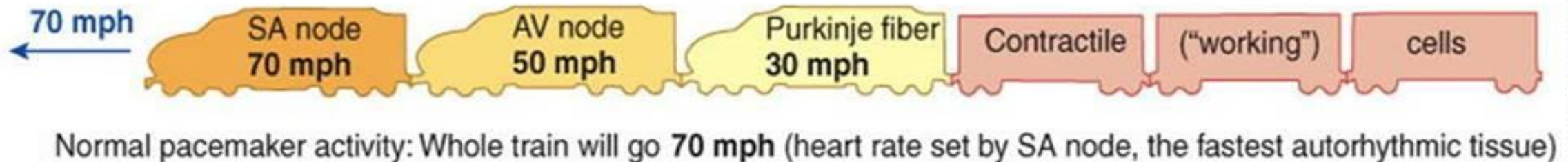
**Bundle
branches**

**Purkinje
fibers**

**Ventricular
syncytium**

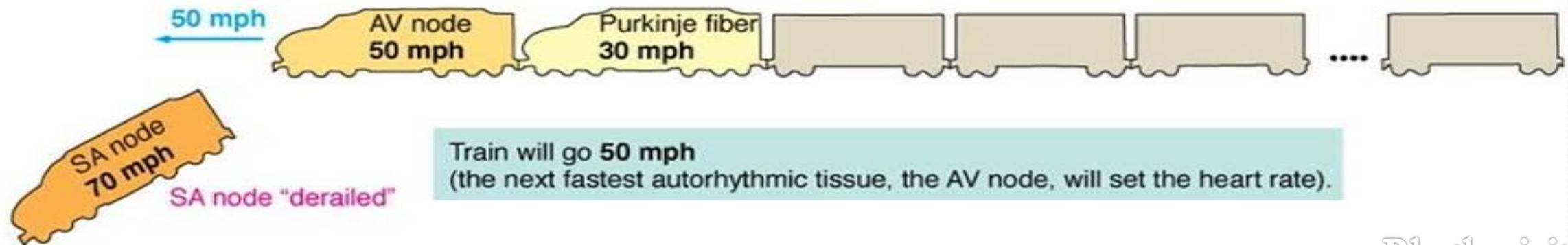
Control of Excitation and Conduction in the Heart

- The S-A node is the normal **Pacemaker** of the Heart.
- It has pacemaker pre-potential (autorhythmic tissue).
- it initiates the excitation wave, drive whole heart and makes the pace (speed) of heart at a rate of 105 impulse/min, inhibited by right vagus nerve to be 70 impulse/min (vagal tone).
- Its rate of rhythmical discharge is faster than that of any other part of the heart, so it derives rest of the heart.



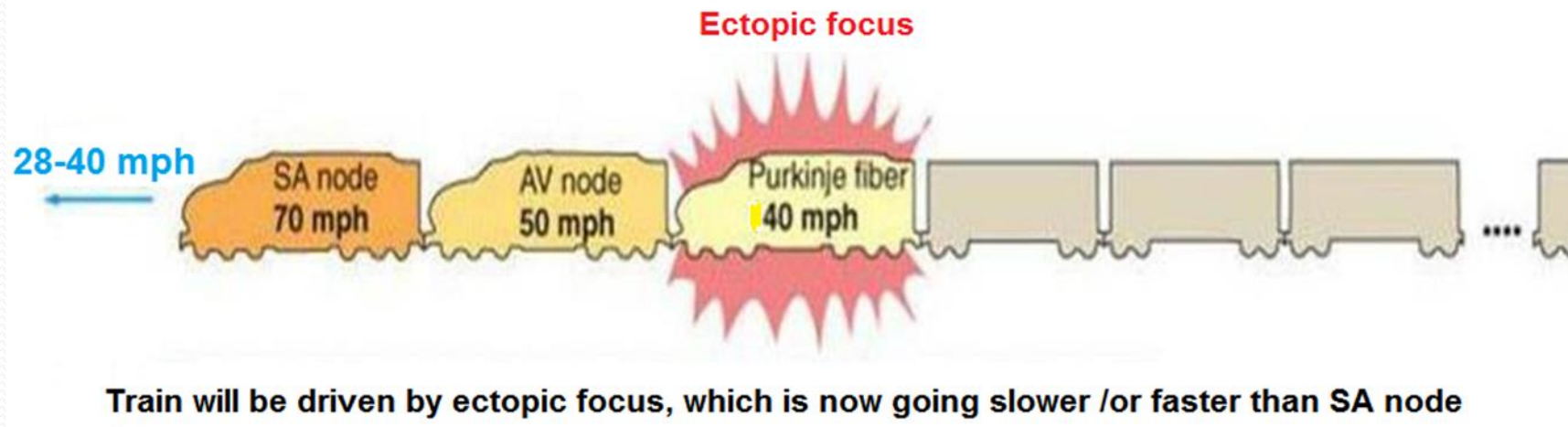
Latent Pacemakers

- A-V node, His bundle & Purkinje fibers have also intrinsic automaticity & ability to set a pace. They are called “latent Pacemakers”.
- Latent Pacemakers are normally suppressed & function only if the S-A node is damaged, or its impulse is blocked, or if the rate of firing of the latent pacemakers increases.
- If S-A node is damaged, A-V node becomes the new pacemaker and heart follow it but at a slower rate (50-60 impulse/min) (A-V nodal rhythm).



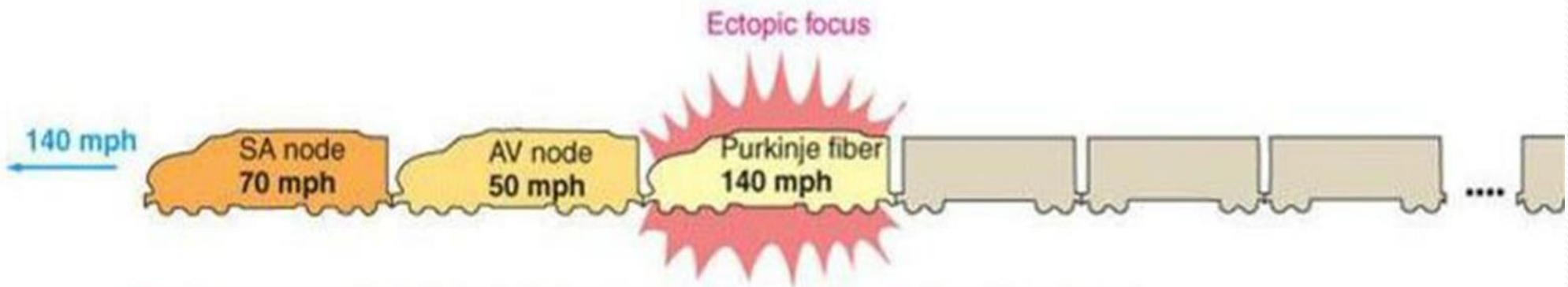
Latent Pacemakers.....Cont.

- If S-A node or A-V node are damaged, His bundle & Purkinji fibers become the pacemaker with a rhythm of 28-40 impulse/min (idioventricular rhythm).
- Rhythmicity is high in S-A node > A-V node > His bundle & Purkinje fibers.



Abnormal (Ectopic) Pacemakers

- Ectopic pacemaker: a pacemaker elsewhere than the SA node
- In some cases, Purkinje fibers can become overexcited = ectopic focus and cause premature ventricular contraction.
- It can occur upon excess caffeine, lack of sleep, anxiety, stress or some organic conditions.



(d)

Train will be driven by ectopic focus, which is now going faster than the SA node (the whole heart will be driven more rapidly by an abnormal pacemaker).

Causes of Ectopic Pacemakers

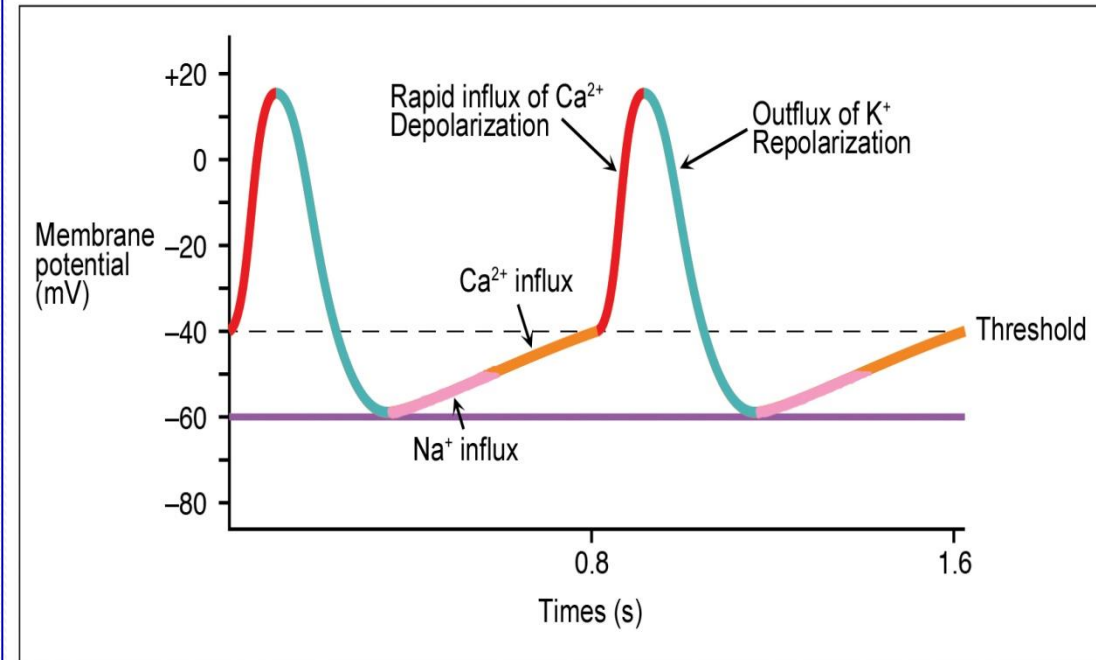
- 1- Any other part of the heart develops a rhythmical discharge rate that is more rapid than that of the SA node
- 2- Blockage of transmission of the cardiac impulse from the S-A node to the other parts of the heart

Example: A-V block

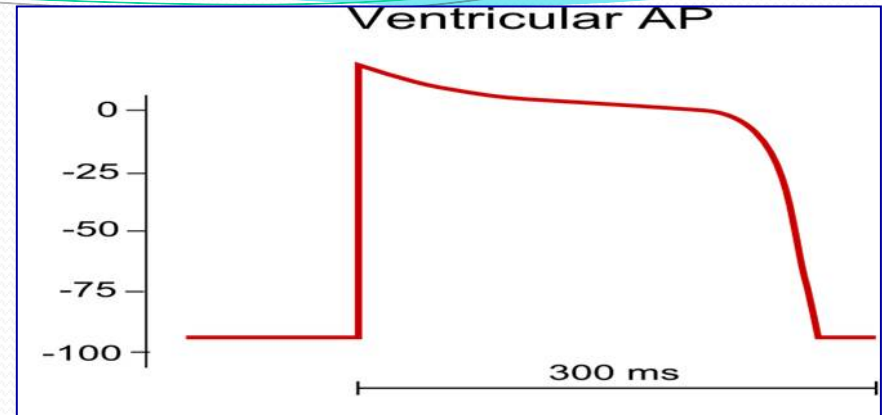
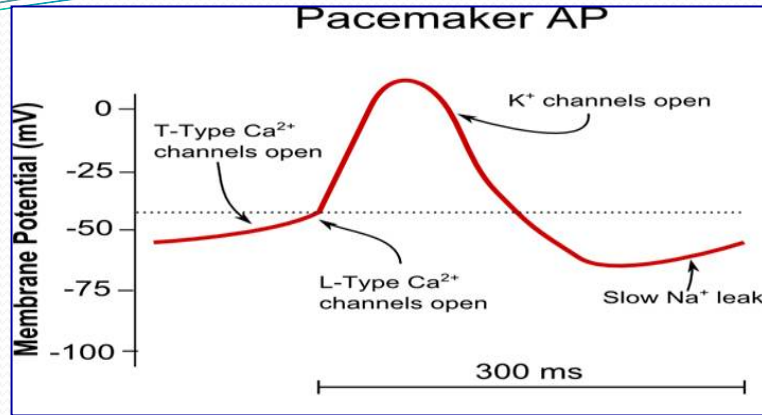
- Cardiac impulses fails to pass from atria into the ventricles
- The atria continues to beat at the normal rhythm rate of the S-A node
- A new pacemaker develops in the Purkinje system with a new rate

Action potential of the pace maker (pace maker potential)

- The cell membrane of pace maker cells is leaky to Na^+ . This decreases gradually MP.
- Then Ca^{++} influx d.t opening of transient Ca^{++} channels decreases MP from -60 mv to a firing level of -40 mv.
- This gradual depolarization is called pace maker potential or pre-potential.
- At firing level, long lasting Ca^{++} channels open & Ca^{++} influx occurs causing fast change of MP from -40 to + 10 mv. (depolarization).
- At peak, K^+ outflux begins & MP returns to -60 mv. (repolarization).
- Then the cycle is repeated by self excitation.



Differences between pace maker P & L AP of myocardial cells



Pace Maker Action Potential

Does not need a stimulus

RMP is -60 mv.

Max. depolarization is +10 mv.

Is of smaller magnitude

Has pre-potential stage

Depolarization is gradual.

Depolarization is due to Ca^{++}

It has spike, no plateau.

Ventricular Muscle Action Potential.

Needs a stimulus

RMP is -90 mv.

Max. depolarization is +20 mv

Is of larger magnitude.

Has no pre-potential stage

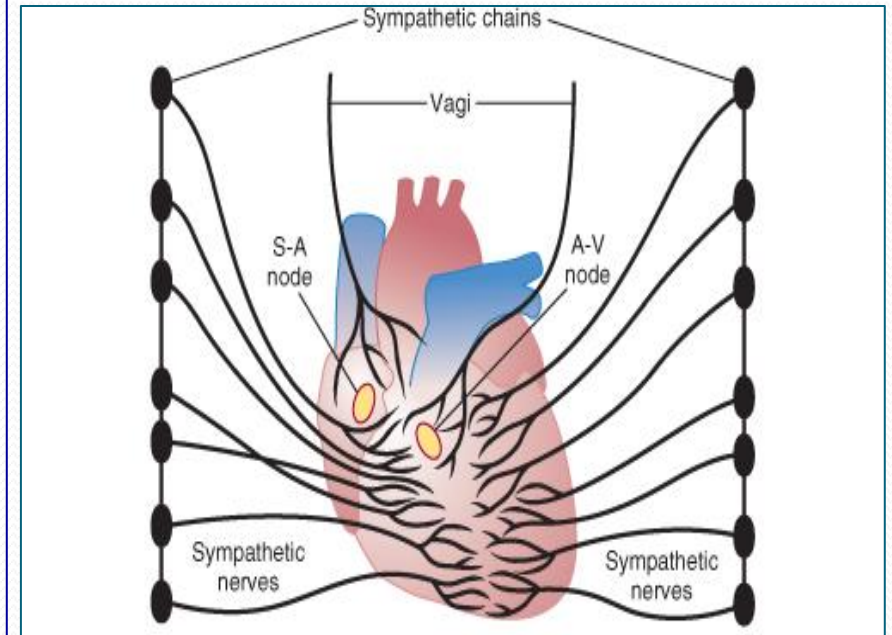
Depolarization is rapid.

Depolarization is due to Na^+ .

It has plateau, no spike

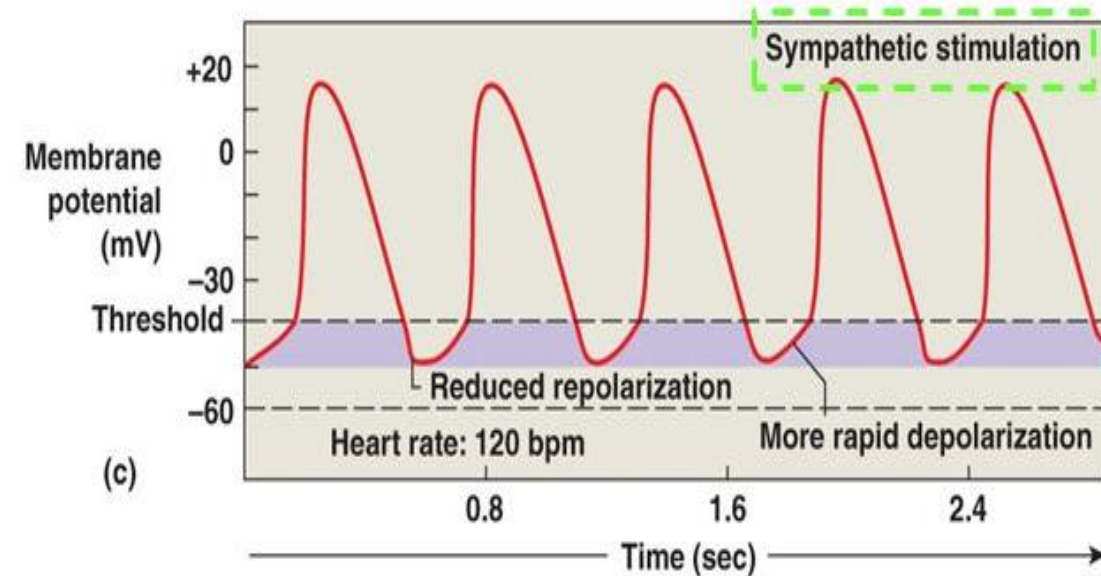
Control of Heart Rhythmicity and Impulse Conduction by the Cardiac Nerves

- The heart is supplied with both sympathetic and parasympathetic nerves
- **Sympathetic nerves**: to all parts of the heart with strong supply to the ventricles
- **Parasympathetic nerves (vagi)**: mainly to the S-A and A-V nodes



Sympathetic stimulation of the heart

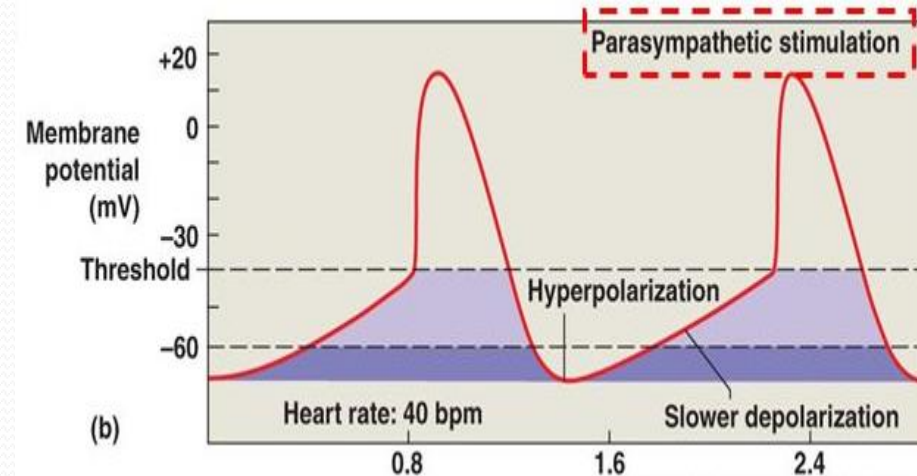
- \uparrow the slope of pre-potential of S-A node (i.e \uparrow rhythm of the S-A node) due to increase the permeability to Na^+ & Ca^{++} , so accelerate the heart rate.
- \uparrow transmission of impulses to the A-V node
- \uparrow force of myocardial contraction



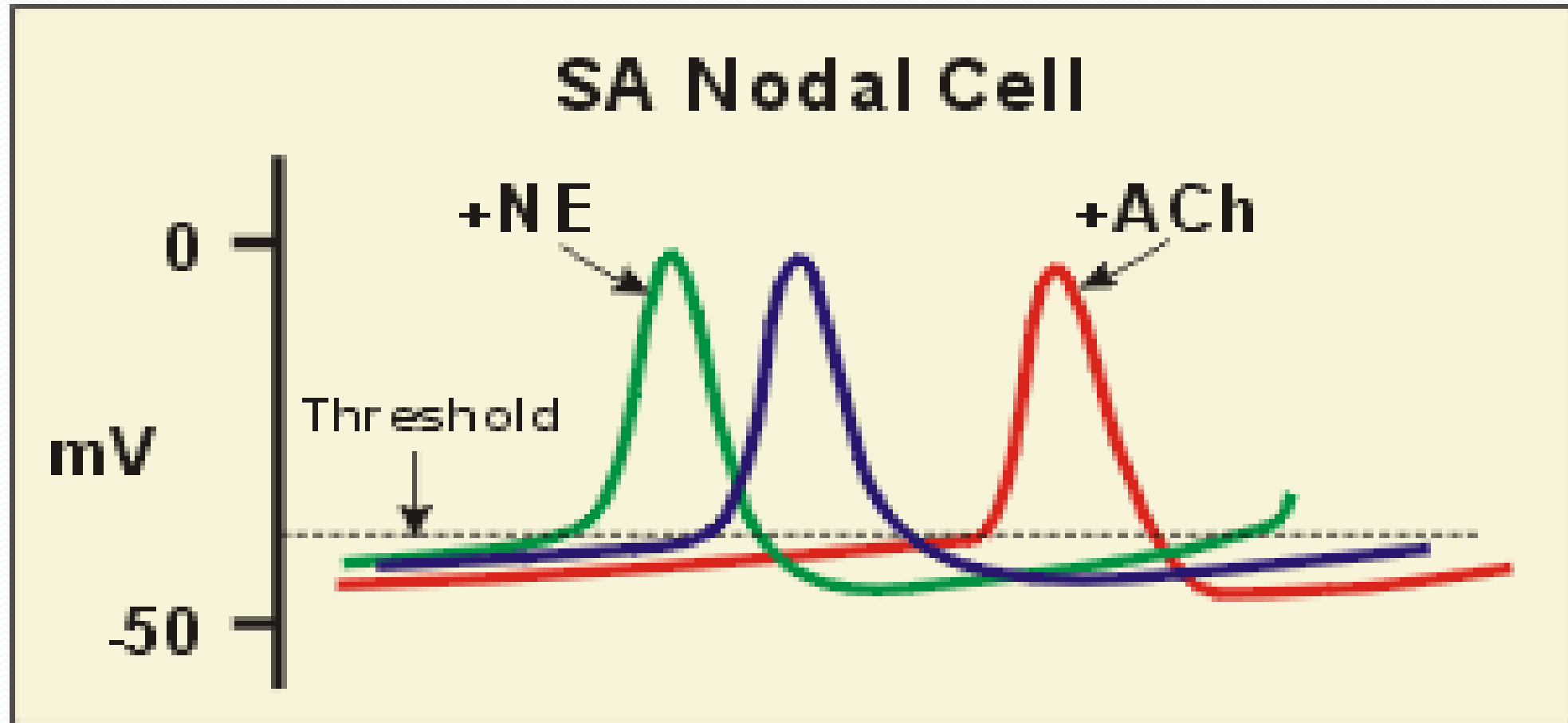
Parasympathetic stimulation of the heart

- ↓ the slope of pre-potential of S-A node due to increase the permeability to K^+ (i.e ↓ rhythm of the S-A node, so slow the heart rate).
- ↓ transmission of impulses to the A-V node
- Strong stimulation of the vagi:
 - Stop completely the rhythmical excitation by the S-A node
 - Block completely transmission of cardiac impulses from the atria to the ventricle
 - Some point in the Purkinje fibers develops a rhythm of its own

“Ventricular Escape”



Sympathetic VS Parasympathetic stimulation of the heart



For further readings and diagrams:

Textbook of Medical Physiology by Guyton & Hall

Chapter 10 (Rhythmical Excitation of the Heart)



Thank You