السلام عليكم ورحمة الله وبركاته

Cardiovascular System Block
Cardiac Electrical Activity
(Physiology)

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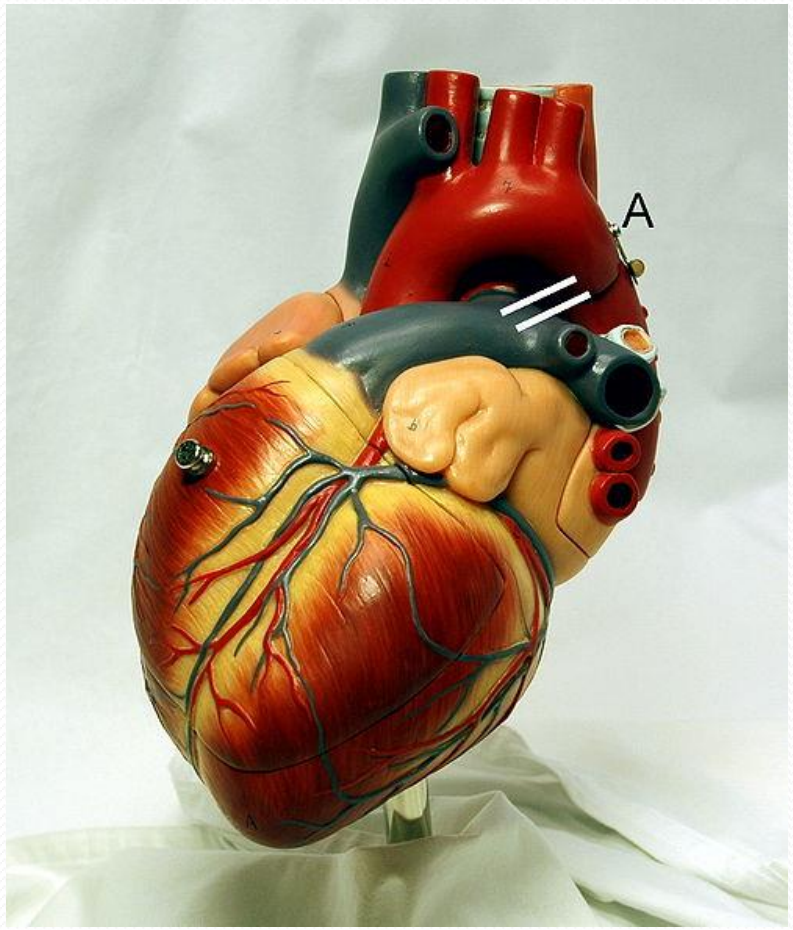
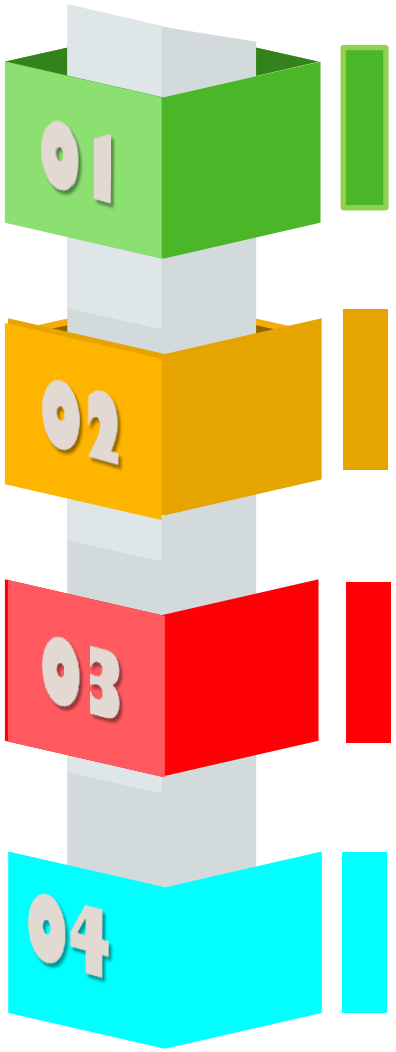


Learning Objectives



01 Know the components of the conducting system of the heart, the conduction velocities & spread of the cardiac impulse through the heart

02 Understand the control of excitation and conduction in the heart

03 Identify the action potential of the pace maker and the differences between pace maker potential & action potential of myocardial cells

04 Describe the control of heart rhythmicity and impulse conduction by the cardiac nerves, what is latent and abnormal pacemakers

Cardiac Electrical Activity

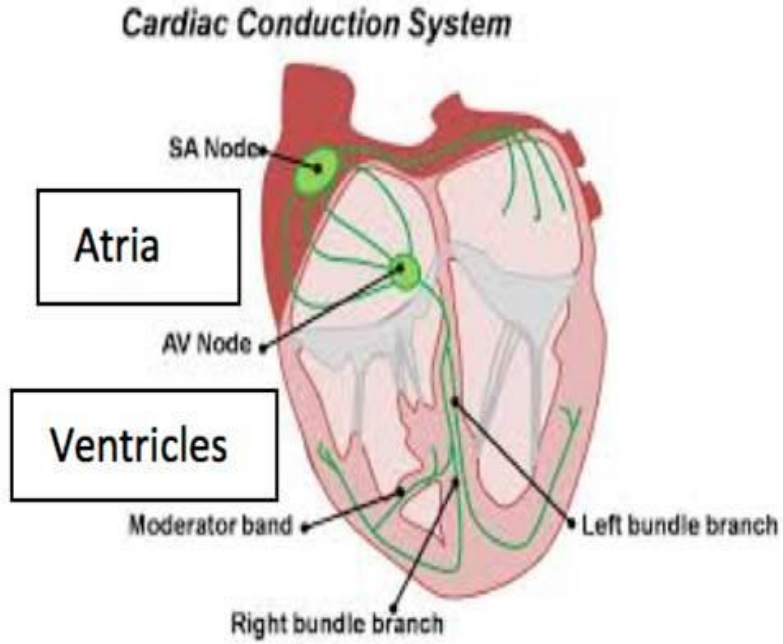
Automaticity of the heart: the heart is capable of:-

- **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 a head of ventricular contraction

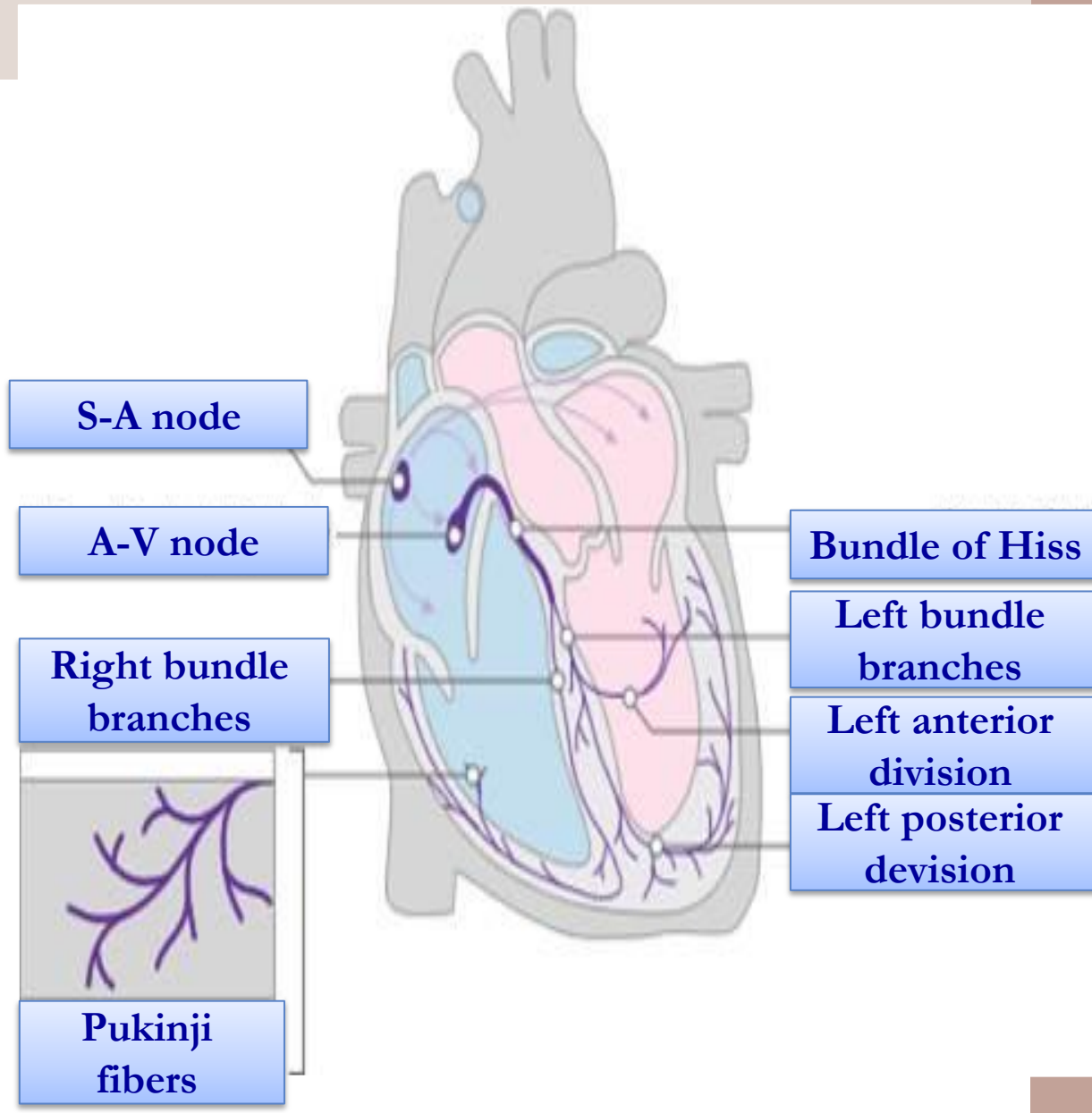
Why?

- To allows filling of the ventricles before they pump the blood into the circulation



Components of the Conducting System

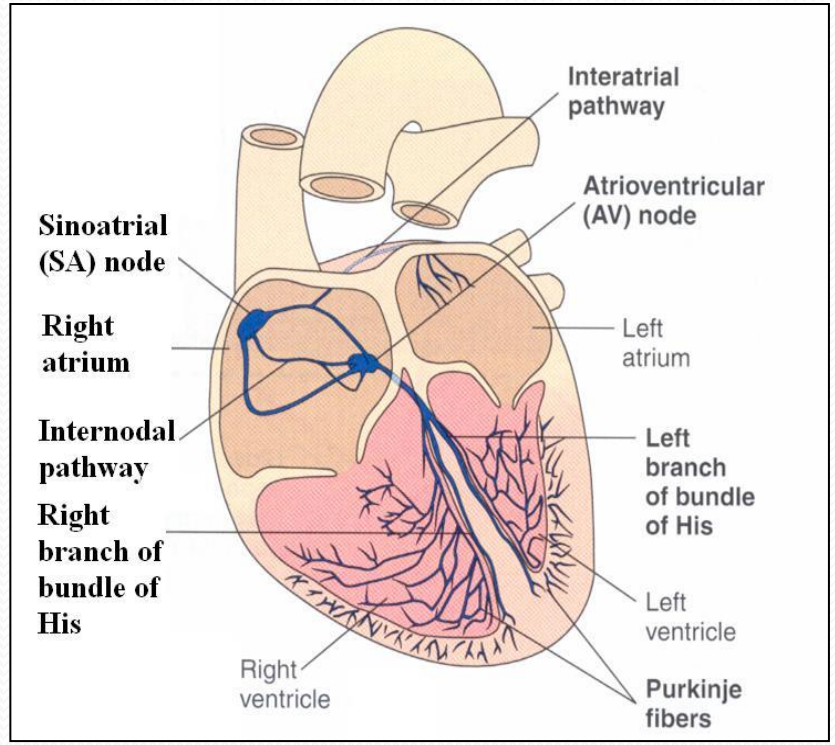
- S-A node
- Internodal pathway
- A-V node
- A-V bundle (Bundle of Hiss)
- Left & right bundle branches
- Pukinji fibers



I- Sinoatrial node (S-A node)

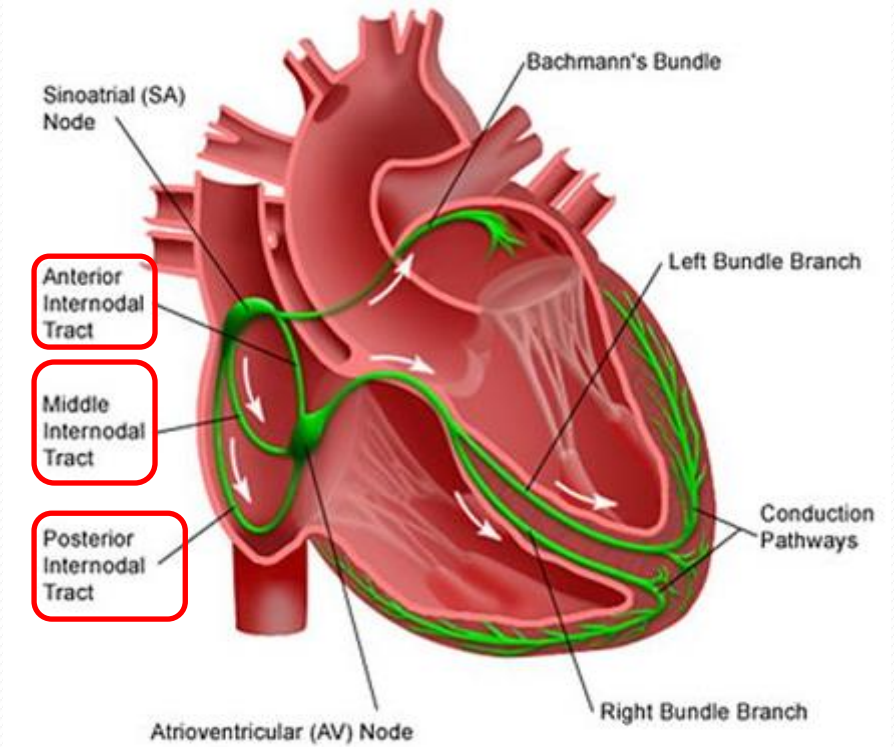
- Located in the superior lateral wall of the right atrium. Its fibers are continuous with atrial fibers.
- It is made of modified cardiac muscles.
- Velocity of conduction between its fibers is 0.05 m/s.
- Its membrane potential is unstable, so it is capable of ***originating*** action potentials.

- ***It is the normal Pacemaker of the heart***
  - Its rate of rhythmic discharge is ***greater*** than any other part in the heart (i.e it has highest frequency).



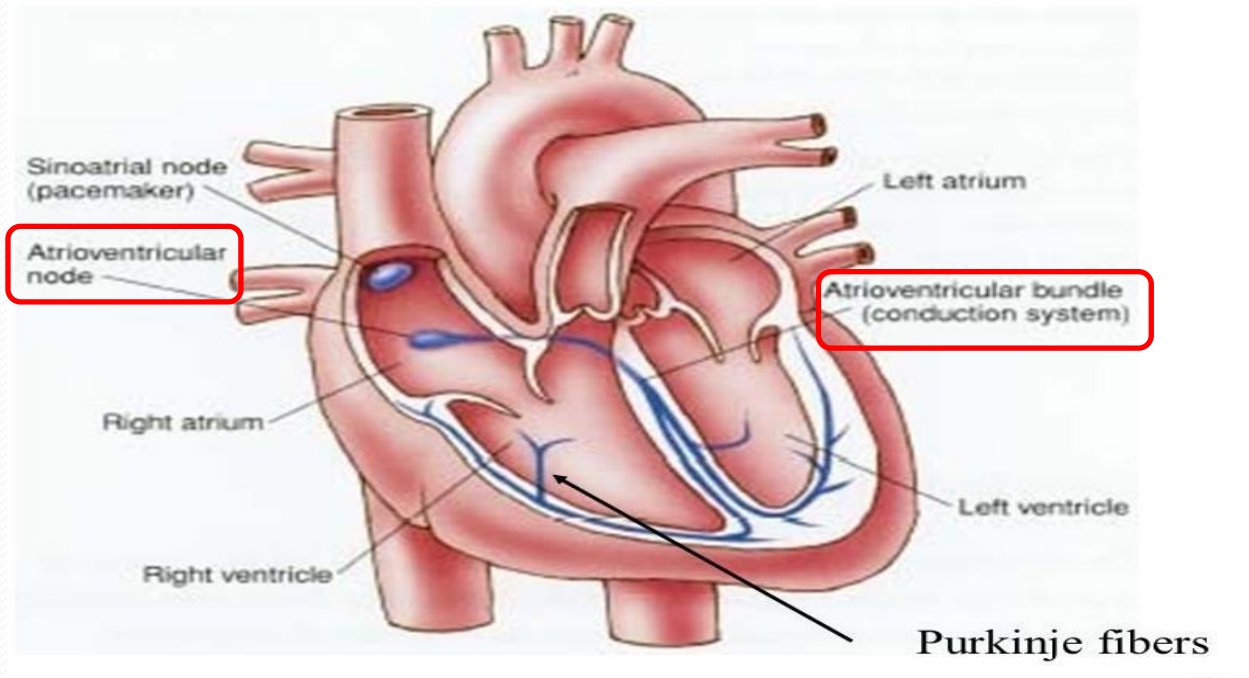
Why?

II- The Internodal Pathway



- Action potential can travel from S-A node to A-V node through internodal pathways (ant. middle, post.) at high velocity of 1 m/s. They are similar to Purkinji fibers.
- Velocity of conduction through the atrial muscle fibers themselves is 0.3 m/s.

III- A-V node & Bundle of Hiss



- Located in the posterior wall of the right atrium.
- It receives impulses from S-A node & transmits it to ventricles through A-V bundle.
- A-V bundle conducts impulses to A-V bundle branch at velocity of 1 m/s.

Delay in the conduction of impulses at A-V node (0.13 sec)

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.

2- To protects ventricles from pathological high atrial rhythm.

Why?

IV- The Purkinje System

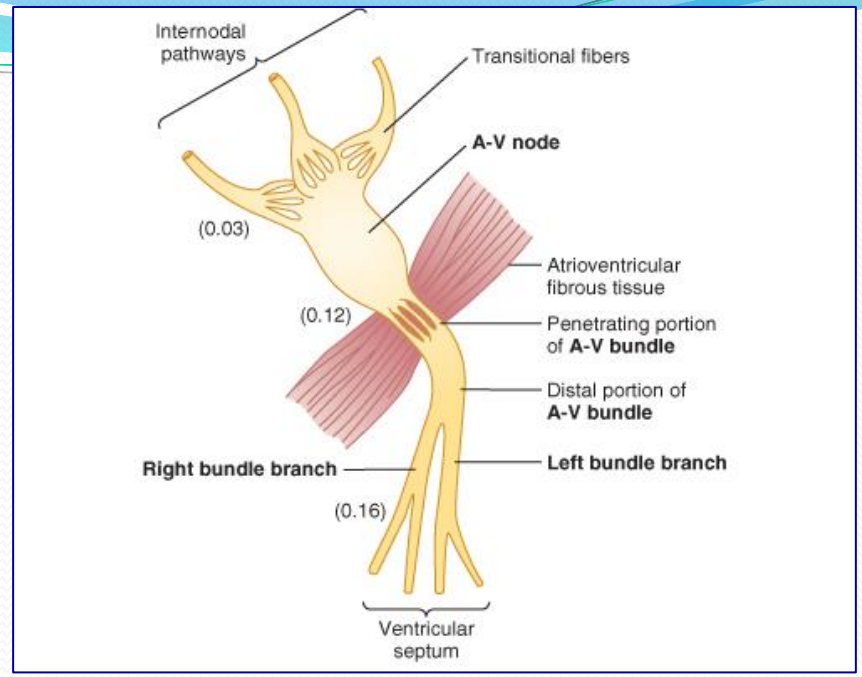
Fibers of A-V bundle penetrate atrioventricular fibrous tissue

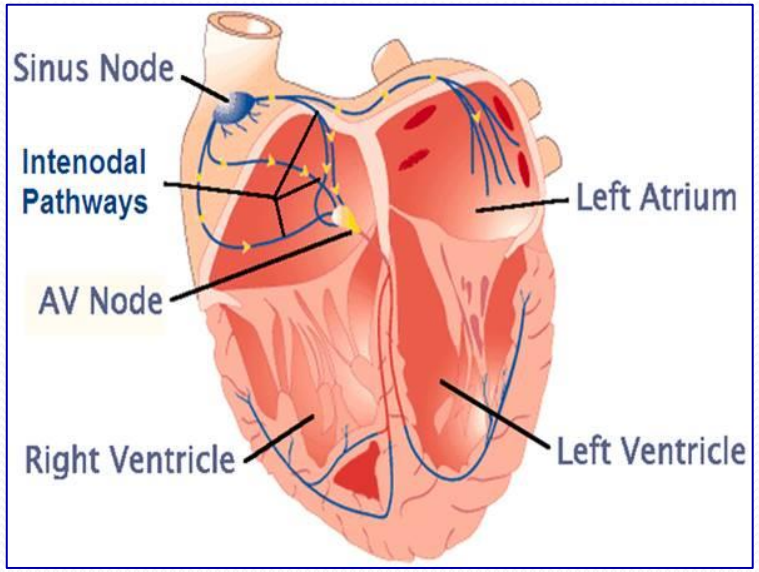
→ divides into right and left bundle branches

→ each branch pass along sides of interventricular septum and spread toward the apex of the heart, then reflect on ventricular wall.

→ divide into small branches (Purkinje fibers)

→ penetrate and become continuous with ventricular cardiac muscle fibers



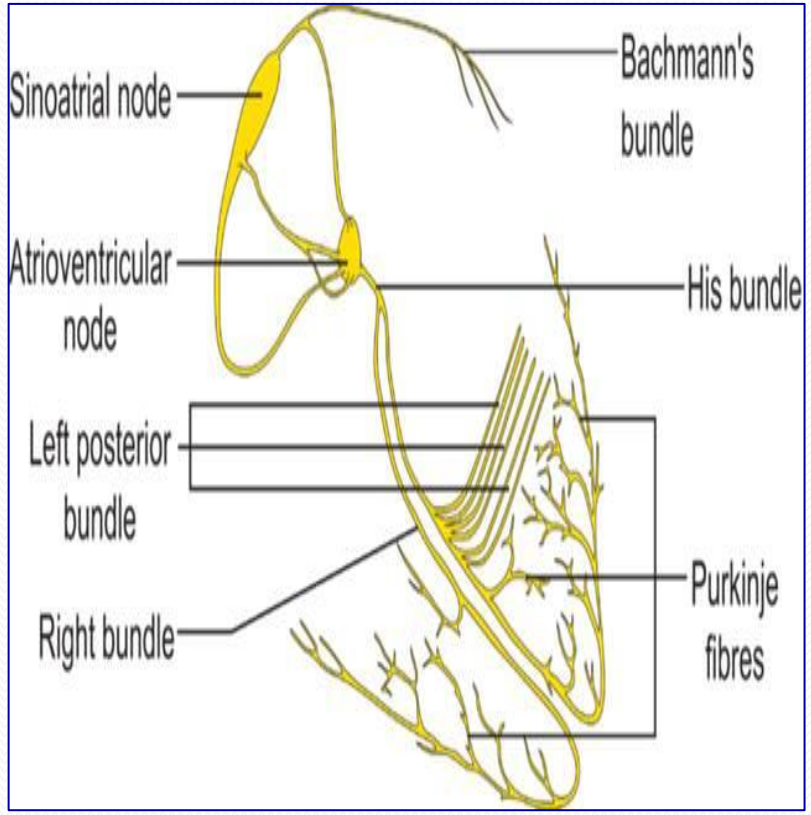


IV- The Purkinje System…..Cont.

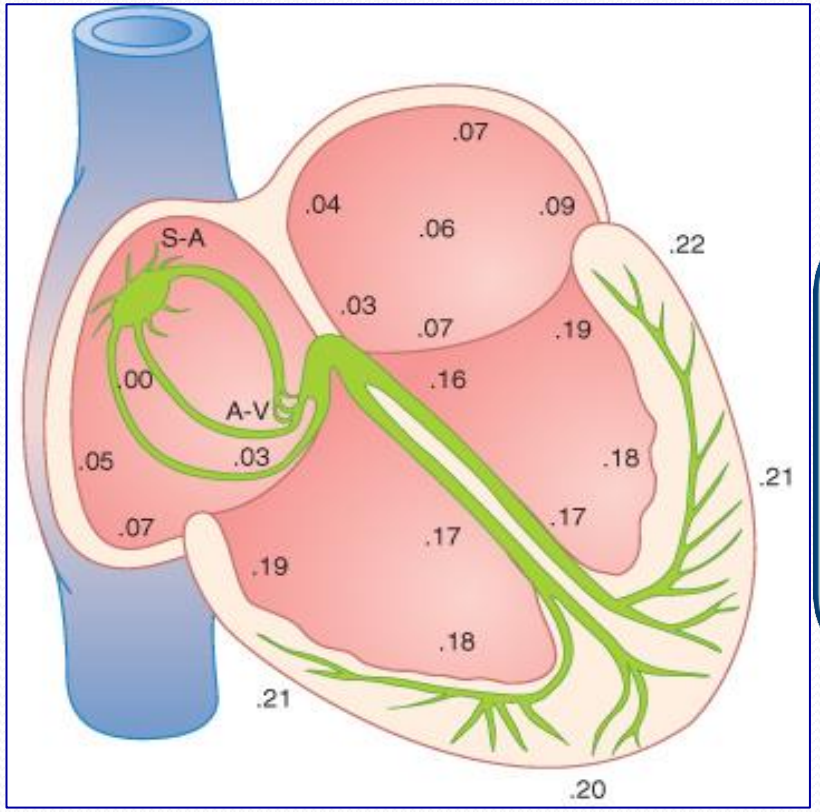
- Purkinje fibers are very large fibers
- Transmit action potentials at a very high velocity (0.1-4.0 m/sec)

Why?

  - very high permeability of gap junctions
  - → ions are transmitted easily from one cell to the next
  - → enhance the velocity of transmission
- Significance: allows ventricular muscle to contract at almost the same time for their effective pumping (synchronous contraction).

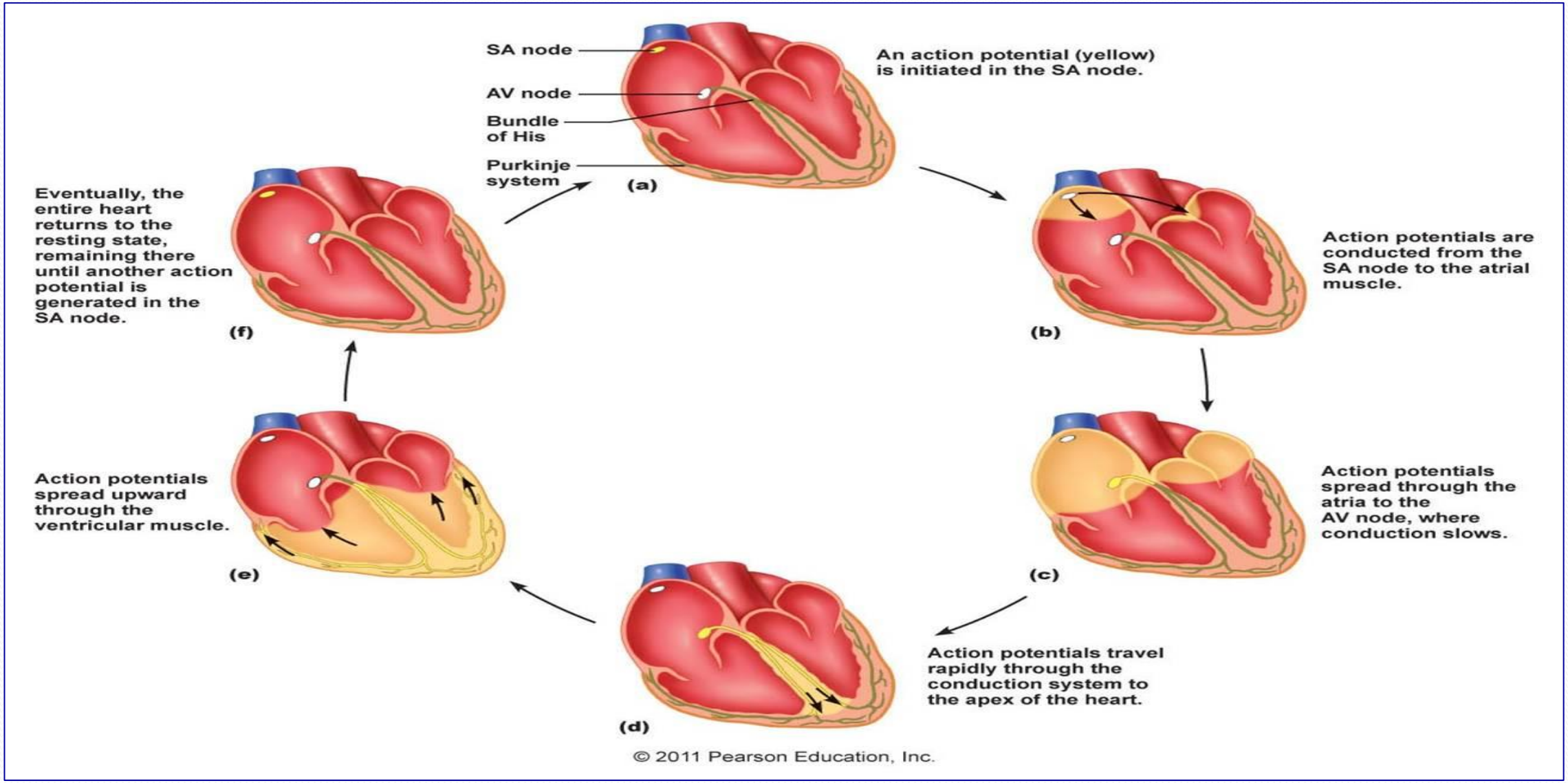


Conduction Velocities & Spread of the cardiac impulse through the heart



SA-node	0.05 m/sec.
AV-node	0.01 m/sec. …(slowest)
Bundle of His	1.00 m/sec.
Purkinje fibers	4.00 m/sec. …(Fastest)
Atrial & Ventricular muscles	0.3-0.4 m/sec.

Conduction System of the Heart



Control of Excitation and Conduction in the Heart

- The cardiac impulse normally arises in the sinus node
- The Sinus Node is the normal **Pacemaker** of the Heart.

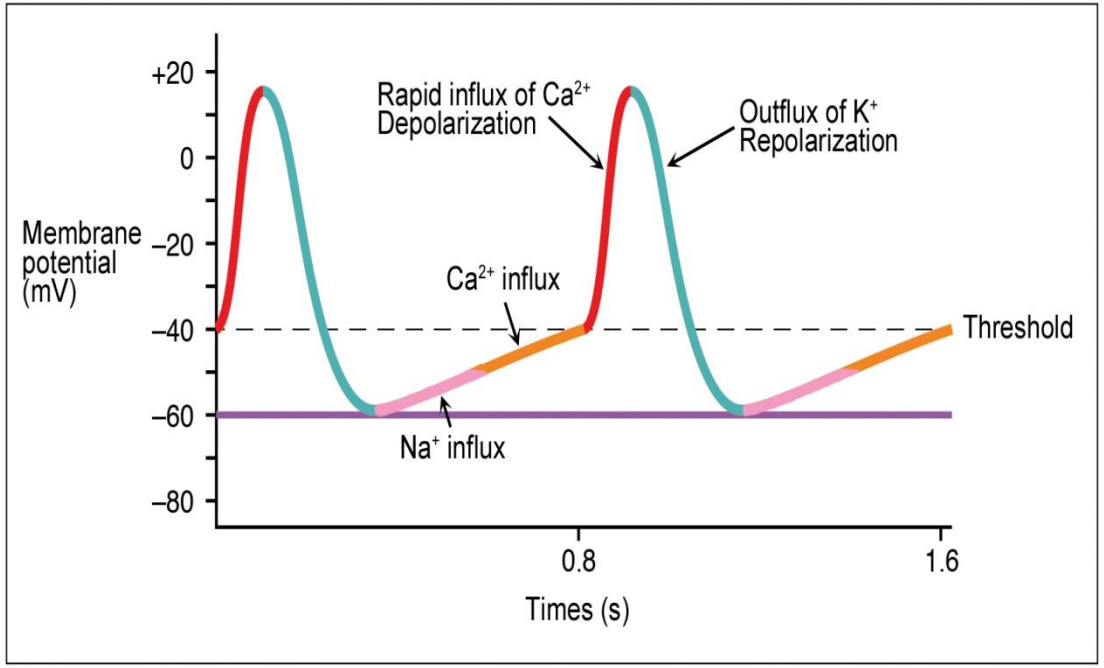
Why?

- It has pacemaker pre-potential (autorhythmic tissue).
- Its rate of rhythmical discharge is faster than that of any other part of the heart (70-80/min), so it derives rest of the heart.

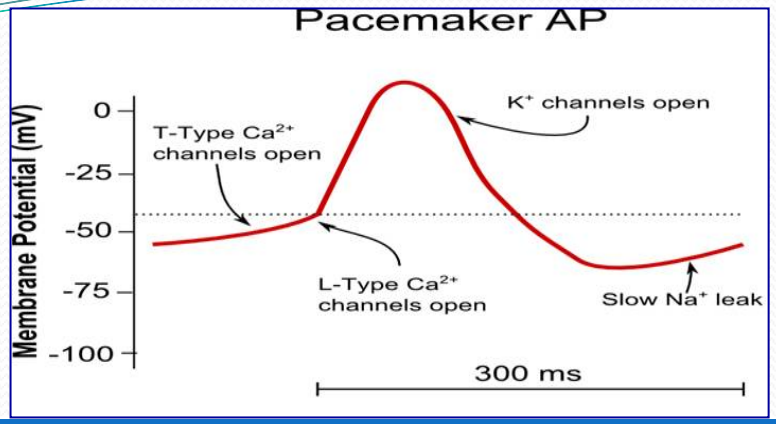
Normal pacemaker activity: Whole train will go **70 mph** (heart rate set by SA node, the fastest autorhythmic tissue)

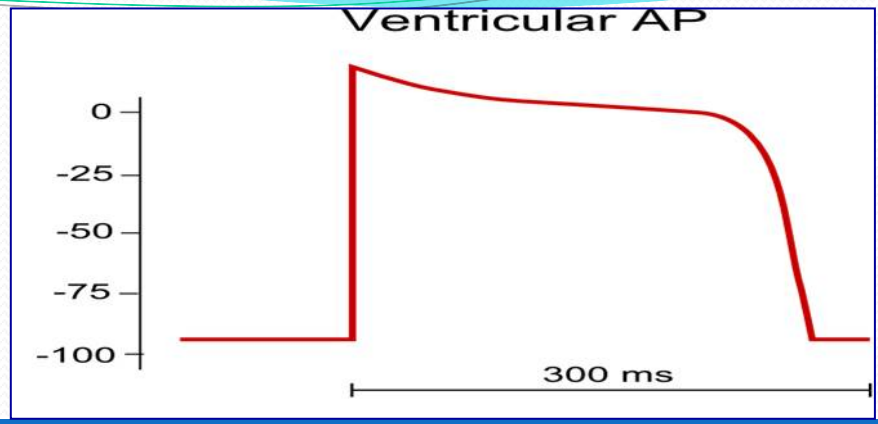
Action potential of the pace maker (pace maker potential)

- 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.



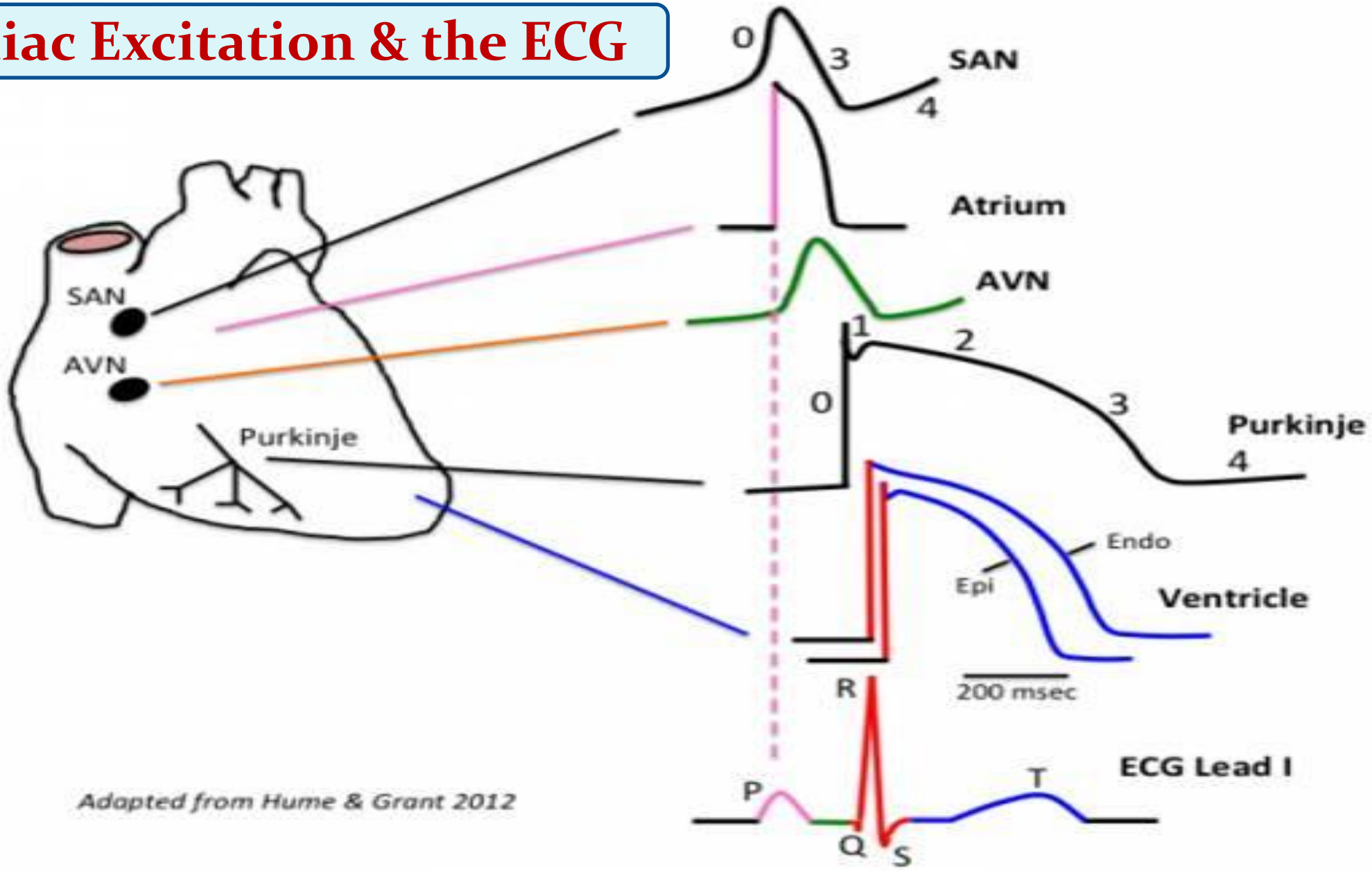
Differences between pace maker P & AP of myocardial cells





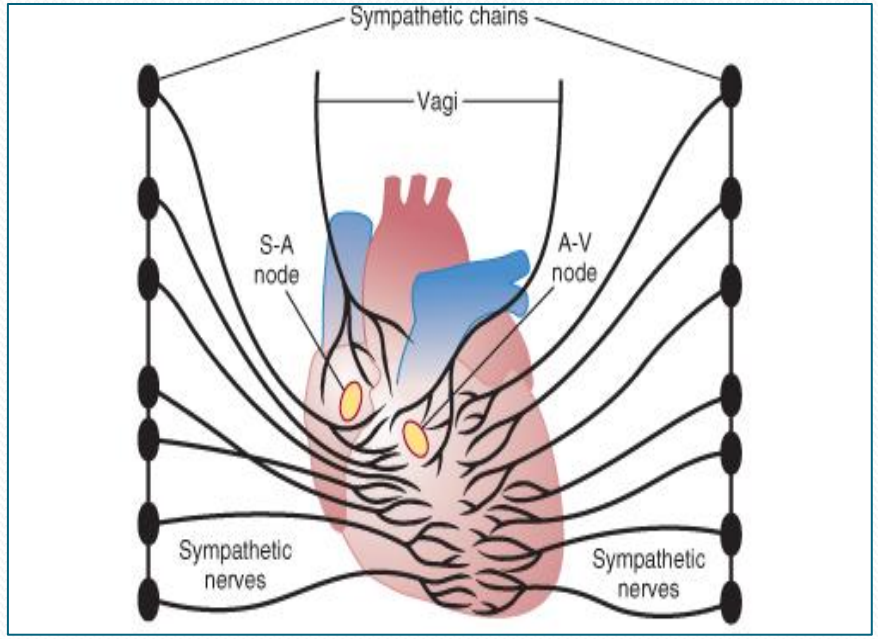
Pace Maker Action Potential	Ventricular Muscle Action Potential.
Does not need a stimulus	Needs a stimulus
RMP is -60 mv.	RMP is -90 mv.
Max. depolarization is +10 mv.	Max. depolarization is +20 mv
Is of smaller magnitude	Is of larger magnitude.
Has pre-potential stage	Has no pre-potential stage
Depolarization is gradual.	Depolarization is rapid.
Depolarization is due to Ca^{++}	Depolarization is due to Na^{+}.
It has spike, no plateau.	It has plateau, no spike

Cardiac Excitation & the ECG



Control of Heart Rhythmicity and Impulse Conduction by the Cardiac Nerves

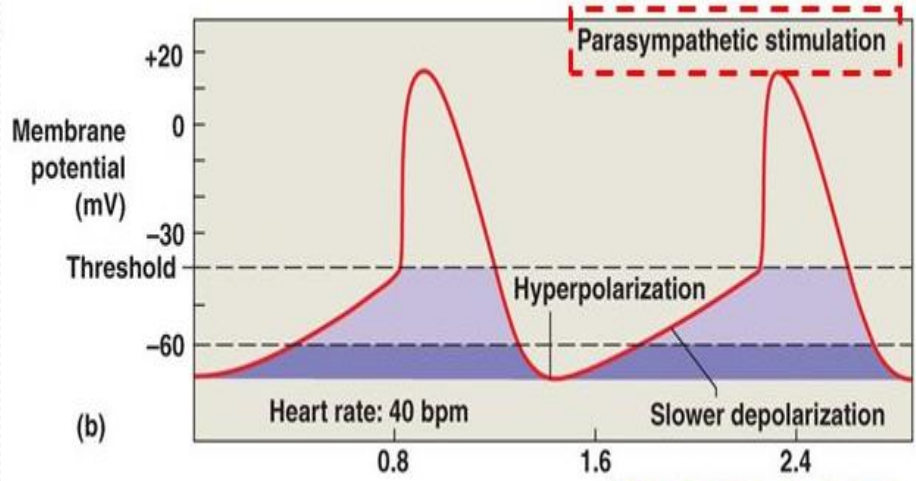
- The heart is supplied with both sympathetic and parasympathetic nerves
- **Parasympathetic nerves (vagi):** mainly to the S-A and A-V nodes
- **Sympathetic nerves**: all parts of the heart with strong supply to the ventricles



Parasympathetic stimulation of the heart

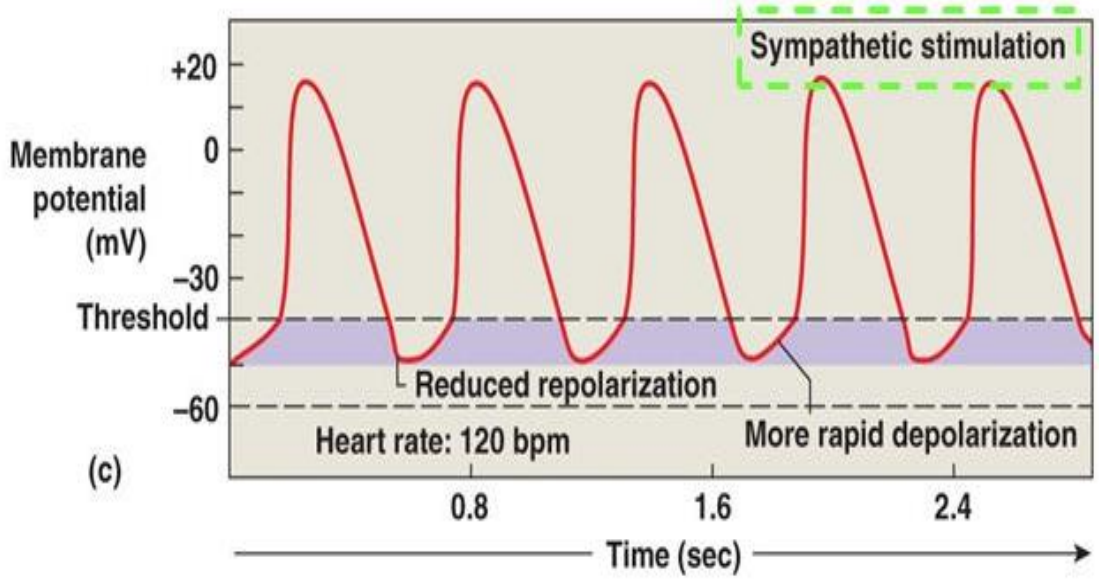
- ↓ the slope of pre-potential of S-A node due to increase the permeability to K^+ (i.e ↓ rhythm of the S-A node, so slow the heart rate).
- ↓ transmission of impulses to the A-V node
- Strong stimulation of the vagi:
  - Stop completely the rhythmical excitation by the S-A node
  - Block completely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

"Ventricular Escape"

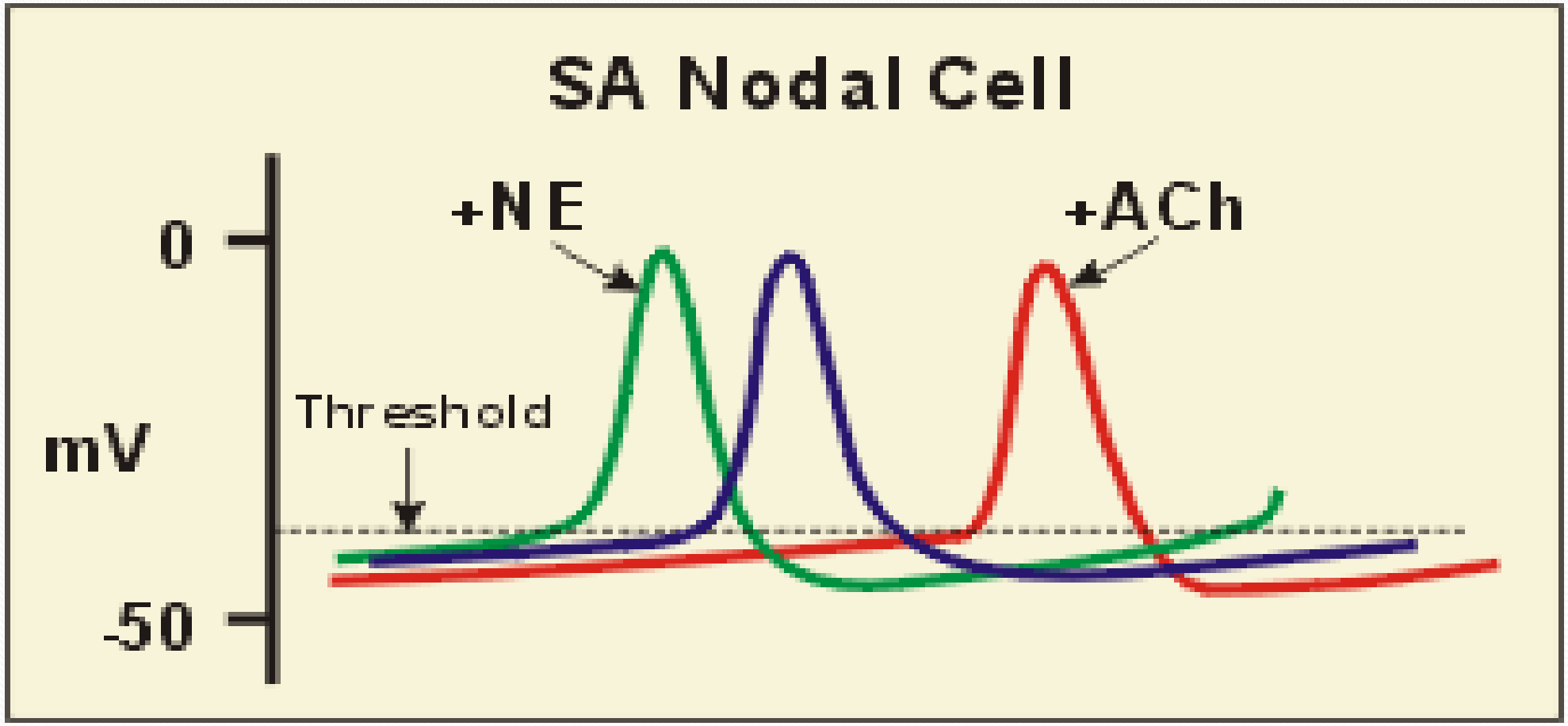


Sympathetic stimulation of the heart

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

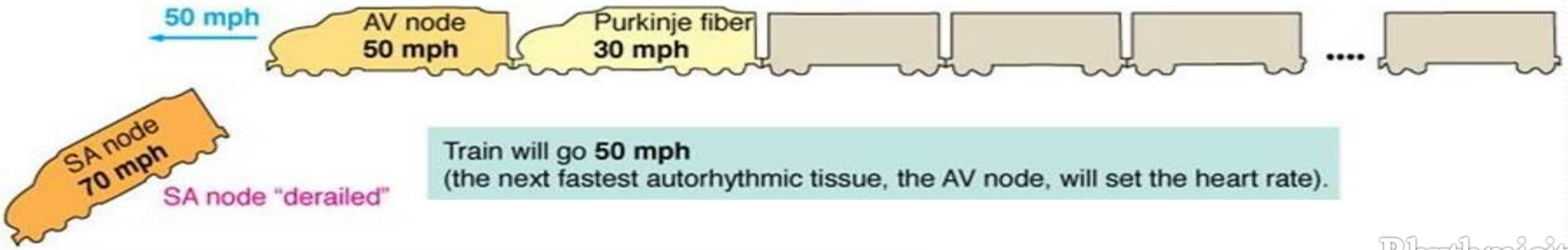


Sympathetic VS Parasympathetic stimulation of the heart



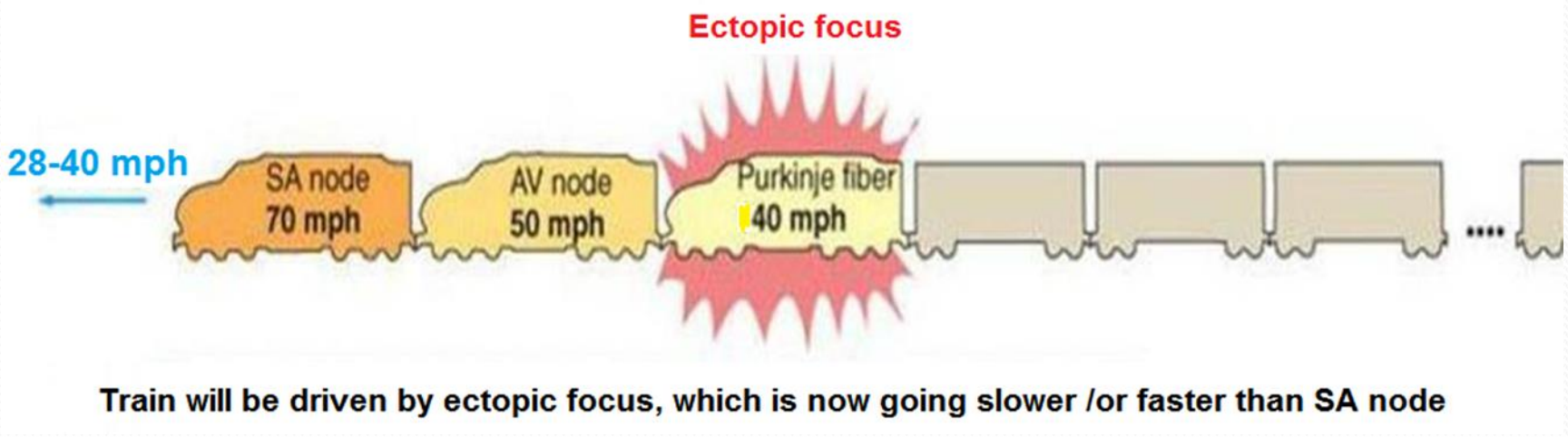
Latent Pacemakers

- S-A node is the normal pace maker of heart, i.e. 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).
- 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).

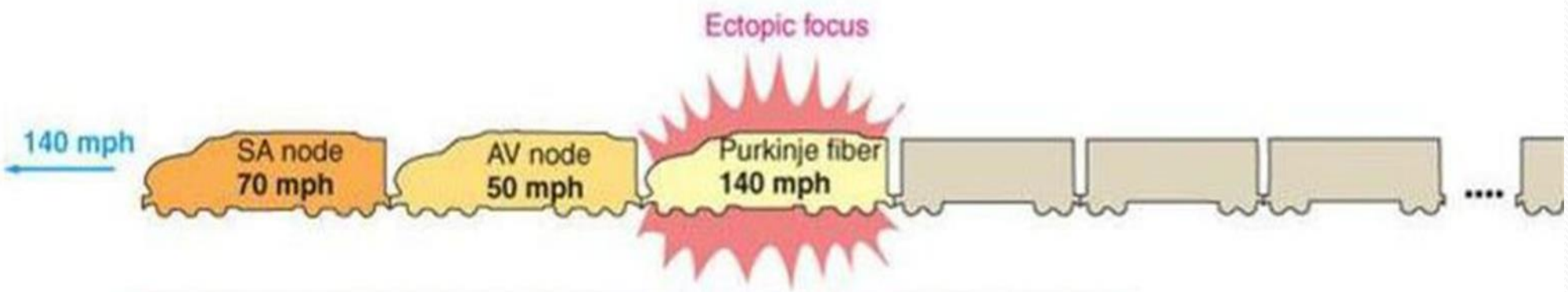


latent Pacemakers…..Cont.

- If S-N 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.



- In some cases, Purkinje fibers can become overexcited = ectopic focus and cause premature ventricular contraction.
- It can occurs 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).

Abnormal (Ectopic) Pacemakers

- ***Ectopic pacemaker***: a pacemaker elsewhere than the sinus node
- The causes:

1- Any other part of the heart develops a rhythmical discharge rate that is more rapid than that of the sinus node

2- Blockage of transmission of the cardiac impulse from the sinus 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

For further readings and diagrams:

Textbook of Medical Physiology by Guyton & Hall

Chapter 10 (Rhythmical Excitation of the Heart)