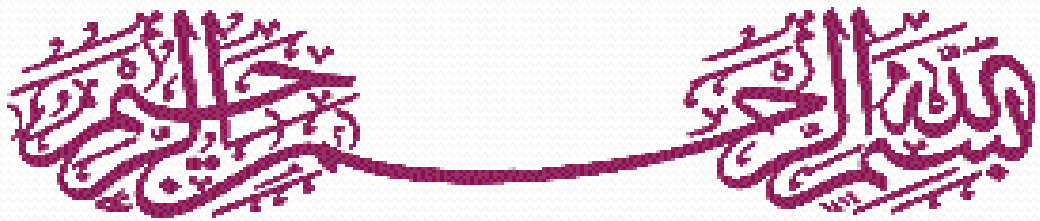

السلام عليكم ورحمة الله وبركاته

Cardiovascular System Block
Cardiac Electrical Activity
(Physiology)

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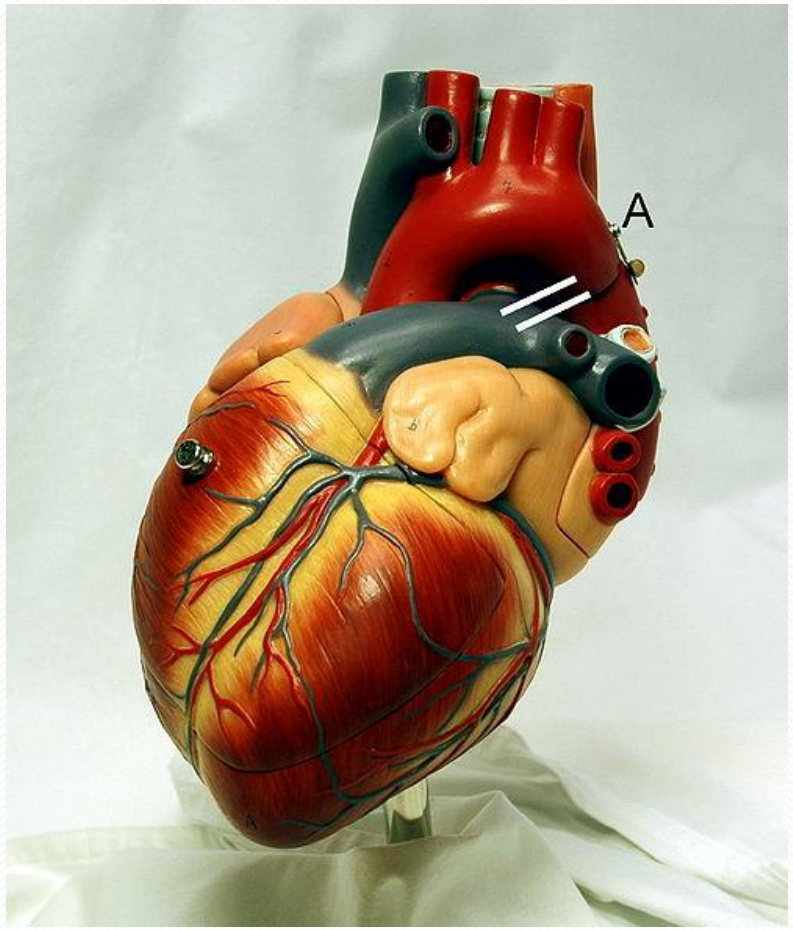


Learning Objectives

- Know the components of the conducting system of the heart
- Discuss 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
- Discuss the differences between pace maker potential & action potential of myocardial cells
- Describe the control of heart rhythmicity and impulse conduction by the cardiac nerves
- Discuss latent and abnormal pacemakers

Cardiac Electrical Activity

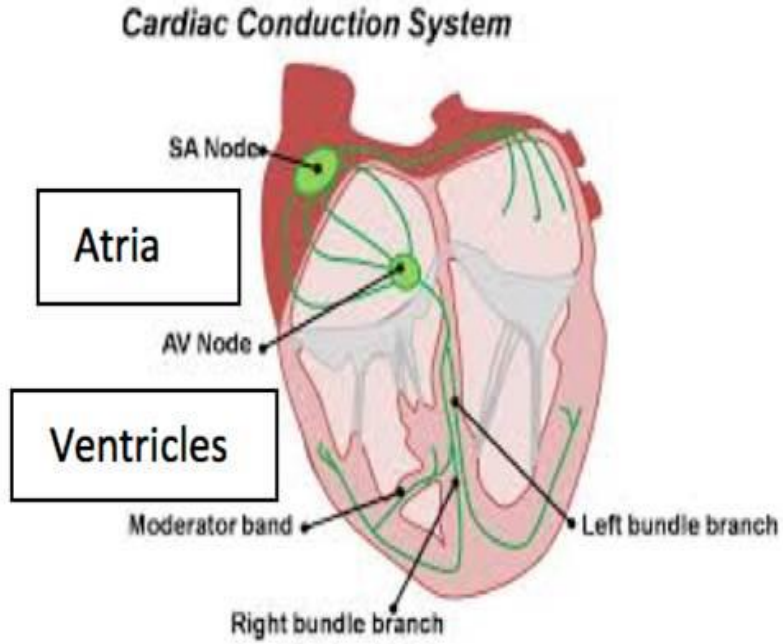
Automaticity of the heart: the heart is capable of:-

- **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

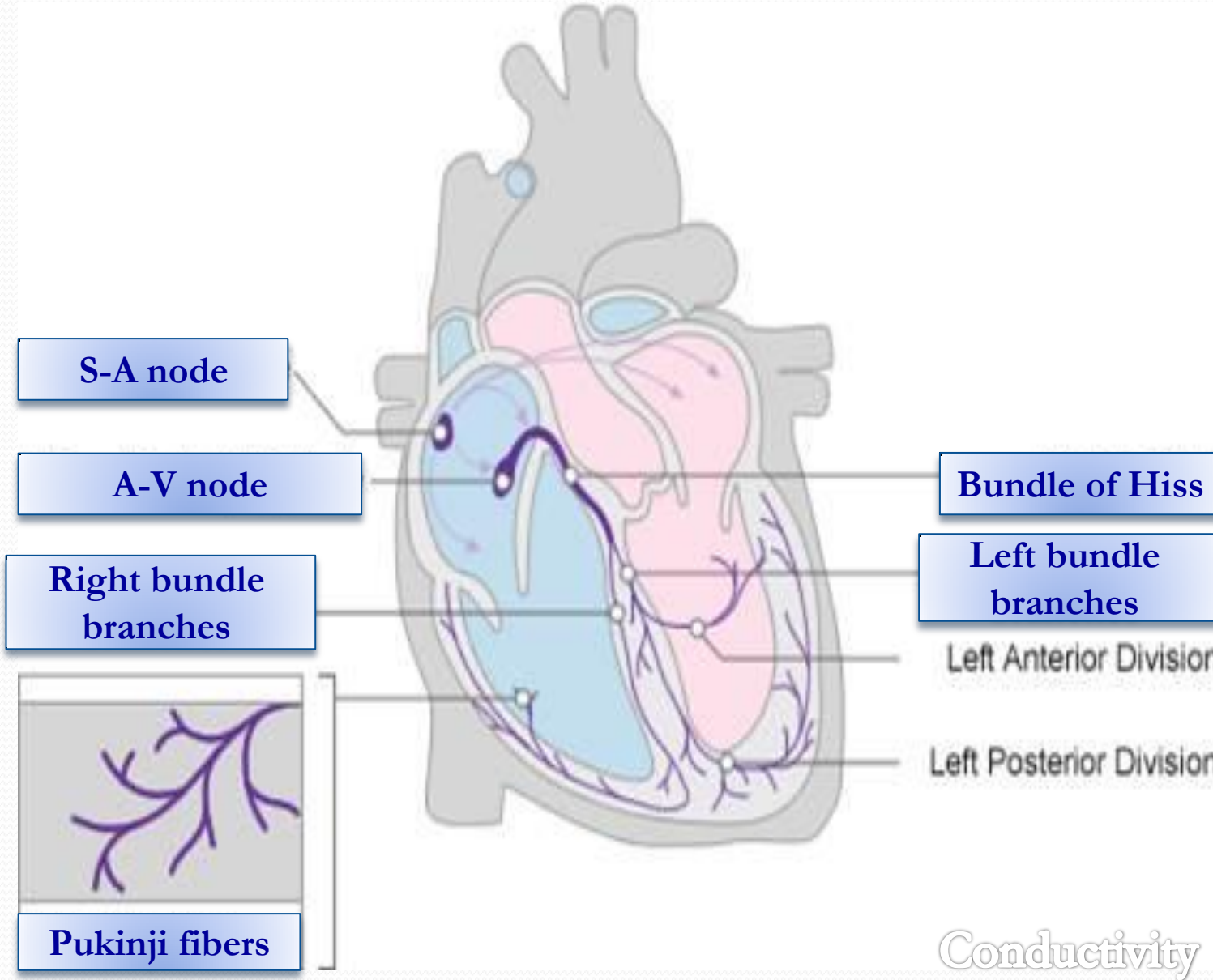
Why?

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



Components of the conducting system

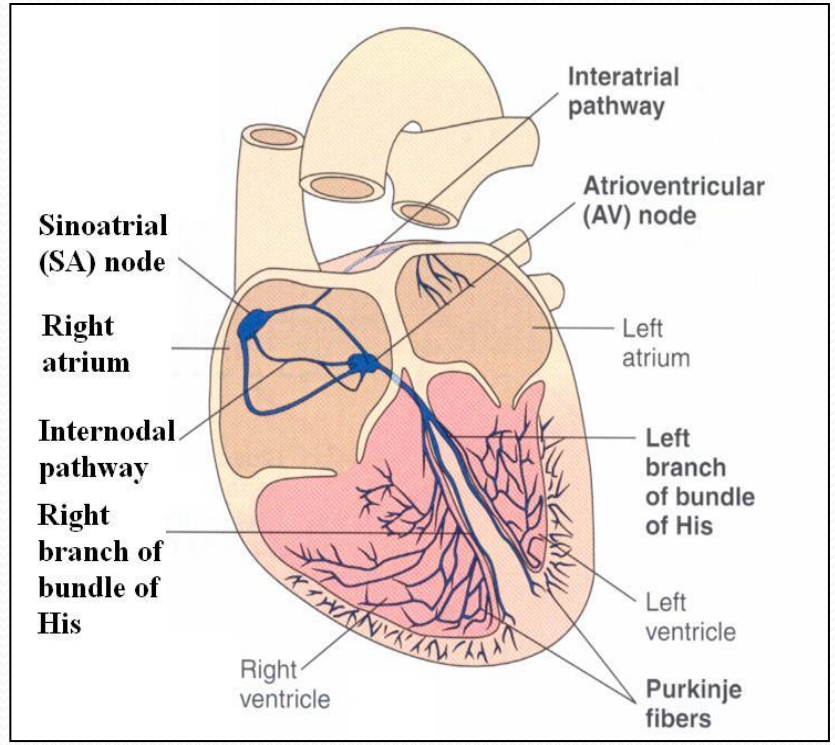
- S-A node.
- Internodal pathway.
- A-V node.
- A-V bundle (Bundle of Hiss).
- Left & right bundle branches.
- Pukinji fibers.



I- Sinoatrial node (S-A node)

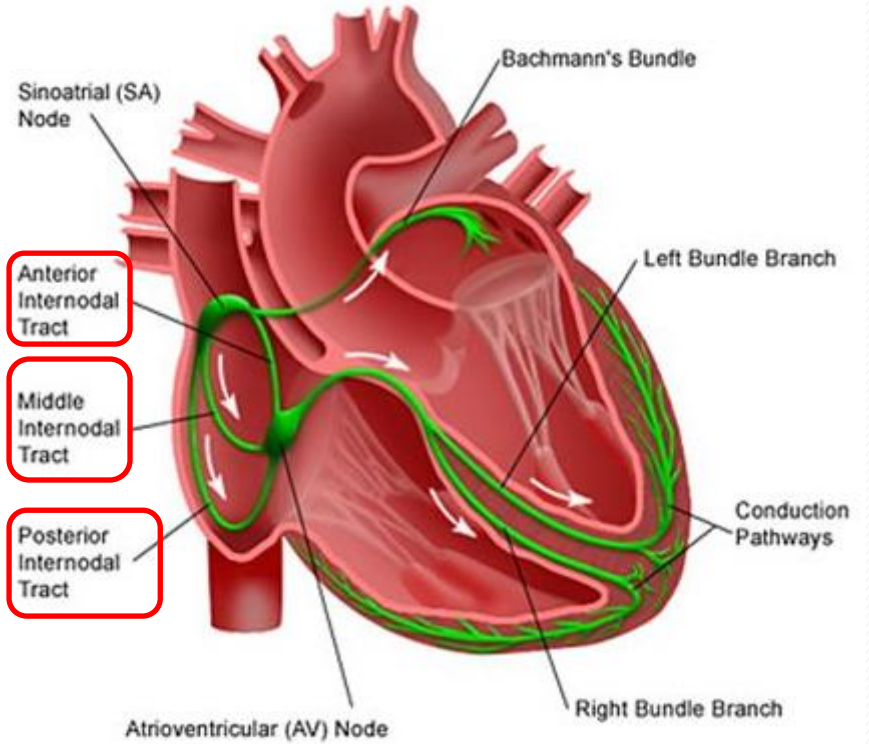
- Located in the superior lateral wall of the right atrium. Its fibers are continuous with atrial fibers.
- It is made of modified cardiac muscles.
- Velocity of conduction between its fibers is 0.05 m/s.
- Its membrane potential is unstable, so it is capable of ***originating*** action potentials

- ***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)



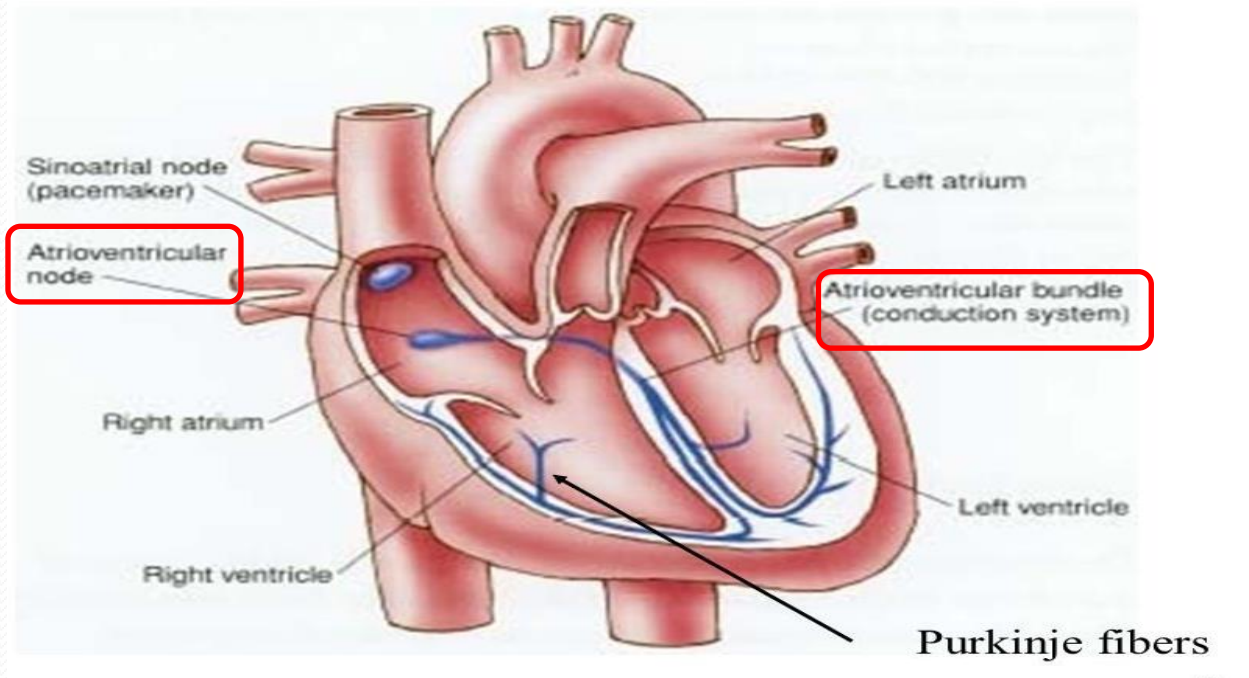
Why?

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

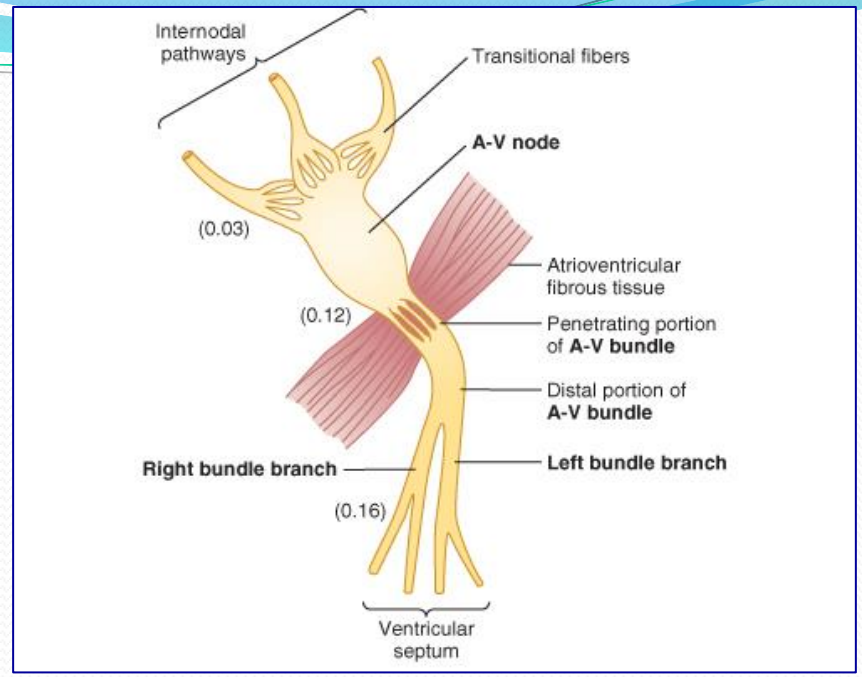
Fibers of A-V bundle penetrate atrioventricular fibrous tissue

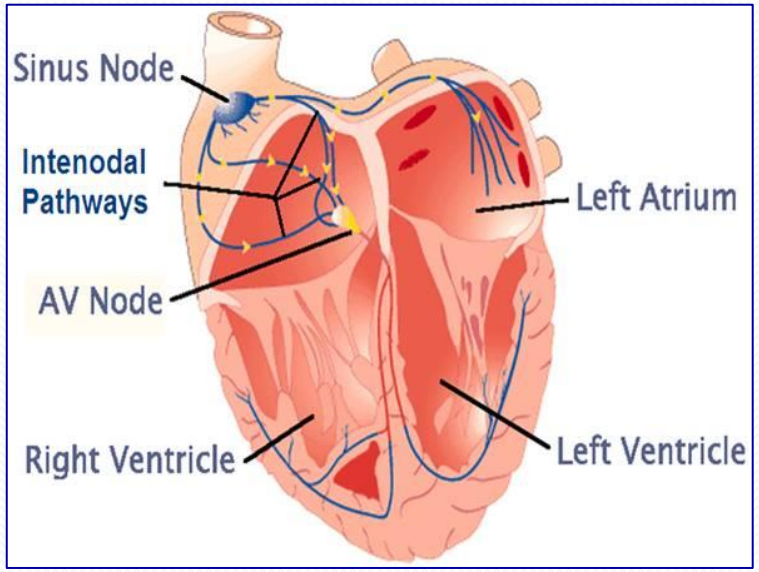
→ divides into right and left bundle branches

→ 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



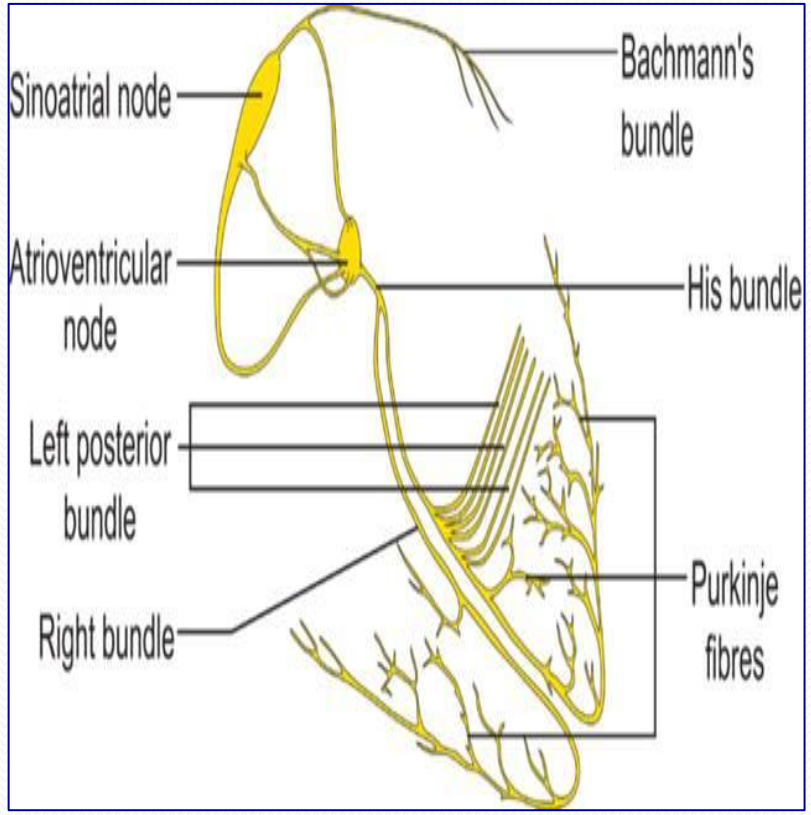


IV- The Purkinje System…..Cont.

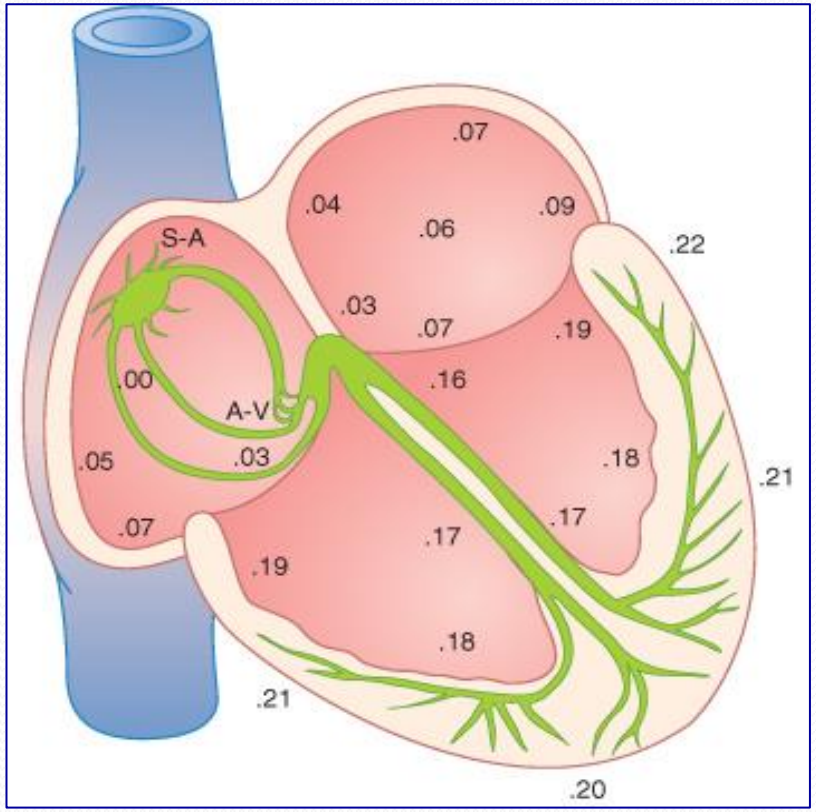
- Purkinje fibers are very large fibers
- Transmit action potentials at a very high velocity (0.1-4.0 m/sec)

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).

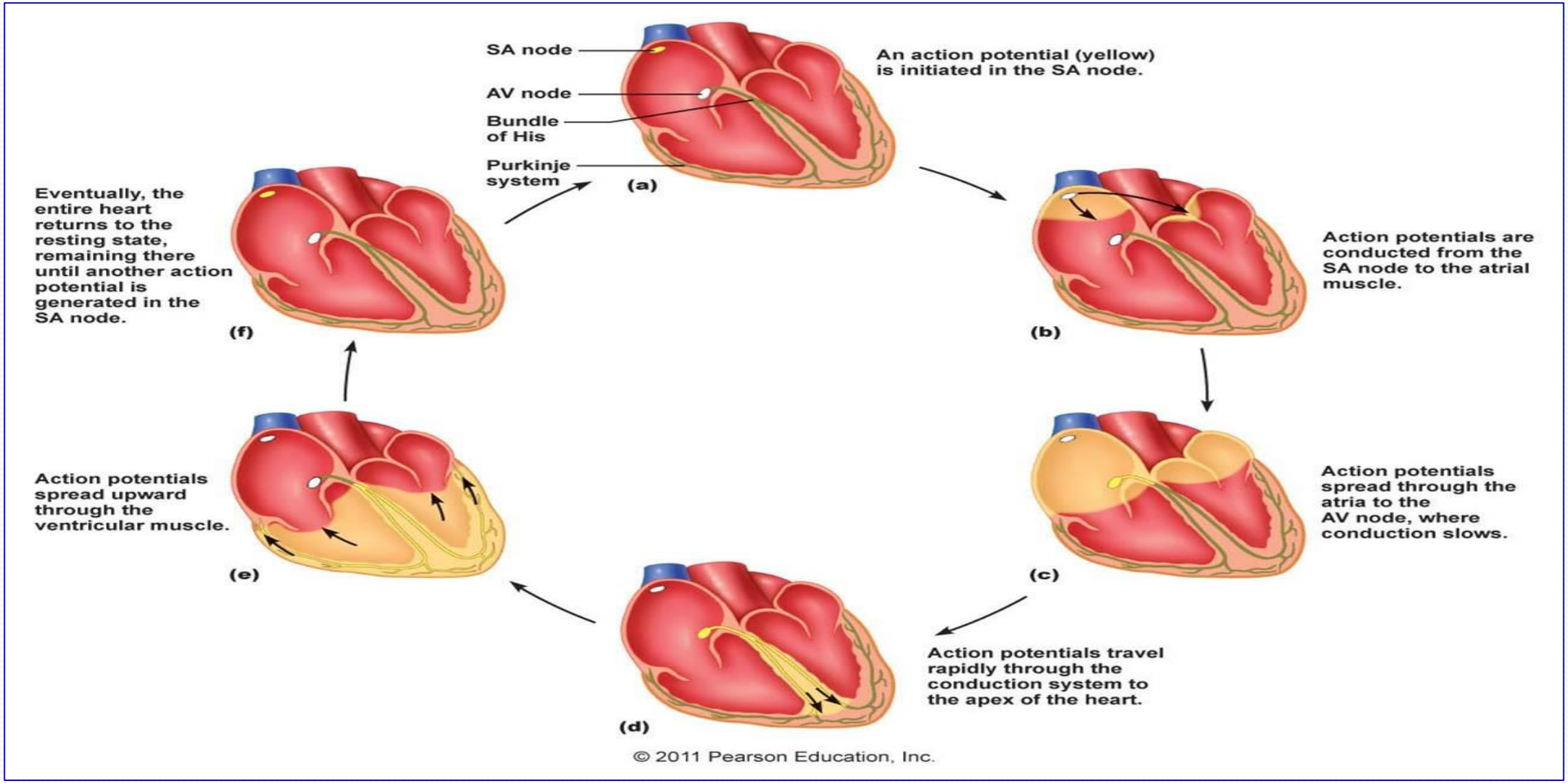


Conduction Velocities & Spread of the cardiac impulse through the heart



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 to 0.4 m/sec.

Conduction System of the Heart

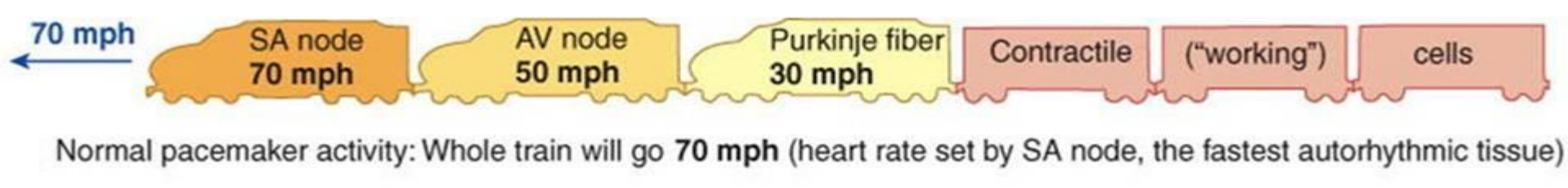


Control of Excitation and Conduction in the Heart

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

Why?

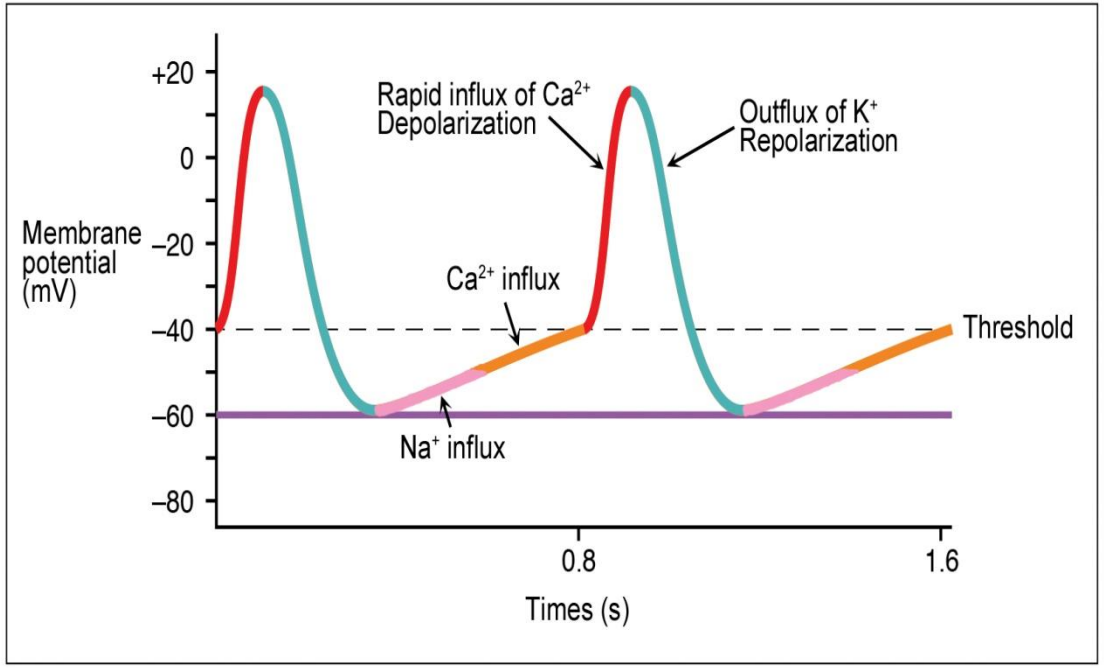
- It has pacemaker pre-potential (autorhythmic tissue).
- Its rate of rhythmical discharge is faster than that of any other part of the heart (70-80/min), so it derives rest of the heart.



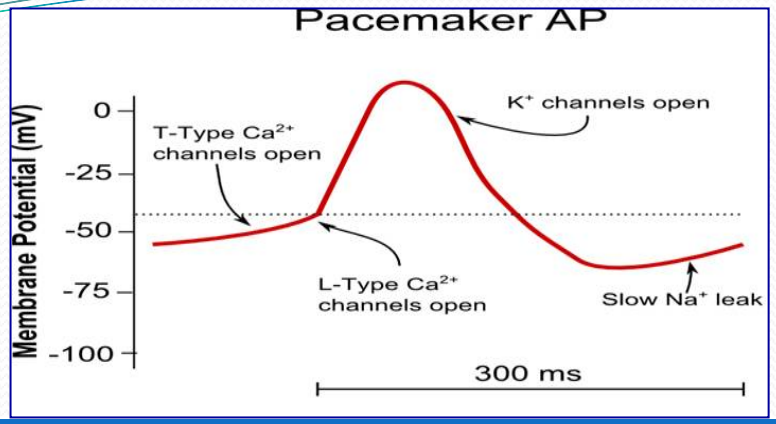
Normal pacemaker activity: Whole train will go **70 mph** (heart rate set by SA node, the fastest autorhythmic tissue)

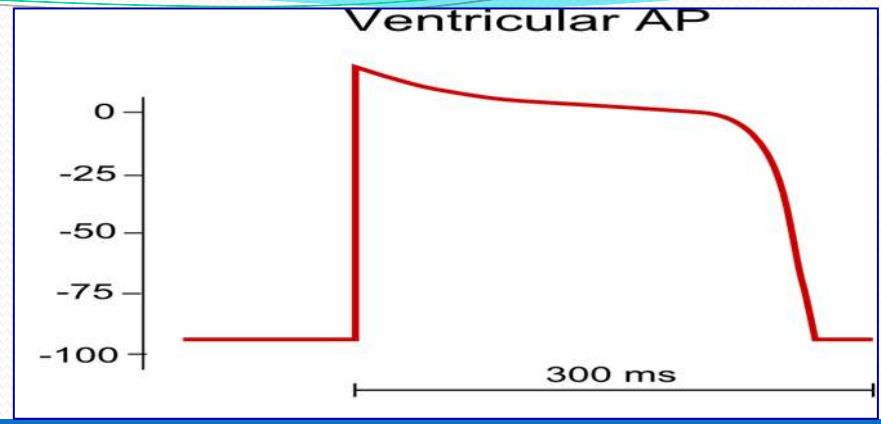
Action potential of the pace maker (pace maker potential)

- 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.



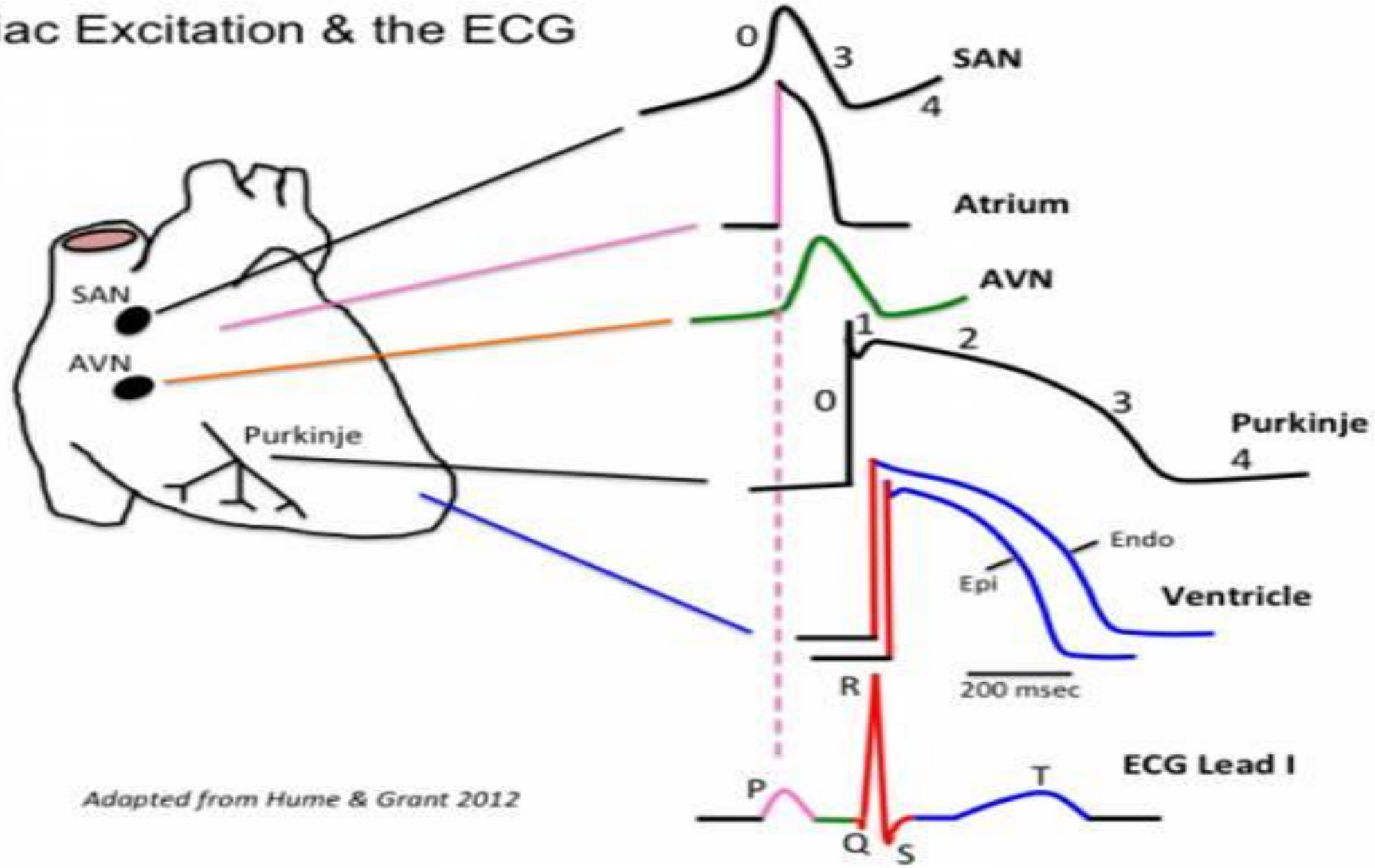
Differences between pace maker P & AP of myocardial cells





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

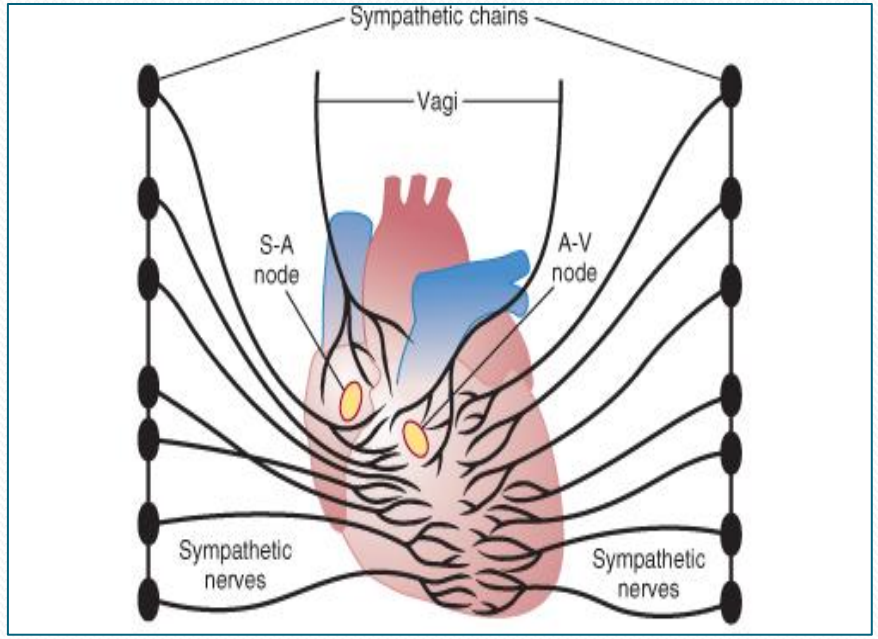
Cardiac Excitation & the ECG



Adapted from Hume & Grant 2012

Control of Heart Rhythmicity and Impulse Conduction by the Cardiac Nerves

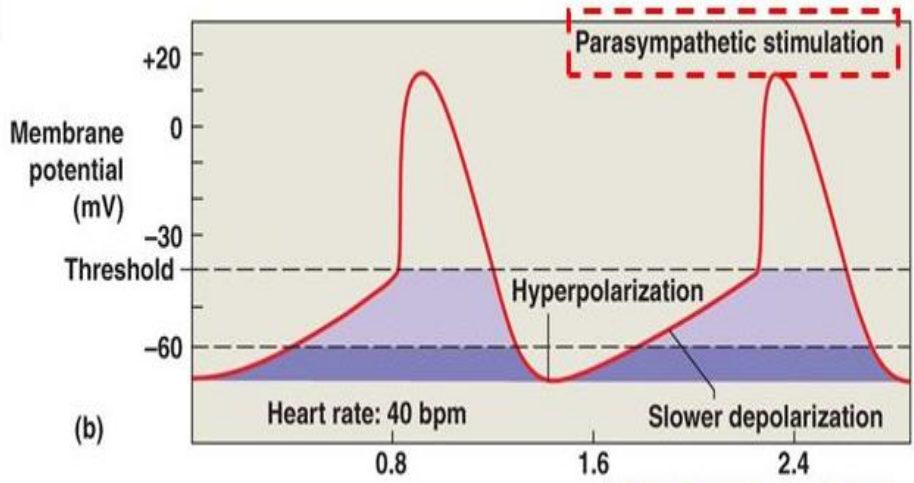
- The heart is supplied with both sympathetic and parasympathetic nerves
- **Parasympathetic nerves (vagi):** mainly to the S-A and A-V nodes
- **Sympathetic nerves**: all parts of the heart with strong supply to the ventricles



Parasympathetic stimulation of the heart

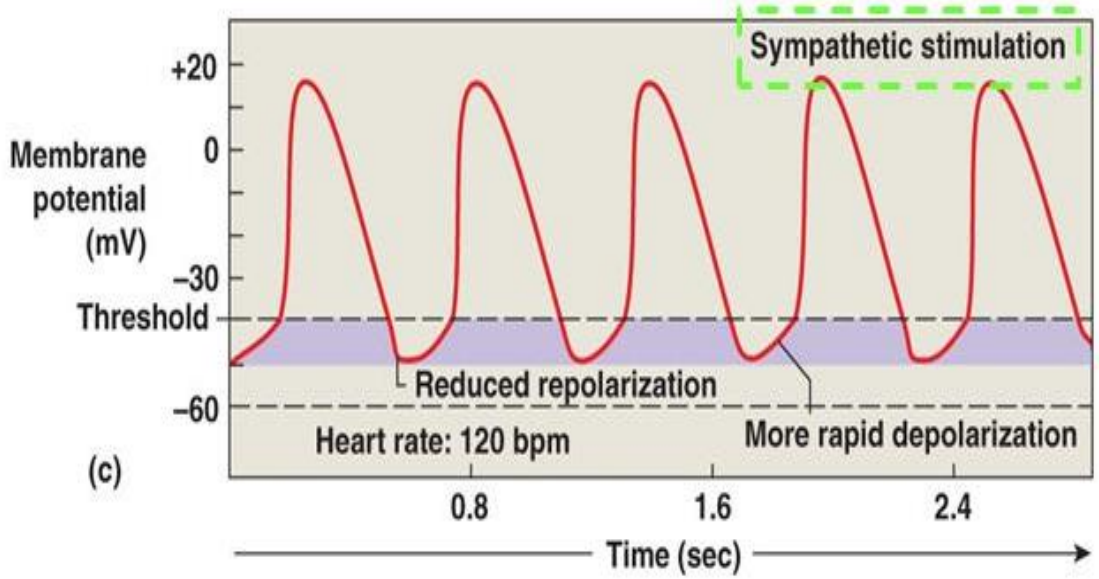
- ↓ the slope of pre-potential of S-A node due to increase the permeability to K^+ (i.e ↓ rhythm of the S-A node, so slow the heart rate).
- ↓ transmission of impulses to the A-V node
- Strong stimulation of the vagi:
  - Stop completely the rhythmical excitation by the S-A node
  - Block completely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

"Ventricular Escape"



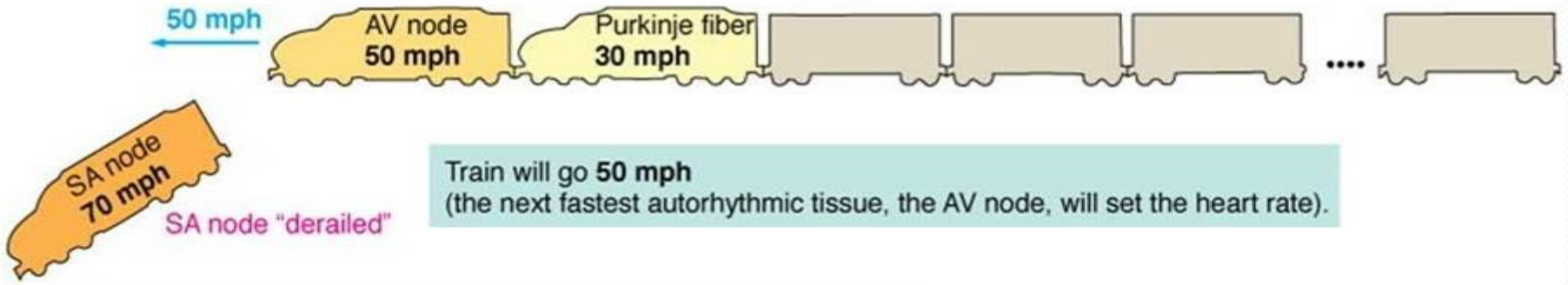
Sympathetic stimulation of the heart

- ↑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



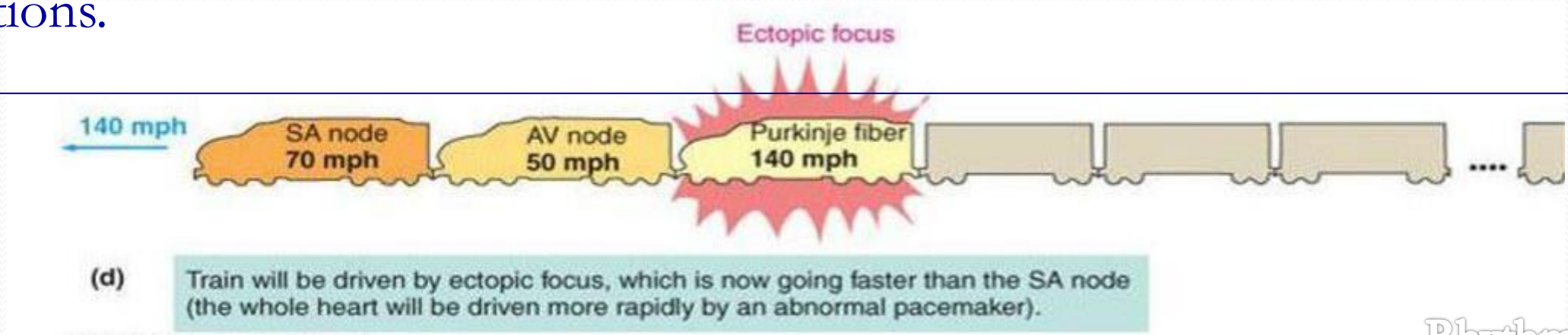
Latent Pacemakers

- 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 20-40 impulse/min (idioventricular rhythm).
- Rhythmicity is high in S-A node > A-V node > His bundle & Purkinje fibers.
- In some cases, the normally slowest 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.



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 rate of rhythm 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)

Thank You