

# Conduction System of the Heart 4

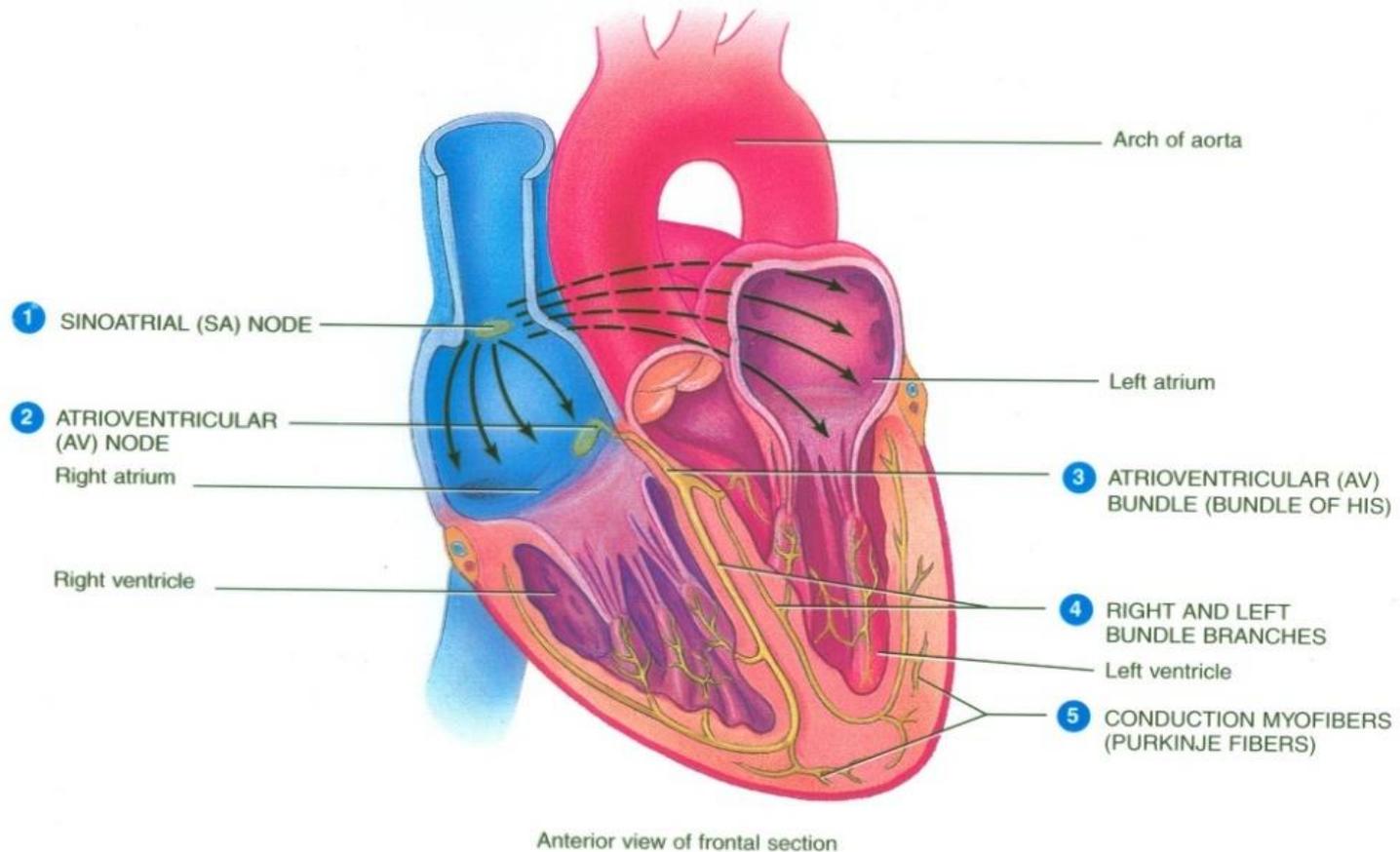
Faisal I. Mohammed, MD, PhD



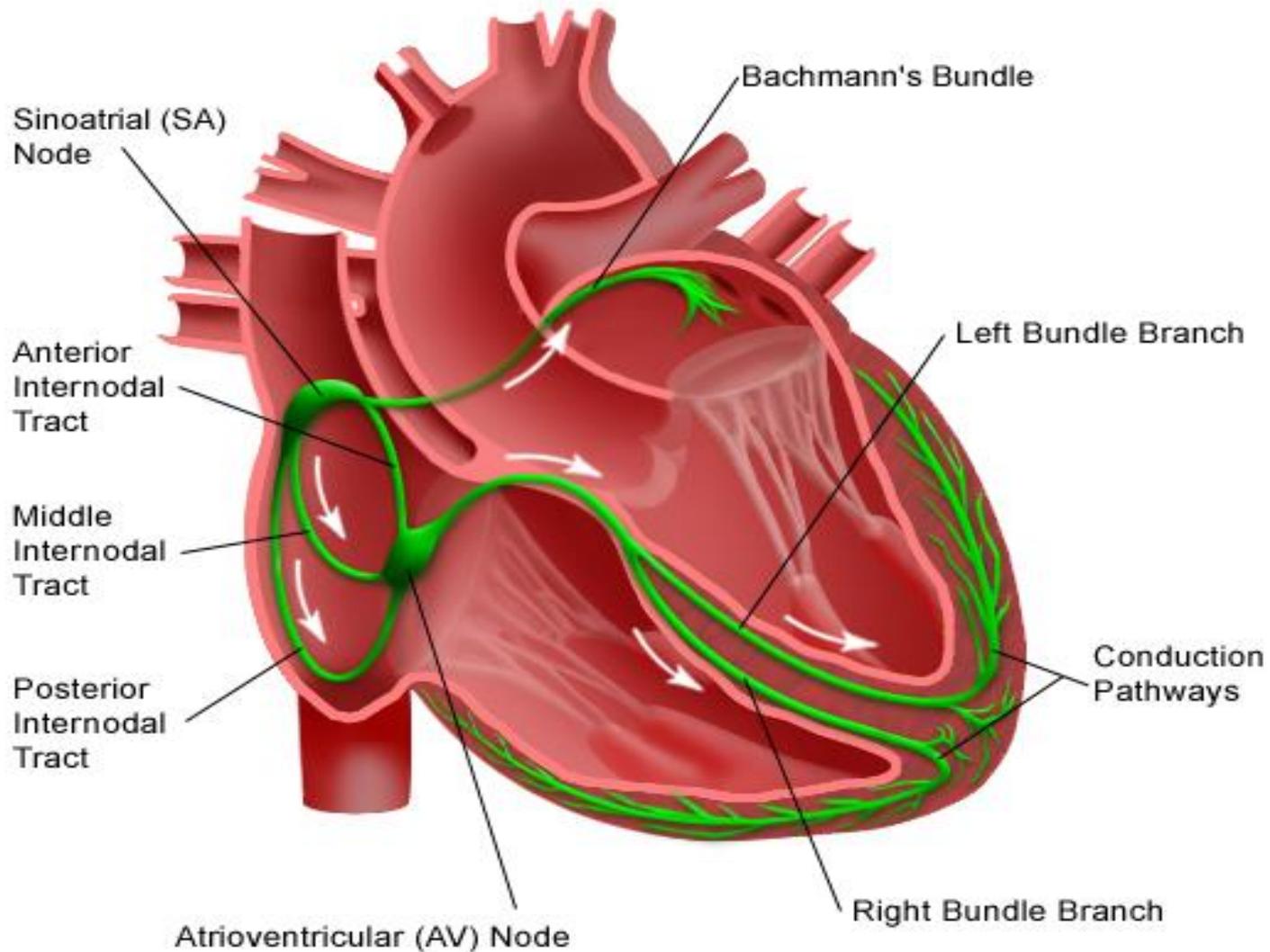
# Objectives

- List the parts that comprise the conduction system
- Explain the mechanism of slow response action potential (pacemaker potential)
- Point out the regulation of the conduction system potential by Autonomic Nerves
- Resource: **Guyton's Textbook of Medical Physiology last edition.**

# Structures of the conduction system

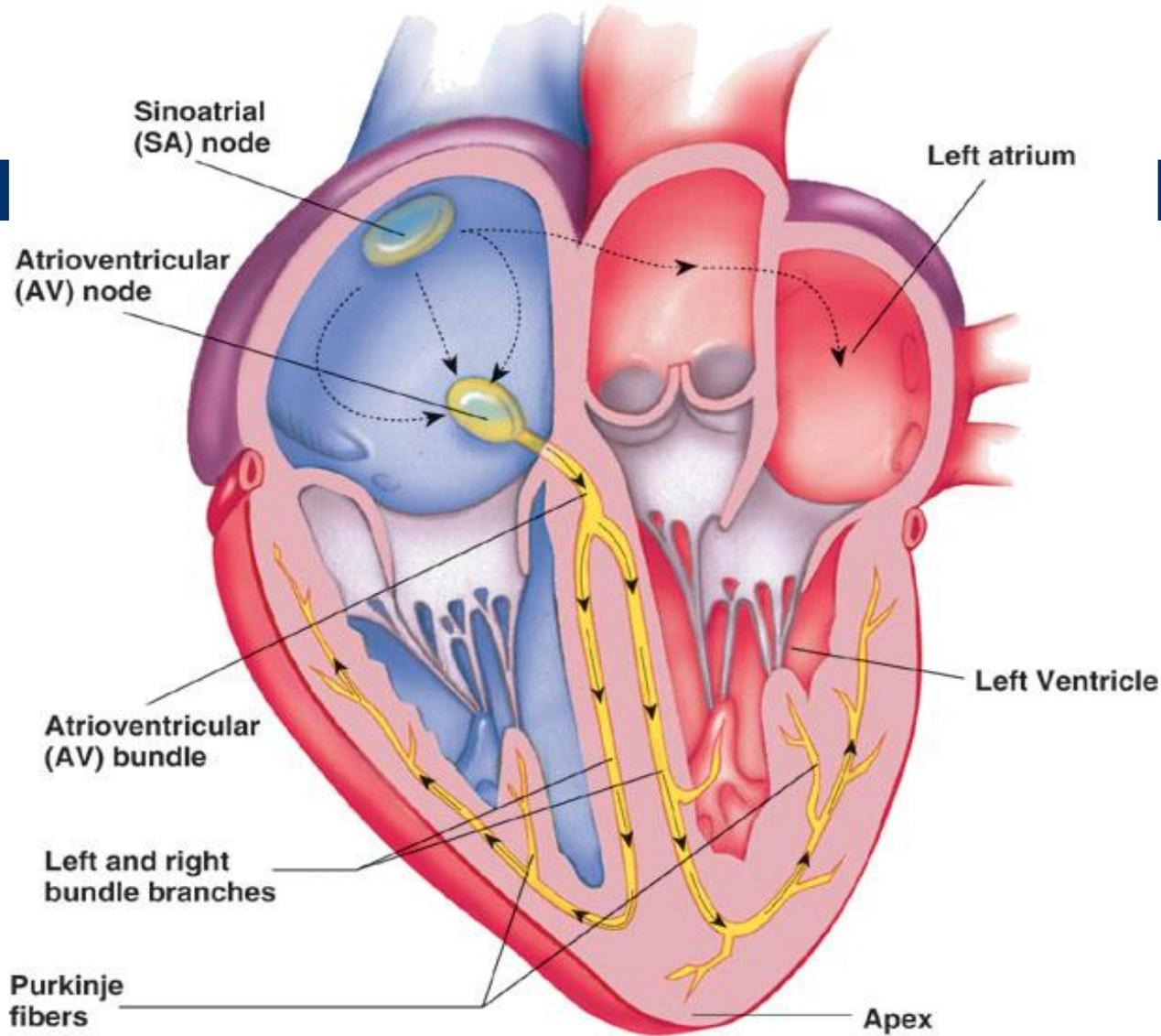


## Electrical System of the Heart

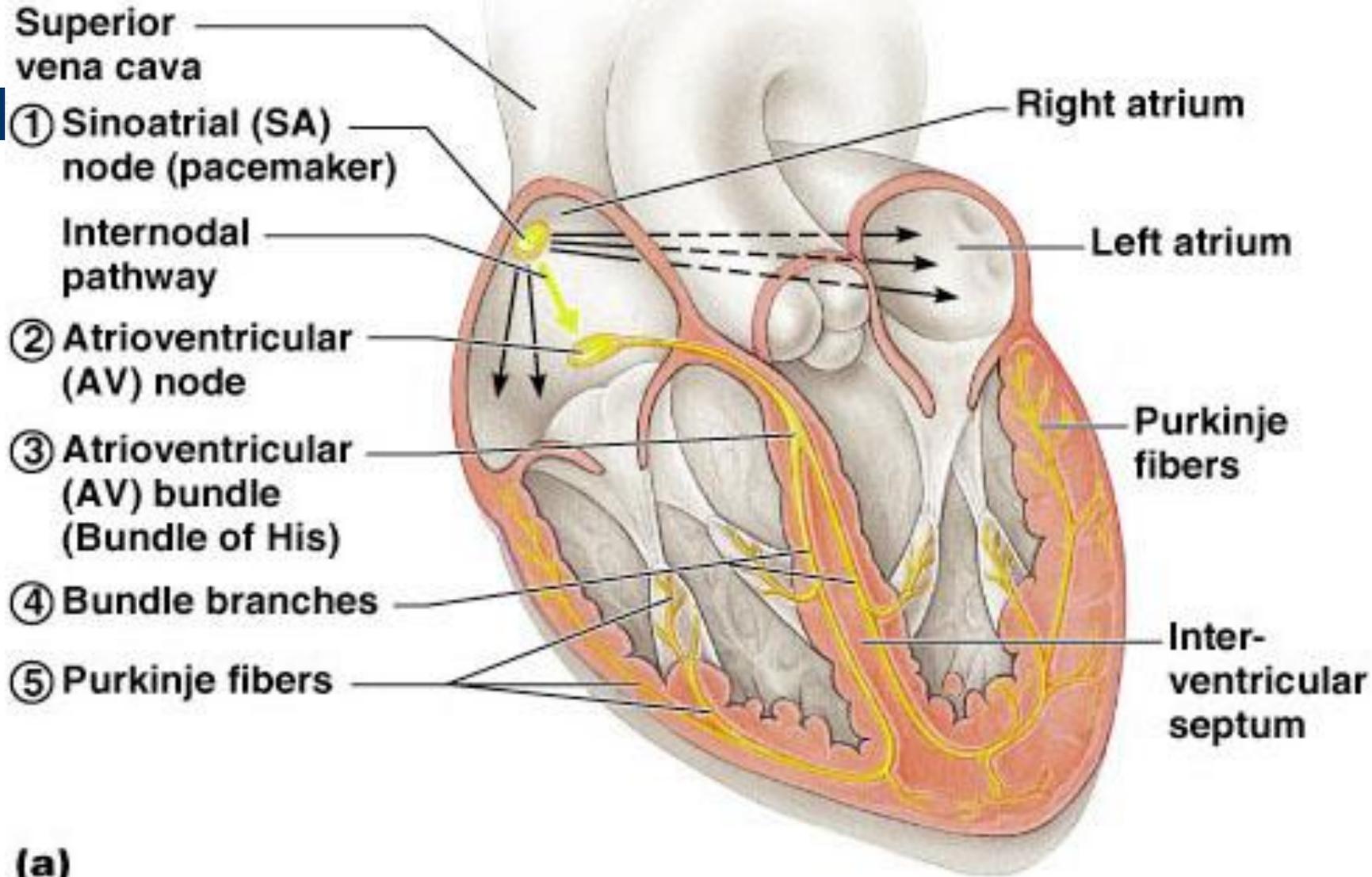


# Conducting System of Heart

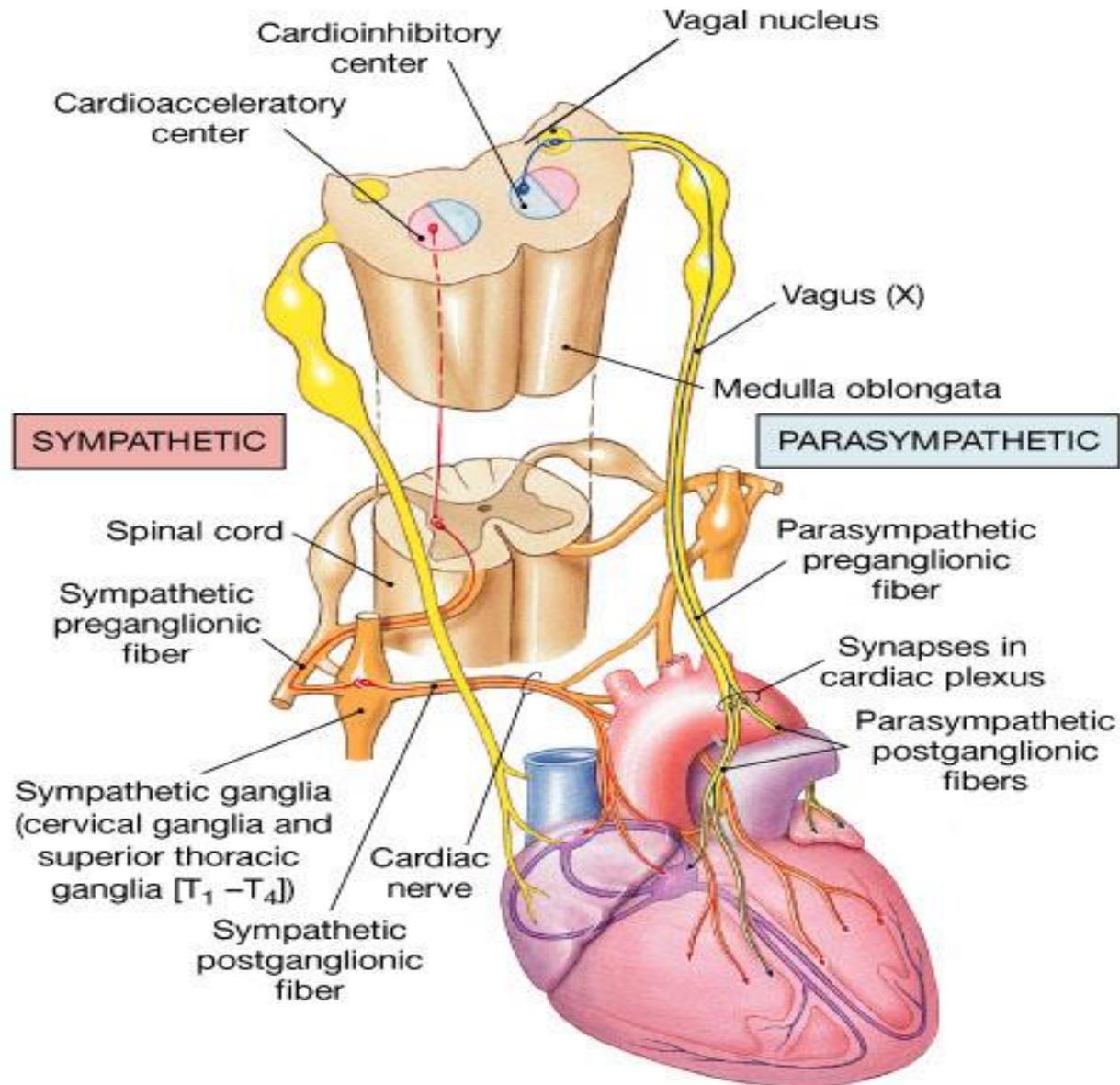
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# Heart Physiology: Sequence of Excitation



# Autonomic Innervation of the Heart



# Intrinsic Cardiac Conduction System

Approximately 1% of cardiac muscle cells are autorhythmic rather than contractile

70-80/min

① Sinoatrial node (pacemaker)

40-60/min

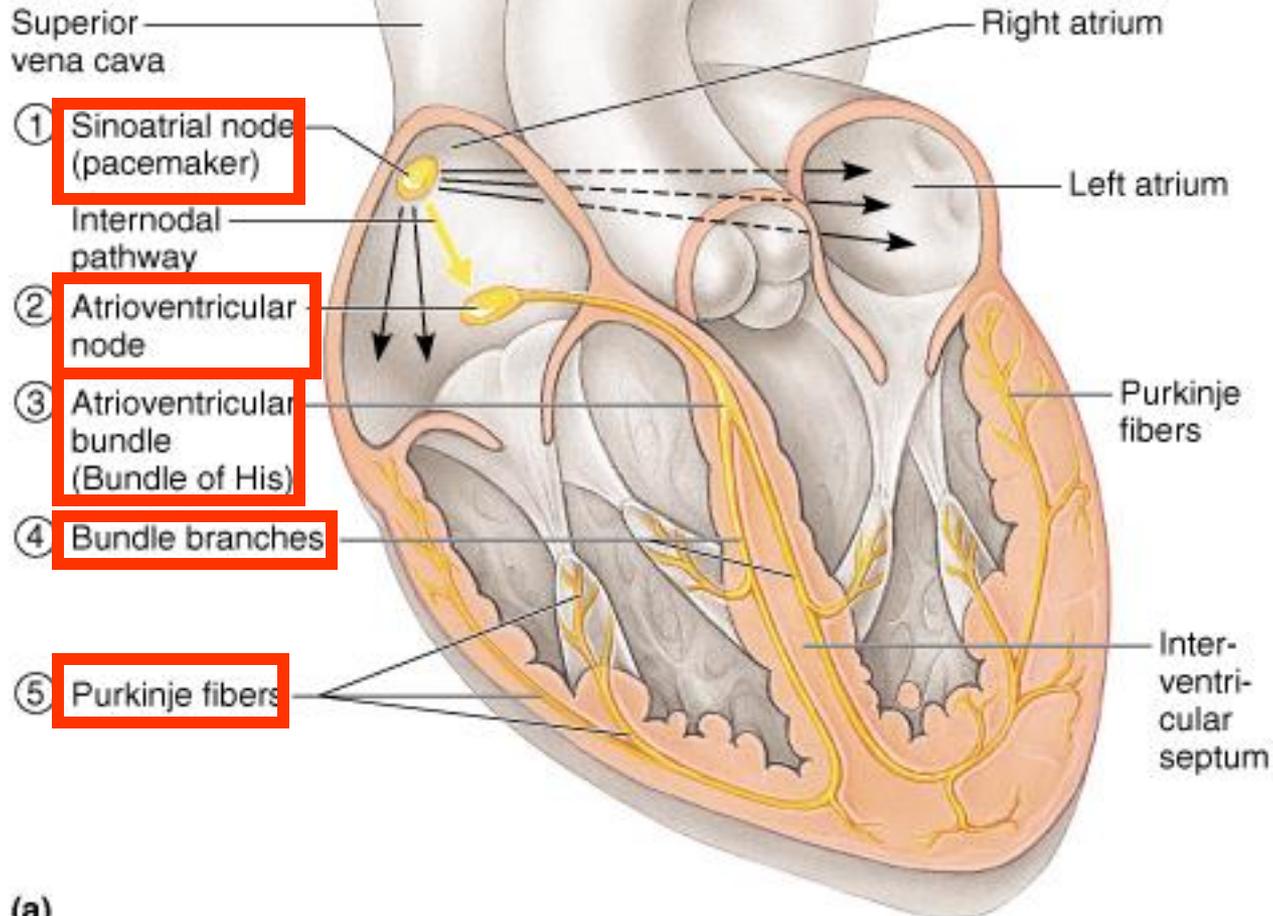
② Atrioventricular node

③ Atrioventricular bundle (Bundle of His)

④ Bundle branches

15-40/min

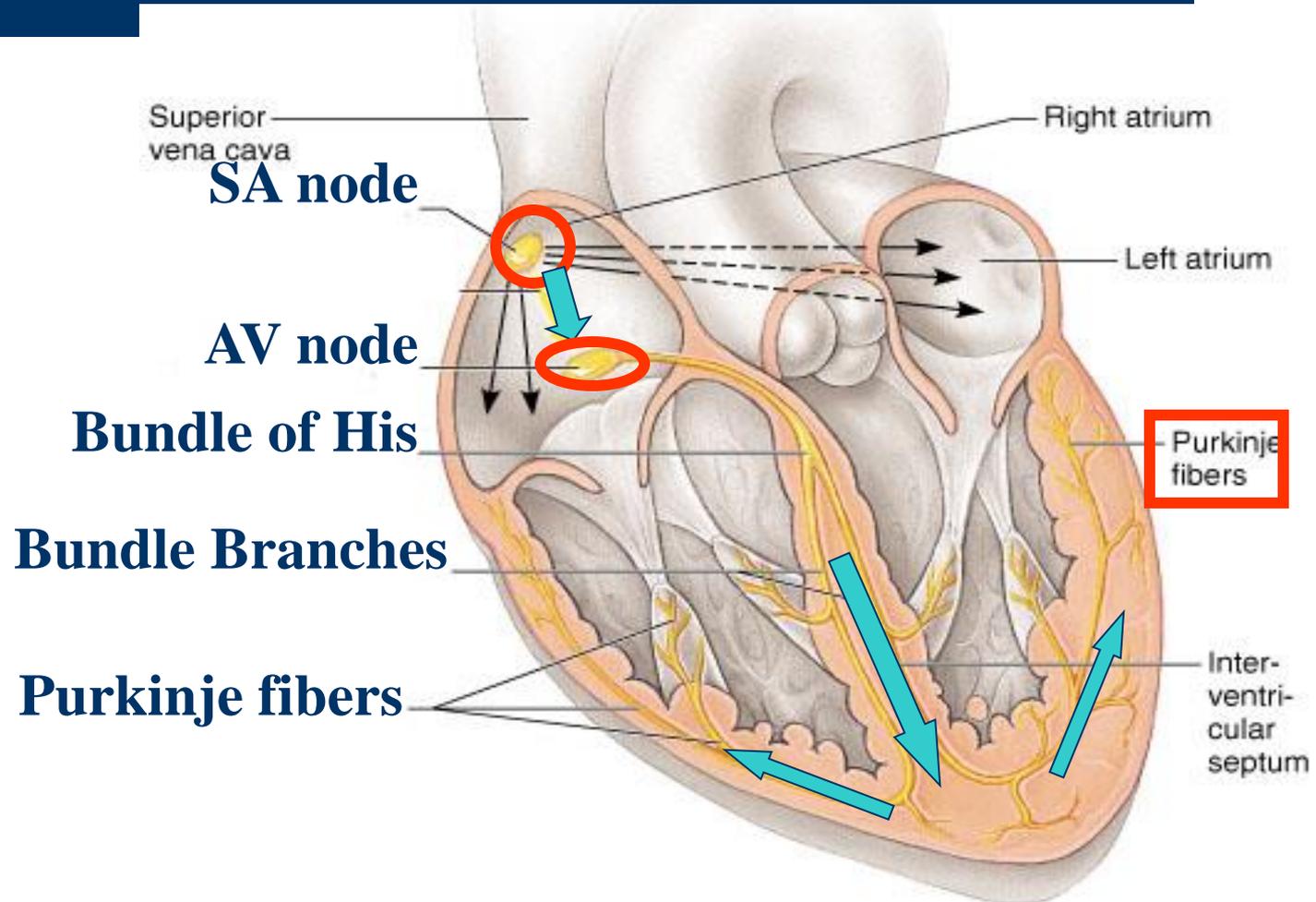
⑤ Purkinje fibers



(a)

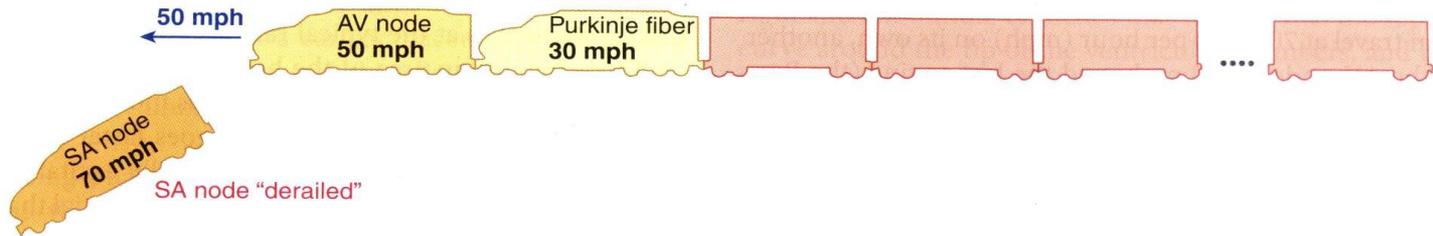
# Intrinsic Conduction System

Function: initiate & distribute impulses so heart depolarizes & contracts in orderly manner from atria to ventricles.

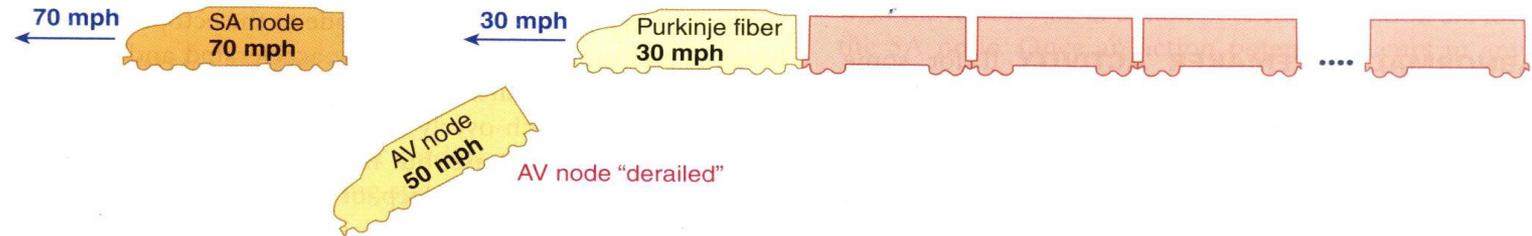




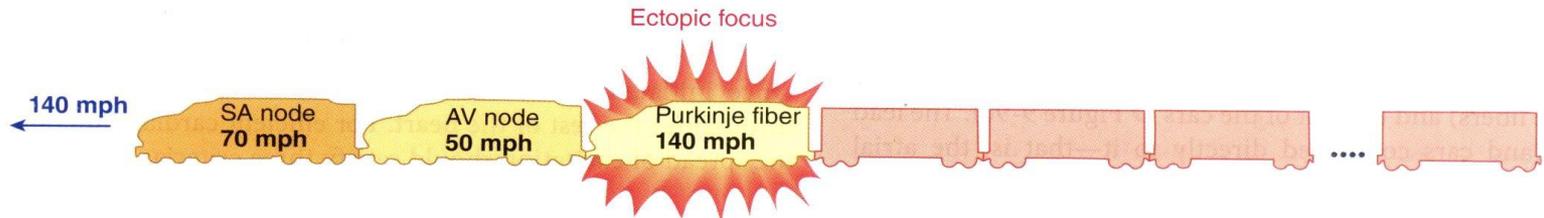
(a) Normal pacemaker activity: Whole train will go **70 mph** (heart rate set by SA node, the fastest autorhythmic tissue).



(b) Takeover of pacemaker activity by AV node when the SA node is nonfunctional: Train will go **50 mph** (the next fastest autorhythmic tissue, the AV node, will set the heart rate).



(c) Takeover of ventricular rate by the slower ventricular autorhythmic tissue in complete heart block: First part of train will go **70 mph**; last part will go **30 mph** (atria will be driven by SA node; ventricles will assume own, much slower rhythm).



(d) Takeover of pacemaker activity by an ectopic focus: 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).

# Components of the Conduction System of the Heart

- Conduction system parts are modified cardiac muscle cells consist of:
  - ❖ SA (sinoatrial) node (*Pacemaker*)
  - ❖ AV (atrioventricular) node
  - ❖ A-V (atrioventricular) bundle
  - ❖ Bundle branches (right and left bundle branches)
  - ❖ Purkinje fibers

# Pathway of Heartbeat

- Begins in the sinoatrial (S-A) node
- Internodal pathway to atrioventricular (A-V) node ??
- Impulse delayed in A-V node (allows atria to contract before ventricles)
- A-V bundle takes impulse into ventricles
- Left and right bundles of Purkinje fibers take impulses to all parts of ventricles

# Sinus Node

- Specialized cardiac muscle connected to atrial muscle.
- Acts as pacemaker because membrane leaks  $\text{Na}^+$  and membrane potential is  $-55$  to  $-60\text{mV}$
- When membrane potential reaches  $-40\text{ mV}$ , slow  $\text{Ca}^{++}$  channels open causing action potential.
- After 100-150 msec  $\text{Ca}^{++}$  channels close and  $\text{K}^+$  channels open more thus returning membrane potential to  $-55\text{mV}$ .

# Internodal Pathways ??

- Transmits cardiac impulse throughout atria
- Anterior, middle, and posterior internodal pathways
- Anterior interatrial band carries impulses to left atrium.

# A-V Node

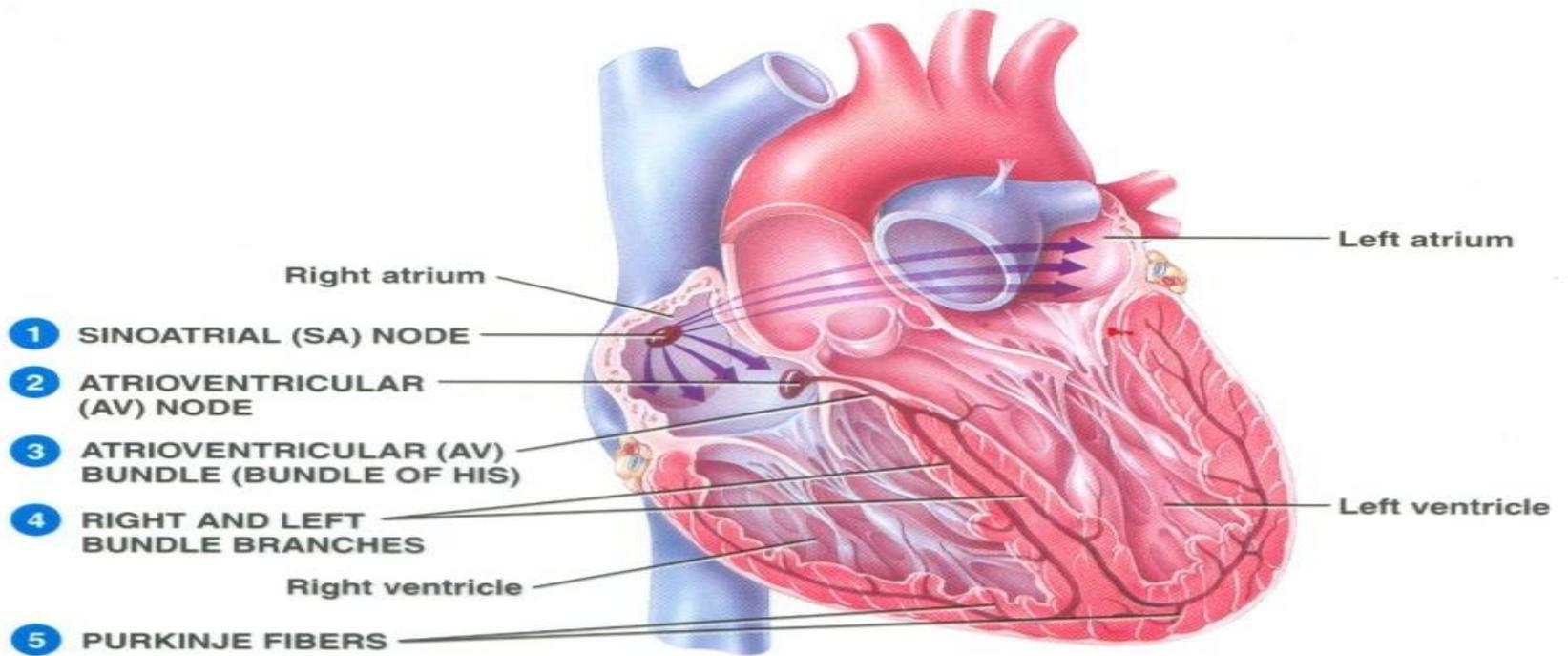
- Delays cardiac impulse
- Most delay is in A-V node
- Delay AV node---0.09 sec.
- Delay AV bundle--0.04 sec.

# Purkinje System

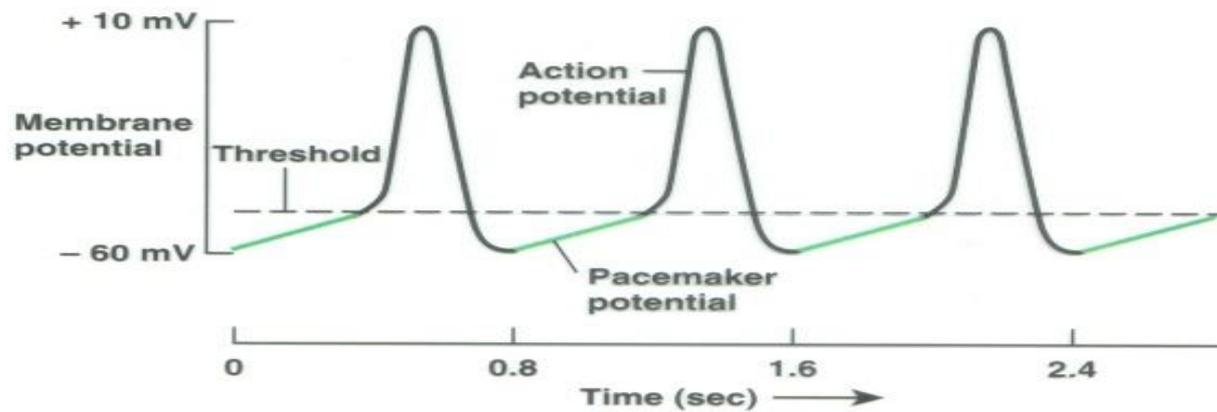
- Fibers lead from A-V node through A-V bundle into Ventricles
- Fast conduction; many gap junctions at intercalated disks

# A-V Bundles

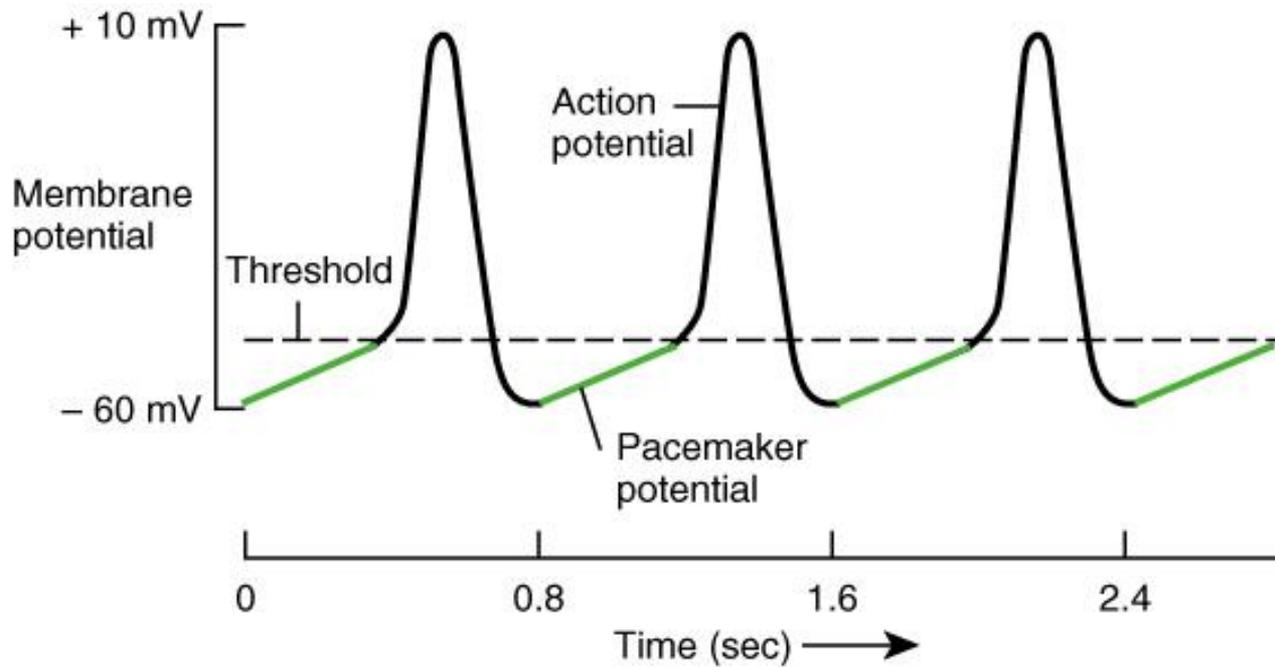
- Normally one-way conduction through the bundles
- Only conducting path between atria and ventricles is A-V node - A-V bundle
- Divides into left and right bundles
- Transmission time between A-V bundles and last of ventricular fibers is 0.06 second (QRS time)



(a) Anterior view of frontal section



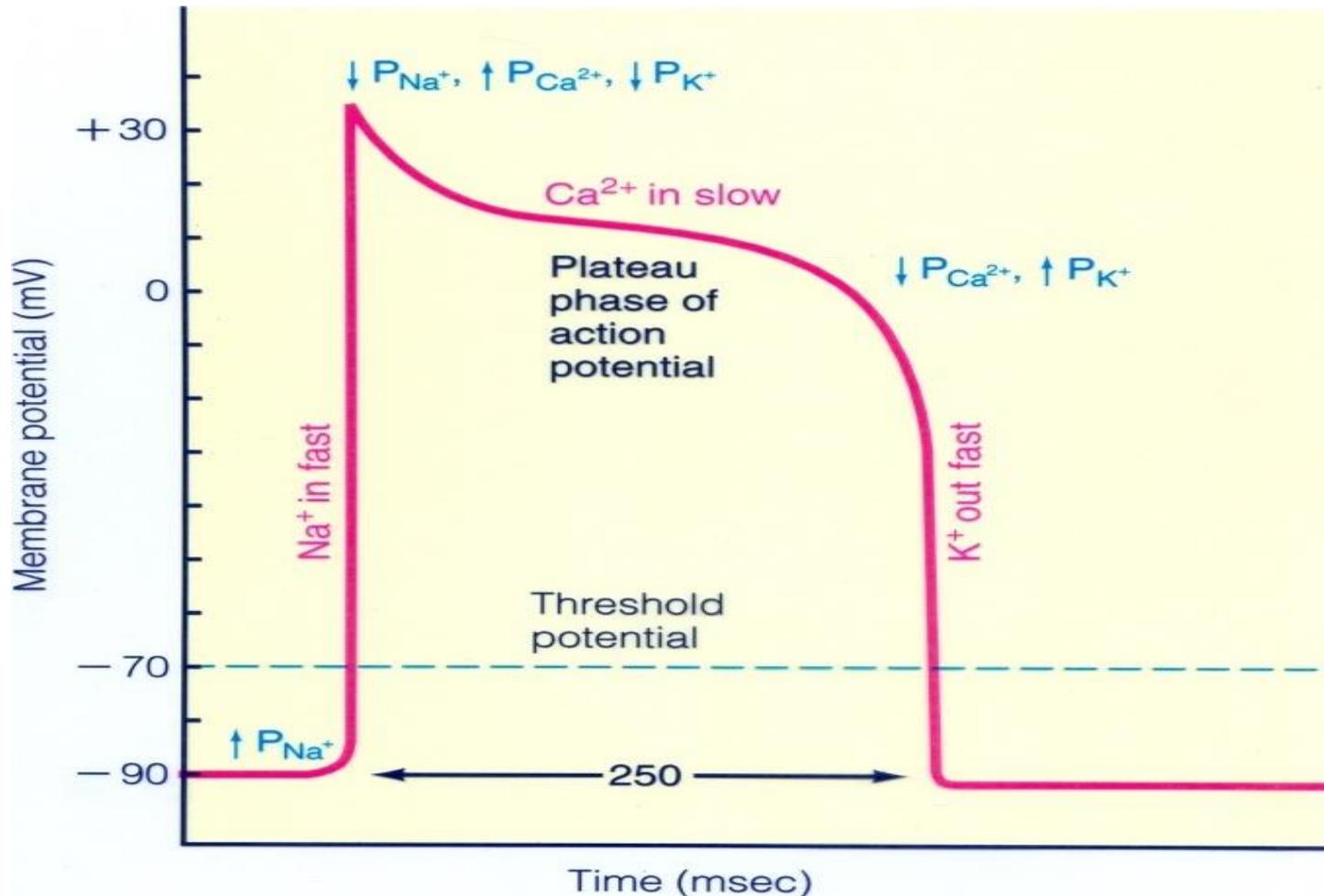
(b) Pacemaker potentials and action potentials in autorhythmic fibers of SA node



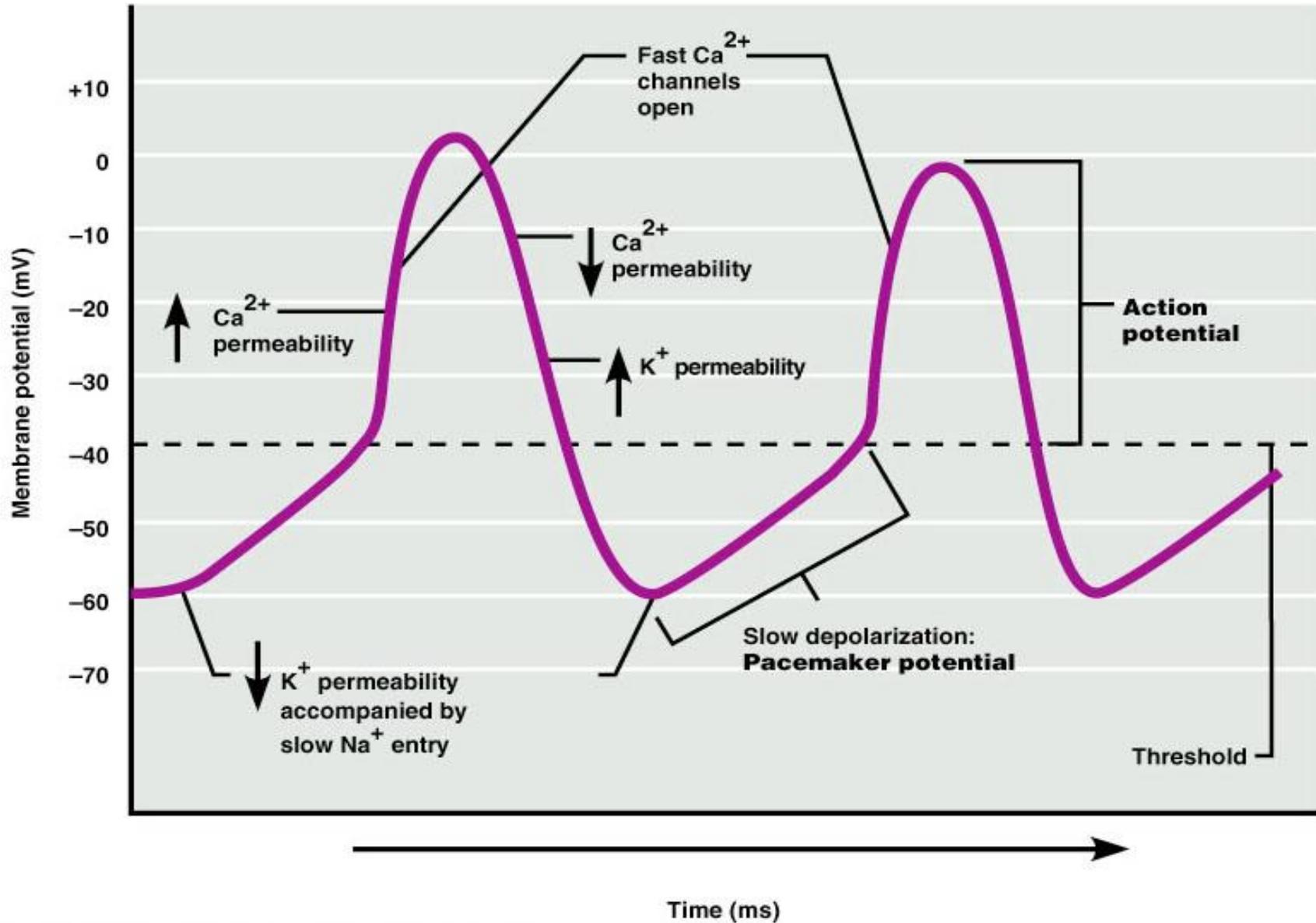
(b) Pacemaker potentials and action potentials in autorhythmic fibers of SA node

20.10b

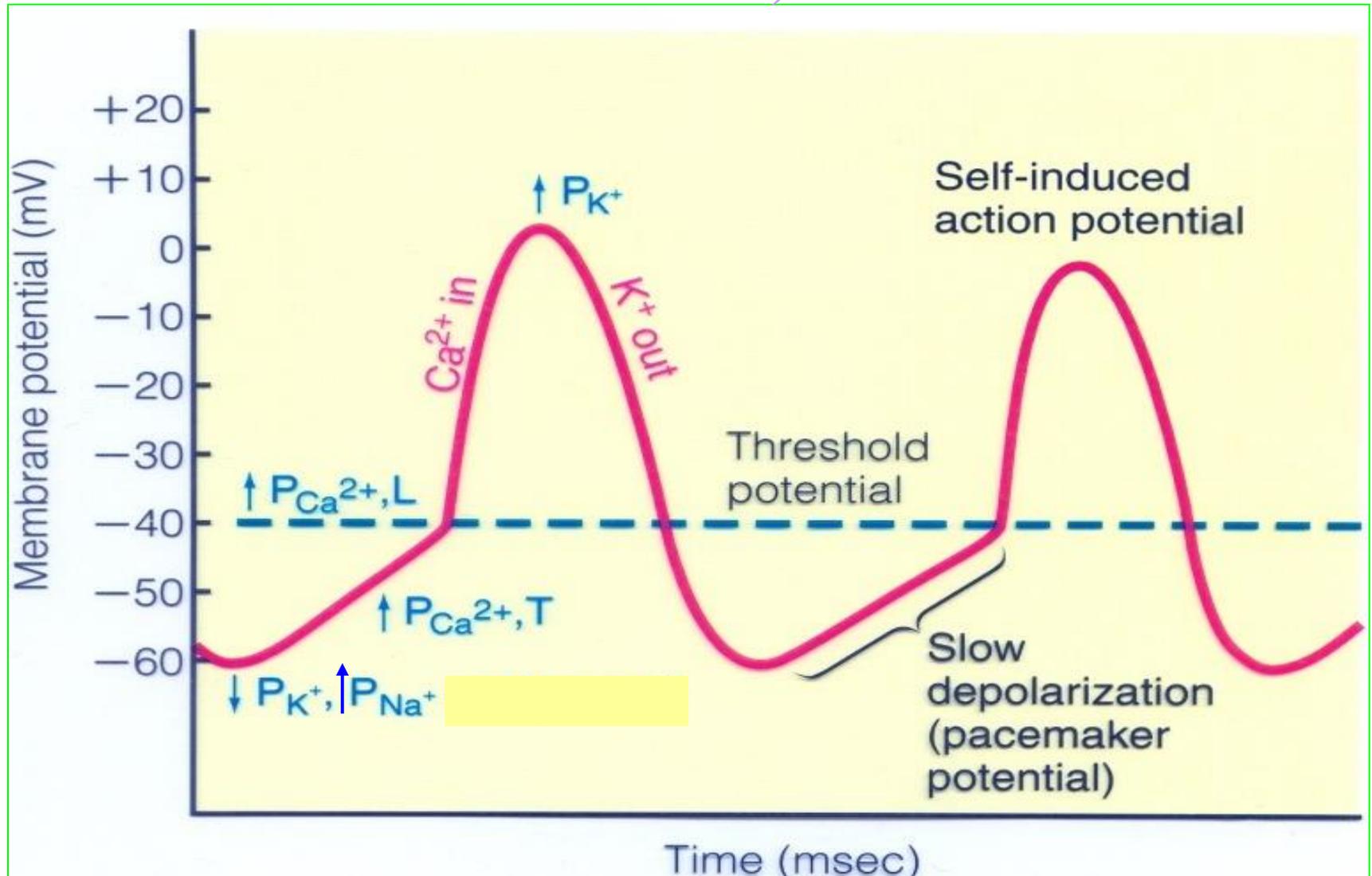
# Fast Response Action Potential of Contractile Cardiac Muscle Cell



# Pacemaker and Action Potentials of the Heart



# Slow Response Action Potential (Pacemaker Potential)



# Intrinsic rate and speed of conduction of the components of the system

- SA node 60-80 action potential /min (*Pacemaker*)
- AV node 40-60 action potential /min
- Purkinje 15-40 action potential /min

## Conduction Speed

- SA node: slow speed of conduction
- Ventricular and Atrial muscle: Moderate speed
- AV node: slowest speed of conduction
- Purkinje fibers: Fastest speed of conduction
- *Ectopic Pacemaker- Abnormal site of pacemaker*

# Extrinsic Innervation of the Heart

- **Vital centers of medulla**

1. Cardiac Center

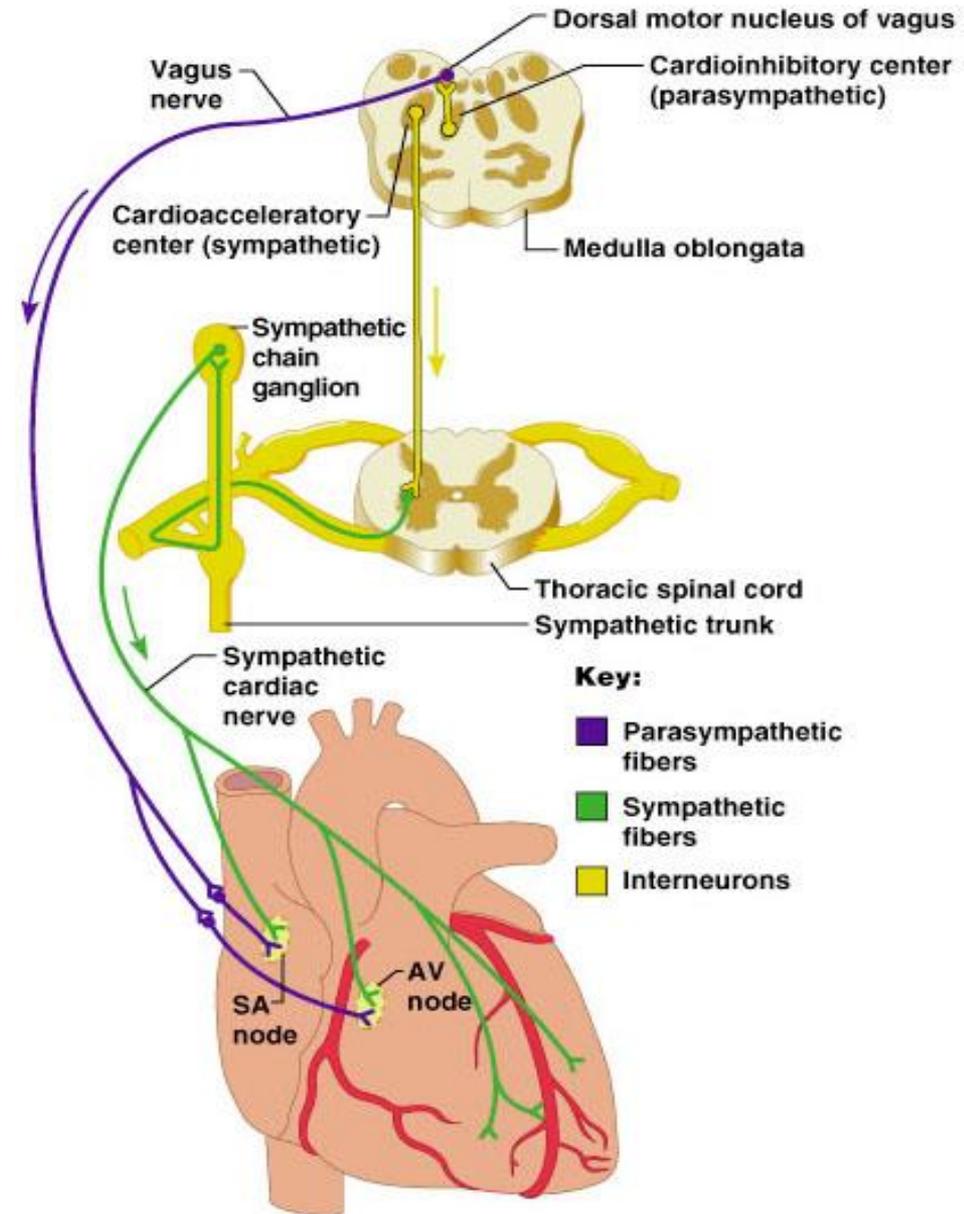
- *Cardioaccelerator center*

- Activates sympathetic neurons that increase HR

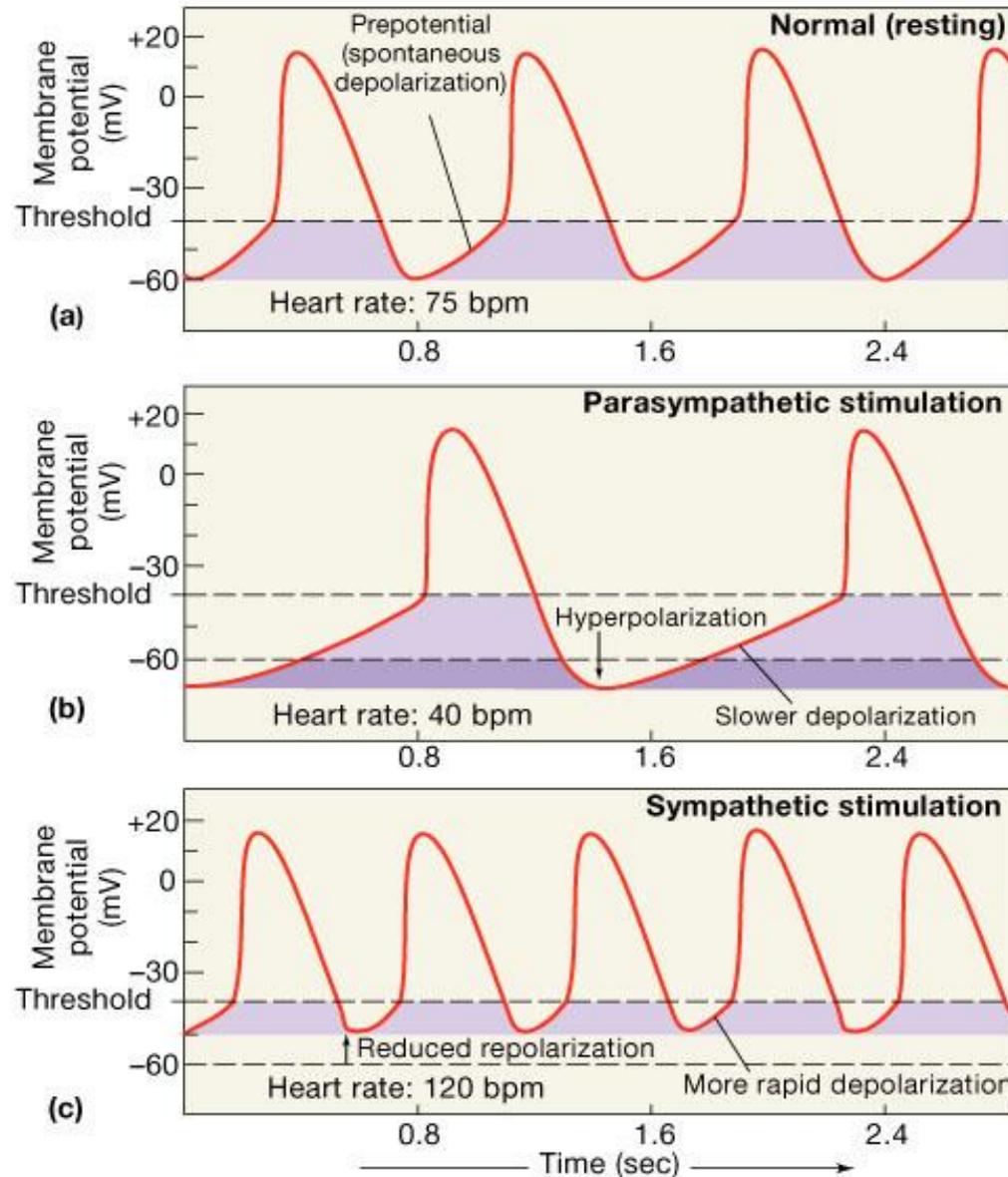
- *Cardioinhibitory center*

- Activates parasympathetic neurons that decrease HR

- Cardiac center receives input from higher centers (hypothalamus), monitoring blood pressure and dissolved gas concentrations



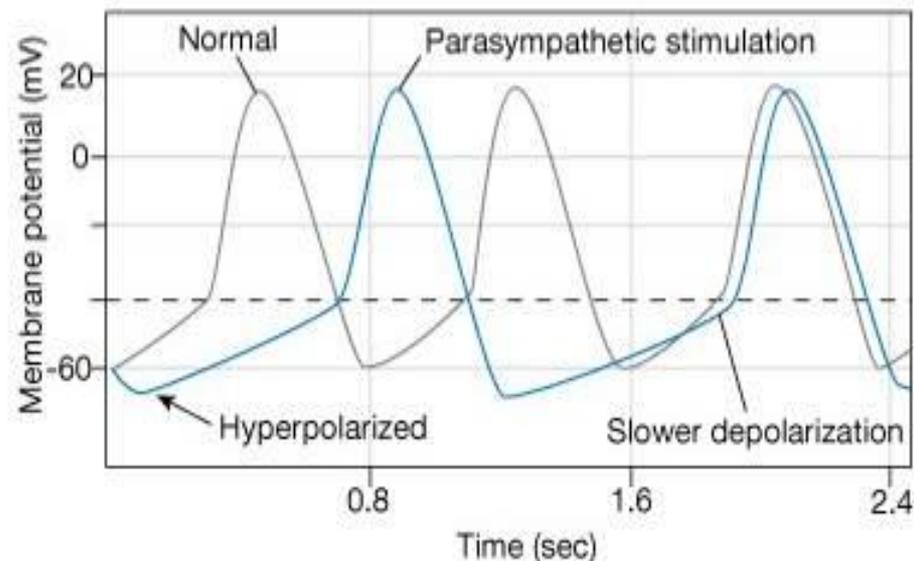
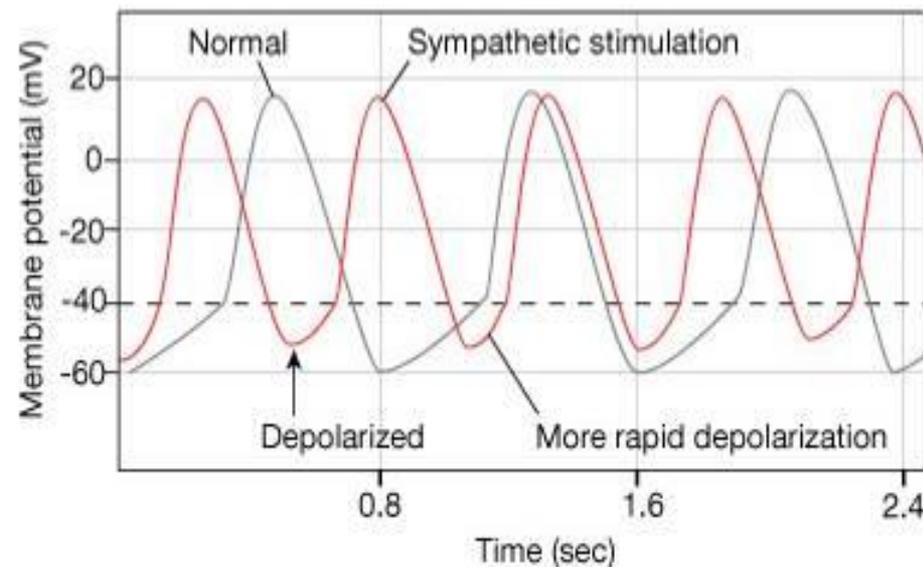
# Pacemaker Function



# Autonomic neurotransmitters affect ion flow to change rate

- **Sympathetic** – increases heart rate by  $\uparrow$   $\text{Ca}^{+2}$  &  $I_f$  channel (net  $\text{Na}^+$ ) flow
- **Parasympathetic** – decreases rate by  $\uparrow$   $\text{K}^+$  efflux &  $\downarrow$   $\text{Ca}^{+2}$  influx

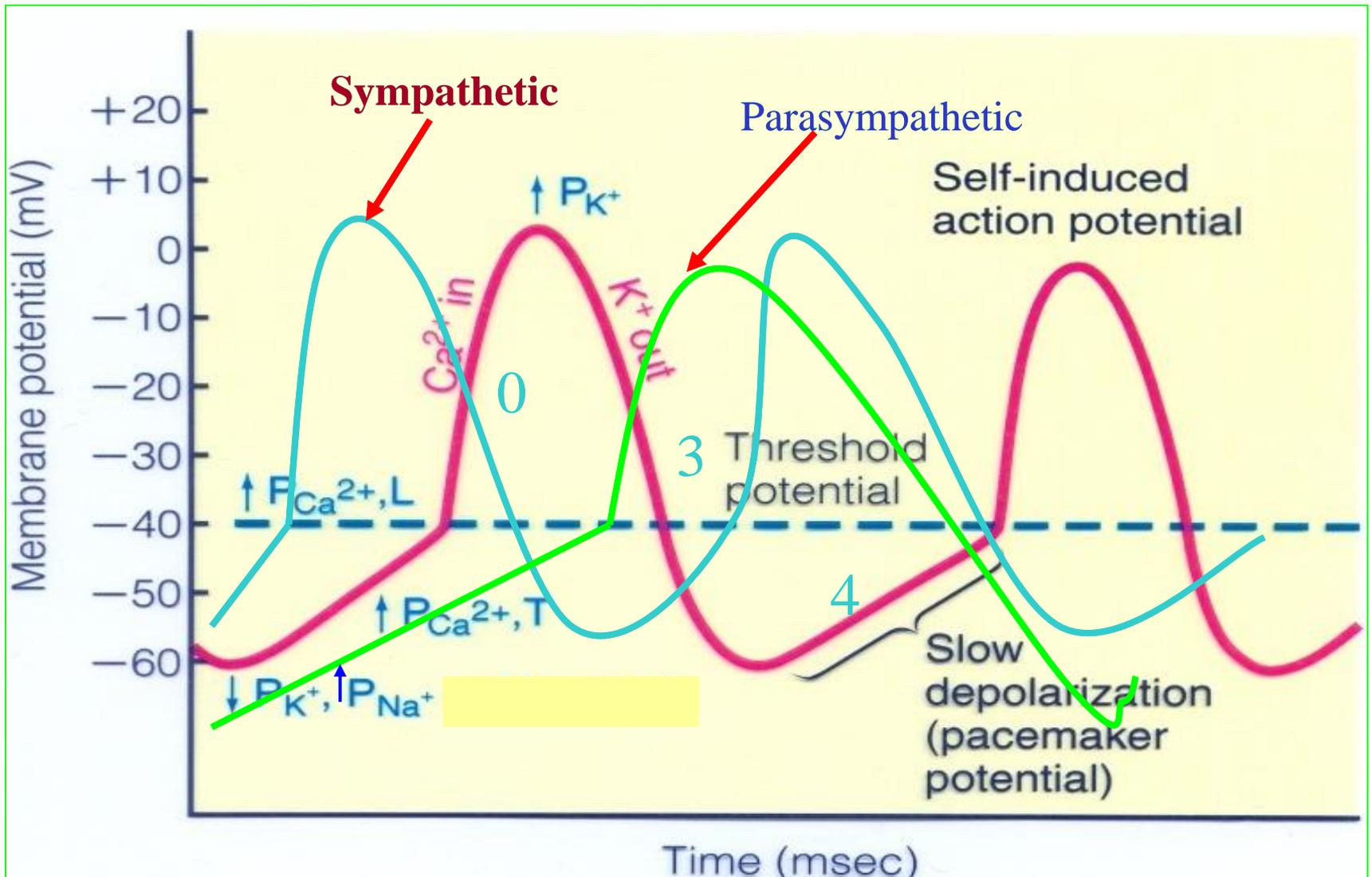
*What part of the graph is not changed by autonomic influences?*



# Effect of autonomic nerve activity on the heart

Region affected	Sympathetic Nerve	Parasympathetic Nerve
SA node	Increased rate of diastole depolarization ; increased cardiac rate	Decreased rate of diastole depolarization ; Decreased cardiac rate
AV node	Increase conduction rate	Decreased conduction rate
Atrial muscle	Increase strength of contraction	Decreased strength of contraction
Ventricular muscle	Increased strength of contraction	No significant effect

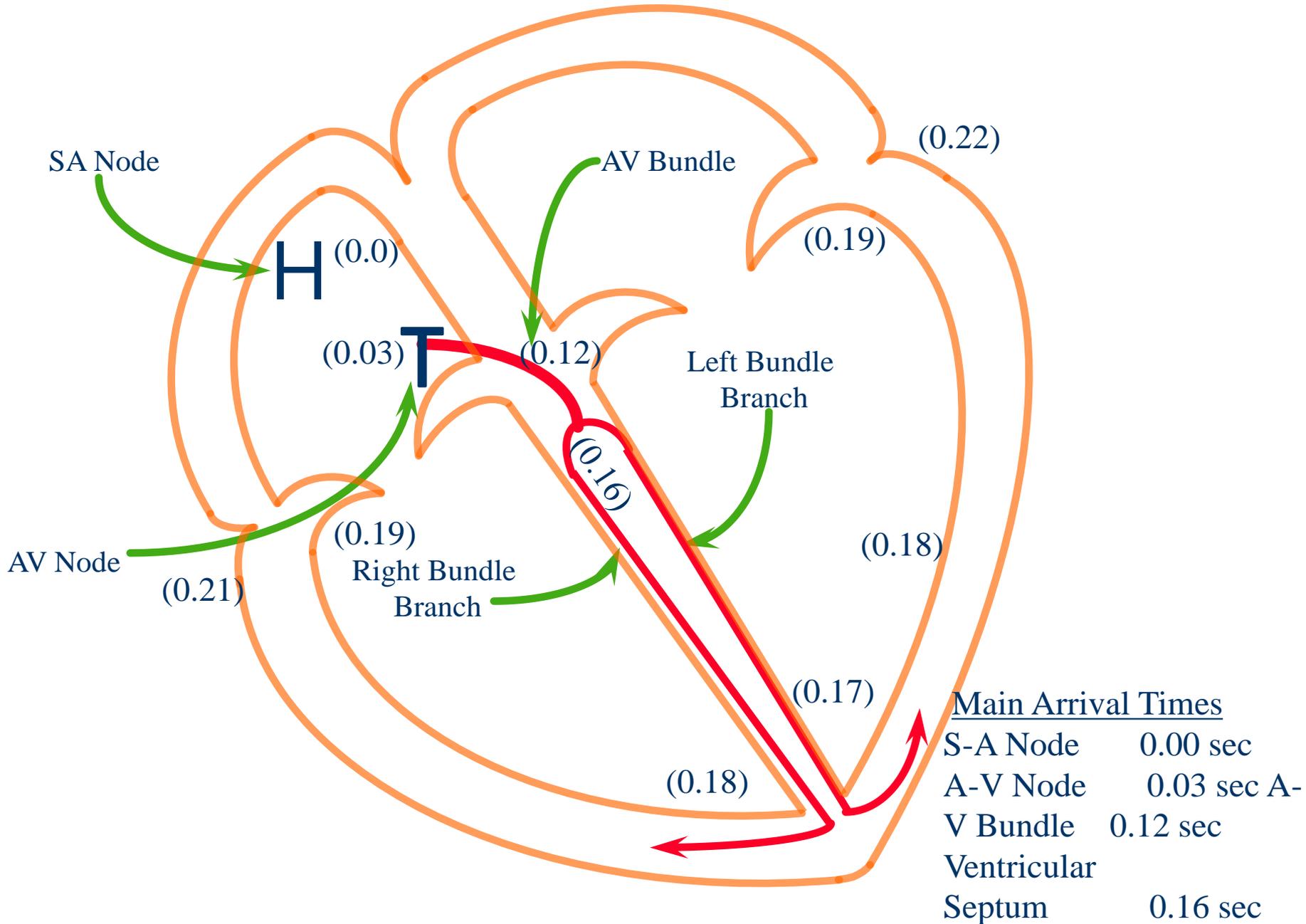
# Effect of Sympathetic & Parasympathetic Stimulation



# Regulation of the heart beat

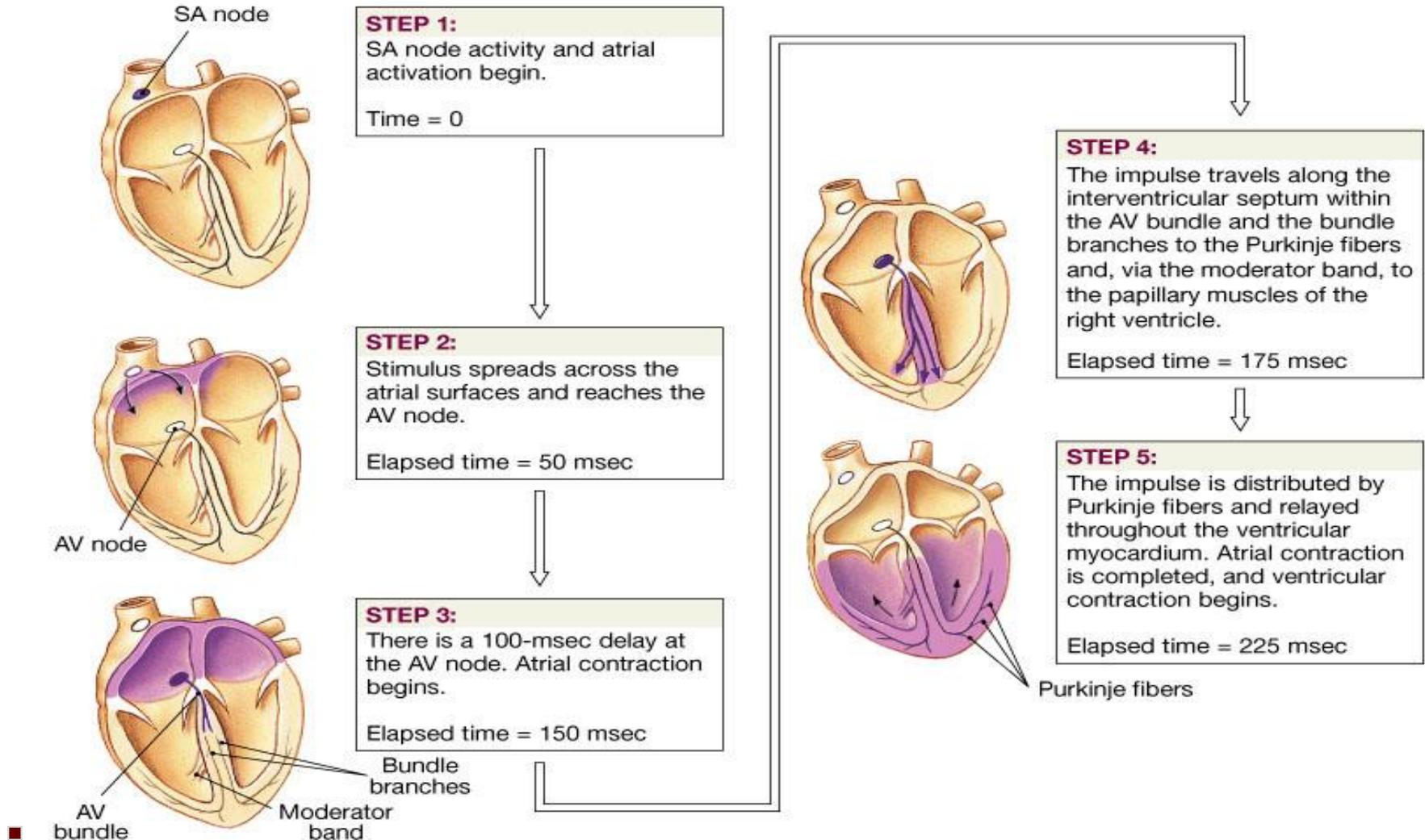
- Sympathetic from the cardiac plexus supplies all parts of the heart (atria, ventricle and all parts of the conduction system)
- Parasympathetic from Vagus nerves supply mainly the atria, SA and AV nodes, very little supply to ventricles
- Sympathetic: increase the permeability of the cardiac cells to  $\text{Na}^+$  and  $\text{Ca}^{++}$  i.e Positive **Chronotropic** and positive **Inotropic** action
- Parasympathetic: Increase the permeability of the cardiac cells to  $\text{K}^+$  and decrease its permeability to  $\text{Na}^+$  and  $\text{Ca}^{++}$
- Negative Chronotropic effect and ?? Inotropic effect
- Ventricular Escape and Overdrive suppression-

# Time of Arrival of Cardiac Impulse



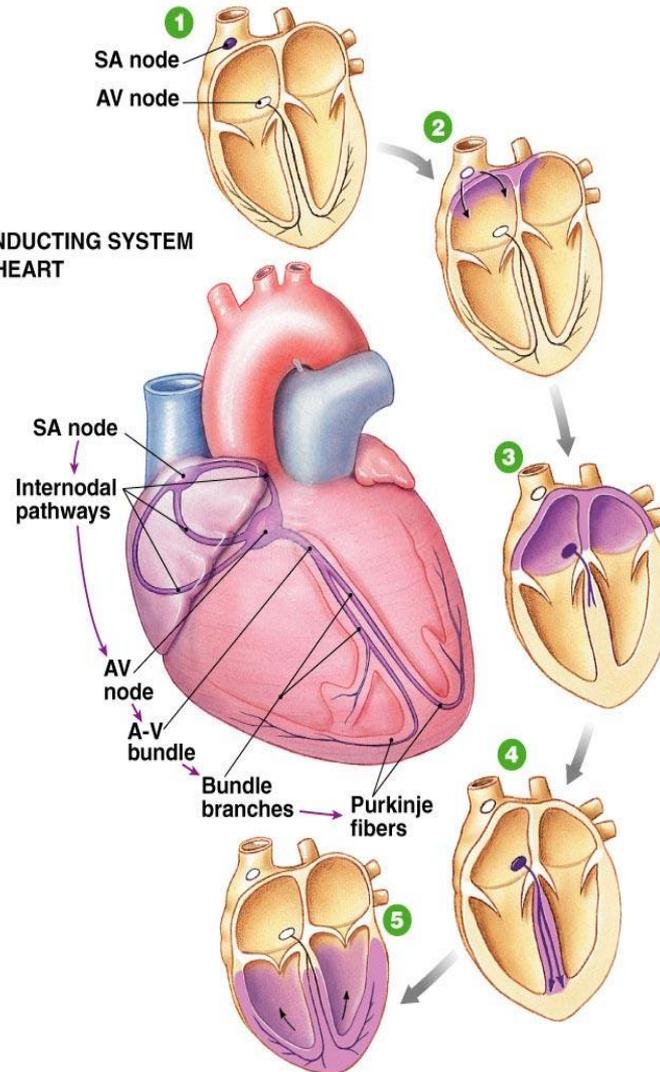
<u>Main Arrival Times</u>	
S-A Node	0.00 sec
A-V Node	0.03 sec
A-V Bundle	0.12 sec
Ventricular Septum	0.16 sec

# Impulse Conduction through the Heart



<b>Tissue</b>	<b>Conduction rate (m/s)</b>
<b>Atrial muscle</b>	<b>0.3</b>
<b>Atrial pathways</b>	<b>1</b>
<b>AV node</b>	<b>0.05</b>
<b>Bundle of His</b>	<b>1</b>
<b>Purkinje system</b>	<b>4</b>
<b>Ventricular muscle</b>	<b>0.3-0.5</b>

THE CONDUCTING SYSTEM OF THE HEART



- 1** SA node depolarizes.
- 2** Electrical activity goes rapidly to AV node via internodal pathways.
- 3** Depolarization spreads more slowly across atria. Conduction slows through AV node.
- 4** Depolarization moves rapidly through ventricular conducting system to the apex of the heart.
- 5** Depolarization wave spreads upward from the apex.

# Sinus Node is Cardiac Pacemaker

- Normal rate of discharge in sinus node is 70-80/min.; A-V node - 40-60/min.; Purkinje fibers - 15-40/min.
- Sinus node is pacemaker because of its faster discharge rate
- Intrinsic rate of subsequent parts is suppressed by “Overdrive suppression”

# Ectopic Pacemaker

- This is a portion of the heart with a more rapid discharge than the sinus node.
- Also occurs when transmission from sinus node to A-V node is blocked (A-V block).

## Ectopic Pacemaker (cont'd)

- During sudden onset of A-V block, sinus node discharge does not get through, and next fastest area of discharge becomes pacemaker of heart beat (Purkinje system).
- Delay in pickup of the heart beat is the “Stokes-Adams” syndrome. New pacemaker is in A-V node or penetrating part of A-V bundle.

# Parasympathetic Effects on Heart Rate

- Parasympathetic (vagal) nerves, which release acetylcholine at their endings, innervate S-A node and A-V junctional fibers proximal to A-V node.
- Causes hyperpolarization because of increased  $K^+$  permeability in response to acetylcholine.
- This causes decreased transmission of impulses maybe temporarily stopping heart rate.
- Ventricular escape occurs.

# Sympathetic Effects on Heart Rate

- Releases norepinephrine at sympathetic ending
- Causes increased sinus node discharge (*Chronotropic effect*)
- Increases rate of conduction of impulse (*Dromotropic effect*)
- Increases force of contraction in atria and ventricles (*Inotropic effect*)

# Thank You

