Conduction System of the Heart 4

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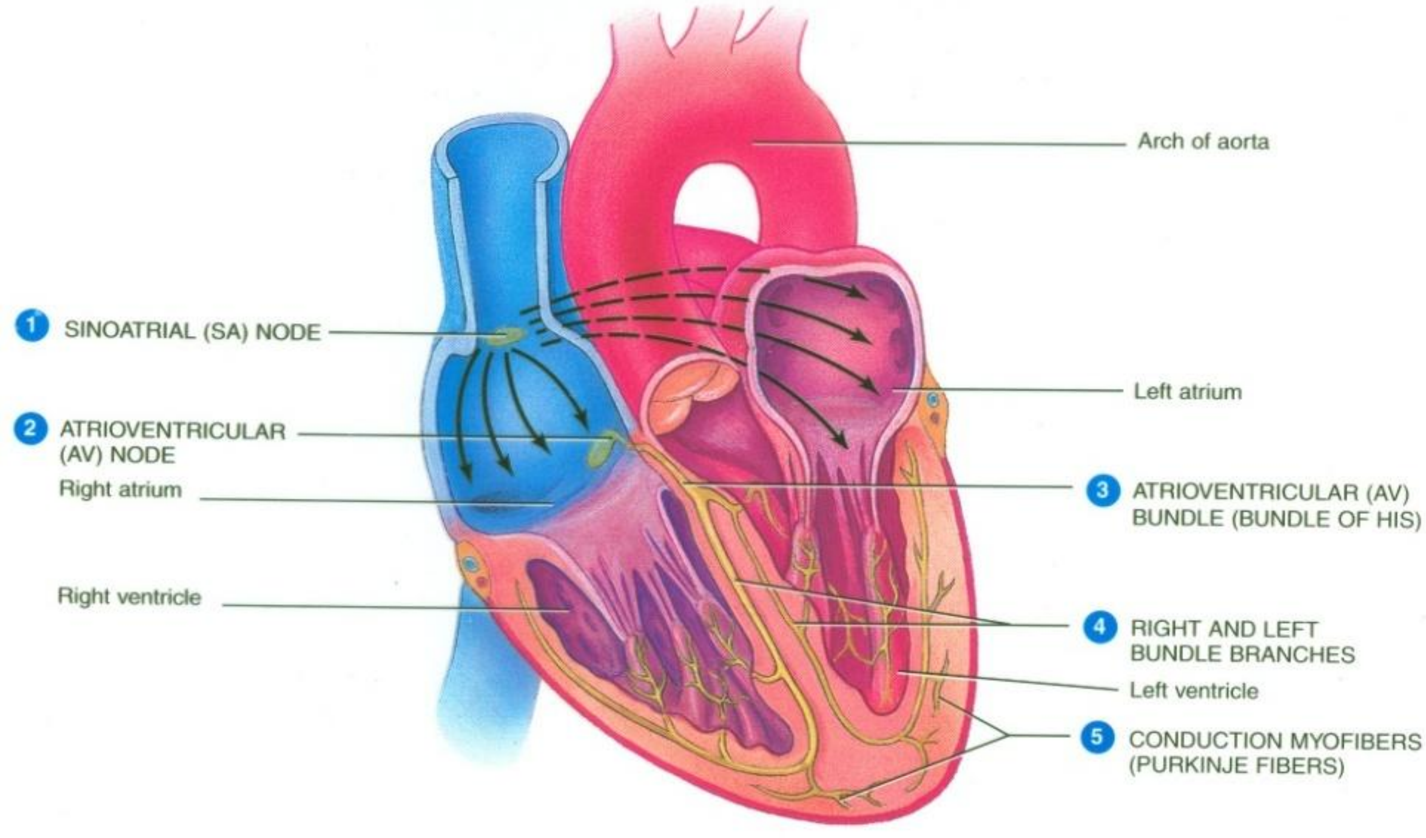
Objectives

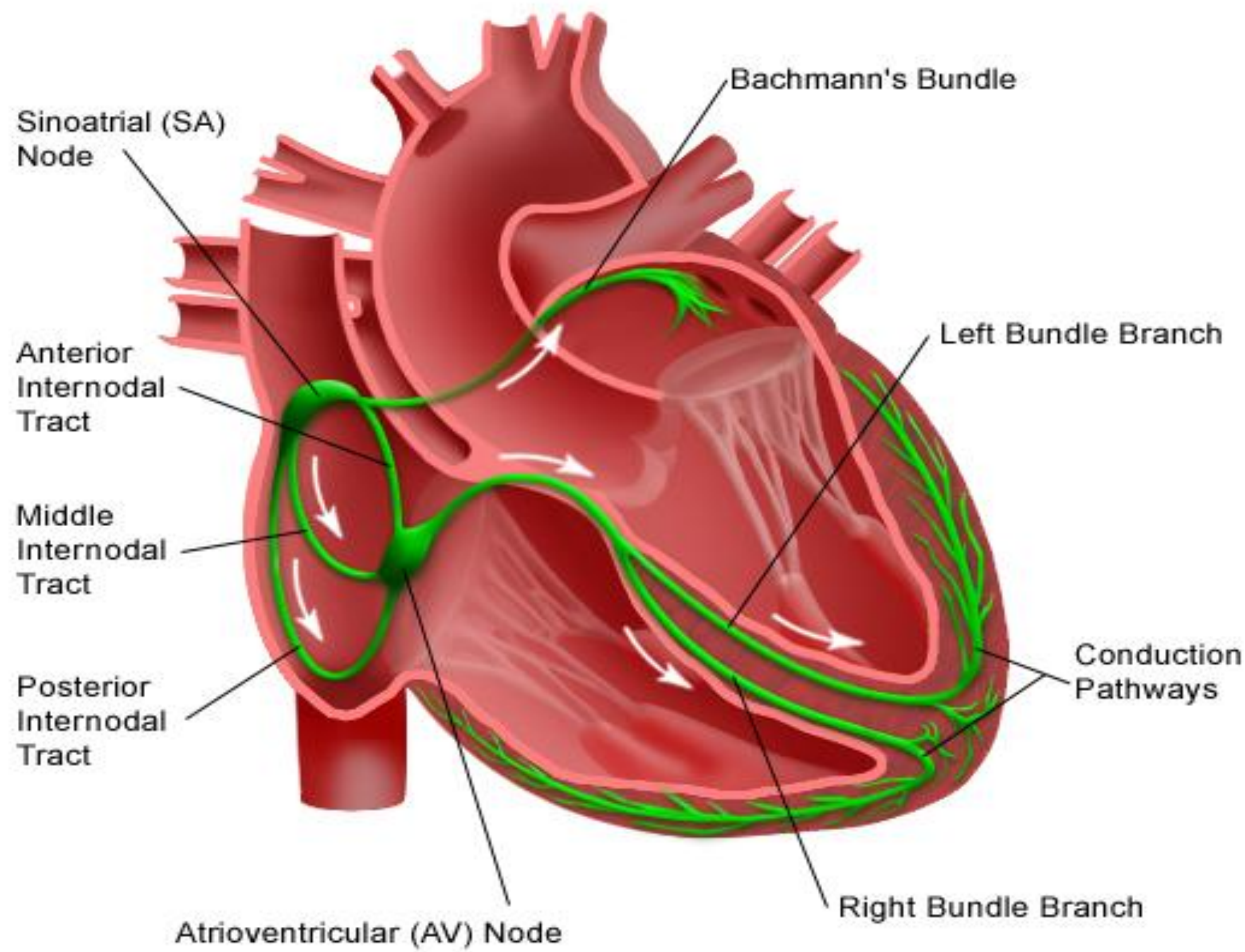
- List the parts that comprise the conduction system
- Explain the mechanism of slow response action potential (pacemaker potential)
- Point out the regulation of the conduction system potential by Autonomic Nerves
- Resource: Guyton's Textbook of Medical Physiology 12th edition 2011.

Structures of the conduction system

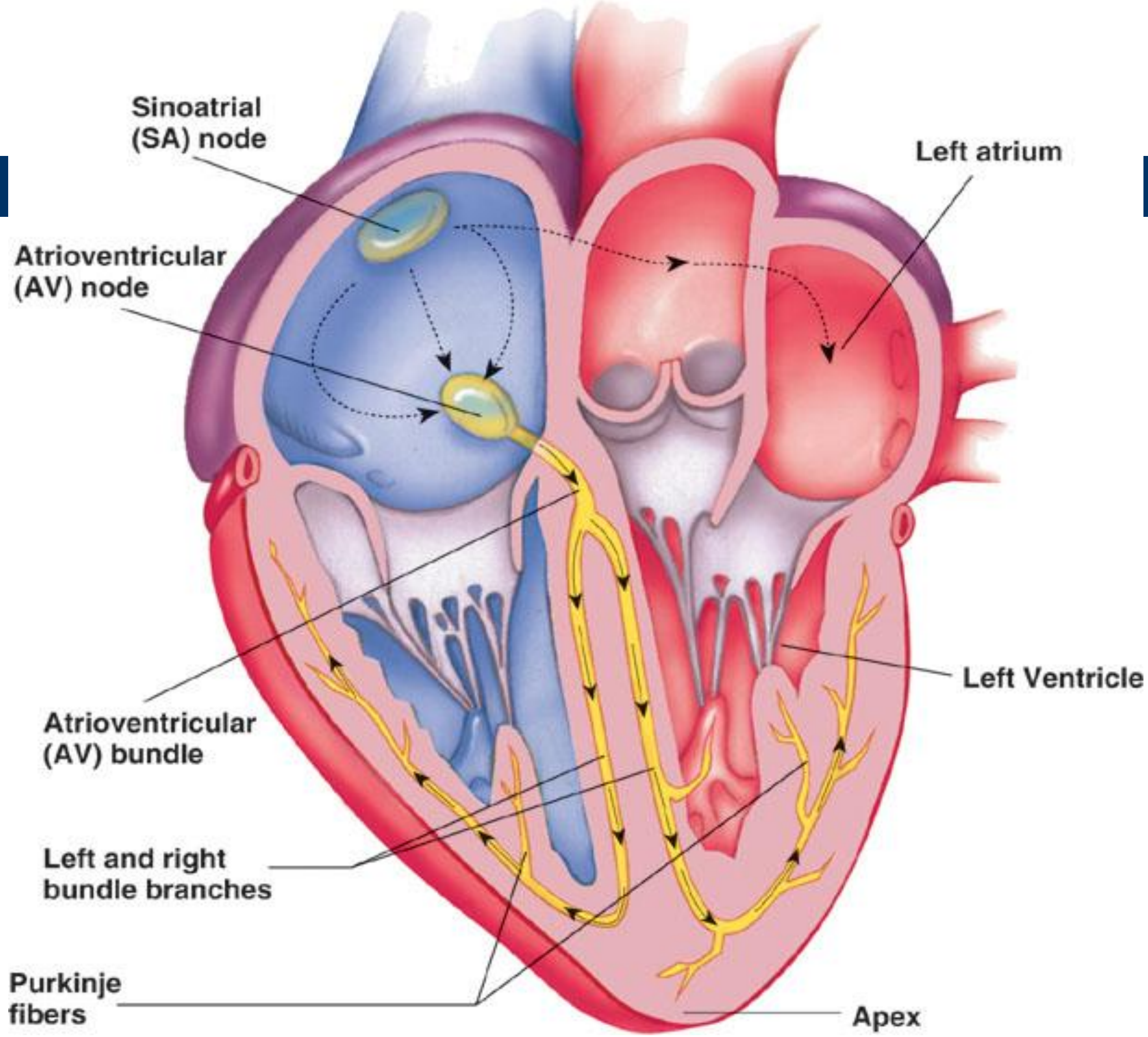


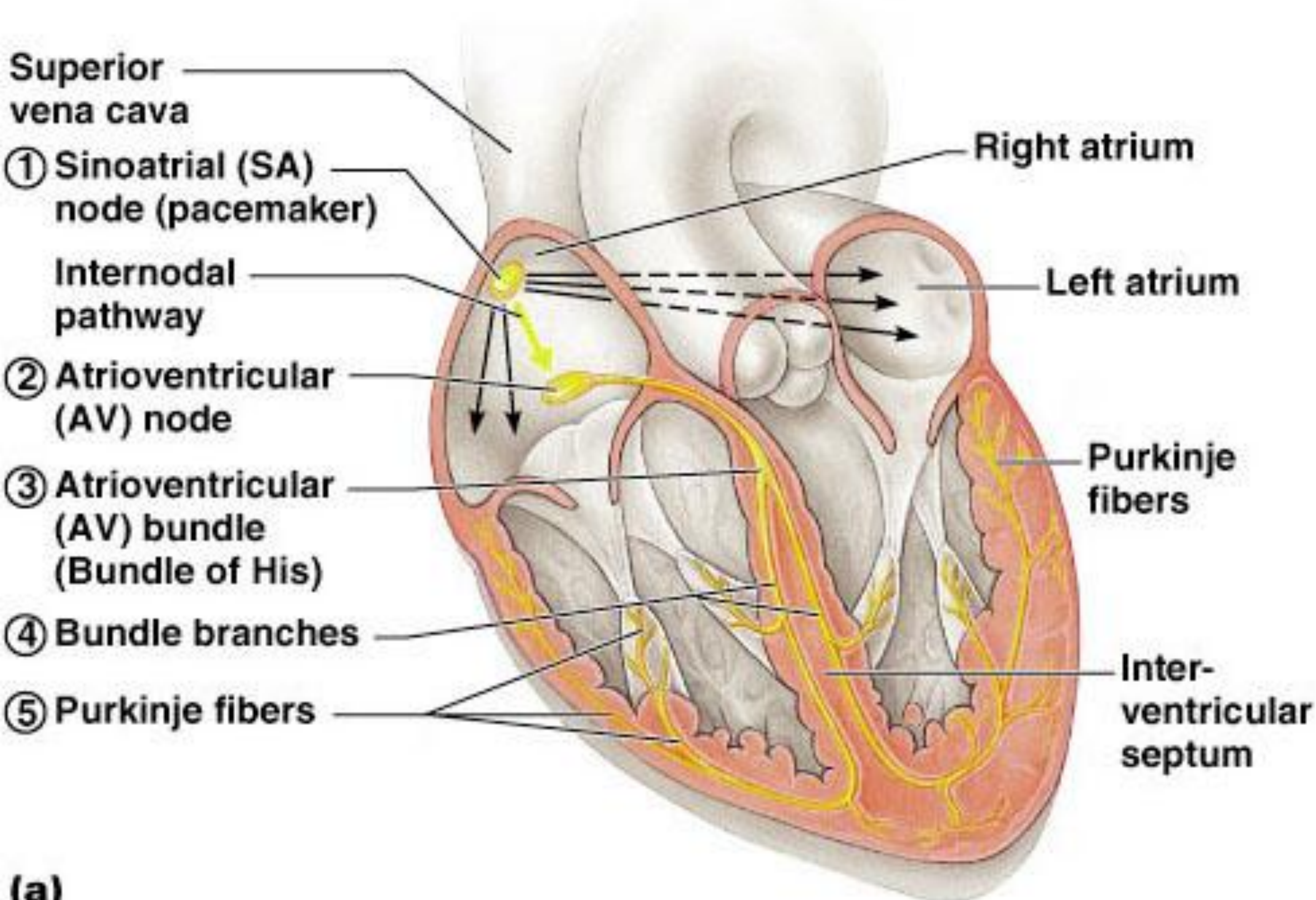
Anterior view of frontal section

Electrical System of the Heart



Conducting System of Heart

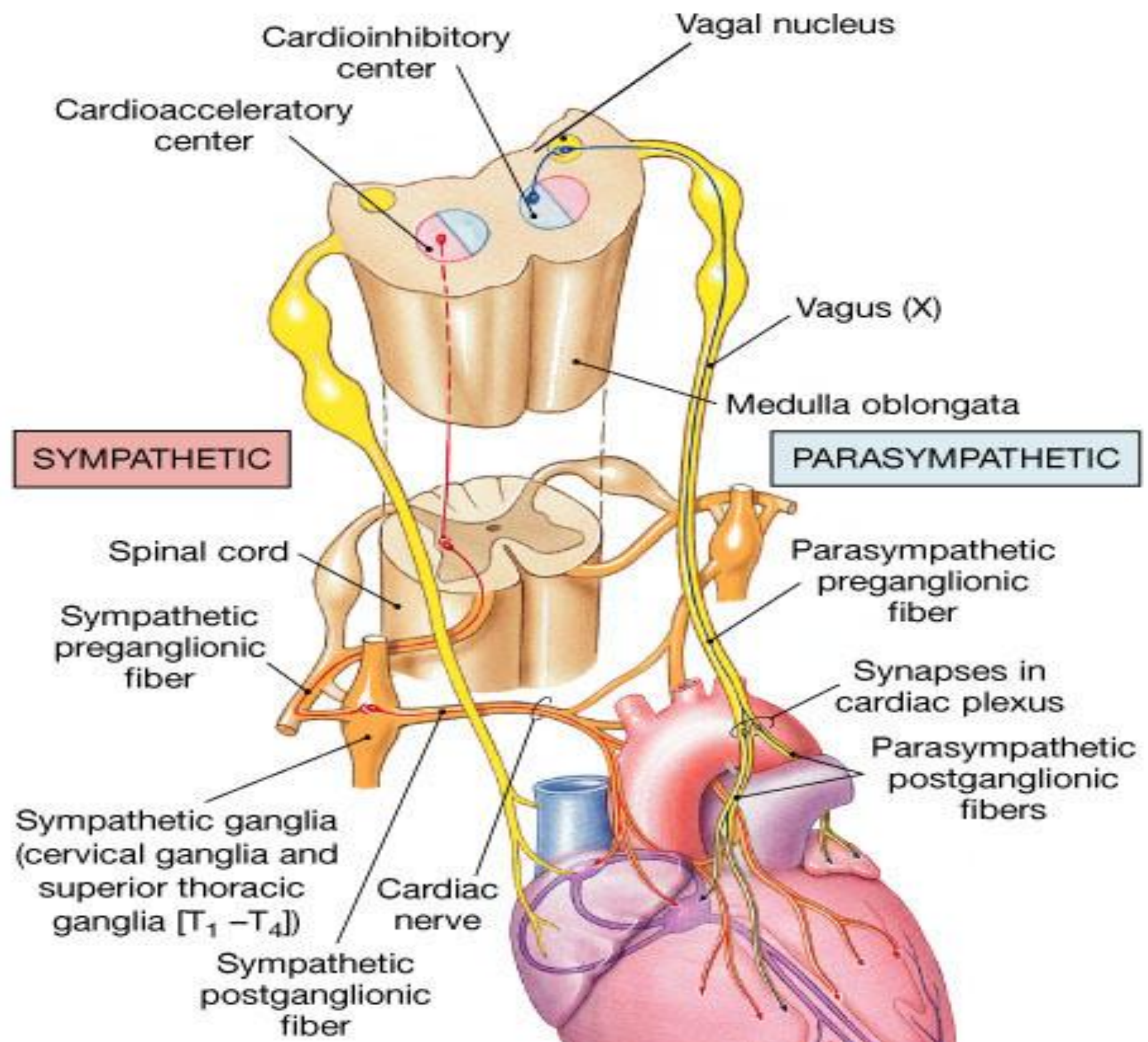




Superior vena cava
① Sinoatrial (SA) node (pacemaker)
Internodal pathway
② Atrioventricular (AV) node
③ Atrioventricular (AV) bundle (Bundle of His)
④ Bundle branches
⑤ Purkinje fibers
Right atrium
Left atrium
Purkinje fibers
Inter-ventricular septum

(a)

Autonomic Innervation of the Heart



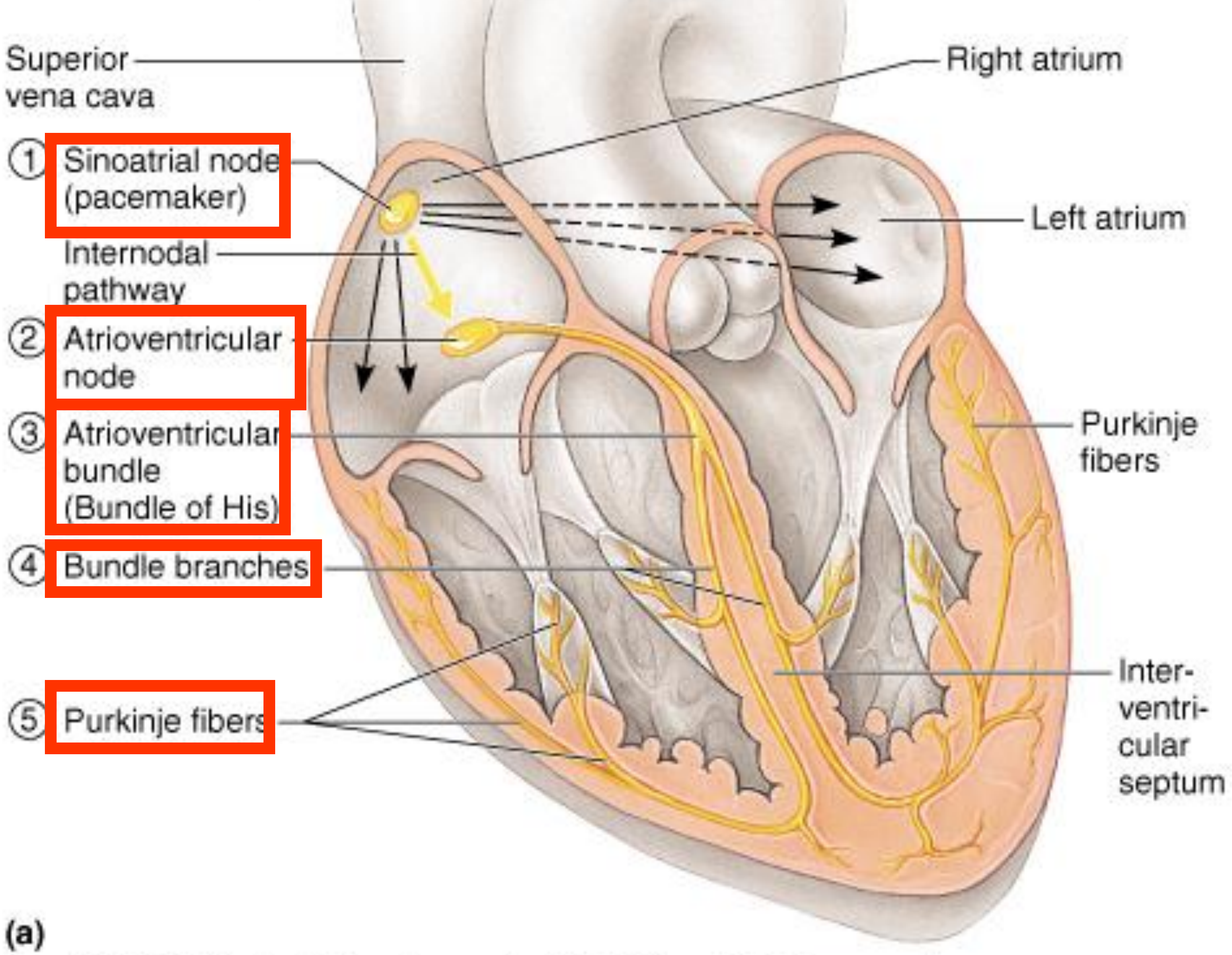
Intrinsic Cardiac Conduction System

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

70-80/min

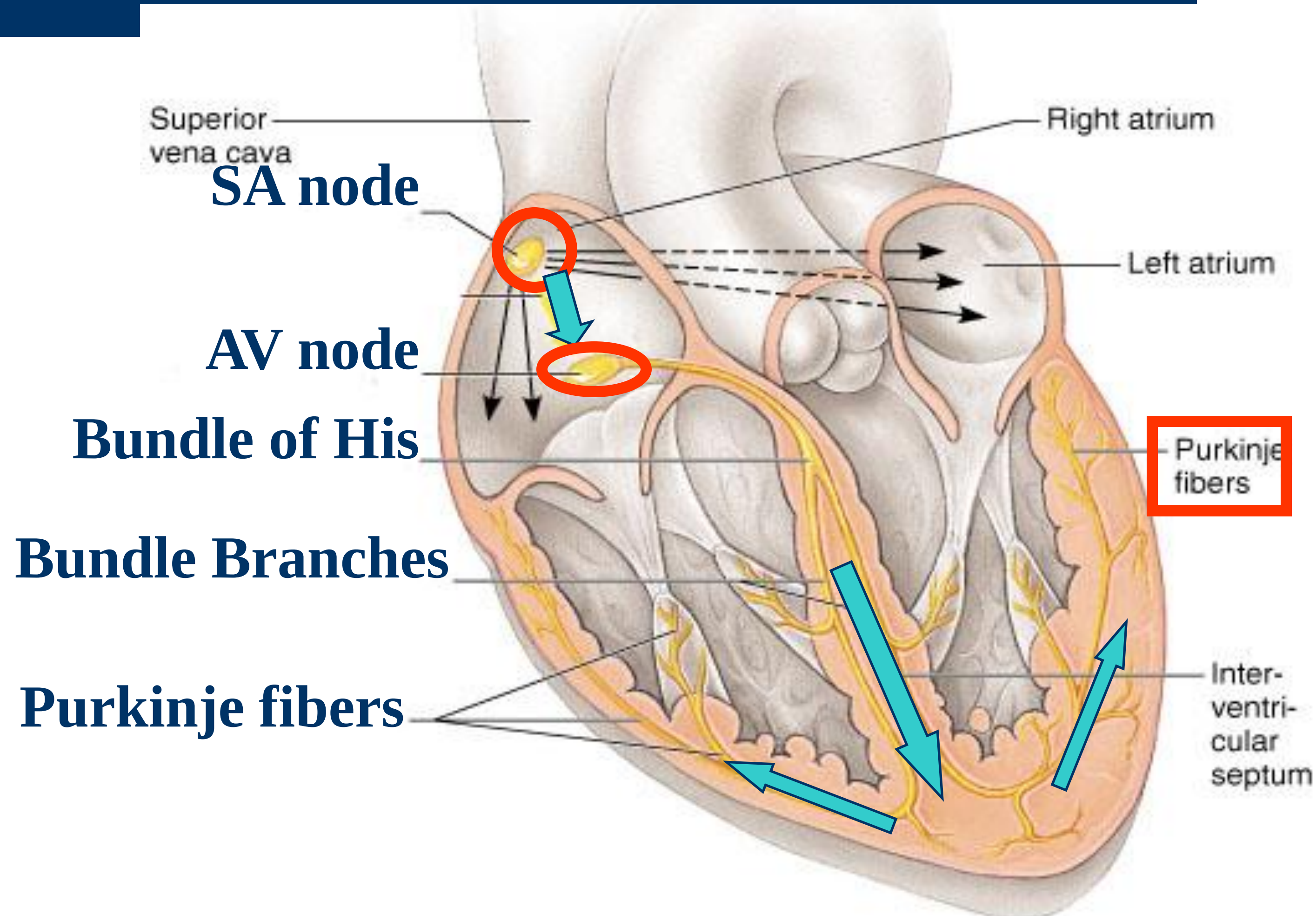
40-60/min

15-40/min



Intrinsic Conduction System

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



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 Na^+ and membrane potential is -55 to -60mV
- When membrane potential reaches -40 mV, slow Ca^{++} channels open causing action potential.
- After 100-150 msec Ca^{++} channels close and K^+channels open more thus returning membrane potential to -55mV.

Internodal Pathways ??

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

A-V Node

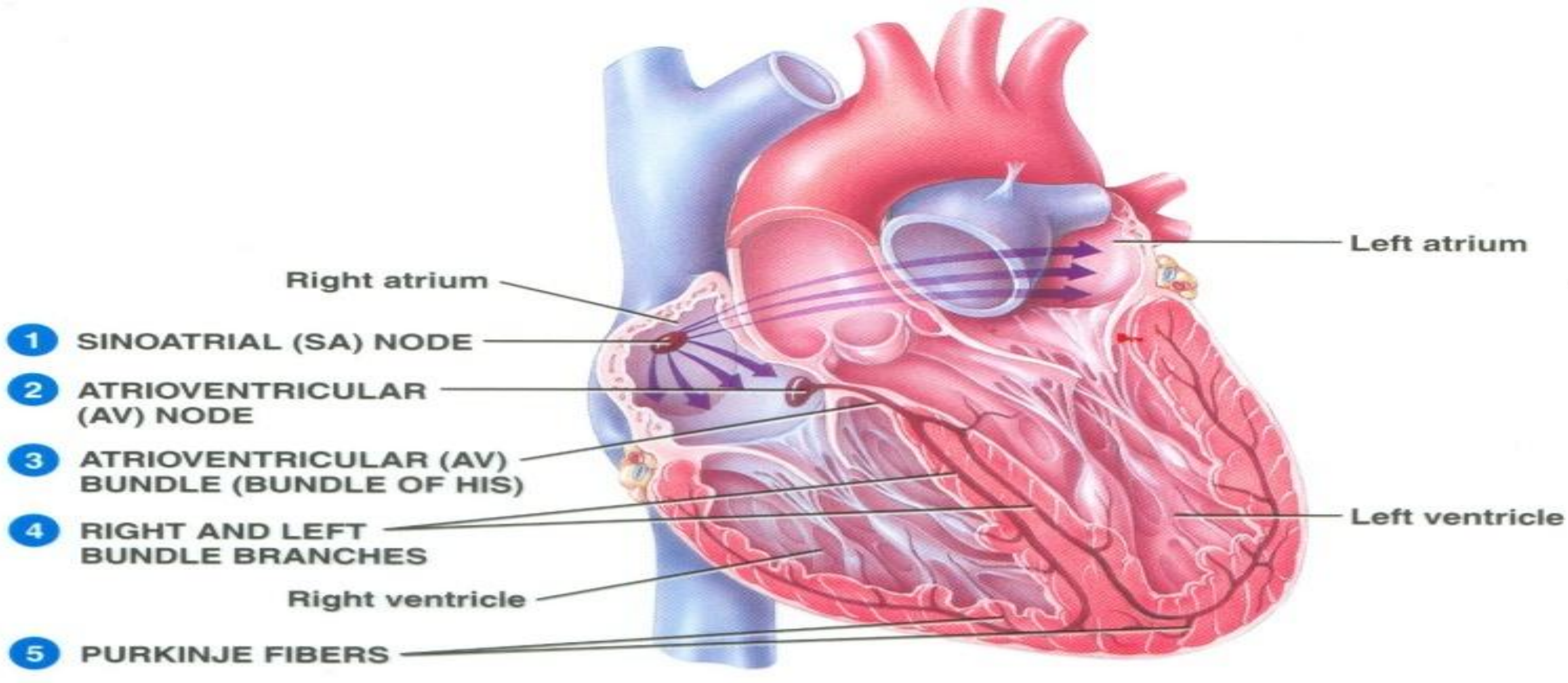
- <u>Delays</u> cardiac impulse
- Most delay is in A-V node
- Delay AV node---0.09 sec.
- Delay AV bundle--0.04 sec.

Purkinje System

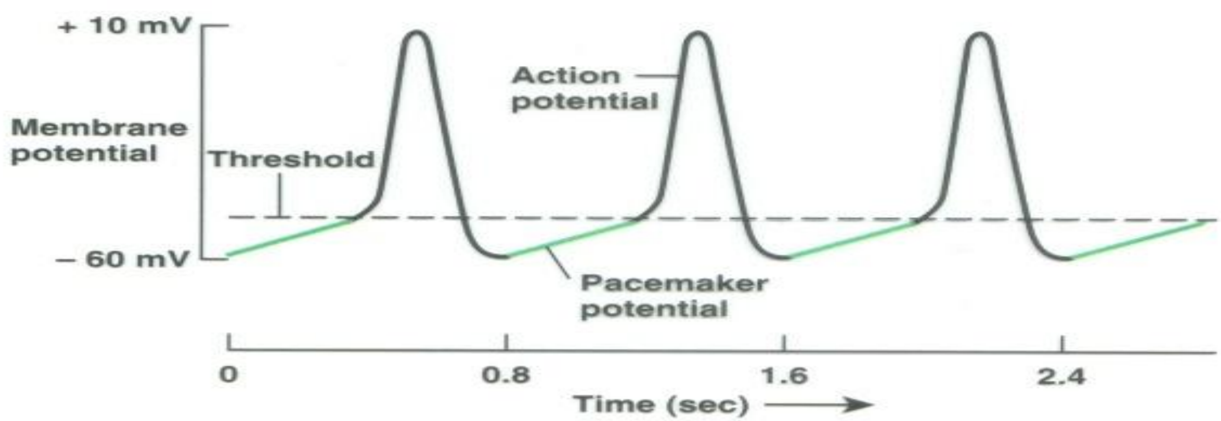
- Fibers lead from A-V node through A-V bundle into Ventricles
- Fast conduction; many gap junctions at intercalated disks

A-V Bundles

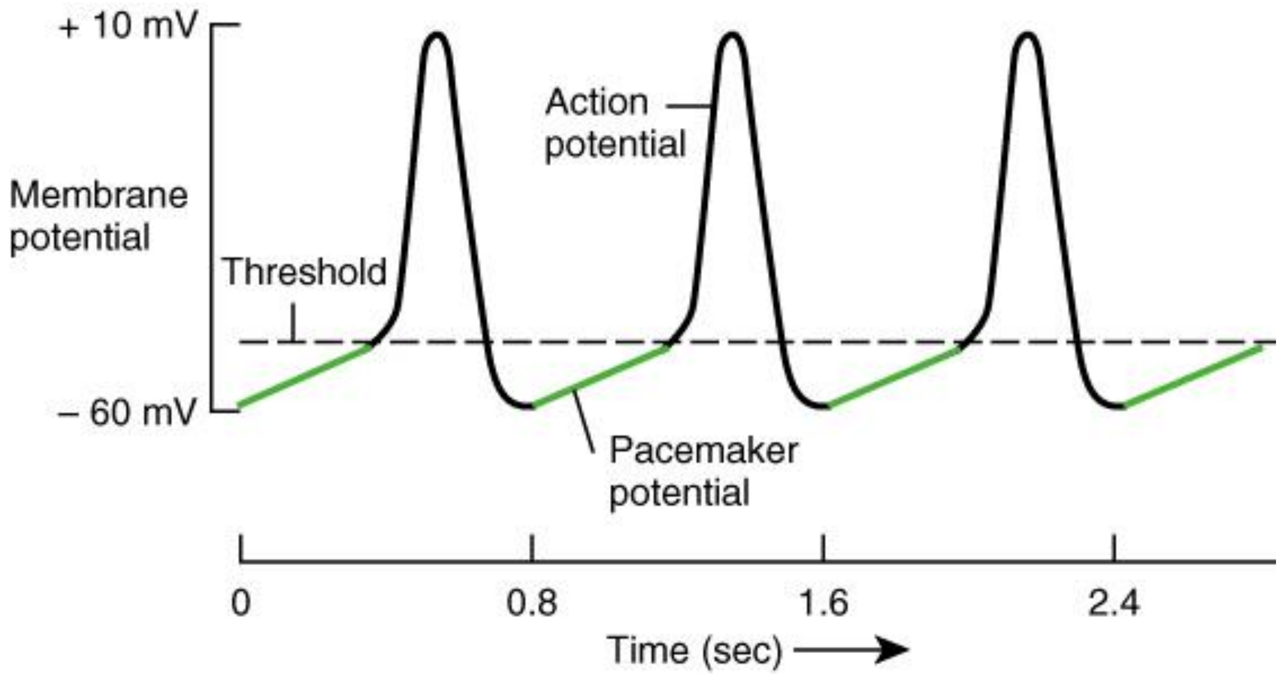
- Normally one-way conduction through the bundles
- Only conducting path between atria and ventricles is A-V node - A-V bundle
- Divides into left and right bundles
- Transmission time between A-V bundles and last of ventricular fibers is 0.06 second (QRS time)



(a) Anterior view of frontal section



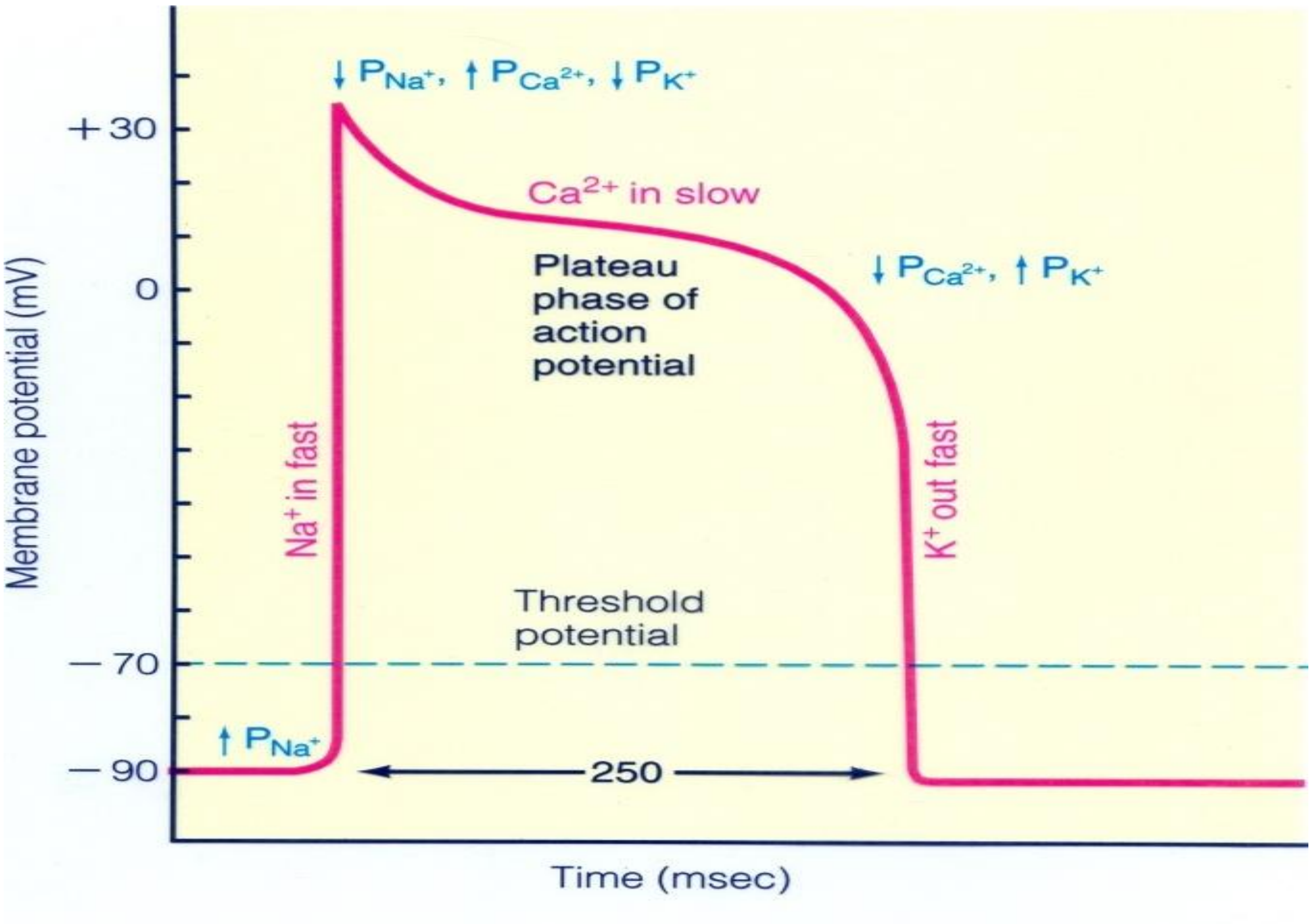
(b) Pacemaker potentials and action potentials in autorhythmic fibers of SA node



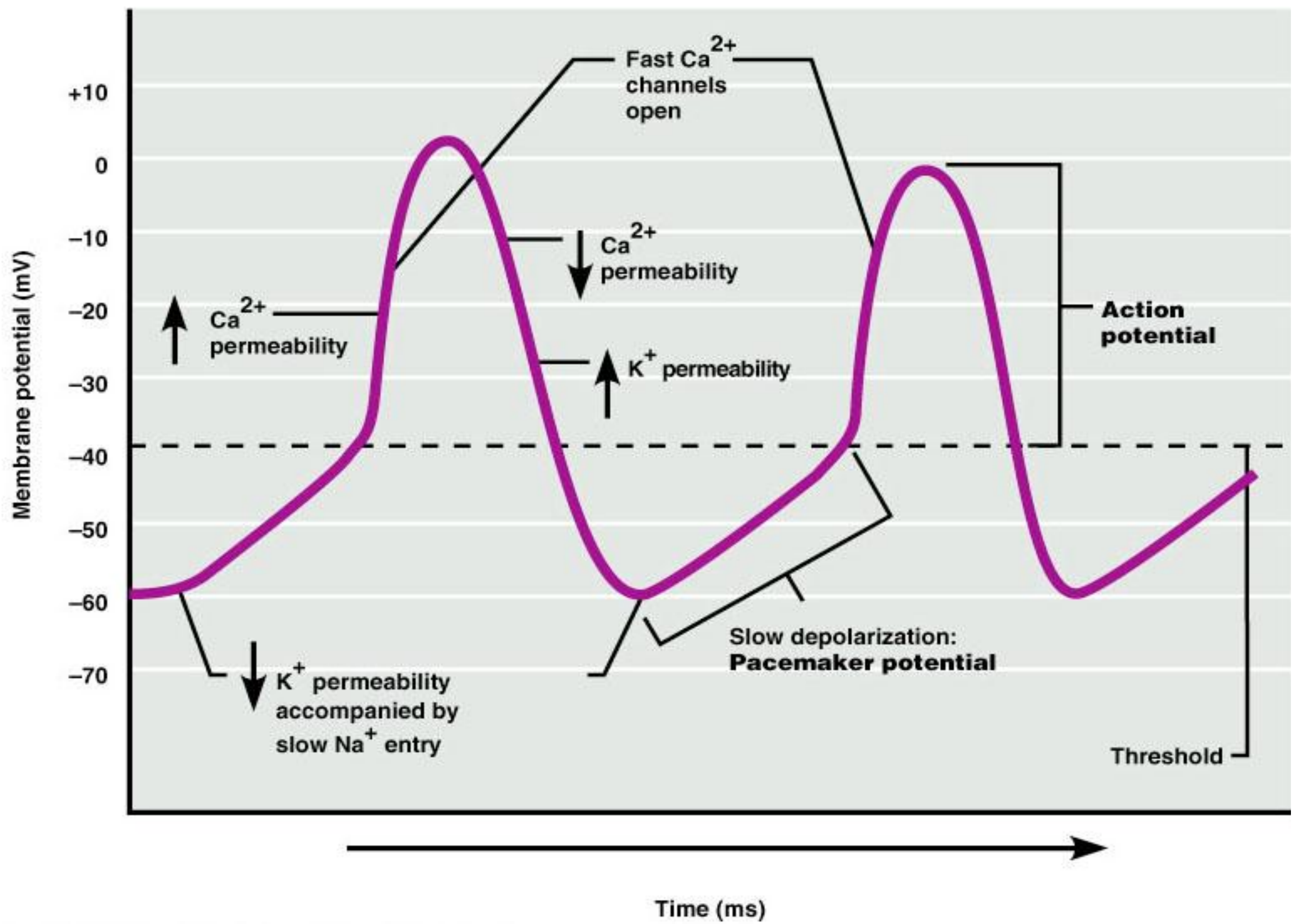
(b) Pacemaker potentials and action potentials in autorhythmic fibers of SA node

20.10b

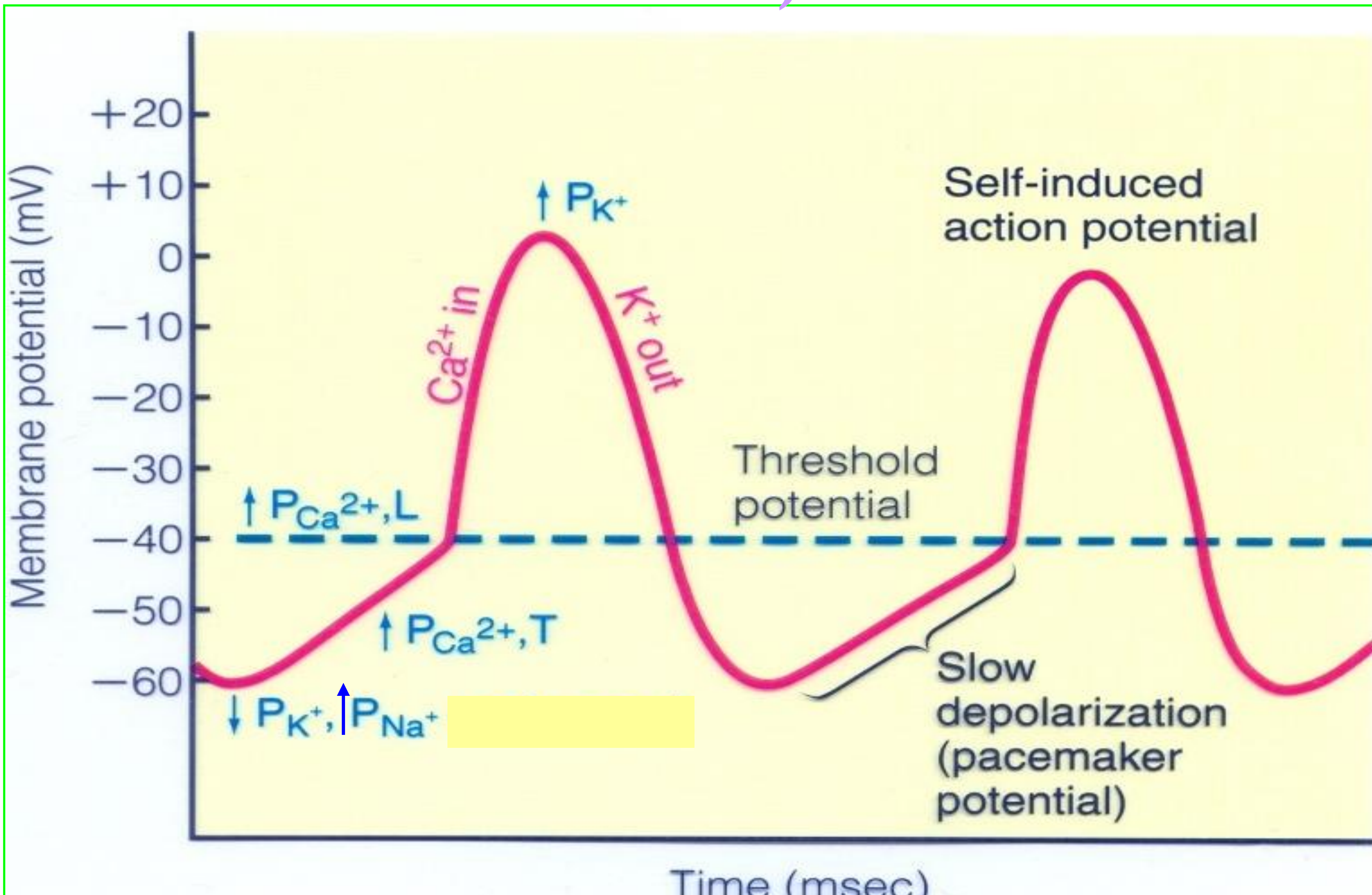
Fast Response Action Potential of Contractile Cardiac Muscle Cell



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

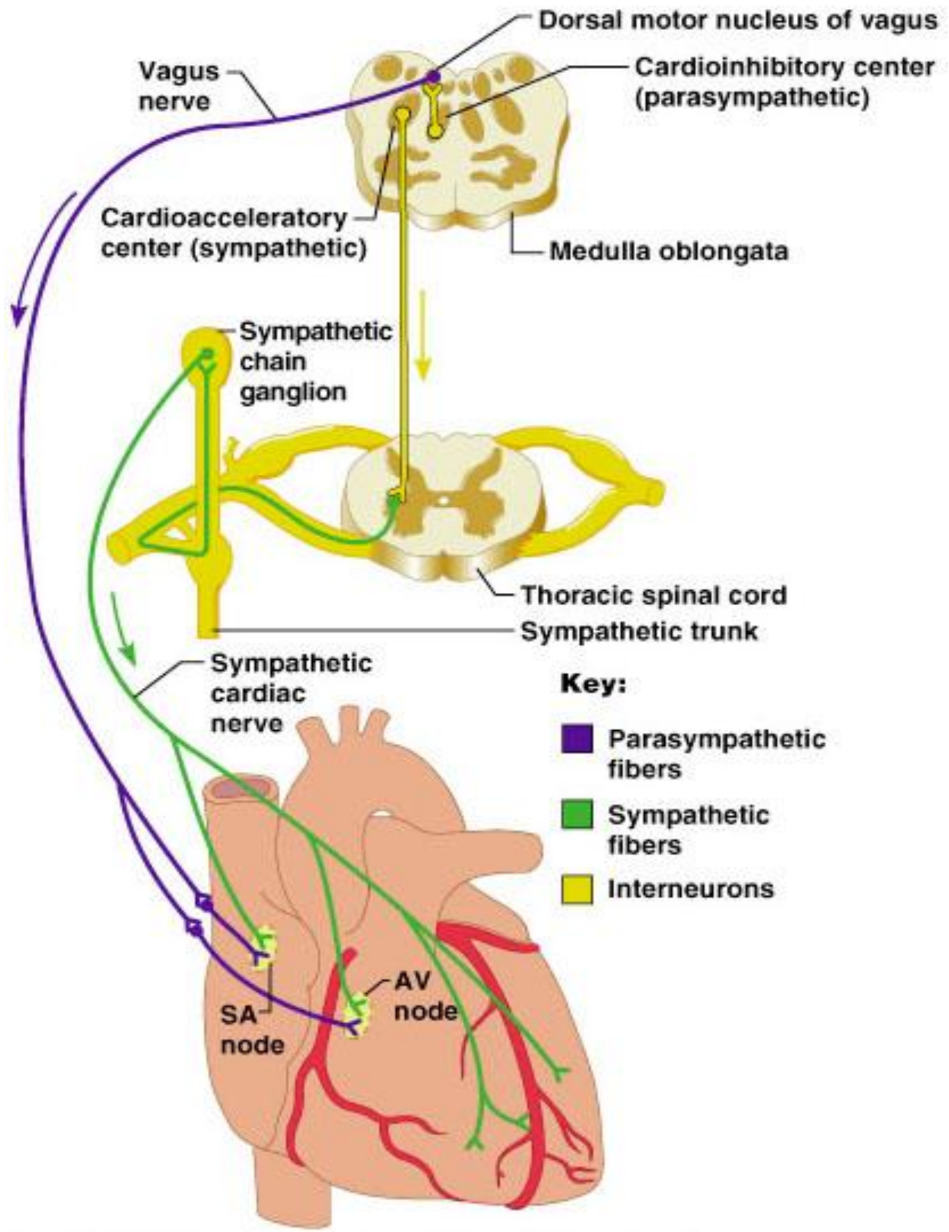
Conduction Speed

- 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***

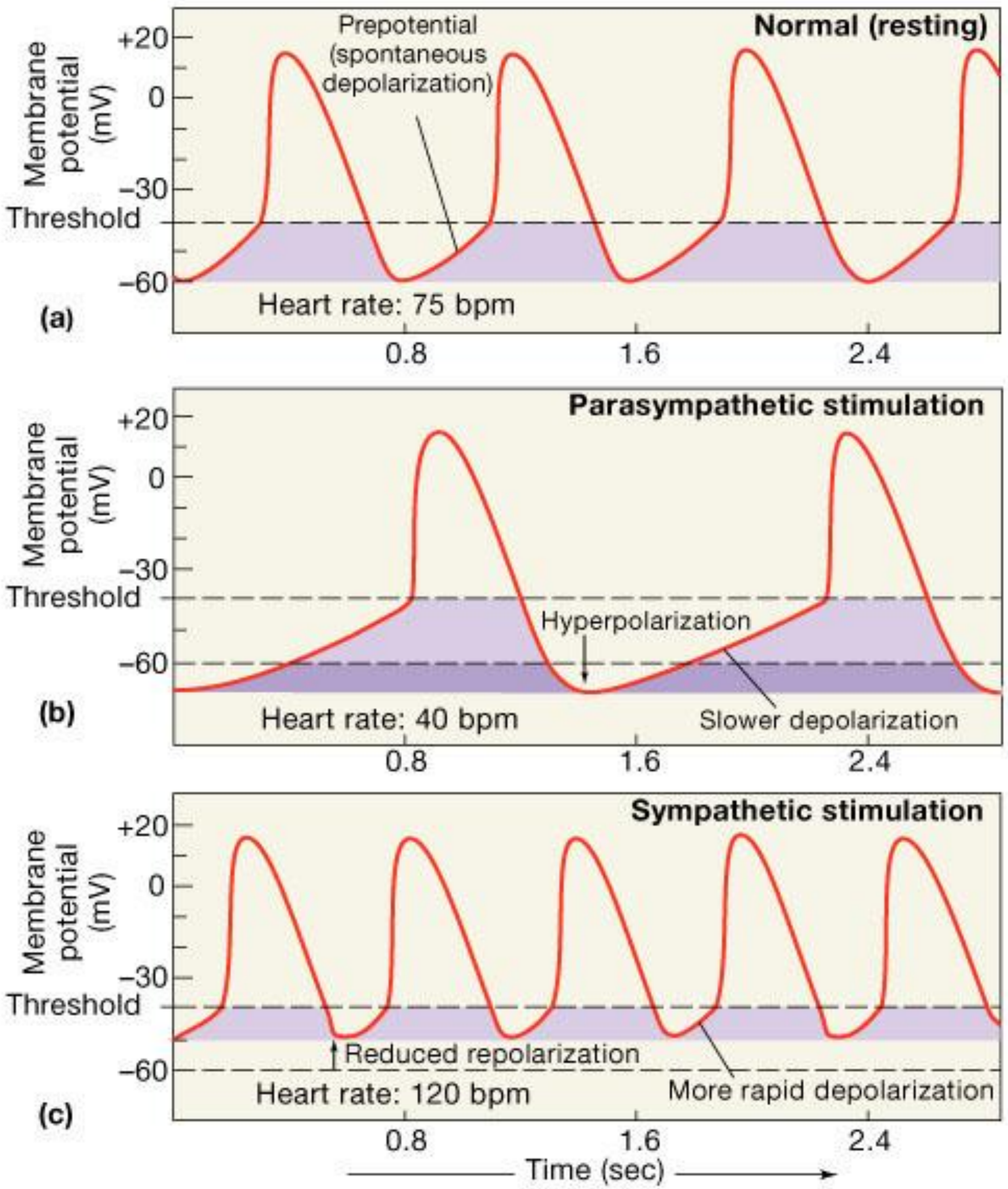
Extrinsic Innervation of the Heart

- **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



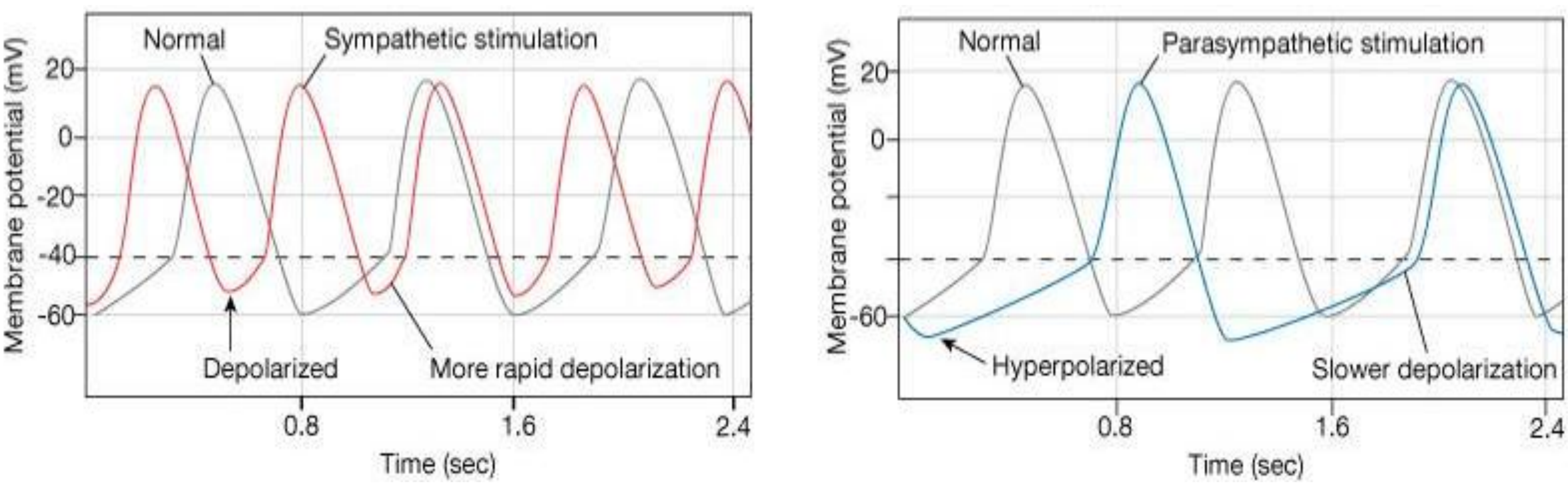
Pacemaker Function



Autonomic neurotransmitters affect ion flow to change rate

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

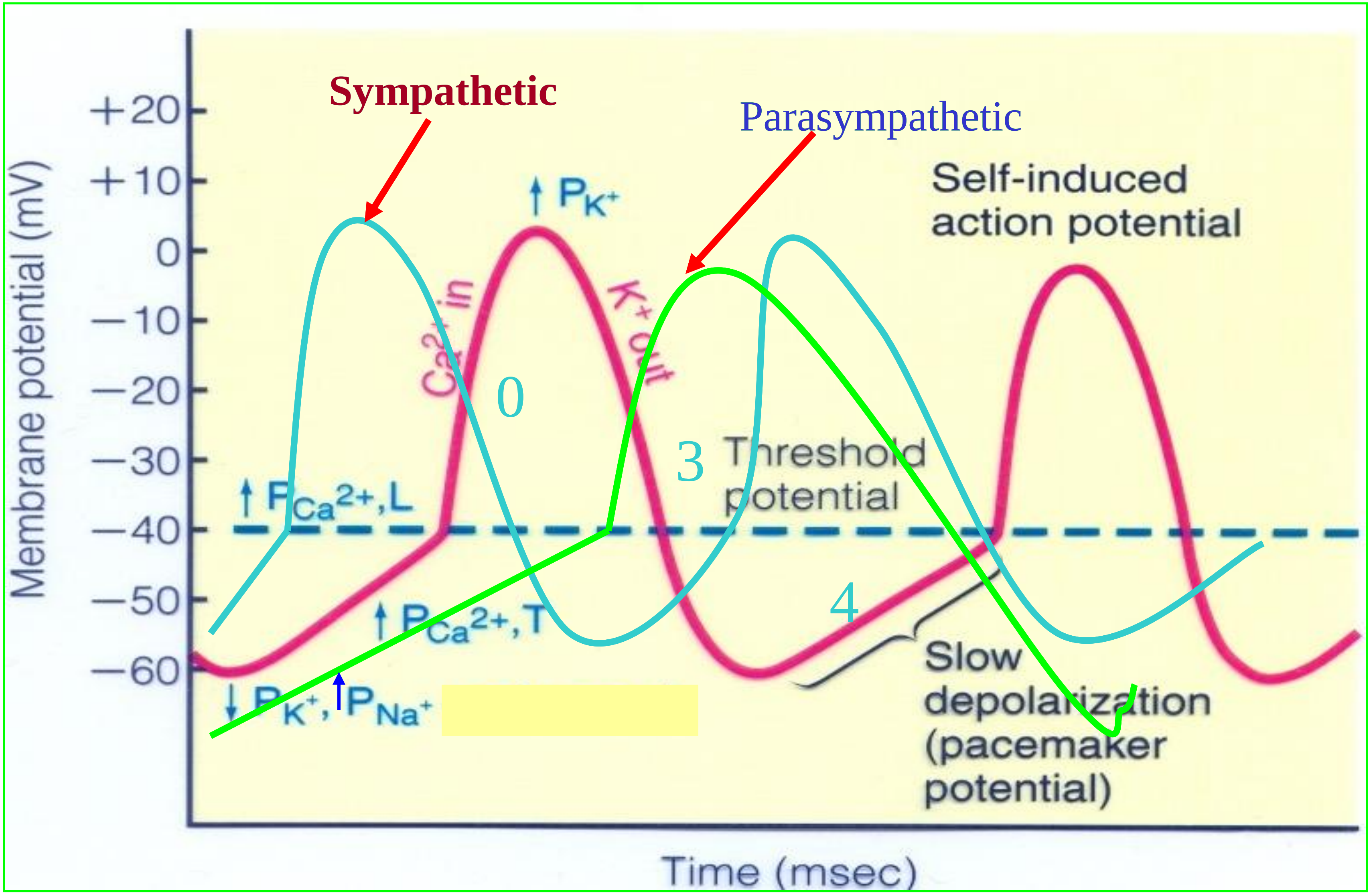
What part of the graph is <u>not</u> changed by autonomic influences?



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

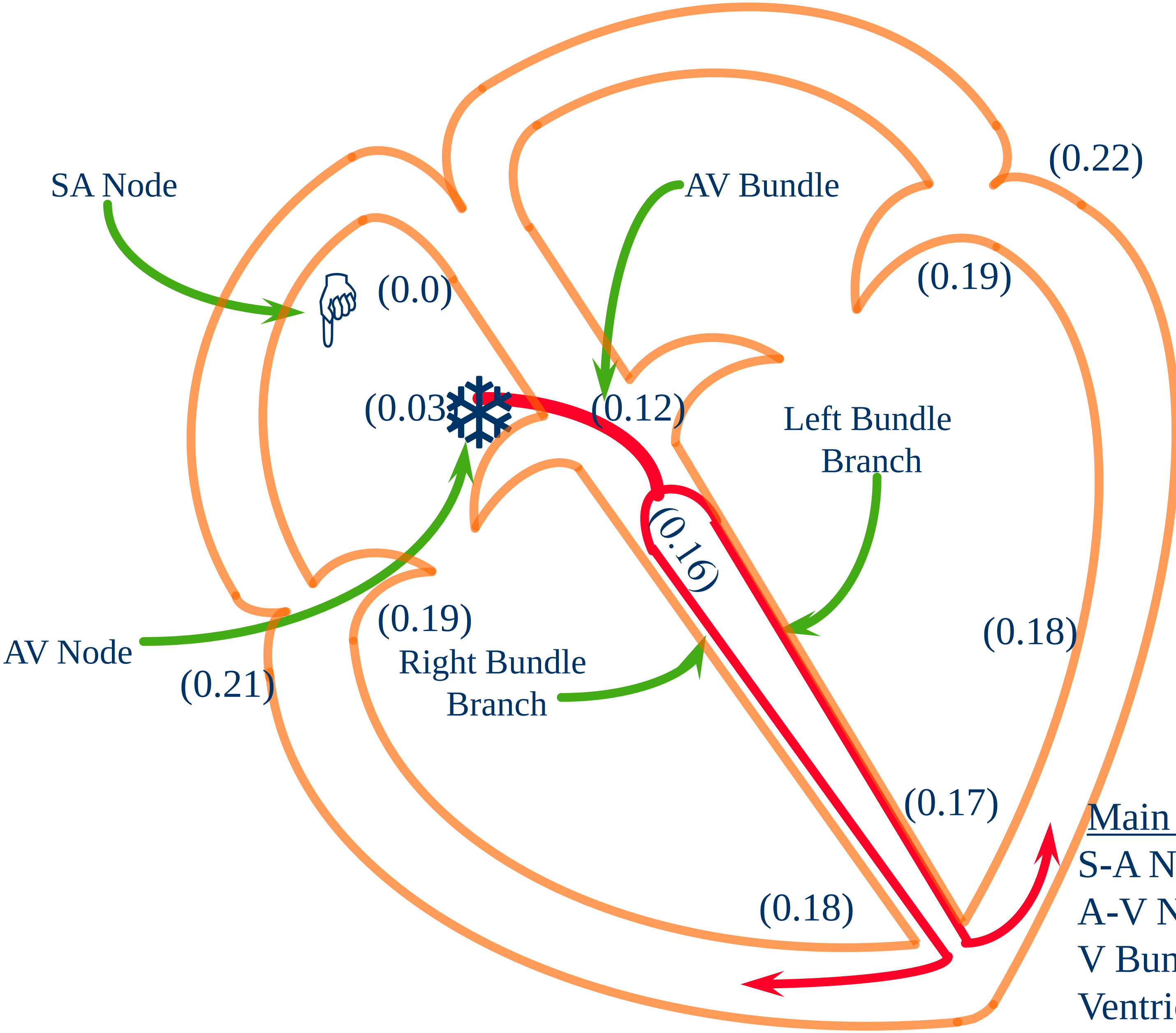
Effect of Sympathetic & Parasympathetic Stimulation



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 Na^{+} and Ca^{++} i.e Positive Chronotropic and positive Inotropic action
- Parasympathetic: Increase the permeability of the cardiac cells to K^{+} and decrease its permeability to Na^{+} and Ca^{++}
- Negative Chronotropic effect and ?? Inotropic effcet
- Ventricular Escape and Overdrive suppression-

Time of Arrival of Cardiac Impulse



<u>Main Arrival Times</u>

S-A Node 0.00 sec

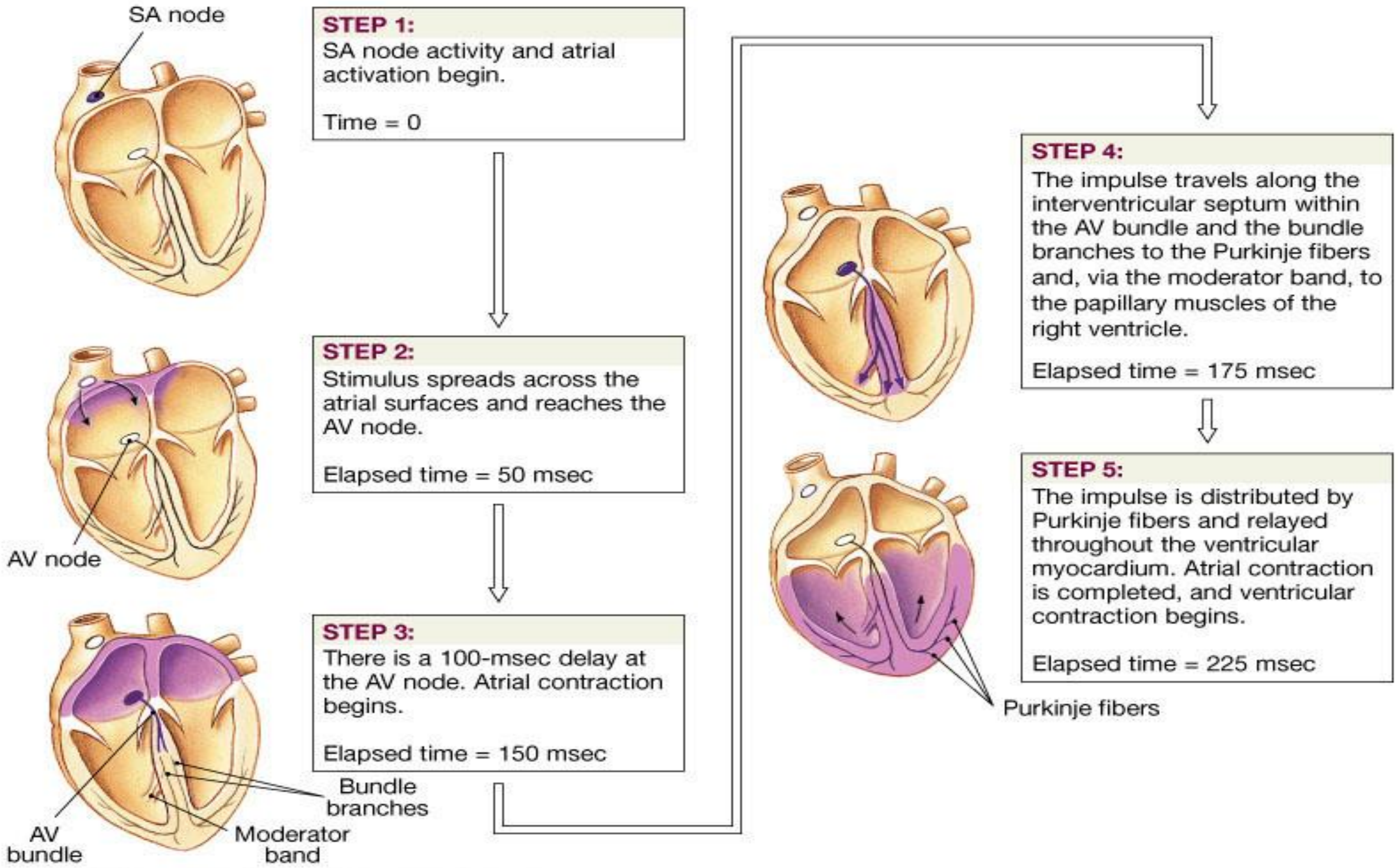
A-V Node 0.03 sec A-

V Bundle 0.12 sec

Ventricular

Septum 0.16 sec

Impulse Conduction through the Heart



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