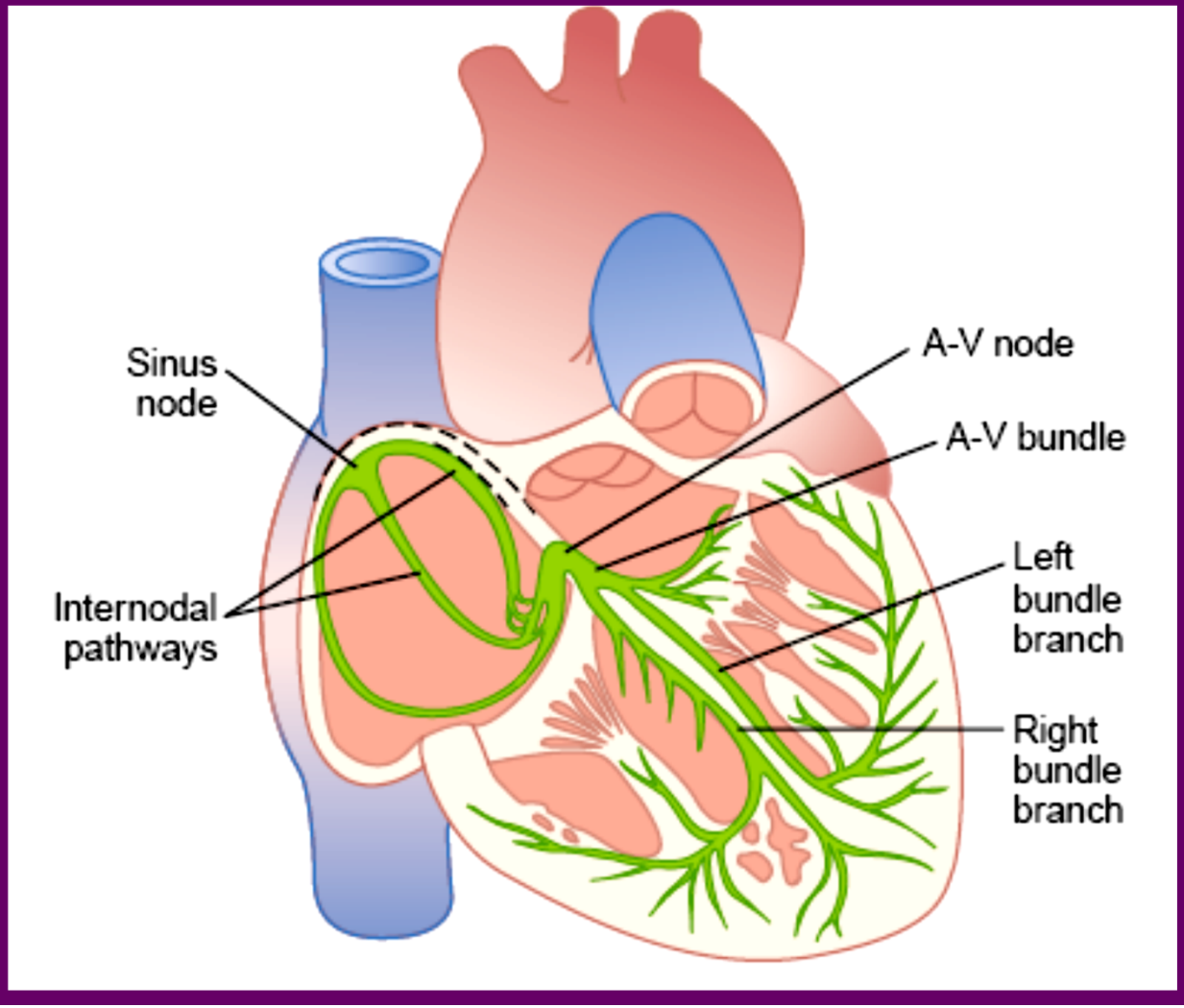
CARDIO-VASCULAR SYSTEM

- Dr. Chetna Ramanuj



PROPERTIES OF CARDIAC MUSCLE

- **Excitability**
- **Contractility and Distensibility**
    - **a) All or none law**
    - **b) Treppe or Staircase phenomenon**
    - **c) Refractory Period**
- **Automaticity**
- **Rhythmicity**
- **Coductivity**
- **Tonicity**

- **Excitability (bathmotropism)**
- **Contractility (inotropism)**
- **Conductivity (dromotropism)**
- **Rhythmicity (chronotropism)**

RHYTHMICITY:

- This is the most important property of the cardiac muscle. The generation of impulse is regular.

- This spacing of impulse generation and transmission is important as it results in regular sequential contractile phenomenon of cardiac muscle

Rhythmicity:

- Every part of the heart shows rhythmicity but its frequency is as follows:
  1. S.A. Node: 70-80/min. Highest rhythmicity
  2. A.V. Node: 40-60/min.
  3. Ventricular muscle: 20-40/min.

- Normal heart rate is about 60-80/min.
- The impulse is generated at the S.A. Node. This is called the "Sinus Rhythm"

AUTOMATICITY:

It is the capability of cardiac muscle to generate propagated action potentials spontaneously.

Nearly all the cardiac muscles have this inherent property. But in normal healthy individuals, this is manifested only in S.A.Node.

Heart can generate its own rhythm even when denervated

Differences in Action Potential:

Two main types of action potentials are observed in the heart.

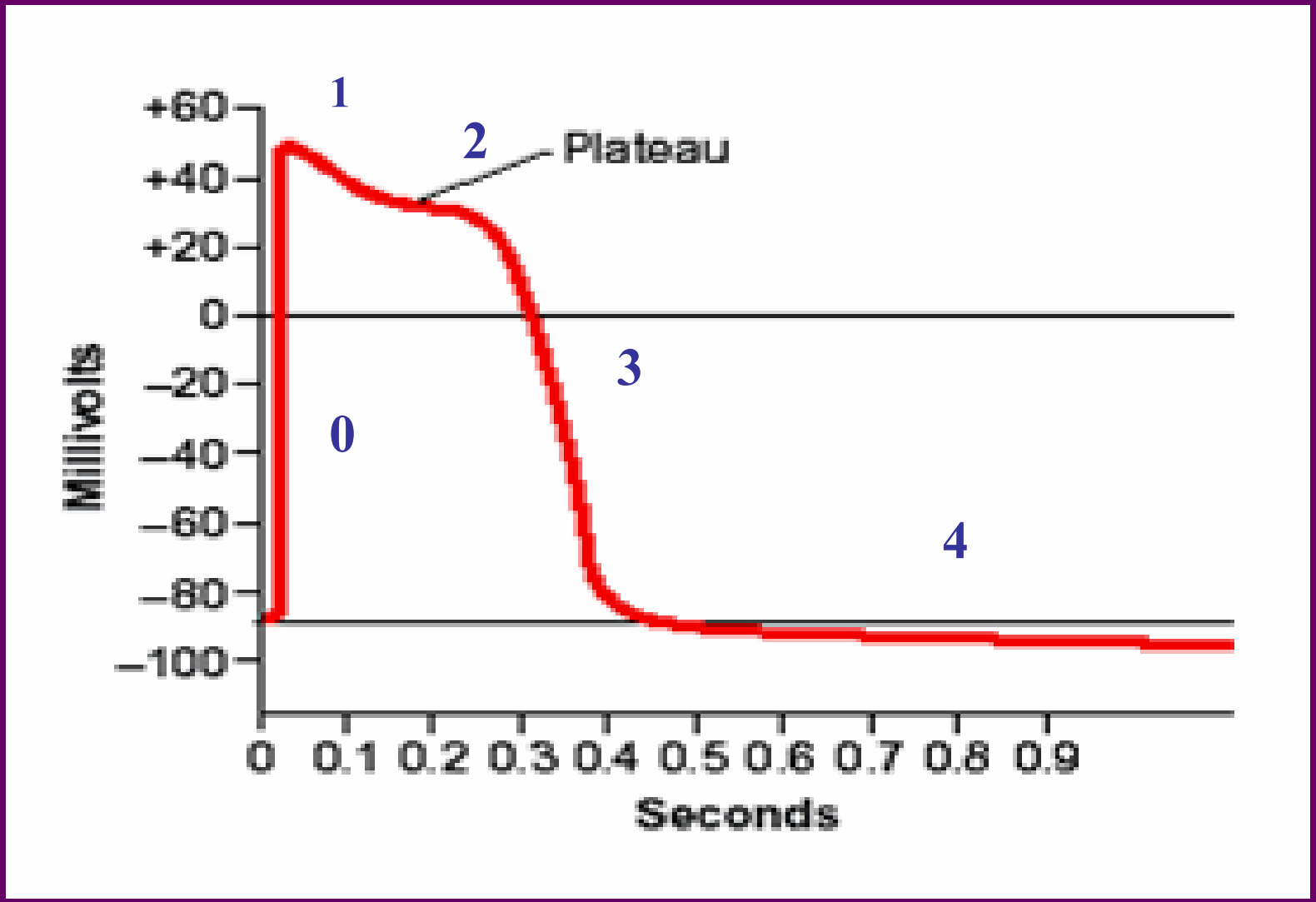
1. Fast Response:

   In normal myocardial fibers and Purkinje fibers

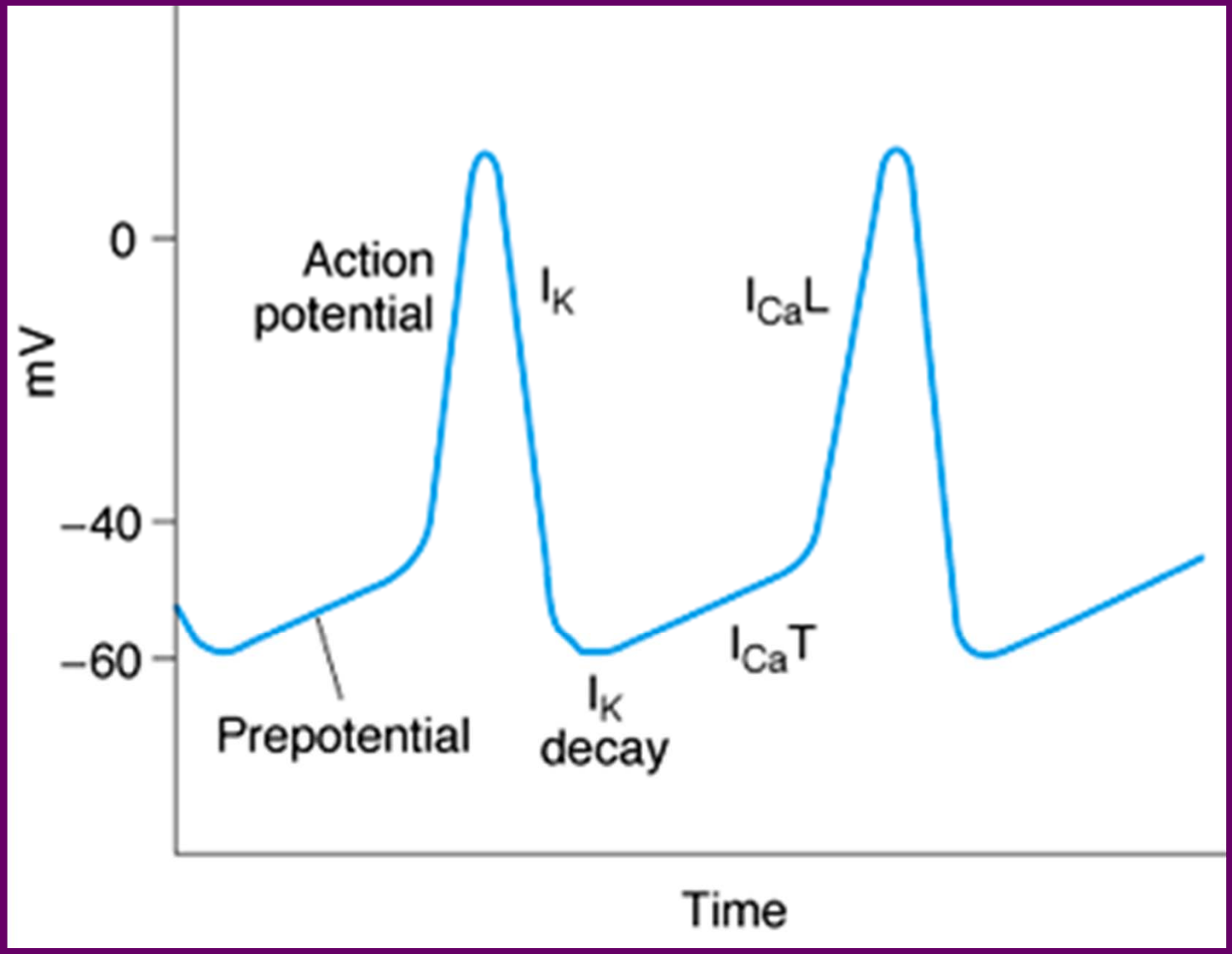
2. Slow Response:

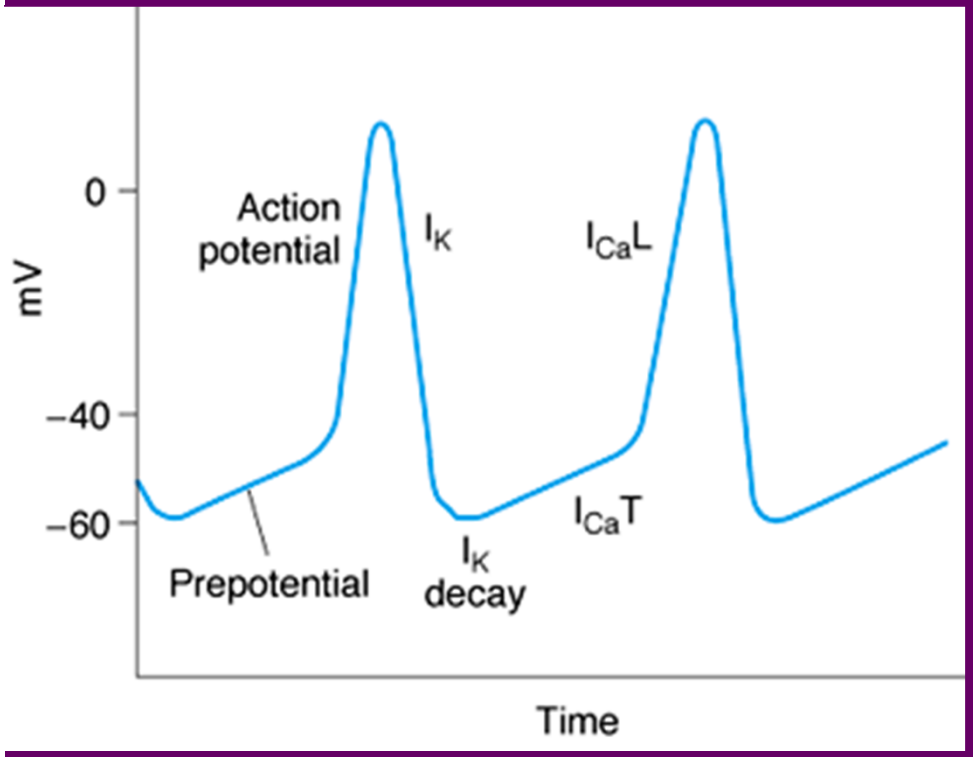
   In SA Node, AV Node

1. Fast Response Type:

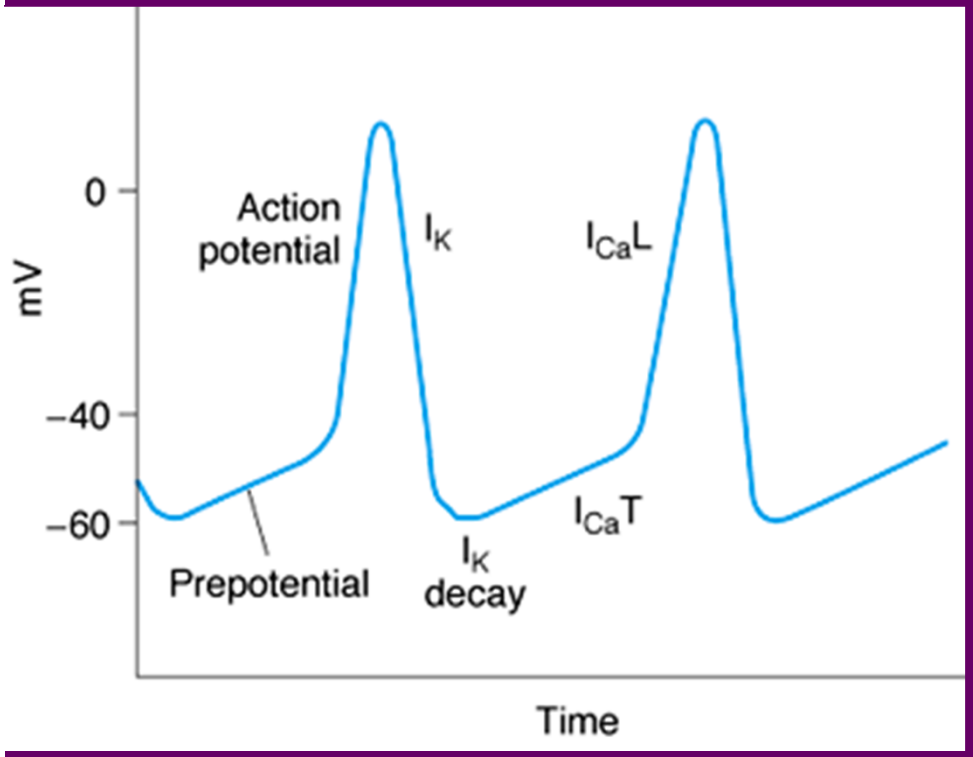


2. Slow Response Type:





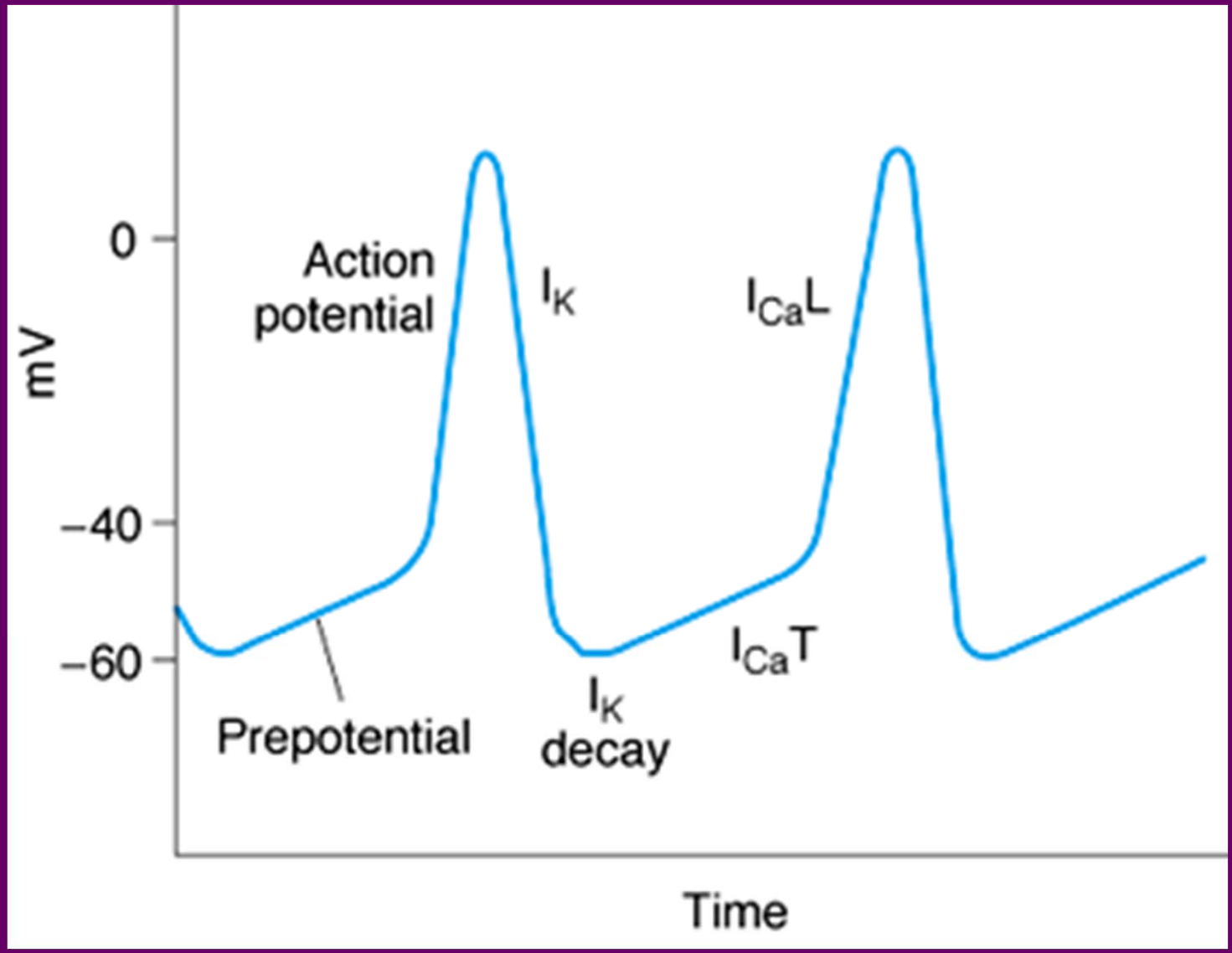
Potential of the SA Nodal fibers between the discharges has a negativity of only -55 to -60 mv as compared to -85 to -95 mv for ventricular muscle fiber. Because cell membranes of SA Nodal fibers are NATURALLY LEAKY to Na^+ ions.



At this level of negativity of -55 mv, the "Fast" Na+ channels are closed and only "Slow" Ca++-Na+ channels are opened.

Therefore, threshold for discharge -40 mv is reached by the entry of Ca++ and Na+ through these slow channels.

So, they cause the action potential in SA Node and AV Node. But, in SA Node, action potential is slower to develop.


0
−40
−60
mV
Action potential
I_K
$I_{Ca}L$
$I_{Ca}T$
Prepotential
I_K decay
Time

From the graph, we can make out that in case of SA Nodal fibers, the negativity is gradually reducing during each beat. Hence, at the completion of the previous beat, the potential in the SA Nodal fiber has already reached the level of -40 i.e. the threshold for firing. This causes the self-excitation of the SA Nodal fiber at the end of each cycle and this cycle continues.

All the cardiac cell types shows this intrinsic capability of self-excitation. But, discharge rate of SA Node is highest, so, SA Node controls the heart's rhythmicity and known as the "PACE-MAKER OF THE HEART"

WHY the leaky Na^+ channels do not cause SA Node to remain depolarized all the time?

Because:

1. Inactivation of Ca^{++} - Na^+ channels after some time
2. Efflux of K^+ causing “Hyperpolarization”

Cause of pacemaker potential:

- SA Node is supplied by vagus nerve and a few sympathetic fibers. This exerts tonic action on SA Nodal fibers and initiates or generate the impulse. But they are not essential because:

- The cell membranes of the SA Nodal fibers are NATURALLY LEAKY to Na^+ ions, that is, resting nodal fibers have a moderate number of channels that are already open to Na^+ ions.

- Therefore, RMP is -55 mv (as a result of leaky channels which leaks Na^+ ions that reduces the negativity inside the cell.)

CONDUCTING SYSTEM OF HEART

ASSOCIATED WITH INITIATION AND

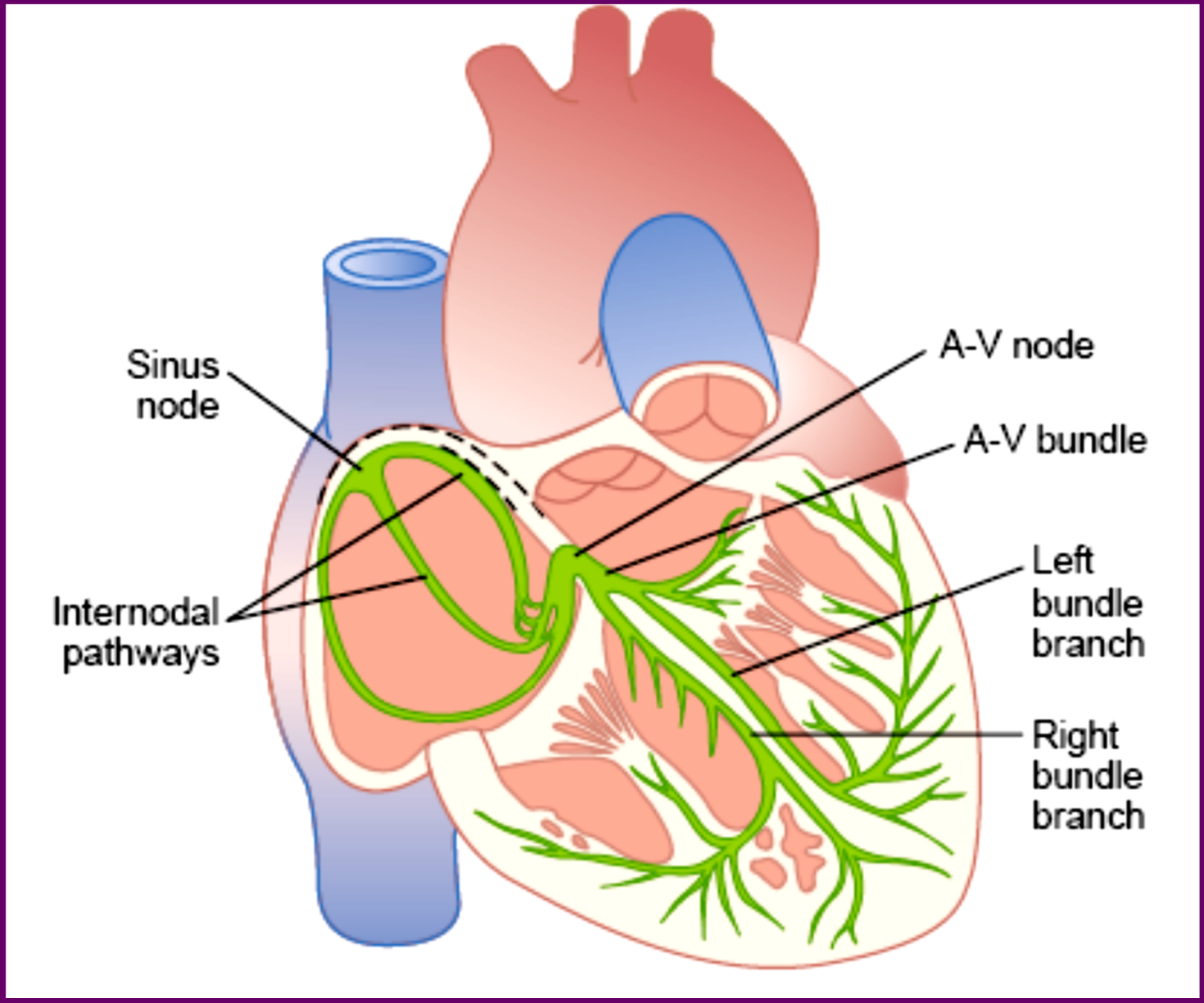
SPREAD OF CARDIAC IMPULSE

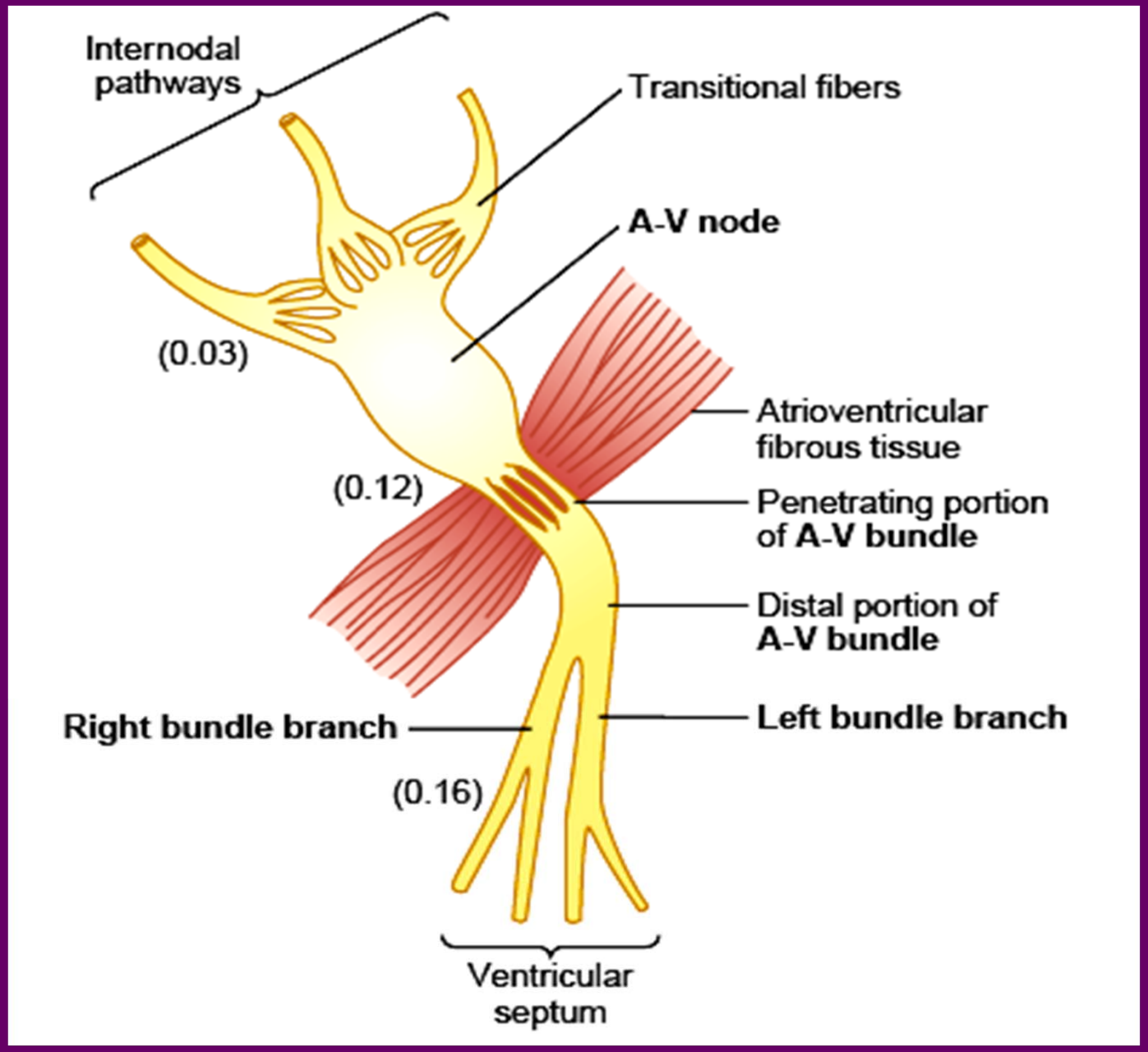
Special junctional tissues of the heart (Conducting system)

The specialized tissues include:

1. Sinus node / Sino- Atrial (S.A.) Node
2. Inter-nodal pathways from S.A. Node to A.V. Node
3. Atrio-Ventricular (A.V.) Node
4. Atrio-Ventricular (A.V.) Bundle/ Bundle of HIS with its right and left branches
5. Purkinje Fibers

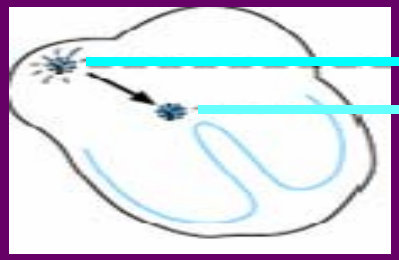
CONDUCTING SYSTEM OF THE HEART



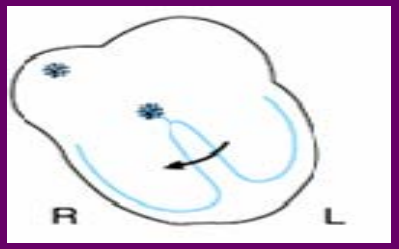

Internodal pathways
Transitional fibers
A-V node
(0.03)
Atrioventricular fibrous tissue
(0.12)
Penetrating portion of A-V bundle
Distal portion of A-V bundle
Right bundle branch
Left bundle branch
(0.16)
Ventricular septum

Conductive system

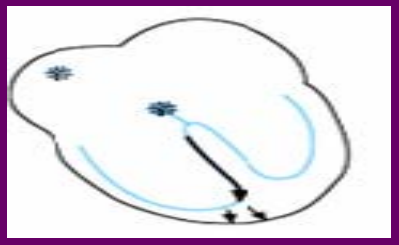
Tissue	Rate of generation of impulse (/s)	conduction rate (m/s)
SA node	72 (highest due to steepest pacemaker potential that's why is pacemaker)	0.05
Atrial pathways		1
AV node	40-60	0.04
Bundle of His	40	1
Purkinje system	24	4
Ventricular & Atrial muscle	Only when diseased or injured	1



Atrial activation



Septal activation from left to right



Activation of anteroseptal region of ventricular myocardium

Activation of major portion of ventricular myocardium from endocardial surfaces

Late activation of posterolateral portion of left ventricle and the pulmonary conus

Law of Cardiac muscles:

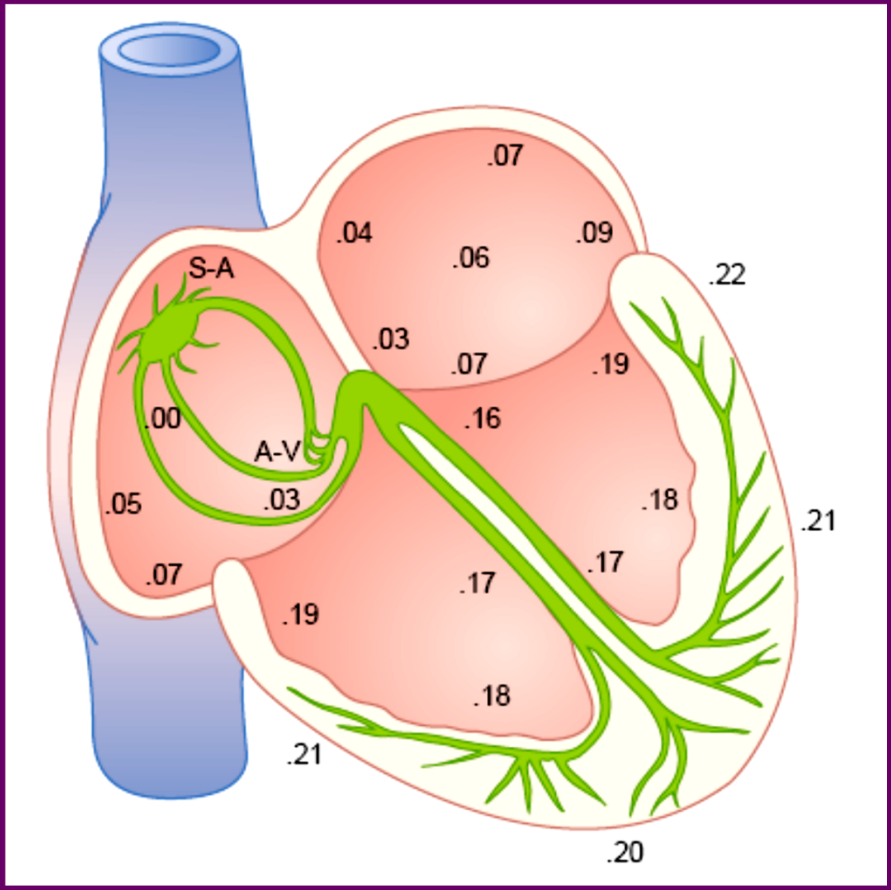
“The rate of conduction increases with the size of fibers and glycogen content”

SPREAD OF WAVE OF DE AND REPOLARIZATION

First part in heart to get depolarized	atria
First part in ventricle to get depolarized	Inter ventricular septum from left to right
Next in ventricle to get depolarized	Apex or anteroseptal part of V. myocardium (endo to epi)
Last part in ventricle to get depolarized	1- base of lt V., 2- pulmonary conus, 3- top of IV septa
First part in ventricle to get repolarized	apical epicardial surface

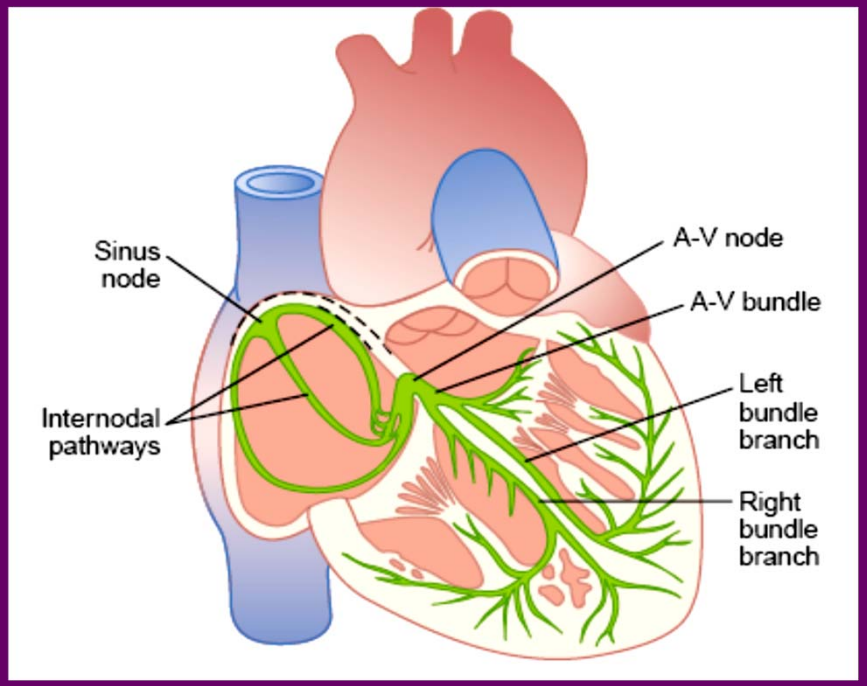
Time taken by impulse to travel

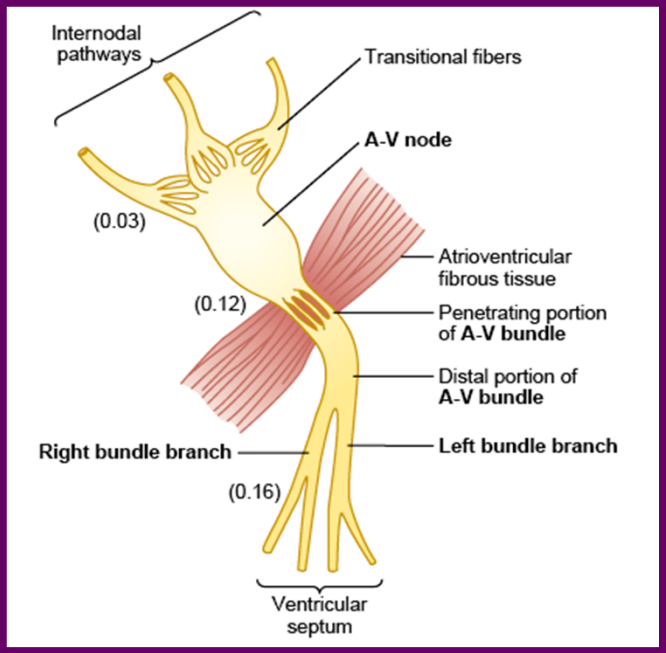
Whole heart	.22 secs
Whole atria	.1 secs
AV node/delay	.1 secs
Whole ventricle	.1 secs



CHARACTERISTIC OF PATHWAY

AV delay	ensure atria depolarizes & contract before v. (lead better filling of v.)
AV conduction	one way & maximum up to 230/mt
high speed of AP in Purkinje	allow simultaneous depolarization & contraction of whole v.



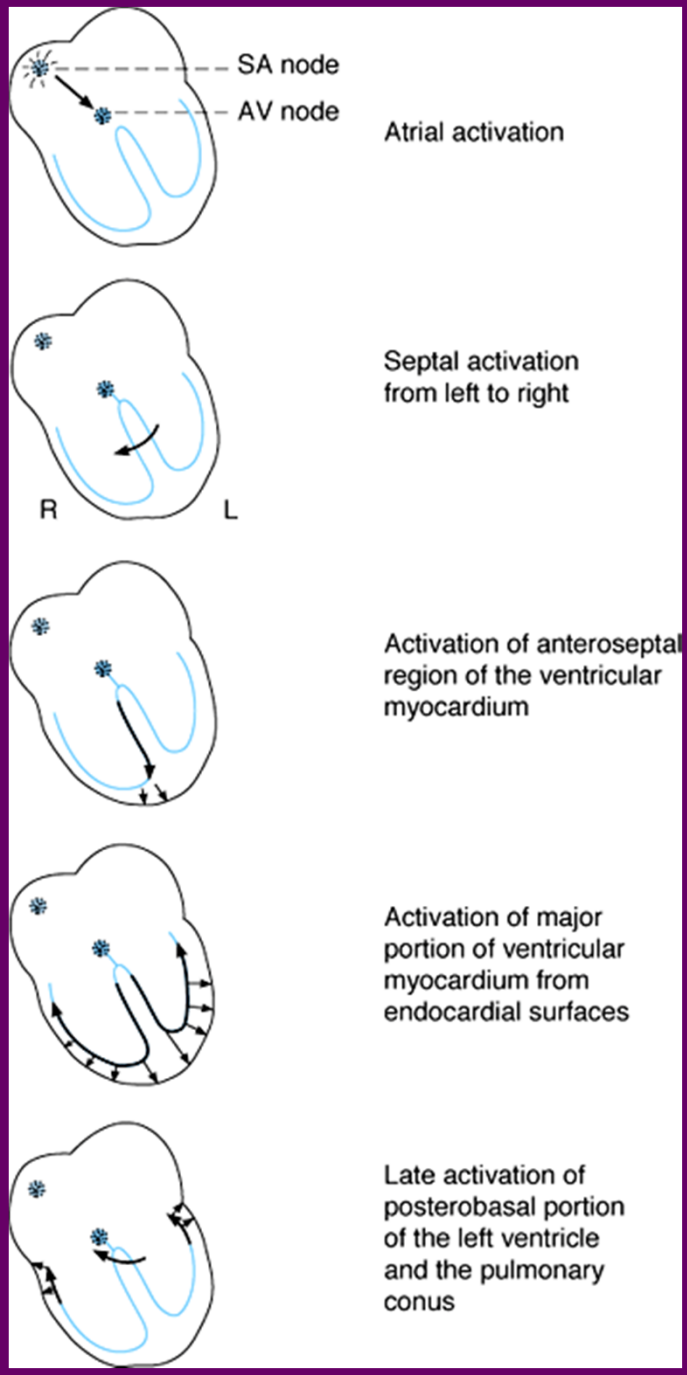


Conduction rate in m/sec

SA node	0.05
Atrial pathways	1
AV node	0.05 (less gap junctions/diameter)
Bundle of His	1
Purkinje system	4 (more gap junctions/diameter)
Ventricular muscle	1

Spread of wave of depolarization in different parts of heart

First part in heart to get depolarized	atria
First part in ventricle to get depolarized	Inter ventricular septum from left to right
Next in ventricle to get depolarized	Apex or anteroseptal part of V. myocardium
Last part in ventricle to get depolarized	1- base of lt V. 2- pulmonary conus 3- base of IV septa



1. S.A. Node:

Location:

Superolateral wall of right atrium, immediately below and lateral to the opening of superior vena cava

Dimensions:

3 mm wide x 15 mm long x 1 mm thick

1. S.A. Node:

Structure:

- Thin, elongated and fusiform muscle fibers
- Muscle fibers are smaller in diameter than those of cardiac muscles
- Nerve cells and post-ganglionic fibers of parasympathatic (vagus) and sympathetic are also present
- Presence of a distinctive cell type known as “P” cells, related to pace-maker activityhas been hypothesized (not confirmed) - 3.5 μ in diameter
- They also contain certain transition cell – 5-10 μ in diameter

1. S.A. Node:

Functions:

- Impulse normally onset in S.A. node
- S.A. node is the PACE MAKER of the heart because its rate of rhythmical discharge is greater than that of any other part of the heart
- Sinus rhythm: 60-80 / min.
- Control the heart rate and decrease or increase the heart rate on various physiological and pathological factors
- Regulated by ANS, hormones like adrenalin, nor adrenalin, thyroxin

1. S.A. Node:

Applied physiology of S.A. node:

1. **Sinus arrest:**
   In this condition, S.A. node fail to initiate the impulse, so, ECG records straight line. After some time, other pace maker tissue initiate the impulses.

2. **S.A. Block:**
   S.A. node initiate the rhythm but fail to propagate from atria to ventricle.

3. **Sick Sinus Syndrome (SSS) or Brady cardia, Tachy cardia:**
   In this condition, S.A. node alternatively generate slow and fast rhythm.

- **In majority of the disorders of the S.A. node, Artificial Pace-maker is required.**

2. INTER-NODAL PATHWAYS

- Inter-nodal pathways are conduction paths for the impulses from S.A. node to A.V. node and left atrium
- They are 3 in numbers

1. Anterior Inter-nodal track: gives one branch going to left atrium- known as “BACHMANN’S BUNDLE”

2. Middle Inter-nodal Track: also known as “WENCKEBACH’S BUNDLE”

3. Posterior Inter-nodal Track: causes rapid conduction. Also known as “THOREL’S TRACK”

3. A.V. Node:

Location:

Posterior septal wall of right atrium, immediately behind the tricuspid valve and adjacent to the opening of coronary sinus.

Dimensions:

10 mm wide x 22 mm long x 3 mm thick

Structure:

Muscle fibers are smaller in diameter than those of cardiac muscles

3. A.V. Node:

Functions:

- It receives impulses from S.A. node and transmits them to ventricles
- Delay in transmission of impulses from atria to ventricles takes place in the A.V. node. Because of the delay, atria contracts ahead of ventricles before ventricular contractions occurs.
- It can also generate its own impulses, but at the slower rate of 40-60 / min. it is known as “NODAL RHYTHM”

3. A.V. Node:

Applied physiology of A.V. node:

Definition:

"Impulses generated in the atria fail to be transmitted to ventricle partly or completely is known as "A.V. Block"

A.V. Block: → Incomplete

→ Complete

I Degree
II Degree } Incomplete

III Degree → Complete

3. A.V. Node:

Applied physiology of A.V. node:

A.V. Block:

I Degree: In this condition, there is a prolonged PR interval more than 0.12 sec. to 0.20 sec.

II Degree: In this condition, some sinus impulses are conducted to ventricle while others are not conducted to ventricles.

III Degree: Sinus impulses totally fail to be conducted to ventricle. This condition is also known as "Complete Heart Block". There is complete A.V. Dissociation.

- When there is II and III degree heart block, the treatment is Artificial Pace-maker

4. A.V. BUNDLE / BUNDLE OF HIS AND ITS BRANCHES

- Discovered by “HIS”
- From the A.V. node, Bundle of HIS arises and then soon bifurcates in to right and left branches
- Right bundle branch is smaller than left bundle branch
- Right bundle branch 1st makes contact with ventricular myocardium near the base of anterior papillary muscle
- Left bundle branch 1st makes contact with ventricular musculature on the left endocardial surface of the inter-ventricular septum, a little distance away from the aortic valve.

4. A.V. BUNDLE / BUNDLE OF HIS AND ITS BRANCHES

Applied physiology:

Blocking occurs as:

i) Right Bundle Branch Block (RBBB)

ii) Left Bundle Branch Block (LBBB)

iii) Right Arterial Hemi Block

iv) Left Arterial Hemi Block

5. PURKINJE SYSTEM OF FIBERS:

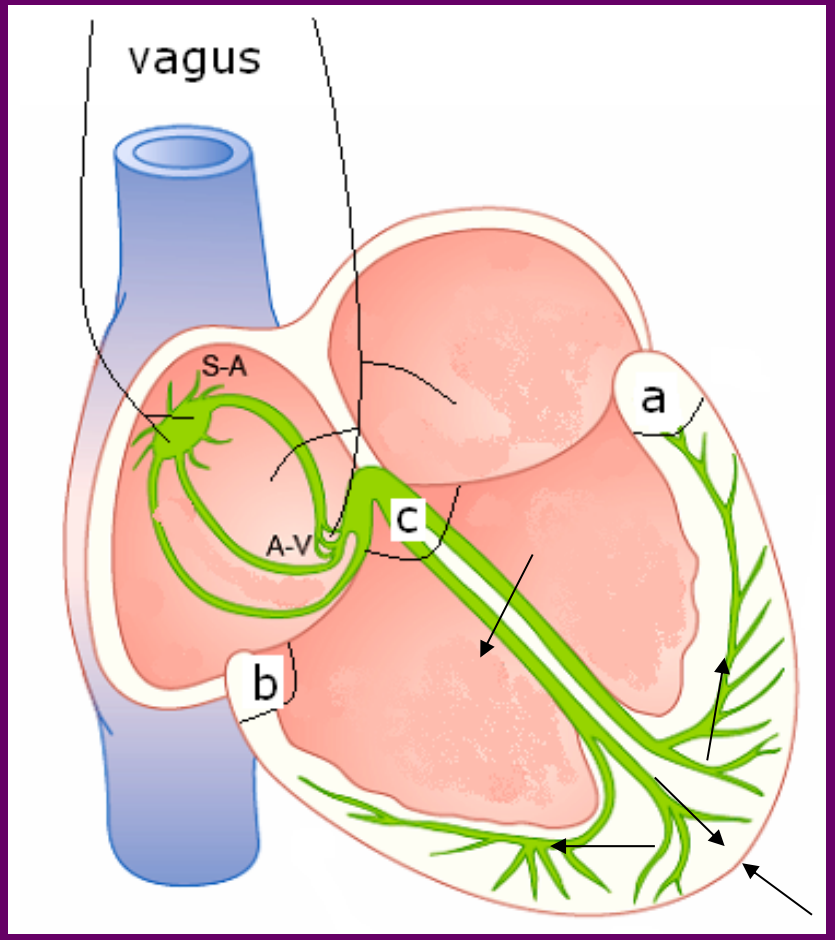
- Branches of bundle of HIS pass through the sub-endocardium and ultimately through the heart muscle- forming Purkinje Fibers.

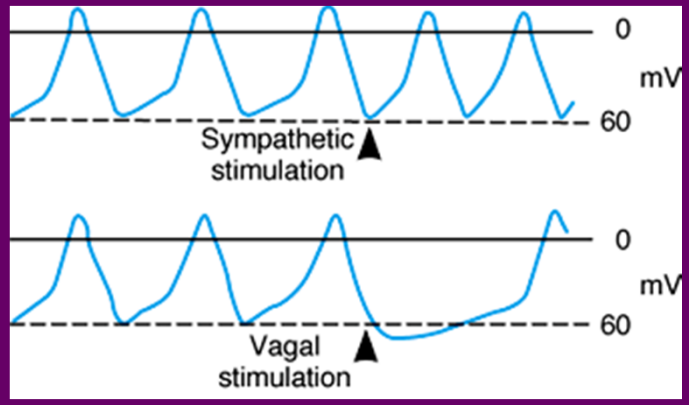
- These fibers penetrates for a short distance in to ventricular musculature before merging with them.

- Purkinje fibers are larger than the ventricular muscle fibers.

Summary of Conductive system

1-conduction rate (1, .05, 4 & .5 m/sec) 2-time taken by impulse (.22, .1, .1, .1 sec) 3- spread of wave of de/ repolarization 4- anatomy of SA & AV node





rate- 72/60/40/24 per mt.

DISCLAIMER

- All figures are taken from Guyton and Hall Textbook of Medical Physiology, 12th Edition.