CONDUCTING SYSTEM OF THE HEART

By

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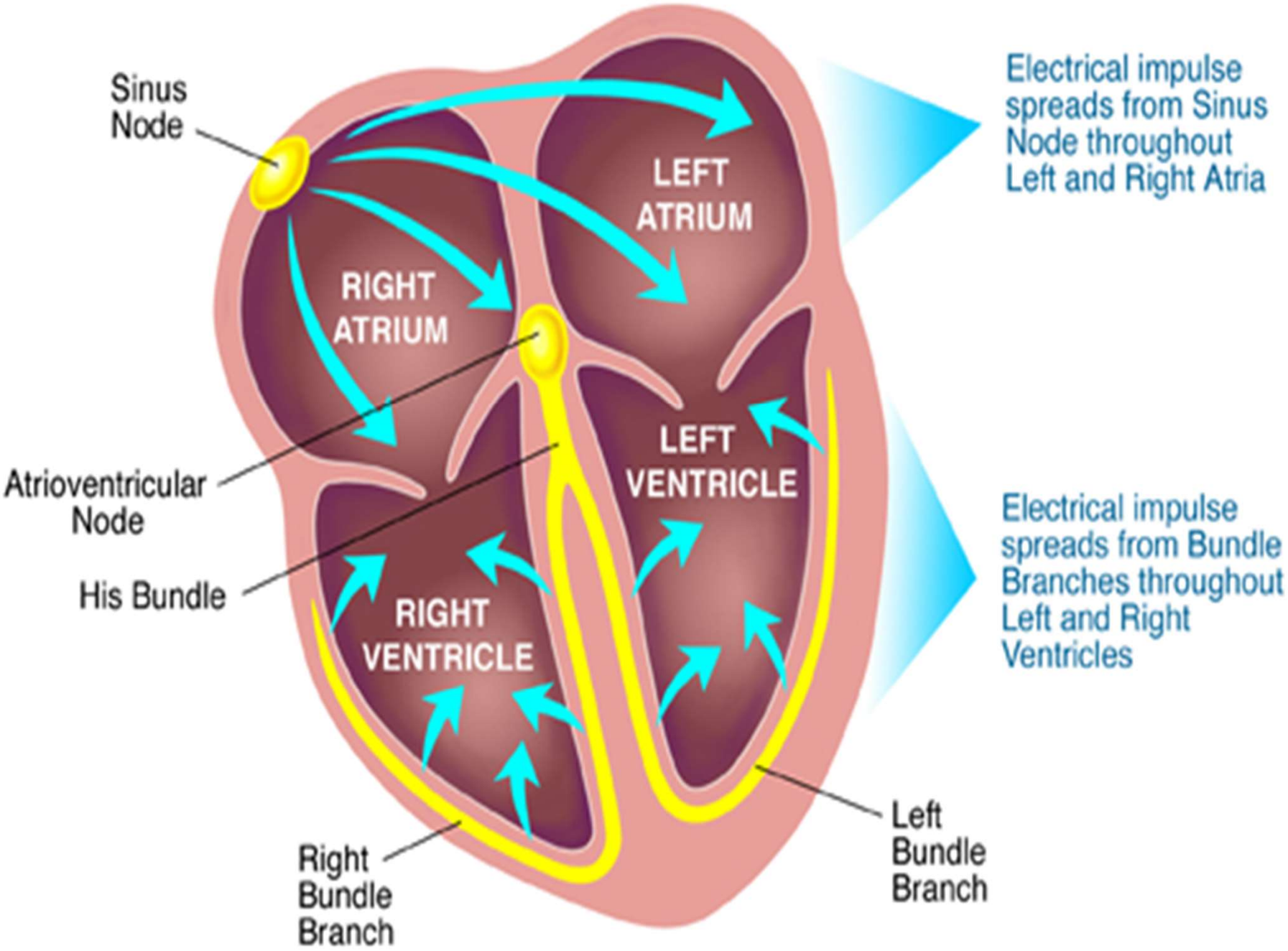
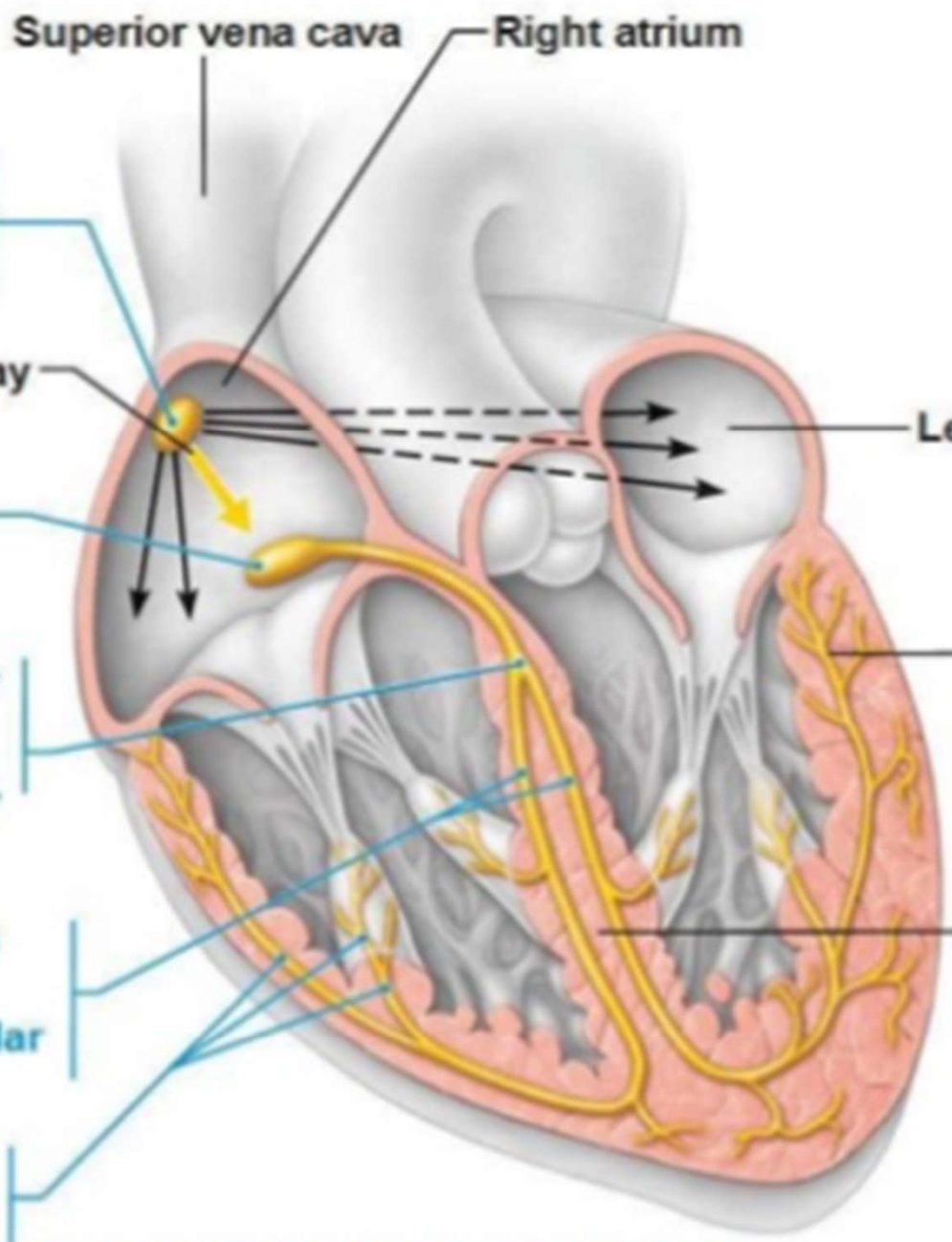
The conduction system of the heart



THE CONDUCTING SYSTEM

- The **heart** is able to contract on its own because it contains specialized cardiac **muscle tissue** that spontaneously forms impulses and transmits them to the myocardium to initiate contraction.

Conducting System, a series of Specialized Cardiac Muscle Cells



(1) The **sinoatrial (SA) node** (pacemaker) generates 70-80 impulses per minute; atria contract.

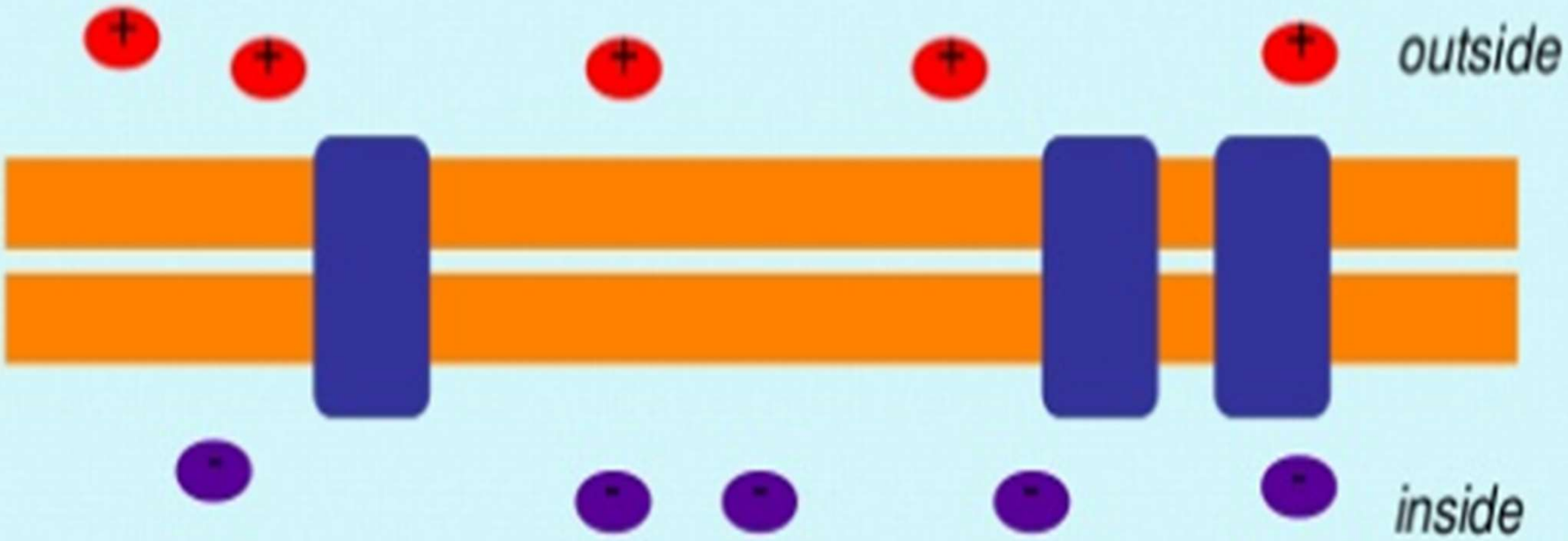
(2) The impulses pause (0.1 sec) at the **AV node so ventricles have time to fill.**

(3) The **atrioventricular (AV) bundle** connects the atria to the ventricles.

(4) The AV bundle branches conduct the impulses through the interventricular septum.

(5) The **Purkinje fibers** stimulate the contractile cells of both ventricles, starting at apex and moving superiorly.

The Resting Potential

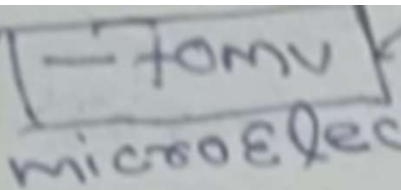


Resting potential of neuron = -70mV

TABLE 3-3

Concentration and Permeability of Ions Responsible for Membrane Potential in a Resting Nerve Cell

ION	CONCENTRATION (millimoles/liter)		RELATIVE PERMEABILITY
	Extracellular	Intracellular	
Na^+	150	15	1
K^+	5	150	50–75
A^-	0	65	0



potential.

Inside the cell there is negative charge.

Extracellular fluid

Intracellular fluid) (-70mv) — Potential difference of

Inside the cell there is

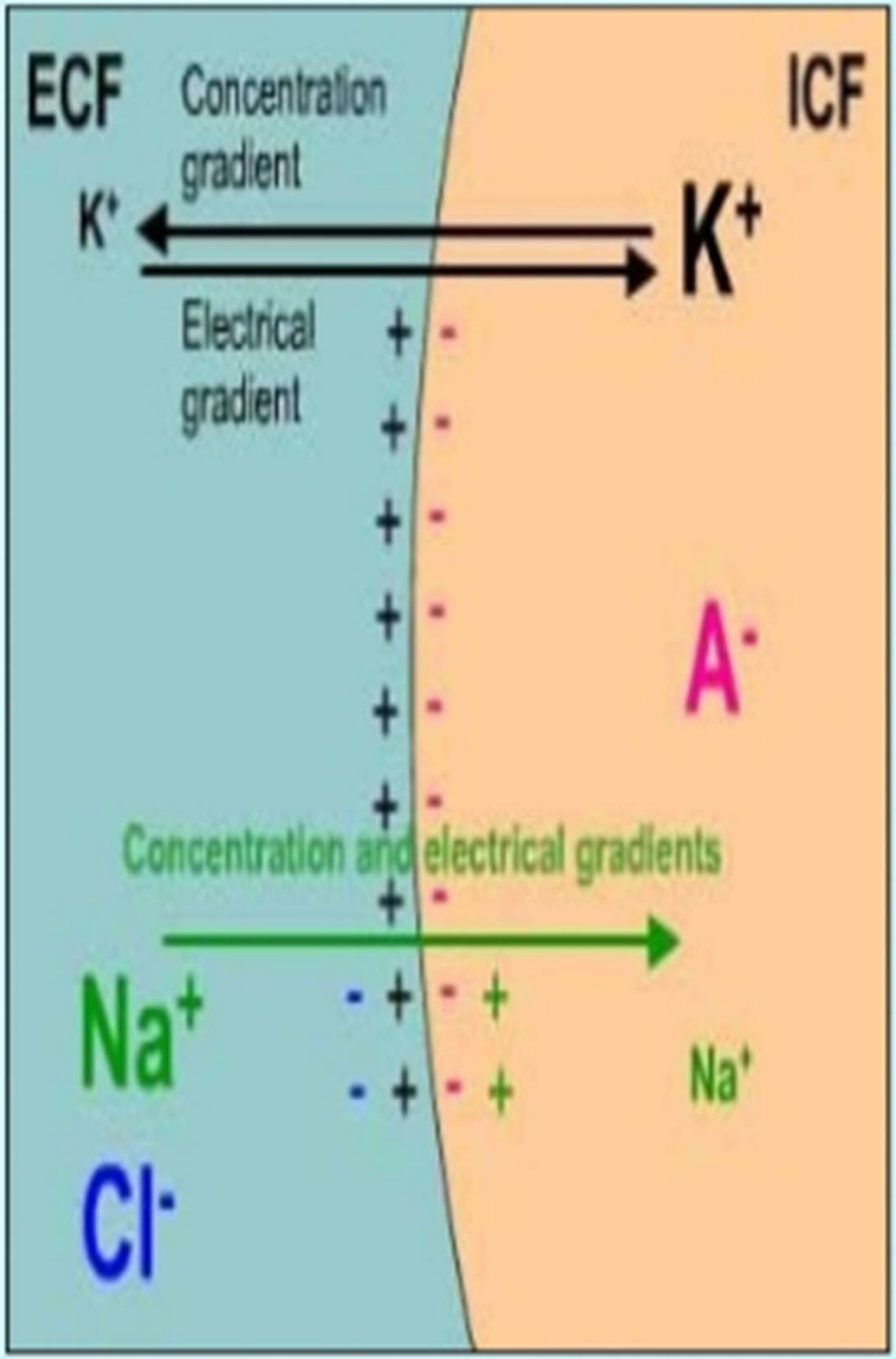
(1) Resting M Potential = -70mV

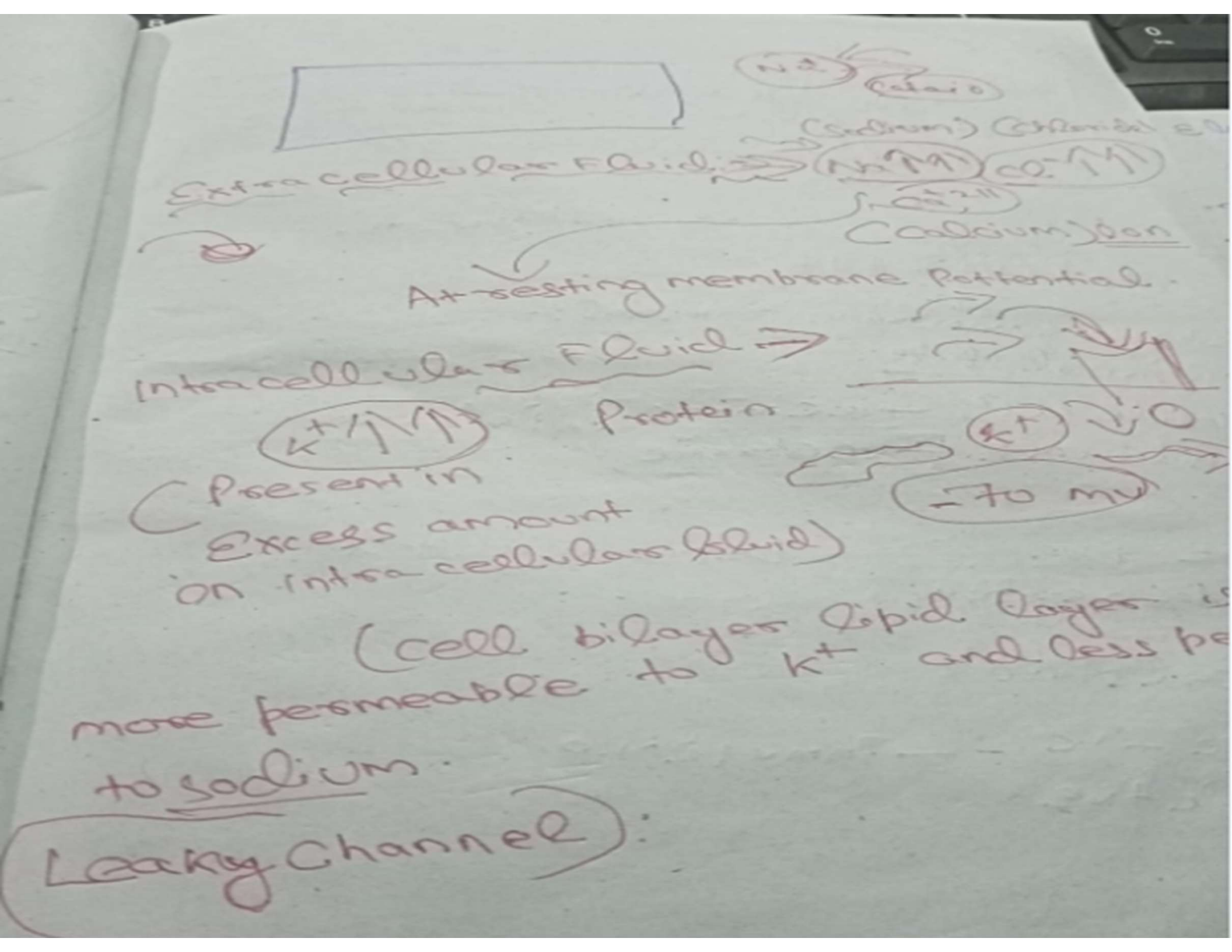
(2) Inside K^+ excess

(3) Cell outside - Na^+ excess.

Key point

- **Concentration gradient for K is towards outside and for Na is towards inside but the electric gradient for both of these ions is towards the negatively charged side of the membrane**




Extracellular Fluid
At resting membrane Pottential.
Intracellular Fluid
Protein
Present in
Excess amount
on intracellular fluid
-70 mV
more permeable to sodium.
Leaky Channel:

- The concentration difference of Na+ and K+ are maintained by the Na+ K+ pump.

- Since the plasma membrane is impermeable to proteins so A- are inside the membrane

More permeability of K+ as compared to Na+ in resting state

- The plasma membrane is more permeable to K+ in resting state than Na+ because the membrane has got more leak channels for K+ than for Na+
- Moreover the hydrated form of K+ is smaller than the hydrated form of Na+

Normal value of RMP in different cells

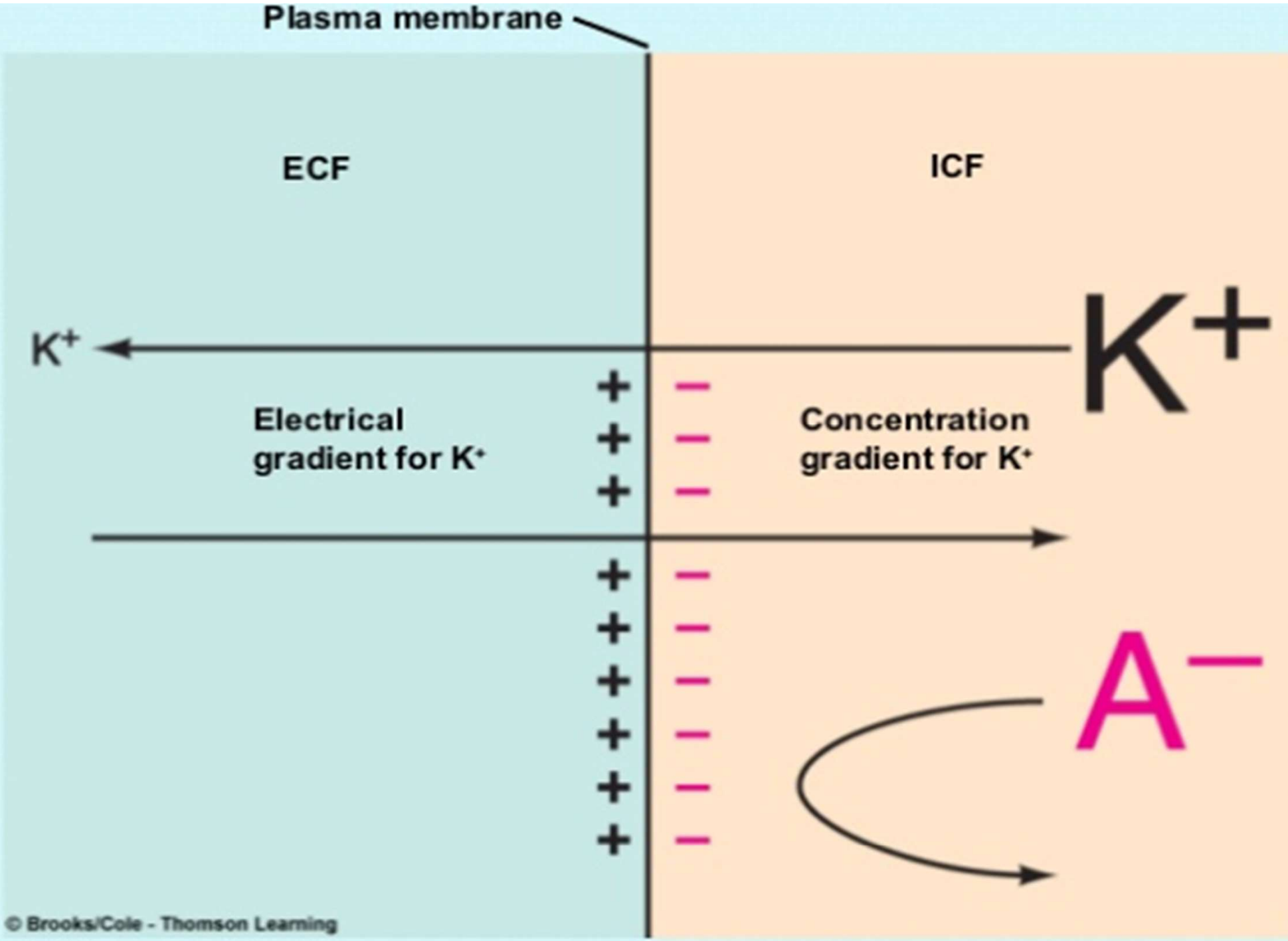
- Resting membrane potentials for cells generally range: -20 mV to -200mV
-

TYPE OF CELL	RMP
SKELETAL MUSCLE	- 90 mvs
SMOOTH MUSCLE	- 60mvs
CARDIAC MUSCLE	- 85 to - 90 mvs
NERVE CELL	- 70 mvs

Effect of sodium-potassium pump on membrane potential

- Makes only a small direct contribution to membrane potential through its unequal transport of positive ions

- Only 20% of the MP is directly generated by Na K pump
- 80% of the MP is caused by the passive diffusion of Na and K down the concentration gradient


Plasma membrane
ECF
ICF
K+
K+
Electrical
gradient for K+
Concentration
gradient for K+
A−
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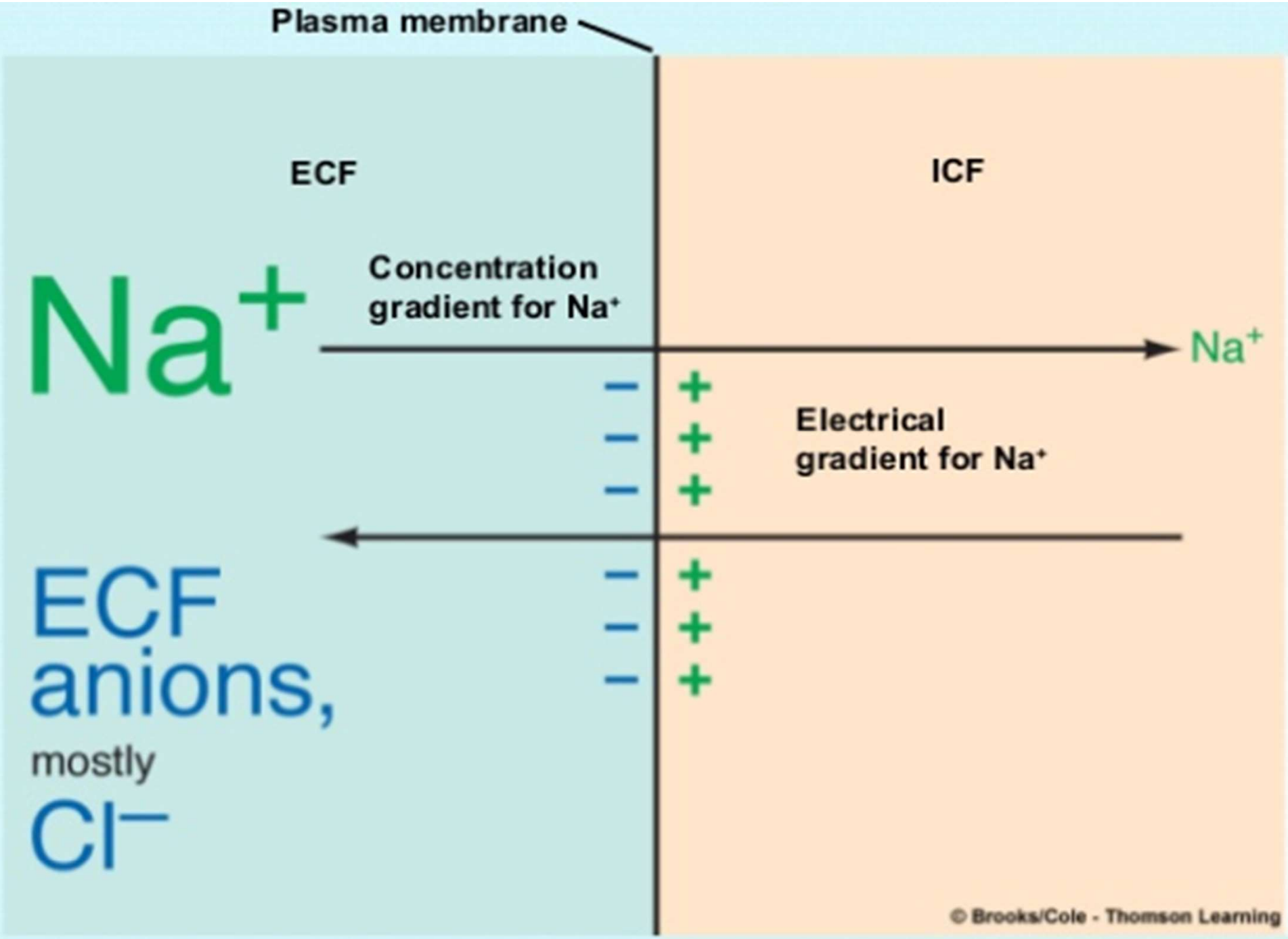
$E_K+ = -94mV$


Plasma membrane
ECF
ICF
Na+
Concentration gradient for Na+
Na+
Electrical gradient for Na+
ECF anions, mostly Cl−
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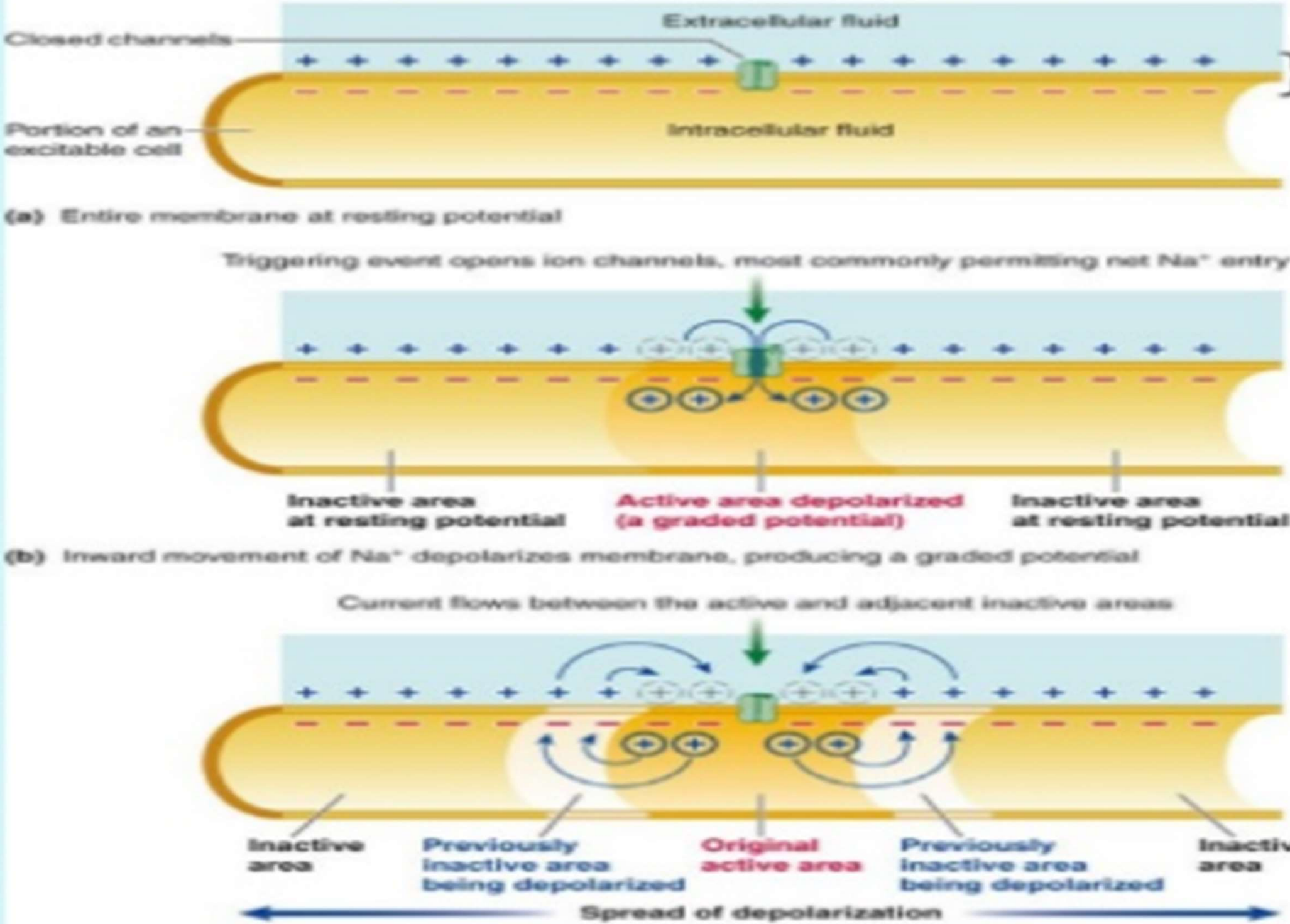
$E_{Na}+ = +61$ mV

- Changes in ion movement in turn are brought about by changes in membrane permeability in response to a triggering agent or a stimuli


Extracellular fluid
Closed channels
Portion of an excitable cell
Intracellular fluid
(a) Entire membrane at resting potential
Triggering event opens ion channels, most commonly permitting net Na+ entry
Inactive area at resting potential
Active area depolarized (a graded potential)
Inactive area at resting potential
(b) Inward movement of Na+ depolarizes membrane, producing a graded potential
Current flows between the active and adjacent inactive areas
Inactive area
Previously inactive area being depolarized
Original active area
Previously inactive area being depolarized
Inactive area
Spread of depolarization
(c) Depolarization spreads by local current flow to adjacent inactive areas, away from point of o

Hyperpolarise cell
— Excess negative charge inside cell

GABA = Inhibitory N.T
— Cl^- open ⟶ Hyperpolarisation

Glycine = Inhibitory N.T
— Cl^- open (Hyperpolarisation)

Glutamate - N.T ⟶ open Ca^{2+} channel
— Excitation
↳ Excitatory N.T

Ach = Heart ↓
(M2) = K^+ = Hyperpolarisation

Adr = Heart ↑
β_1 - Ca^{2+} = Depolarisation

R.M.P = (-70 mV) (↑ Na^+) / ↑ Cl^- Excess (E.C.F)

1 +ve
Na
-70 1 Mol ↓ (5 Na)
A^+ — ↑↑ Excess
will neutralise 1 -ve — 2m so - (-69)
will neutralise the negative and become depolarised

⟶ -65 m.V

Chloride can't move down outside to inside -70

$-70 - 10 = -80$ mV

Chloride channel open (Hyperpolarisation)

e^-

Polarised stable

Hyperpolarised stable -120mV

K^+ channel open

K^+ outside

K^+ inside

-70mV

$1K^+$

$-70 - 10 \times -7$

$-70 - 10$mV $= -80$mV

Hyperpolarised stable.

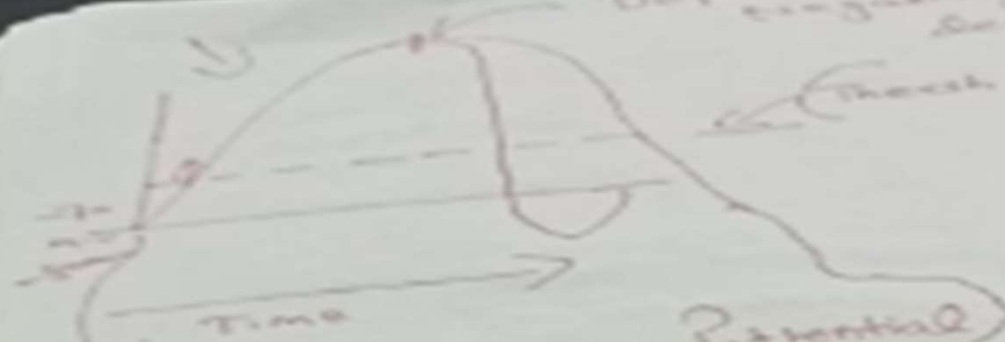
↳ Hyperpolarisation

outside

(Depolarisation)

Ca^{+2} inside

Na^+



Depolarisation
singularity of the cell
decreases →

(Threshold Potential
(-60mv)
voltage sensitive
ion channel
open

Resting Membrane Potential

More sodium will not
go in.
→ K^+ channel open

Sodium channel
open in 2 stage
(1) Partial Depln
(2) Complete "

(Impulse) → 10 pressure sensitive channel
open

Potential difference
move forward
negative.
(-70mv)

-60mv
voltage sensitive channel
open

Repolarisation

K^+ channel open (Polarised state) Na^+

$K^+ \rightleftharpoons Na^+$

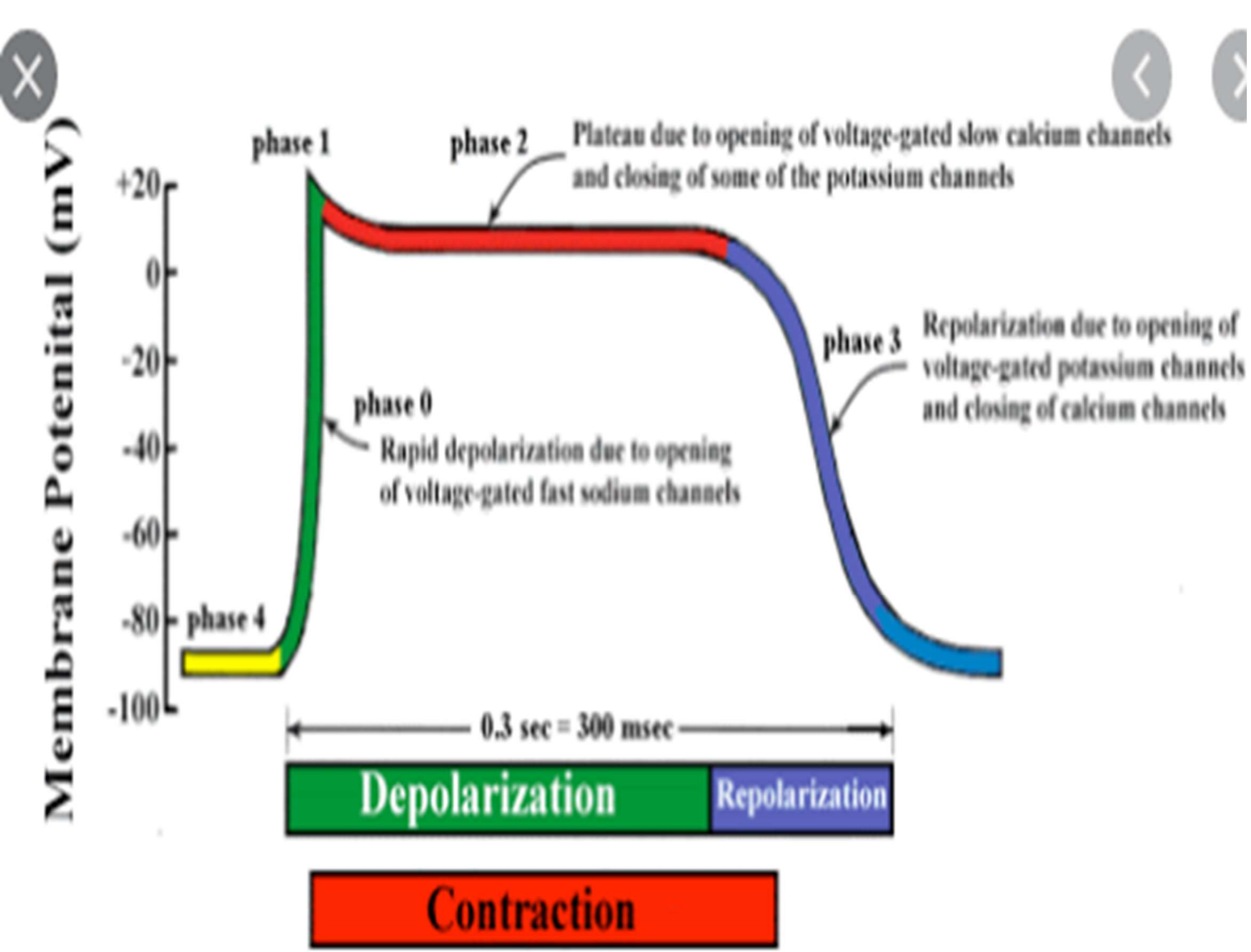
$-70mV$

(-70mV)

Na^+

↑ K^+ (More Repolarised state)

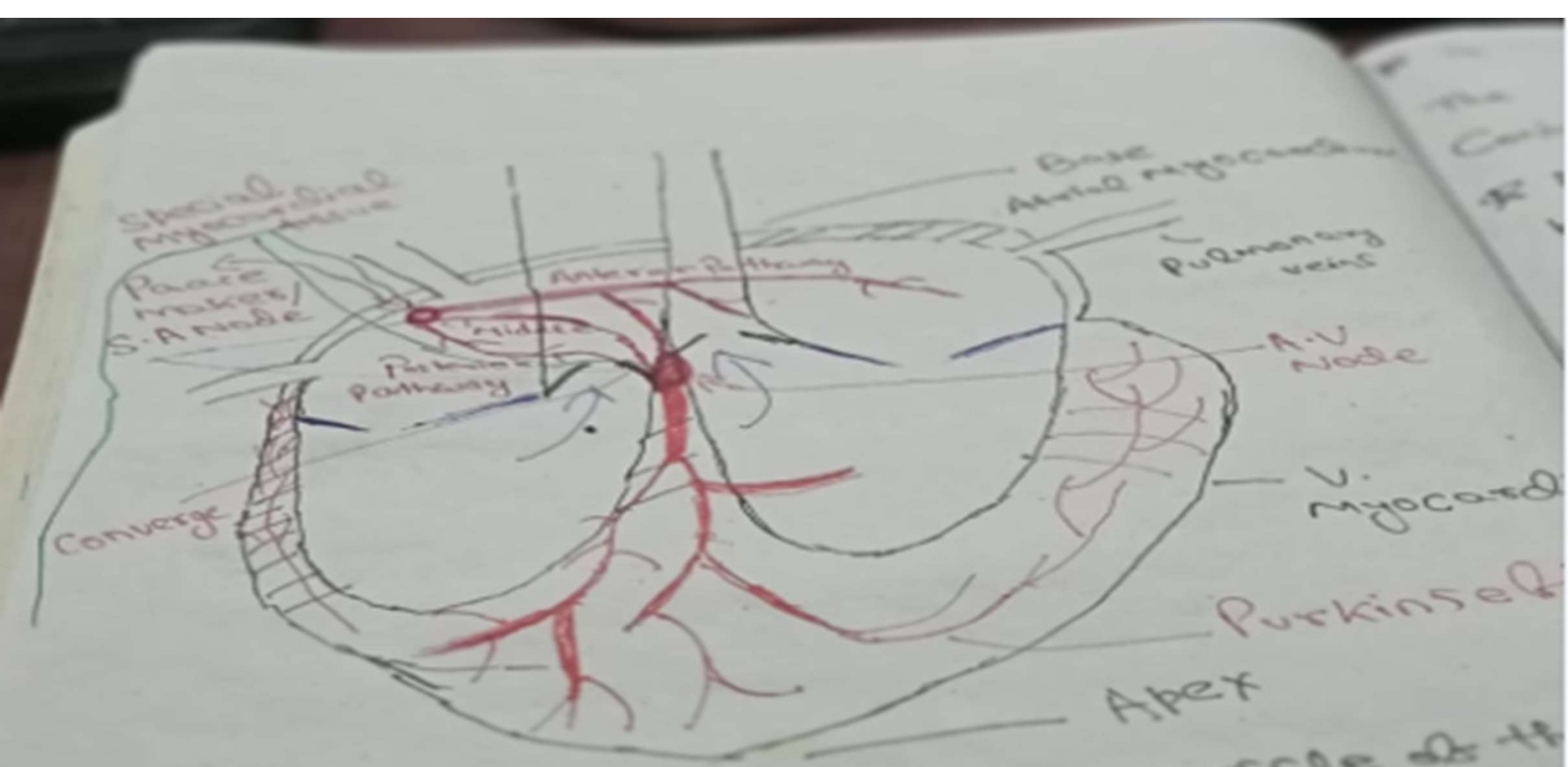
↓ Na (More inside


Membrane Potenital (mV)
+20
0
-20
-40
-60
-80
-100
phase 1
phase 2
Plateau due to opening of voltage-gated slow calcium channels
and closing of some of the potassium channels
phase 3
Repolarization due to opening of
voltage-gated potassium channels
and closing of calcium channels
phase 0
Rapid depolarization due to opening
of voltage-gated fast sodium channels
phase 4
0.3 sec = 300 msec
Depolarization
Repolarization
Contraction

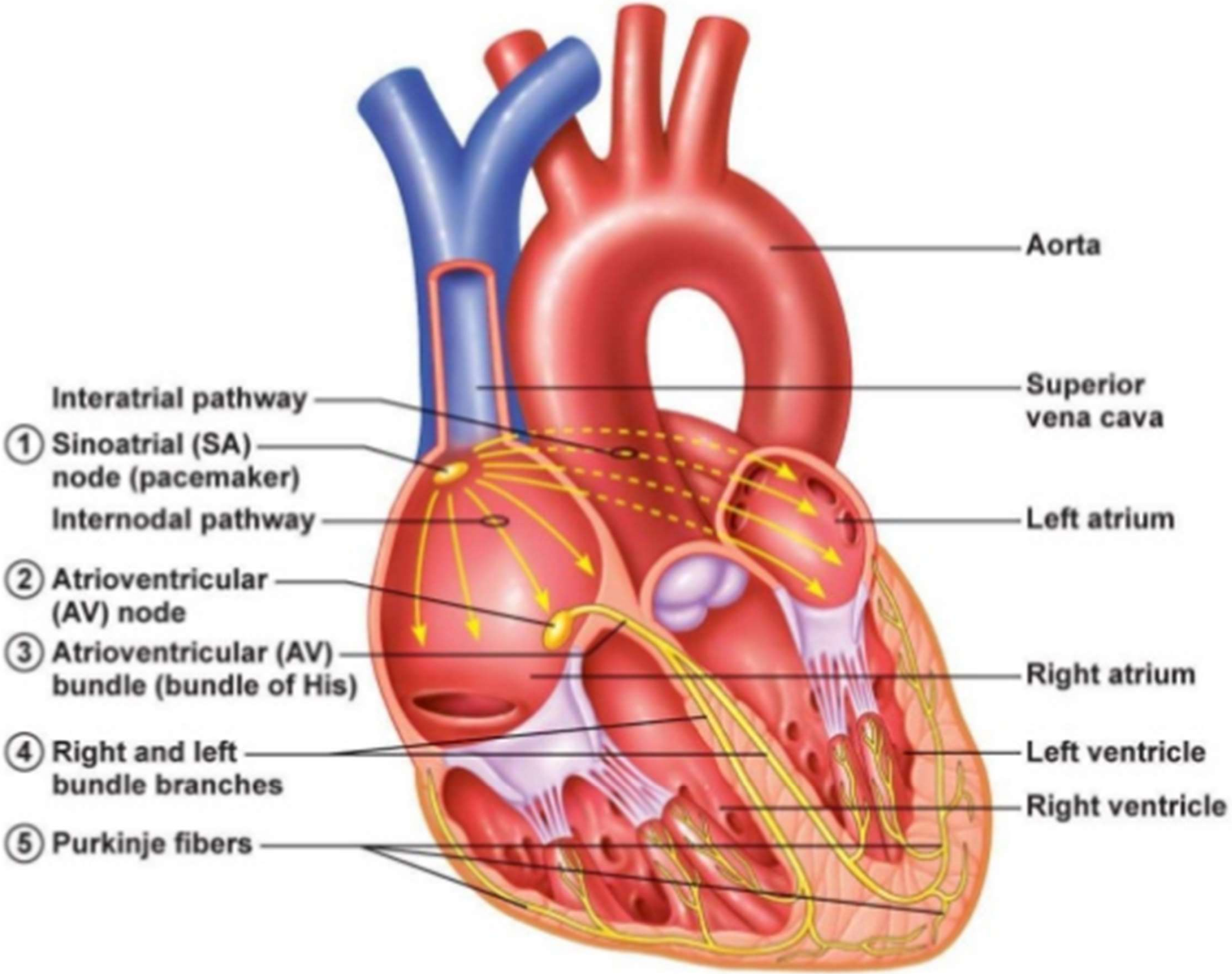
COMPONENTS

- The conducting system of the heart is composed of the following 5 components:.

1. Sinuatrial node (SA node).
2. Atrioventricular node (AV node).
3. Atrioventricular bundle (of His).
4. Left and right branches of bundle (of His).
5. Subendocardial Purkinje fibres.



Myocardium — Contractile muscle of the heart


Aorta
Superior vena cava
Interatrial pathway
1 Sinoatrial (SA) node (pacemaker)
Internodal pathway
Left atrium
2 Atrioventricular (AV) node
3 Atrioventricular (AV) bundle (bundle of His)
Right atrium
4 Right and left bundle branches
Left ventricle
Right ventricle
5 Purkinje fibers

SINO ATRIAL NODE :

- It is a small horseshoe-shaped mass having specialized myocardial fibres, situated in the wall of the right atrium in the upper part of sulcus terminalis just below the opening of **superior vena cava**.
- It is called pacemaker of the heart since it generates impulses (about 70/minute).
- It initiates the contraction of cardiac muscle producing heart beat.

• Sino Atrial node generates sinus rhythm.
•It is specialized myocardial tissue electrically active.
•This area is electrically intrinsically unstable.
• Without any hormonal influence or any neurological influence it has abilty to depolarise.

• It depolarise spontaneously around about 90-100 times a minute . Therefore generating a new electrical nerve impulse .
•S.A node governs other electrical active tissues.

•Even the indivisual myocardial cell s spontaneously depolarise but at a lower rate as compared to S.A node.
•S.A Node is the physiological origin of the electrical activity required to stimulate myocardial cell inorder to generate myocardial contraction. .

•Atria need to contrac t first in response to impulse originating from the sino auricular node.
•Preferential conducting pathway carrying impulse to different part of Atrium.

•Most physiologist agree there are 3 preferential pathways :

• Specialized tissue which conduct electrical activity freely.

•Posterior Pathway
•Middle Pathway
•Anterior Pathway

• Anterior pathway also takes impulse across the left atrium.
•As the track goes through the atrial areas smaller branches come off then these convey electrical activities to the atrial myocardial cell.
•Atrial Myocardial cell contract due to depolarisation.

•These conducting pathways take the impulse to atria then to atrial myocardium and causes the atrial to contract down the way into ventricles.

AURICULO VENTRICULAR NODE:

It is smaller compared to the SA node.

– located in the right atrium near the junction with the **interventricular septum** near the opening of the coronary sinus.

It conducts the cardiac impulse to the ventricle by the atrioventricular bundle.

• It is known as pace setter.
• Conducting Pathway converge at A.V Node and it is somertimes called as collecting Node.
•It collect impulse from the Atria.
•Conducting Pathway are called as Internodal Tracks.
•Valves lie more or less in a plane in the middle of the heart.
• Valves are made up of fibrous tissue called collagen which are made up of electrically insulating substance.As a result impulse cannot cross the boundary that is from atrial compartment to ventricular compartment.

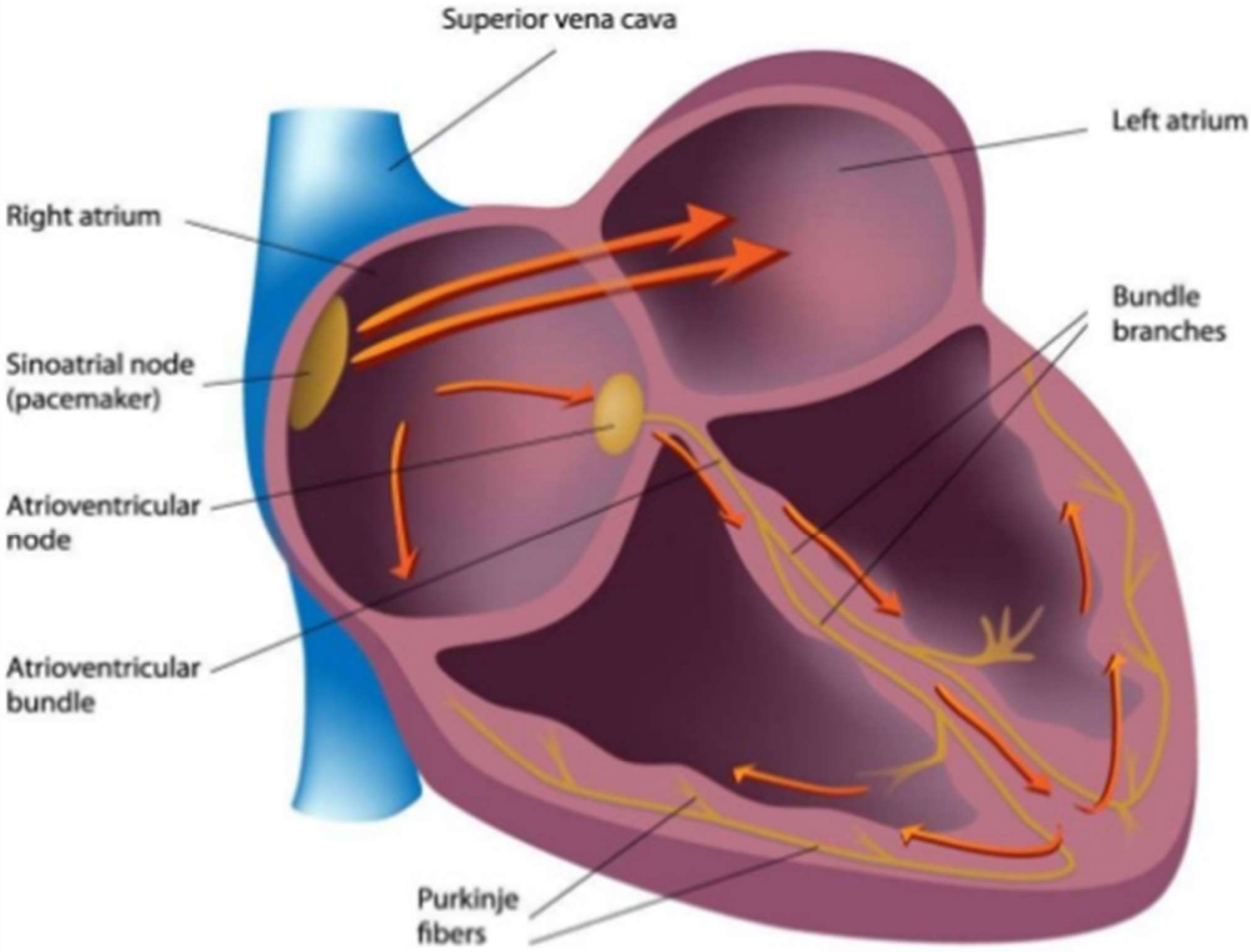
•The only way the impulse can go from the Atria to ventricles in a physiologically healthy indivisual is by the A.V node.

•Heart to contract basically fro m the bottom being the cardiac apex as the impulse is going through the A.V node is delayed about 40 milisecond.

•Delay is important because during that period blood moves from Auricle to Ventricle.

•The ventricle will be filled with blood prior to ventricular contraction

The Cardiac Conduction System



ATRIOVENTRICULAR BUNDLE (OF HIS)

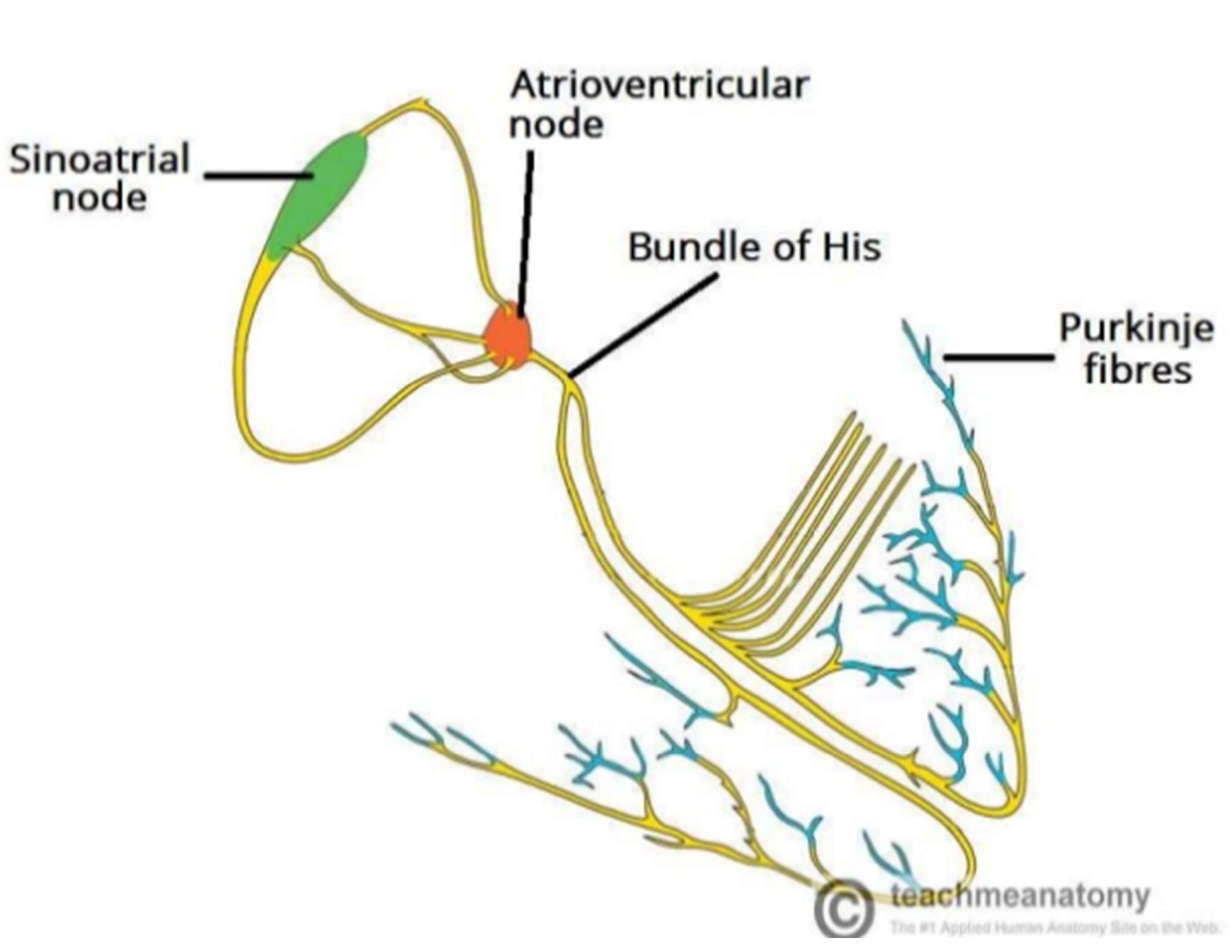
- It begins from AV node, crosses the AV ring and runs along the inferior part of the membranous part of the interventricular septum where it divides into the right and left branches extending inferiorly to the interventricular septum and superior to the lateral walls of the ventricles.
- Since the skeleton (fibrous framework) of the heart separates the muscles of atria from the muscles of the ventricles, the bundle of His is the only means of conducting impulses from the atria to the ventricles.

Atrioventricular Bundle

- The **atrioventricular bundle** (bundle of His) is a continuation of the specialized tissue of the AV node, and serves to transmit the electrical impulse from the AV node to the Purkinje fibres of the ventricles.
- It descends down the membranous part of the interventricular septum, before dividing into two main bundles:
- **Right bundle branch** – conducts the impulse to the Purkinje fibres of the right ventricle
- **Left bundle branch** – conducts the impulse to the Purkinje fibres of the left ventricle.

LEFT AND RIGHT BRANCHES OF THE BUNDLE (OF HIS)

- The right branch enters down the right side of the interventricular septum and after that becomes subendocardial on the right side of the septum.
- A large part of it continues in the septomarginal trabeculum (moderator band) to reach the anterior papillary muscle and anterior wall of the ventricle. Its Purkinje fibres then spread out underneath the endocardium.
- The left branch descends on the left side of the ventricular septum, divides into Purkinje fibres that are distributed to the septum and **left ventricle**.


Atrioventricular node
Sinoatrial node
Bundle of His
Purkinje fibres
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The #1 Applied Human Anatomy Site on the Web.

Purkinje Fibres

- The **Purkinje fibres** (sub-endocardial plexus of conduction cells) are a network of specialized cells. They are abundant with glycogen and have extensive gap junctions.
- These cells are located in the **subendocardial surface** of the ventricular walls, and are able to rapidly transmit cardiac action potentials from the atrioventricular bundle to the myocardium of the ventricles.
  - This rapid conduction allows **coordinated ventricular contraction** (ventricular systole) and blood is moved from the right and left ventricles to the pulmonary artery and aorta respectively.

Overview of Heart Conduction

The sequence of electrical events during one full contraction of the heart muscle:

An excitation signal (an action potential) is created by the **sinoatrial (SA) node**.

The wave of excitation spreads across the **atria,** causing them to contract.

Upon reaching the **atrioventricular (AV) node**, the signal is delayed.

It is then conducted into the **bundle of His**, down the interventricular septum.

The bundle of His and the **Purkinje fibres** spread the wave impulses along the ventricles, causing them to contract.