

CARDIOVASCULAR SYSTEM: CARDIAC ACTION POTENTIAL

For:

Semester II

CC2TH/ GEN 2TH

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INTRODUCTION

Nerves and muscles are called **excitable tissues** because they respond to:

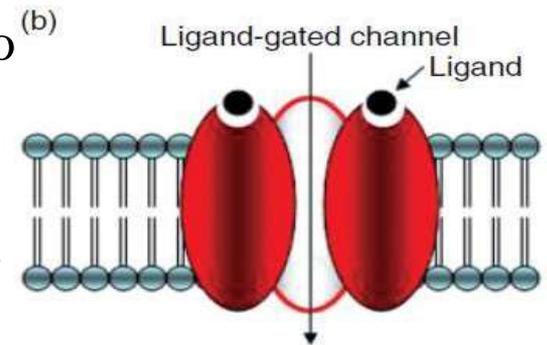
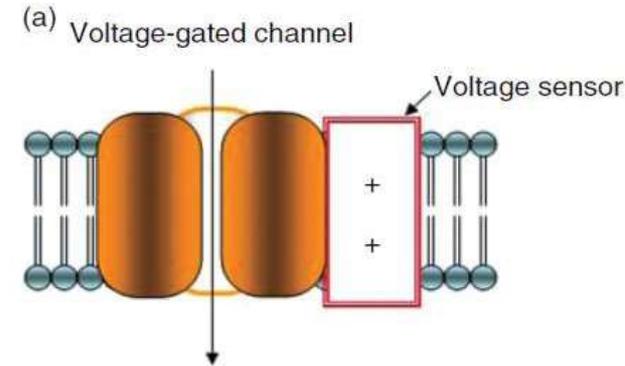
- Chemical.
- Mechanical.
- Electrical stimuli.

Production of signals depend on two basic features of the plasma membrane of excitable cells:

- Resting membrane potential
- Ion channels

ION CHANNELS

- Ion channels open and close due to **the presence of gates.**
- **There are different kinds of ion channels:**
 - **Leakage channels:** open and close randomly
 - **Voltage-gated channels:** opens to a change in membrane potential (voltage).
 - **Ligand-gated channels:** opens and close in response to chemical stimulus, such as Ach.
 - **mechanical gated channels:** open or close in response to mechanical stimulation, such as touch or tissue stretching.



RESTING MEMBRANE POTENTIAL

- It is the potential difference across the cell membrane at rest.
- It is negative inside with respect to outside the membrane.
- Cells in their resting state are said to be polarised.
- Cells with automaticity do not have a static RMP
- **THRESHOLD POTENTIAL** is the critical level to which the membrane potential must be depolarized to initiate an action potential.

Extracellular fluid

Chloride ion

Sodium ion

K⁺ leakage channel

Na⁺ leakage channel

Na⁺/K⁺ ATPase

3 Na⁺

ATP

ADP

2 K⁺

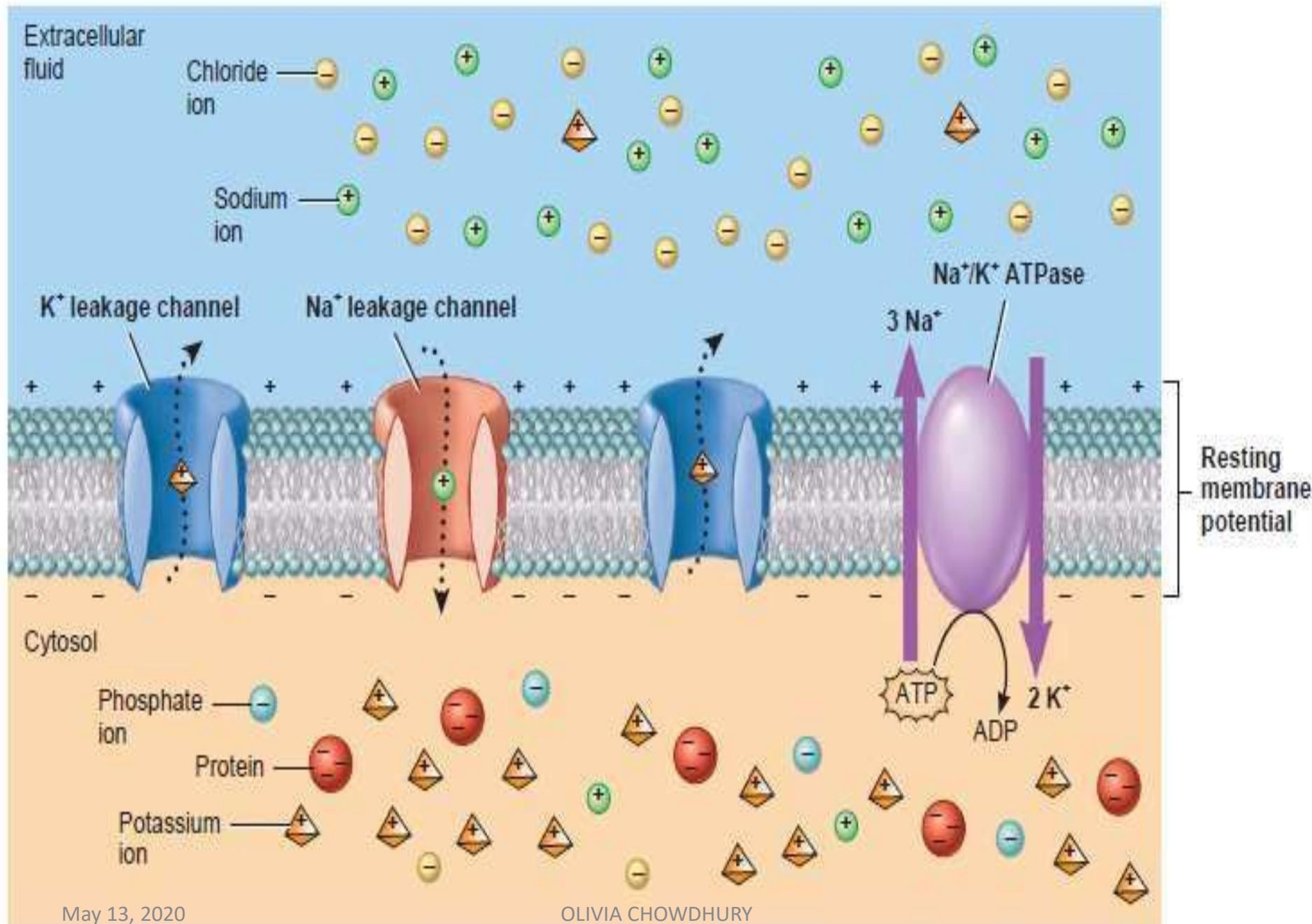
Resting membrane potential

Cytosol

Phosphate ion

Protein

Potassium ion



CONCENTRATION OF MAJOR IONS ACROSS CELL MEMBRANE DURING RESTING STATE

Ion	Extracellular Conc (mmol)	Intracellular Conc (mmol)	Ex (mV)
Na ⁺	145	20	+52
K ⁺	4	135	-92
Ca ²⁺	2	10 ⁻⁴	+129
CL ⁻	120	10	-64

ACTION POTENTIAL

- Action Potential is a sudden reversal of membrane polarity when a stimulus strikes the cell membrane.
- Action potential in cardiac muscle is different from that of other tissues such as skeletal muscles and nerve tissues.
- Duration of action potential in cardiac muscle is 250 to 350ms (0.25 to 0.35s)

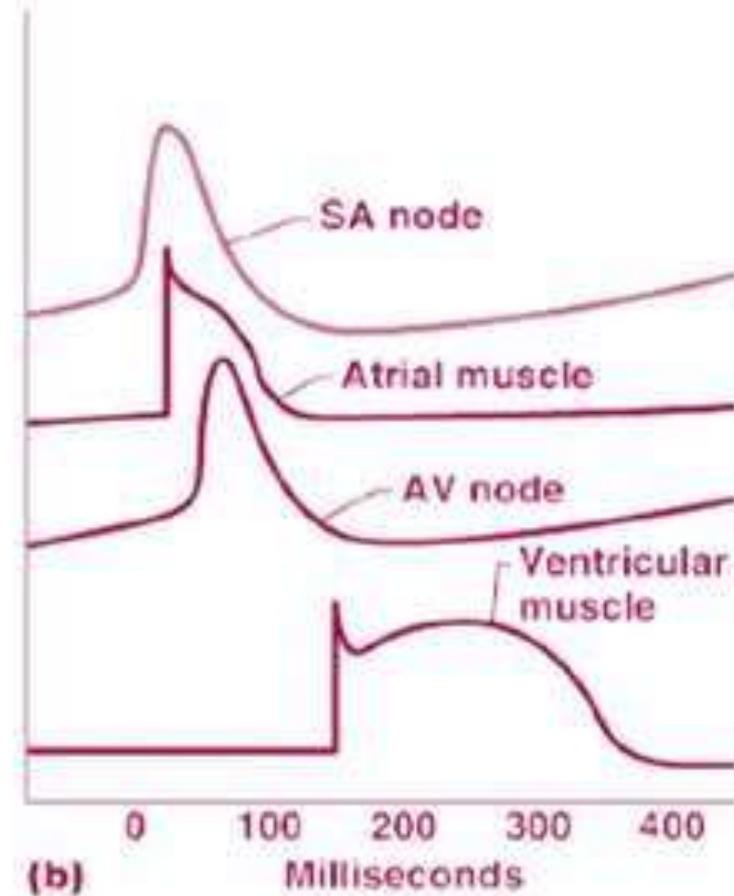
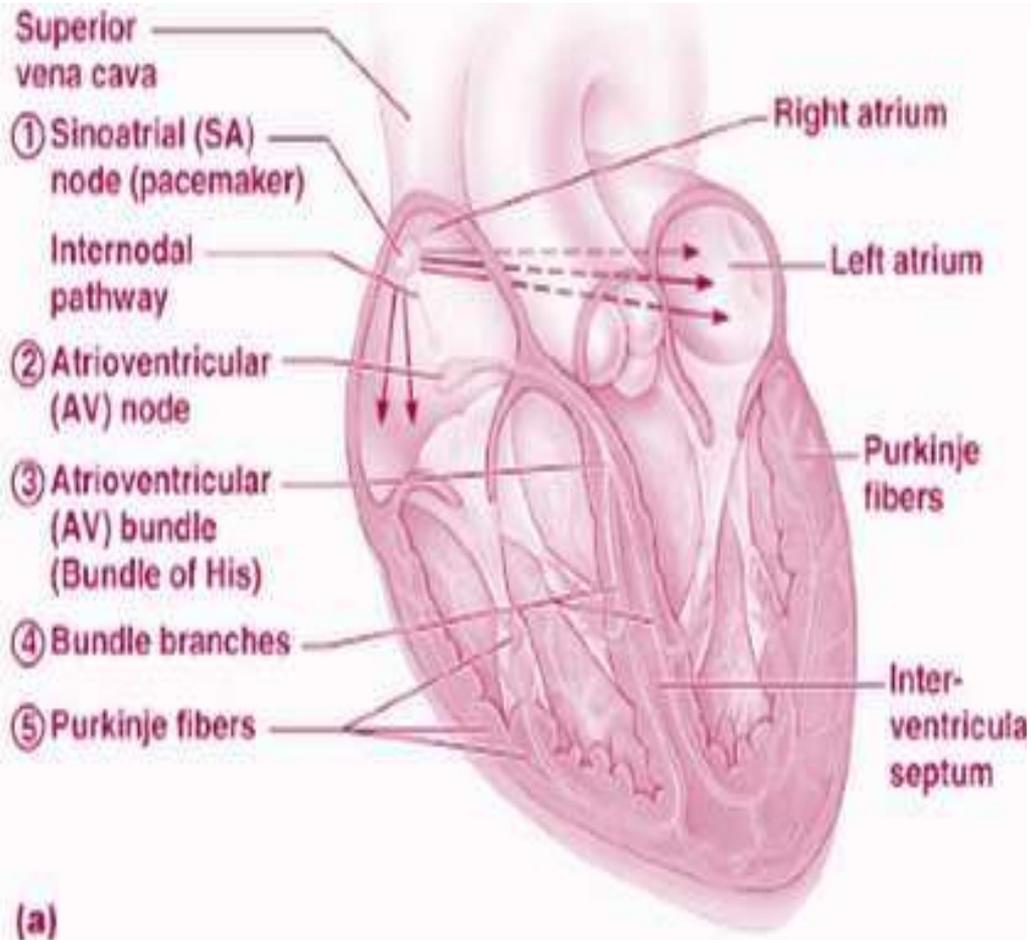
BASIS OF ACTION POTENTIAL IN GENERAL

- When a cell membrane is stimulated by a physical or a chemical stimulus, **the cell membrane permeability to Na^+ is dramatically increased.**
- Sodium channels open and the sodium ions rush through the channels to the inside the cell **causing the inside the membrane to become positive** with respect to the outside.
- This is called *depolarization*.
- The membrane potential becomes **reversed and reaches +35 mV.**
- Towards the end of depolarization, sodium permeability decreases and **potassium permeability increases.**
- K^+ ions leave the cell down their concentration gradient, **causing the inside the membrane to return quickly to its original potential.**
- This is called *repolarization*.
- The membrane potential is then brought back to **-70 mV**

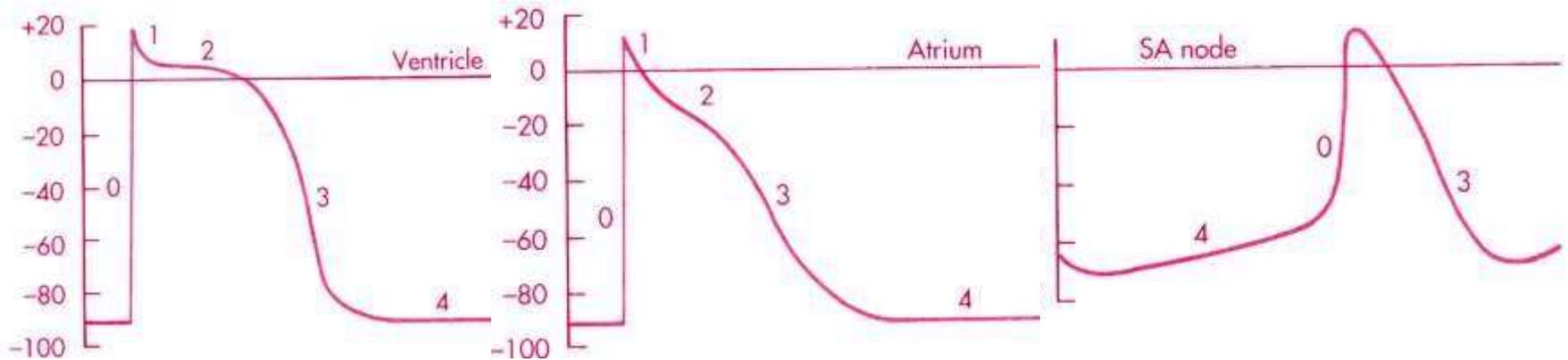
SITES OF ACTION POTENTIAL GENESIS IN THE HEART

- Nodal tissue – AV node and SA node**
- HIS- Purkinje fibres**
- Atrial Muscle**
- Ventricular Muscle**

SITES OF ACTION POTENTIAL GENESIS IN THE HEART



PHASES OF CARDIAC ACTION POTENTIAL



Phase 0

- Upstroke or rapid depolarization

Phase 1

- Early rapid repolarization

Phase 2

- Plateau

Phase 3

- Final rapid repolarization

Phase 4

- Resting membrane potential and diastolic depolarization

IONIC BASIS OF ACTION POTENTIAL IN CARDIAC MYOCYTES (Atria & Ventricles)

- **Initial Depolarization (Phase 0)**- due to opening of sodium channels and the rapid influx of sodium ions.
- **Initial Repolarization (Phase 1)**- due to the transient (short duration) opening of potassium channels and efflux of a small quantity of potassium ions from the muscle fiber -the fast sodium channels close suddenly and slow sodium channels open , resulting in slow influx of low quantity of sodium ions.

• **Plateau Or Final Depolarization (Phase 2)**- slow opening of calcium channels -these channels are kept open for a longer period and cause influx of large number of calcium ions. -because of the entry of calcium and sodium ions into the muscle fiber, positivity is maintained inside the muscle fiber producing prolonged depolarization i.e., *plateau*.

• **Final Repolarization (Phase 3)**- due to efflux of potassium ions-number of potassium ions moving out of the muscle fiber exceeds the number of calcium ions moving in -it makes negativity inside, resulting in final repolarization- potassium efflux continues until the end of repolarization.

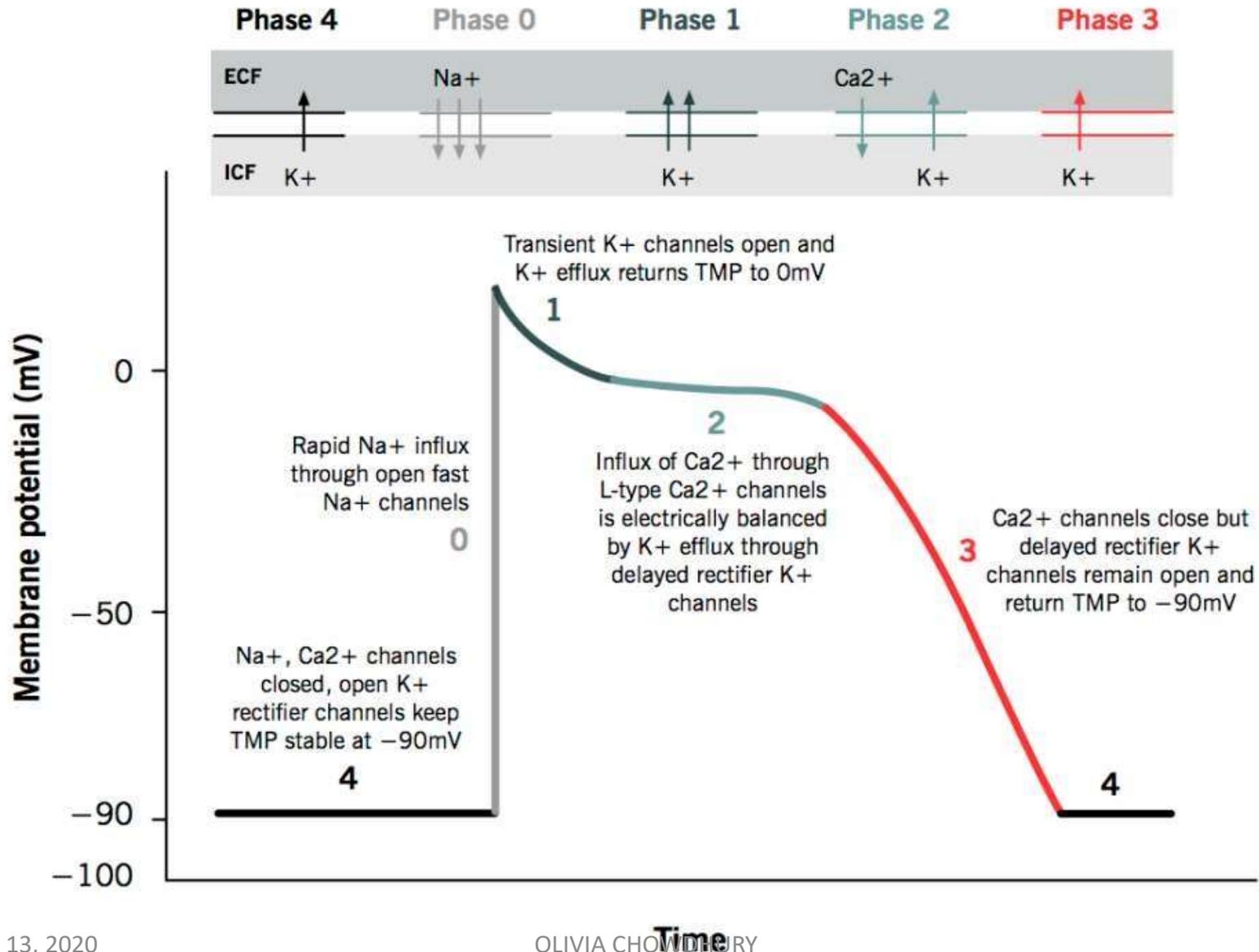
Restoration Of Resting Membrane Potential

(Phase 4)- At the end of the repolarization, all sodium ions, which had entered the cell throughout the process of action potential move out of the cell and potassium ions move in to the cell, by activation of **sodium-potassium pump**.

Simultaneously, excess of calcium ions, which had entered the muscle fiber also move out through sodium-calcium pump. Thus, the resting membrane potential is restored.

Action potential of cardiac muscles

Grigoriy Ikonnikov and Eric Wong



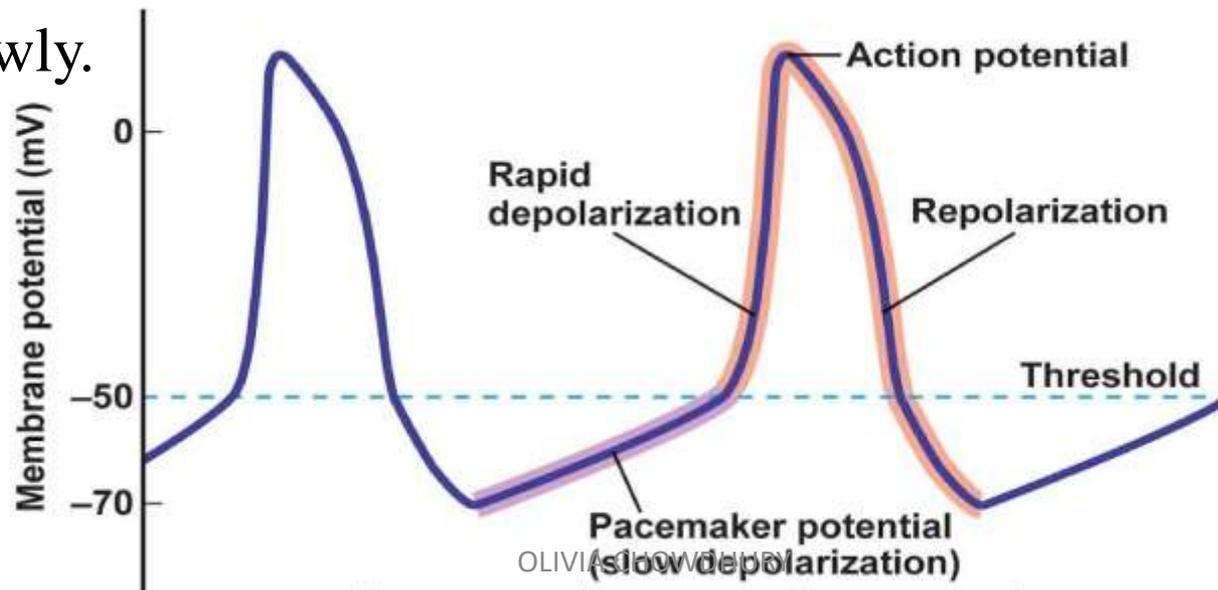
ELECTRICAL POTENTIAL IN SA NODE

- Pacemaker potential is the unstable RMP in SA node.
- It is also called prepotential.
- In SA node , each impulse triggers the next impulse.
- RMP in SA node has a negativity of -55 to -60 mV.

ACTION POTENTIAL IN SA NODE

Depolarization starts very slowly and the threshold level of -40mV is reached very slowly.

- After the threshold level, rapid depolarization occurs upto $+5\text{mV}$.
- It is followed by rapid repolarization.
- Once again, the RMP becomes unstable and reaches the threshold level slowly.



IONIC BASIS OF ELECTRICAL ACTIVITY IN PACEMAKER

The sodium ions leak into the pacemaker fibers and cause slow depolarization (initial part of pacemaker potential).

- Then, the calcium channels start opening.
- At the beginning, there is a slow influx of calcium ions causing further depolarization in the same slower rate (later part of the pacemaker potential).

Depolarization

When the negativity is decreased to -40mV , which is the **THRESHOLD LEVEL**, the action potential starts with rapid depolarization.

➤ The depolarization occurs because of influx of more calcium ions.

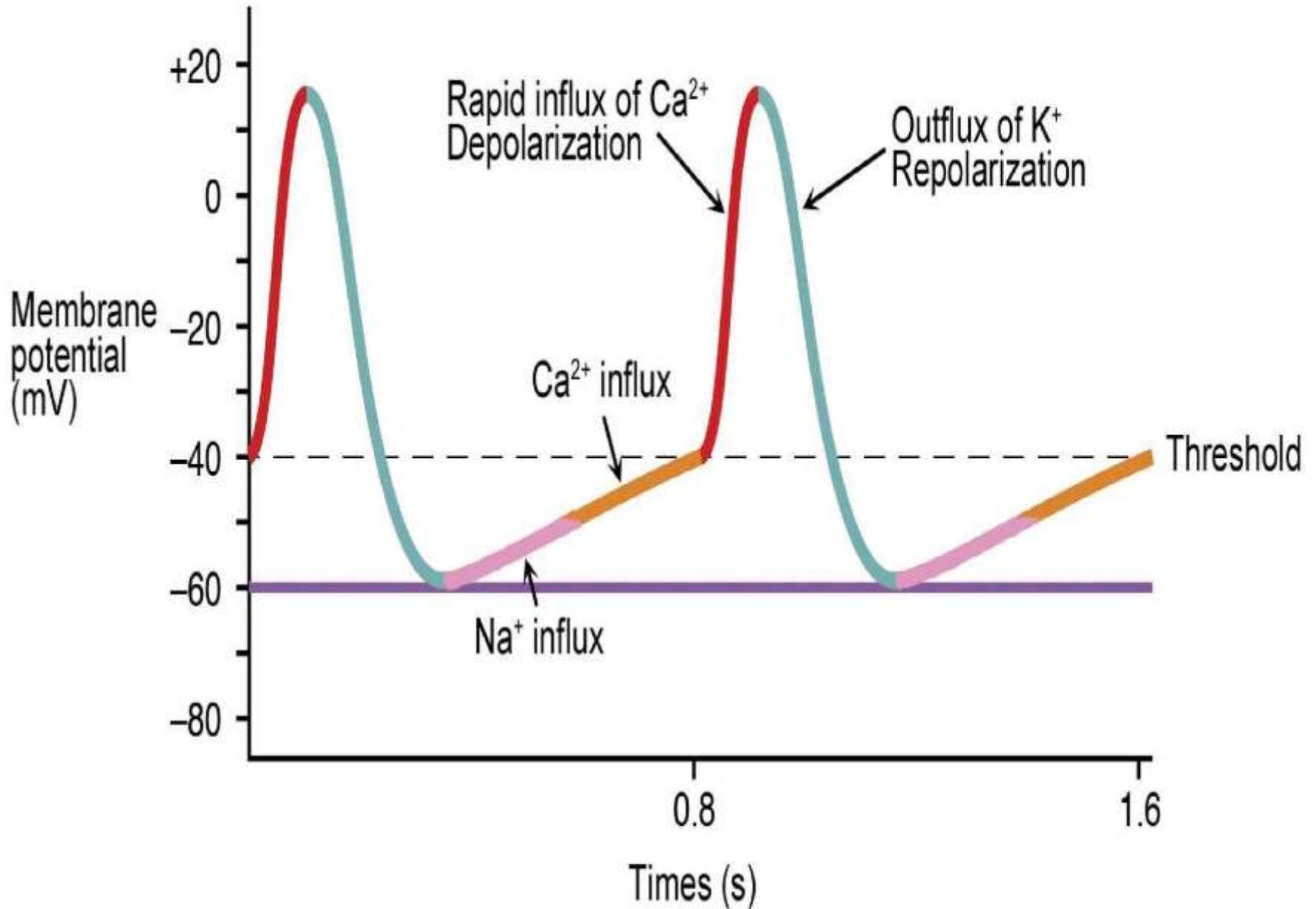
Repolarization

After rapid depolarization, repolarization starts.

- It is due to the efflux of potassium ions from pacemaker fibers.
- Potassium channels remain open for a longer time, causing efflux of more potassium ions.
- It leads to the more negativity, beyond the level of RMP.
- It exists only for short period.
- Then , the slow depolarization starts once again, leading to the development of pacemaker potential, which triggers the next action potential.

Diastolic Depolarization

- In SA node, the resting membrane potential does not remain constant in diastole but gradually depolarizes and when it reaches the threshold potential, it produces spontaneous action potential.
- This property possessed by the spontaneously discharging cells is known as phase 4 diastolic depolarization and automaticity results when it leads to the initiation of action potential



**THANK
YOU!!**