◉Sheet ○Slides

Number

25

Done by:

Albandari Alardhi.

Corrected by:

Riham Abu Arrah

Doctor

Yanal Shafagoj

→ **Today we are going to talk about Excitable tissues.**
Tissues in our bodies are either excitable or non-excitable.

1)Excitable cells: need to be excited to perform their function ...
for example: nerve cells & muscle cells.

2)Non-excitable cells: can perform their function without excitation …
For example: endocrine cells & hormonal cells.

What does excitation mean?

Excitation is reversing the membrane potential (which is negative at rest), making it positive on the inside, or making it zero (the cell at rest is polarized and by excitation we remove polarization).

How do we perform excitation?

We can make the cell positive on the inside by allowing the entry of sodium ions **(Na^+)** or calcium ions **(Ca^{2+})** or both **(positively charged).**
sometimes we may allow chloride ions **(negatively charged)** to leave the cell.

Note: Dr.Yanal didn't focus on **Cl^-**

- **Na^+** is smaller in size than Ca^{2+}.However, **Na^+** can't enter through **Ca^{2+}** channels, it must influx through its own channels.
- **Na^+** will enter through sodium channels, **Ca^{2+}** will enter through calcium channels
- **Na^+** concentration outside the cell is 140 MEQ/L ... and its concentration inside is 14 MEQ/L (the concentration outside is 10 times greater than inside).

By opening the Sodium Channels, **Na^+** will flow inside (Current) because of the concentration gradient, making the membrane potential Positive.

What do we mean by Flow ?

Flow: Something is happening per unit time … and it is a general phase. (In physiology, we talk about flow of electrons so it's called "Current").

Ex: Amount of **Na^+** entering the cell per min/sec/hour …etc.
Circulation of blood.
Diffusion of glucose across the membrane.

- Current is: a Flow of charges per unit time.
- Current needs driving force (DF): Without DF, we have no flow!
- Flow is directly proportional to DF
- Flow is inversely proportional to Resistance

Ohm's Law:

$I = \Delta V/R$

I: Current
ΔV: DF (Voltage Difference)
R: Resistance

- Driving Force: the voltage difference between two areas.
- Resistance: a vague concept has no specific definition, tells us how difficult an event is going to be (expression of difficulty).
- Resistance is opposite to permeability (how easy an event is going to be).
- We usually use "Resistance" or "Conductance" to talk about charges, and permeability to talk about non-charged molecules such as glucose.

In our bodies, we have 3 compartments:

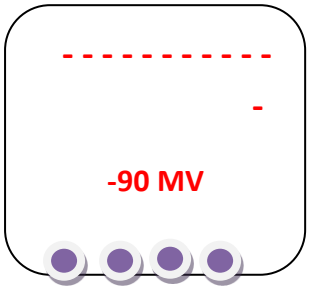
1-intracellular: which is inside the cell.
2-interstitial: which is outside the cell.
3- intravascular: which is outside the cell, but inside the capillaries(Plasma).

- Compartment No.1 is separated from No.2 by the cellular membrane.
- Compartment No.2 is separated from No.3 by the capillary wall (endothelium).
- Interstitial and intravascular (plasma) are almost similar with the exception of proteins, while intracellular and interstitial are totally different.

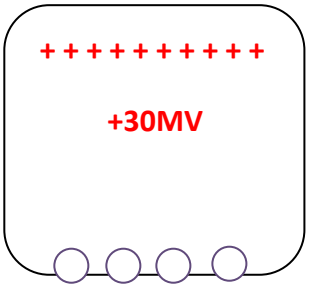
→ [**Na^+**] inside the cell (intracellular) = 14 MEQ/L
→[**Na^+**] outside the cell (interstitial/intravascular) = 140 MEQ/L

What is excitation-contraction coupling ??

when you excite the cell (reverse the membrane potential), the muscle contracts … so you coupled the excitation which is electrical, with the contraction, which is mechanical.



The cell at rest
(no stimulus)
Na$^+$ channels are closed



Na$^+$ channels are opened
by stimulus
Na$^+$ will enter because of **ΔV**

The cell is under two different forces:

1) Chemical Force (Concentration Gradient): this will keep pushing **Na**$^+$ inside.
2) Electrical Force: when inside becomes **+Ve**, it will stop the entry of **Na**$^+$, because **Na**$^+$ is **+Vely** charged and the inside is **+Ve** too.

→ When these two forces are equal and opposite to each other, no more **Na**$^+$ will enter the cell even if **Na**$^+$ channels are still opened (Net **Na**$^+$ entry = 0).

How much positive inside do we have to reach in order to overcome chemical force??

at what point the electrical force equals the chemical force and opposes it?
when these two forces are equal and opposite → **Net Na**$^+$ **influx is zero** (we reach equilibrium)
This is already calculated by **Nernst Equation**:

E(mV)= -61 * log ([C]I / [C]o)
E = equilibrium potential for a univalent ion.
[C]i = concentration inside the cell
[C]o= Concentration outside the cell.

E(**Na**$^+$) = -61 * log (14/140)= **+61 mV**

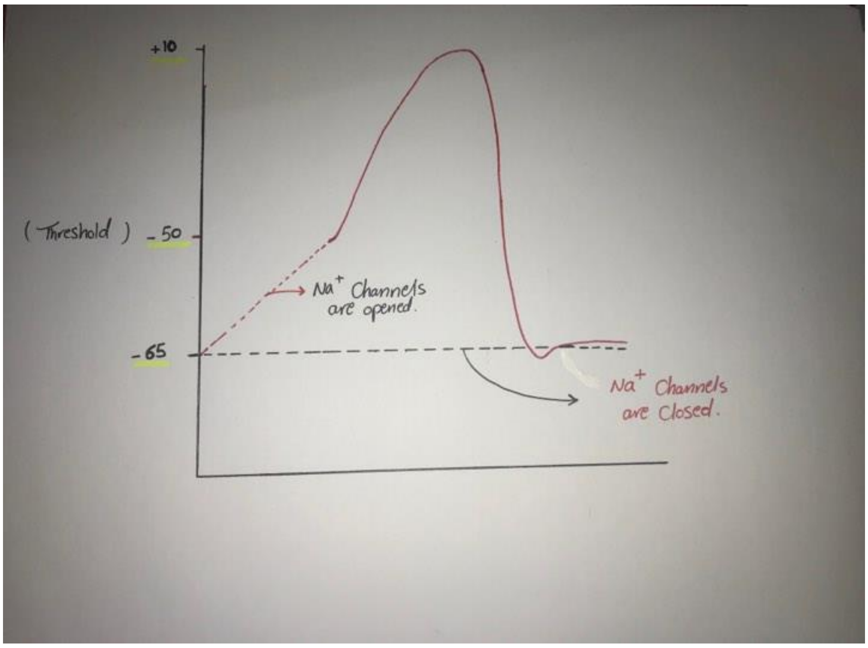
What does this (+61 mV) mean ?

+61 mV is the **Na^+** Equilibrium Potential: if **Na^+** channels remained opened, Na^+ will influx until the inside becomes +61 mV then stops and **Net Na^+ movement is Zero** …
This is when Electrical Force equals and opposes Chemical Force.
So:
If we leave **Na^+** channels open, it will never reach +62 mV.

>>>

For potassium: [**K**+]i= 150 and [**K**+]o= 4
E(**K**+) = -61 log (150/4)= -90 mV

For Calcium: [**Ca^{2+}**]i=10^-8 and [**Ca^{2+}**]o= 10^-3
E(**Ca^{2+}**) = -61 log 10^-8 / 10^-3 = +150 mV



We have different resting membrane potentials according to the type of cell:

- -90 mV for cardiac cells.
- -30 mV for muscle cells.
- -5 mV for red blood cells.

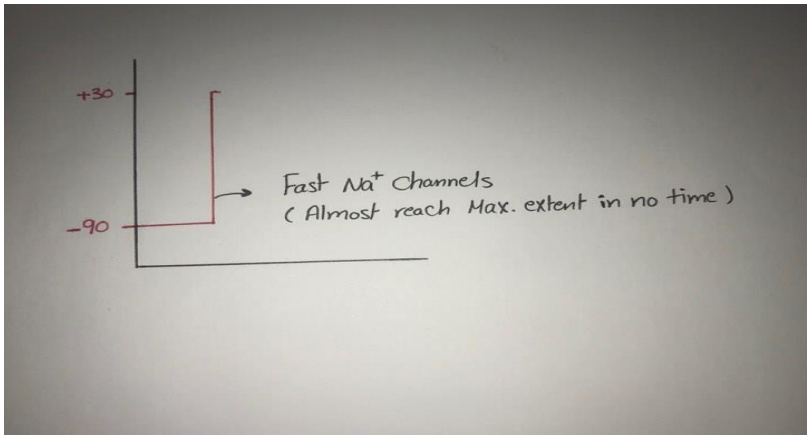
→ -90 mV means that K^+ channels are open, while Na^+ channels are closed.
→ -65 mV means that both K^+ & Na^+ channels are open, but K^+ channels are more opened. **Why?**
→ -5 mV means that Na^+ channels are open more than K^+ because -5 is closer to +61 which is E(Na^+).

→ What do we need to know to predict the membrane potential?
Ans: we need to know the conductance for each ion.

Types of Na+ channels:

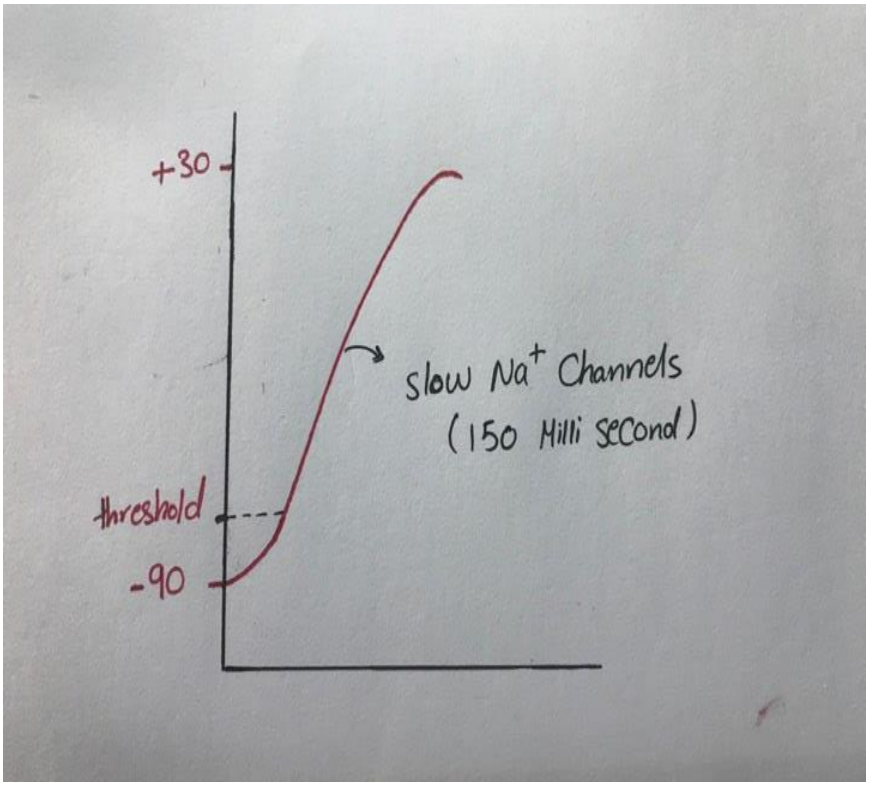
1-Fast Na+ channel

They bring membrane potential to the maximum extent in no time (positive feedback → required).



2-Slow Na+ channel

They bring the membrane potential to the maximum extent within around 150 millisecond.



3- Leakage Na+ channels (both electrical & chemical favor entry of Na+)
They allow **Na+** to enter the cell at rest … without any external stimulus.

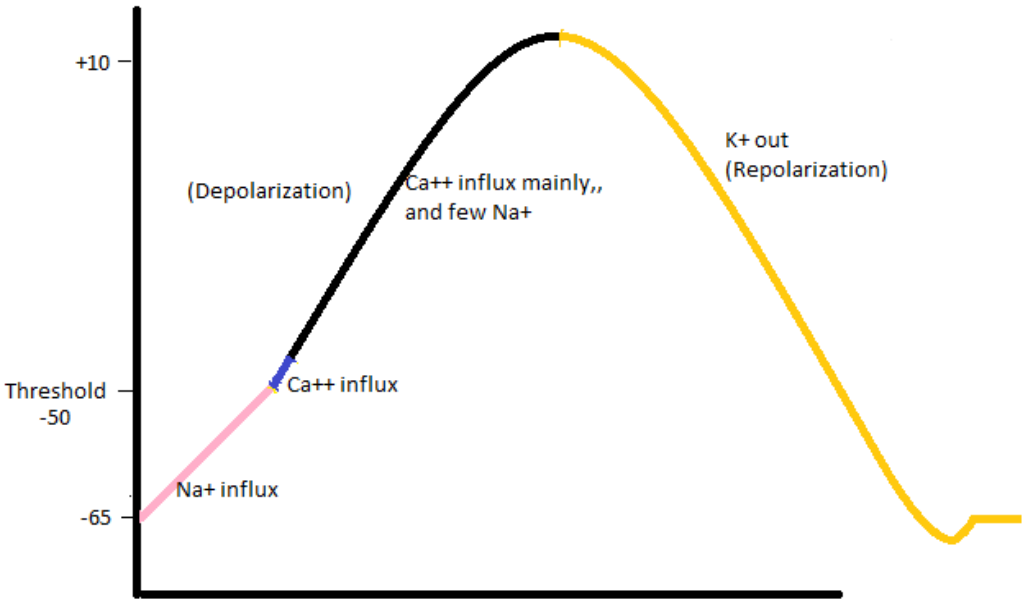
→ Cells that contain the 3rd type (Leakage **Na+** channels**)** are called self-excitable cells (Don't need NS or Hormones & will reach the threshold by its own without stimulus), exist in the heart and they are the pacemaker cells (Pace = rhythm).

Cardiac cells

- Exist in the heart.
- Very small cells (diameter = 3 micrometers).
- These cells are not contractile cells (they lack actin and myosin, so they don't contract).
- Their cell membranes contain leakage channels, so they can bring themselves to the threshold, fire and give action potential that is carried to the heart later on.

✓ more leaky → we reach threshold faster → faster heart rate.

- ✓ less leaky → we reach threshold slower → slower heart rate.
- ✓ sympathetic makes **Na+** channels more leaky → accelerates heart rate.
- ✓ parasympathetic makes **Na+** channels less leaky → decelerates heart rate.



watch this video for further understanding:
https://www.youtube.com/watch?v=FaeJRnEVh5Q