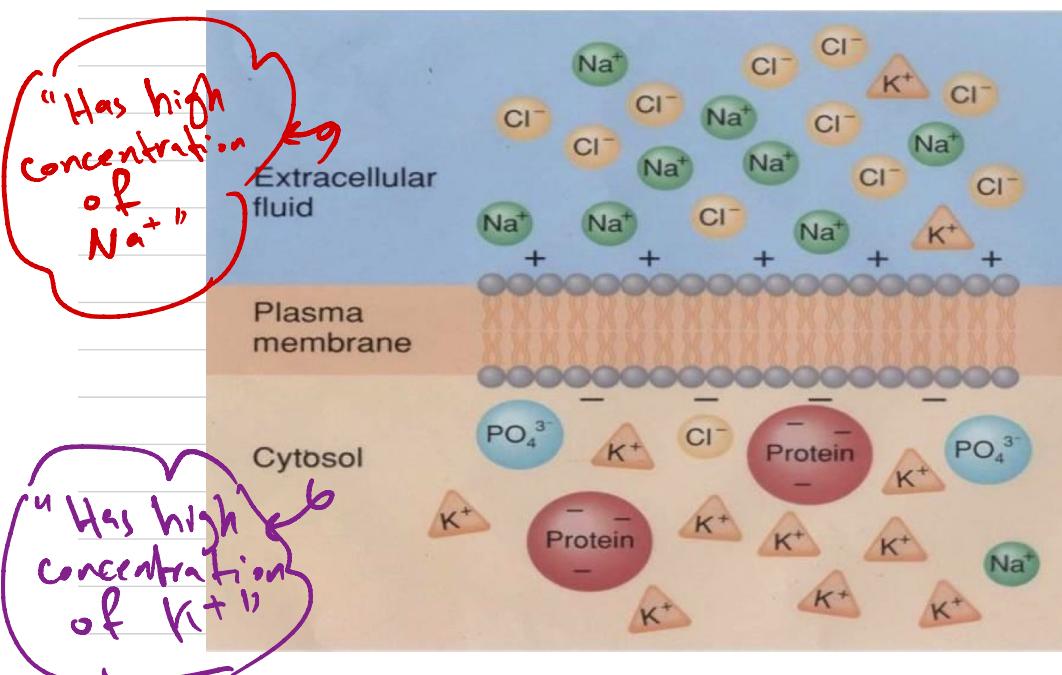


"Sheet 5"

We will talk about what happen when charged particles transport across the plasma membrane.

We know that the plasma membrane separates two different compartments

Concentrated Na^+ outside / Concentrated K^+ inside



How we are keeping that concentration?
One reason is the Na^+-K^+ pump.

⇒ There's high tendency for Na^+ to move from outside to inside

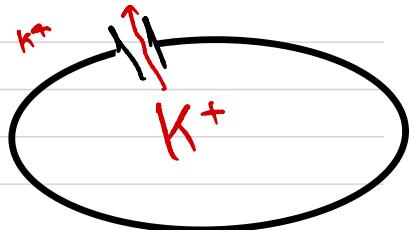
& there's also high tendency for K^+ to move from inside to the outside

We'll start an assumption حيث ان الماء موجود في الخلية

Assume that the membrane is permeable for potassium and not permeable for sodium and anything else, what will happen?

Potassium will move from inside to outside

the potassium will stop moving (No net change)

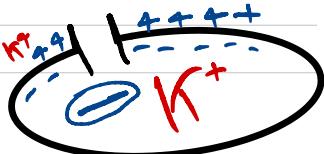


Until it reaches equilibrium

Q] What's the equilibrium exactly is?

≤ It's only concentration gradient \Rightarrow the equilibrium that we are talking about is the electrochemical gradient

⇒ the movement of K^+ from in to out will create an electrical potential (gradient)



And that potential will **Oppose** the chemical potential (the positive outside will prevent K^+ from moving to the ECF)

So: electrochemical equilibrium

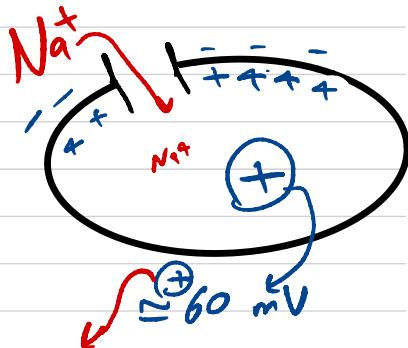
$E_{\text{Chemical}} = E_{\text{Electrical}}$ gradient & oppose it ; E : energy generated by

So the electrical potential will prevent more K^+ from moving outside

& all of this will create large negative charge inside. ($\approx -95 \text{ mV}$)

Another assumption:- what will happen if the membrane is only permeable for Na^+ ?

- Na^+ will move from out to in
- that will make the inner positive relative to the outside
- And it will reach equilibrium



Reminder: what is meant by that charge?

⇒ it means that the inside is positive relative or comparing to outside

- We can calculate the electrical potential that prevent more ions to move in the same concentration gradient direction. (when reaching equilibrium)

Nernst equation

E: Electrical Potential

$$E = \frac{RT}{ZF} \ln \frac{[C]_{\text{out}}}{[C]_{\text{in}}}$$

R (Gas Constant) = 8.314472 (J/K·mol)

T (Absolute Temperature) = t °C + 273.15 (°K)

Z (Valence) (e.g.: Na+ = +1 Cl- = -1)

F (Faraday's Constant) = 9.6485309 × 10⁴ (C/mol)

[C]out (Outside Concentration, mM)

[C]in (Inside Concentration, mM)

∴ from equilibrium :

$$\Delta G_{\text{conc}} + \Delta G_{\text{volt}} = 0$$

$$2FV_{\text{oltage}} - RT \ln \frac{C_o}{C_i} = 0$$

$$V = \frac{RT}{2F} * \ln \frac{C_o}{C_i}$$

* Another form

$$V = 2.3 \frac{RT}{ZF} * \log \frac{C_o}{C_i}$$

$$V = \frac{2.3 \times 8.314 \times (273.15)}{2 \times 9.64 \times 10^4}$$

$$V = \frac{61.54}{mV} * \log \frac{C_o}{C_i}$$

milli - Volt

* Concentration of Ions :-

Ion	Extracellular (mM)	Intracellular (mM)	Nernst Potential (mV)
Na ⁺	145	15	60
Cl ⁻	100	5	-80
K ⁺	4.5	160	-95
Ca ²⁺	1.8	10 ⁻⁴	130

It depends
on the
direction
of moving

Calculate :-

I) Na⁺

$$E = 61.54 \times \log_{10} \left(\frac{145}{15} \right)$$

$$\approx 60 \text{ mV}$$

II) K⁺

$$E = 61.54 \times \log_{10} \left(\frac{4.5}{160} \right)$$

زن (E) كهر (أنتري) 2 يطلع الجواب
بالسلسلة تلقاً (E) من اللوغرارتم
 $\approx -95 \text{ mV}$

Another way :-

$$E = 61.54 \times \log_{10} \frac{C_o}{C_i}$$

$$\Rightarrow E = 61.54 \times \log_{10} \frac{C_i}{C_o}$$

لما اعده
بينه
البط
والنفاس

$$= -61.54 \times \log_{10} \left(\frac{160}{4.5} \right)$$

$$\approx -95 \text{ mV}$$

يطلع له
ز

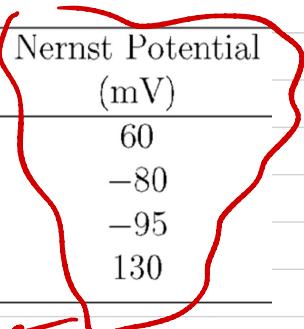
If the membrane is only permeable for K⁺,

the membrane potential will be -95 mV

* * * *

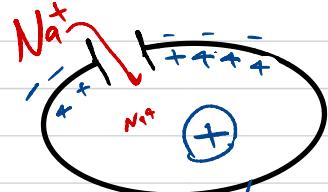
	Extracellular (mM)	Intracellular (mM)	Nernst Potential (mV)
Ion			
Na^+	145	15	60
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K^+	4.5	160	-95
Ca^{2+}	1.8	10^{-4}	130

It depends on the direction of moving

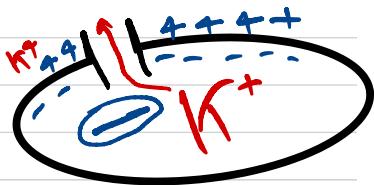


Think in this way:-

Na^+ is more out than in, so it will enter the cell and increase the positivity ($\text{Na}^+ = +60$)



K^+ is more in than out, so it will leave the cell and decrease the positivity inside ($\text{K}^+ = -95$) increase the negativity inside



We noticed that

Cl^-

- Chlorine movement creates potential \ominus inside
- Potassium movement creates potential \ominus inside too!

Okay, but what if the membrane is permeable for many ions? (K^+ | Na^+ | C^{-}) (Normal State)

How we can calculate its potential

⇒ You'll reach a point (equilibrium)

Goldman Hodgkin Katz equation

$$E_m = \frac{RT}{F} \ln \left(\frac{P_{Na^+} [Na^+]_o + P_{K^+} [K^+]_o + P_{Cl^-} [Cl^-]_i}{P_{Na^+} [Na^+]_i + P_{K^+} [K^+]_i + P_{Cl^-} [Cl^-]_o} \right)$$

P multiply $[Na^+]_o$

i = Conc. inside

O = Conc. outside

P = permeability of the membrane to that ion.

(ز) الموجود = في الواقع؛ أي كانا دخلناهما بالفقر

And that's the reason why C1 & C10
are switched

When we return to our first assumption
(membrane is only permeable for K^+)

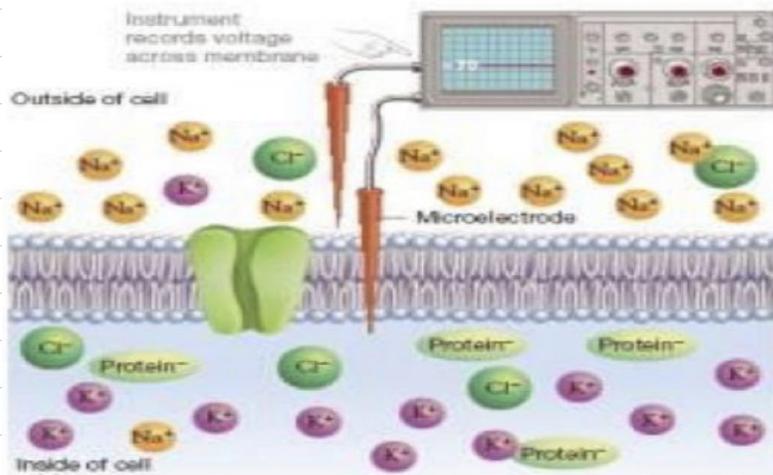
→ Permeability of Na^+ = Zero

→ " of Cl^- = Zero

$$E_m = \frac{RT}{F} \ln \left(\frac{P_{Na^+}[Na^+]_o + P_{K^+}[K^+]_o + P_{Cl^-}[Cl^-]_i}{P_{Na^+}[Na^+]_i + P_{K^+}[K^+]_i + P_{Cl^-}[Cl^-]_o} \right)$$

We return to Nernst equation

* The potential can be measured by electrodes



* The electrodes are put just across the membrane (not inside deeply)

- Deeply inside is electroneutral, so you won't get a correct read

* excitable cells have very high permeability for K^+ & low permeability for Na^+

So that will establish a potential which is closely equal to the potassium gradient (-86 mV for example)

* Na^+/K^+ pump is also responsible in establishing the resting membrane potential.

→ By activating that pump, the membrane potential will get more negative inside (-4 mV)

⇒ $-86 + -4 = -90 \text{ mV}$ and that is the resting membrane potential

* 3 factors determine the resting membrane potential:

1) High permeability for K^+

2) Low permeability for Na^+

3) The Na^+/K^+ pump

The high concentration of proteins inside
is not a reason of the resting potential

Not even the proteins on the
membrane.