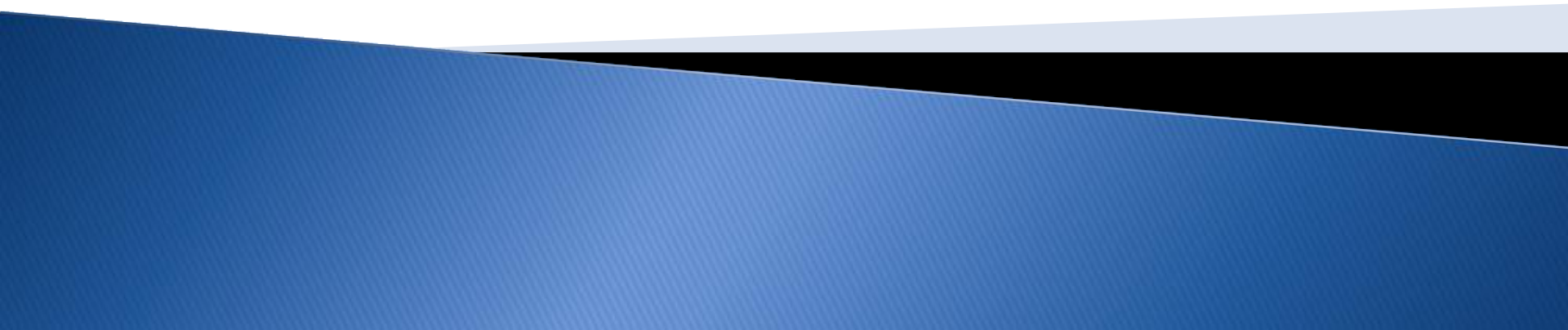


Nerve -muscle physiology

Membrane potential

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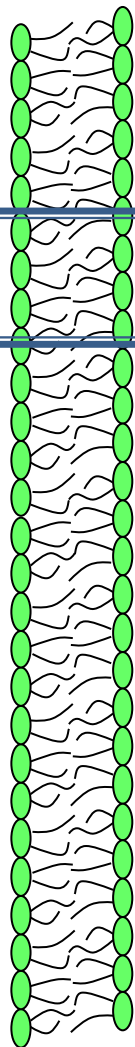
objectives

- ▶ membrane potential
 - ▶ RMP
 - ▶ Development of RMP
 - ▶ Nernst equation and Goldman equation
- 

Membrane potential

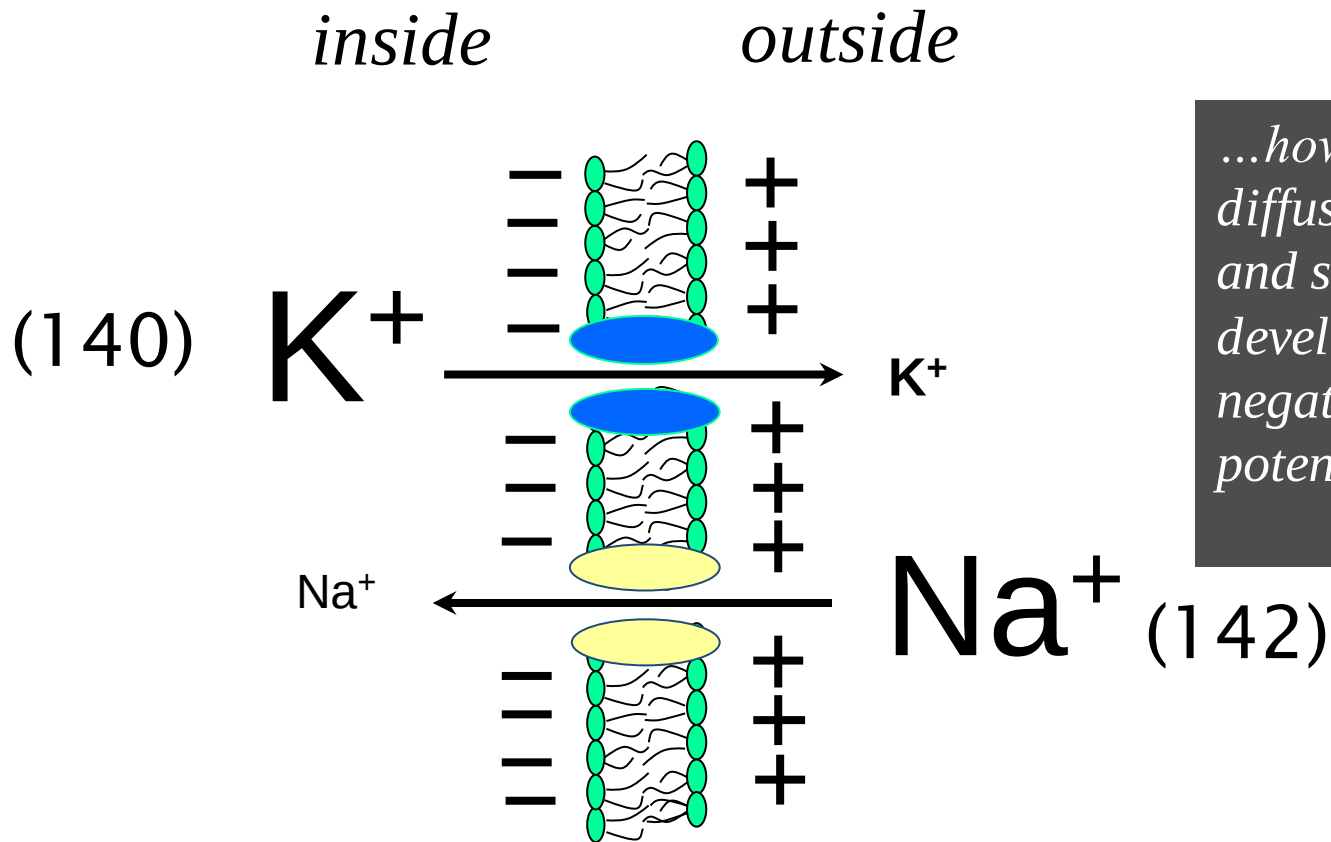
- ▶ Electrical potential exist across the membrane of essentially all cells of the body.
- ▶ Excitable cell like nerve and muscle are capable of generating own electrochemical impulse and in other cells change in the membrane potential plays role in controlling many cell functions.
- ▶ This in the range of -10mV to -90mV , the $-ve$ sign indicating inside of the cell is $-ve$ with respect to outside.
- ▶ When measured in resting cell it is called *Resting Membrane Potential(RMP)*.

Molecular Gradients across the membrane



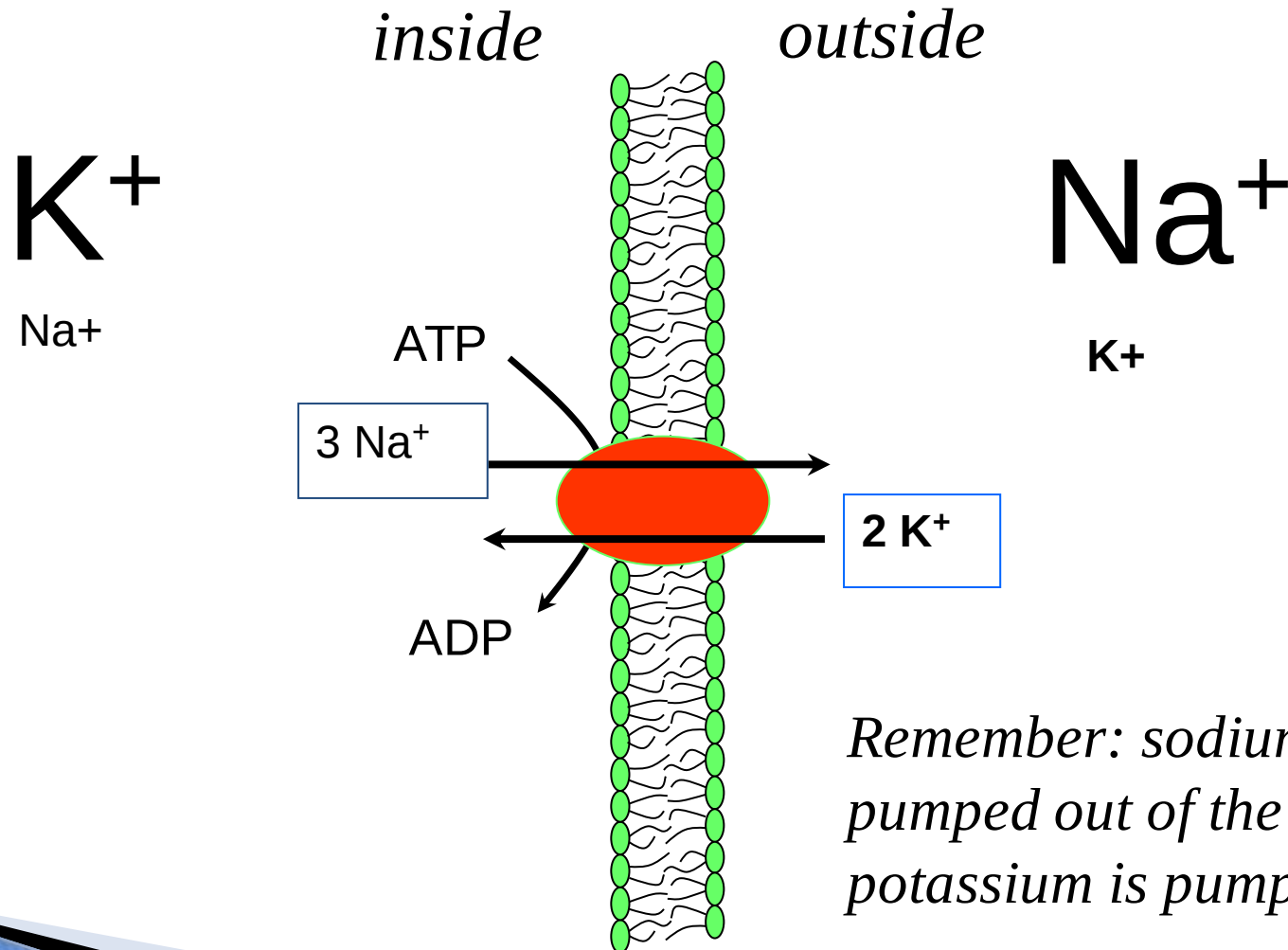
	<i>inside</i> (in mM)	<i>outside</i> (in mM)
Na ⁺	14	142
K ⁺	140	4
Mg ²⁺	0.5	1-2
Ca ²⁺	10 ⁻⁴	1-2
H ⁺ (pH 7.2)		(pH 7.4)
HCO ₃ ⁻	10	28
Cl ⁻	5-15	110
SO ₄ ²⁻	2	1
PO ₃ ⁻	75	4
protein	40	5

Simple diffusion



...how can passive diffusion of potassium and sodium lead to development of negative membrane potential?

Active Transport (Na-K pump)



Development of RMP

If a membrane were permeable to only K^+ then...

- ▶ *K^+ would diffuse down its concentration gradient until the electrical potential across the membrane prevent the further diffusion.*
- ▶ *The electrical potential that counters net diffusion of K^+ is called the K^+ equilibrium potential (E_K).*
- ▶ *Or also called as Nernst potential for K^+ .*

Nernst equation

- ▶ The potential level across the membrane that will exactly prevent net diffusion of an ion in either direction through the membrane is called Nernst potential for that ion.
- ▶ The magnitude of this potential is determined by NERNST EQUATION.

At Equilibrium

Electromotive = Chemical

$$nFV = RT \ln \frac{X_o}{X_i}$$

V = voltage

•R = the gas constant (2 cal mol⁻¹ °K⁻¹)

T = absolute temperature (°K)

F = Faraday's constant (2.3x10⁴ cal V⁻¹ mol⁻¹)

n = valence (charge) of the ion

Nernst Equation:

$$\Delta E = \left(\frac{-60mV}{z} \right) \log \frac{[X^+]_A}{[X^+]_B}$$

(Don't forget about “**z**”...valence of ion)

- Use to calculate the **membrane potential** of **an ion at equilibrium**
- Represents **the electrical potential** necessary to maintain a certain concentration gradient of a permeable solute.

The Potassium Nernst Potential

...also called the equilibrium potential

$$E_K = -61 \log \frac{K_i}{K_o}$$

Example: If $K_o = 5 \text{ mM}$ and $K_i = 140 \text{ mM}$

$$E_K = -61 \log(140/5)$$

$$E_K = -61 \log(28)$$

$$E_K = -94 \text{ mV}$$

*So, if the membrane were permeable only to K^+ ,
 V_m would be -94 mV*

If a membrane were permeable to only Na^+ then....

- ▶ Na^+ would diffuse down its concentration gradient until potential across the membrane countered diffusion.
- ▶ The electrical potential that counters net diffusion of Na^+ is called the Na^+ equilibrium potential .

The Sodium Nernst Potential

$$E_K = -61 \log \frac{Na_i}{Na_o}$$

Example: If $Na_o = 142$ mM and $Na_i = 14$ mM

$$E_K = -61 \log(14/142)$$

$$E_K = -61 \log(0.1)$$

$$E_K = +61 \text{ mV}$$

So, if the membrane were permeable only to Na^+ , V_m would be +61 mV

Goldman's Equation

$$E_m = (60\text{mv}) \log \frac{(P_k [K]_o + P_{Na} [Na]_o + P_{Cl} [Cl]_i)}{(P_k [K]_i + P_{Na} [Na]_i + P_{Cl} [Cl]_o)}$$

- Used to calculate overall membrane potential when **multiple ions** are involved.
- Incorporates **permeability** of each ion.
- Permeability of $K^+ > Na^+ > Cl^-$... thus..

**K+ drives Resting
Membrane Potential**

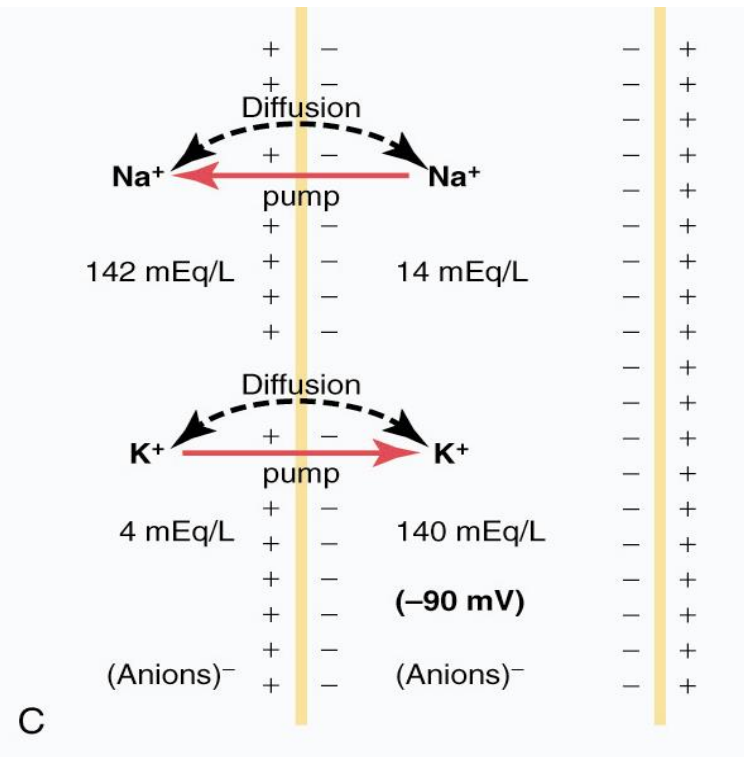
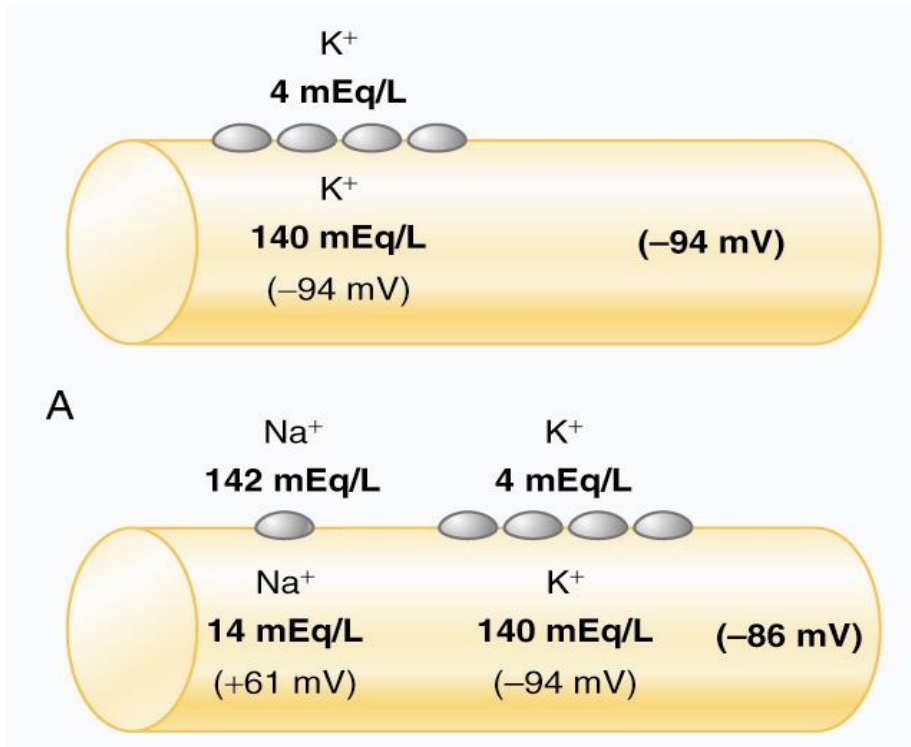
In the Resting State Potassium Controls the Membrane Potential of Most Cells

- ▶ Resting cells have more open K channels than other types
- ▶ More K^+ passes through membrane than other ions– therefore K^+ controls the potential
- ▶ It is further helped by the high intracellular K con due to the activity of Na–K pump.
- ▶ Blood K^+ must be closely controlled because small changes will produce large changes in the membrane potentials of cells

*The resting membrane potential is
closest to the equilibrium potential for
the ion with the highest permeability!*



Resting Membrane Potential Summary



In summary,

- ▶ *If the membrane were permeable only to K^+ , V_m would be -94 mV*
- ▶ *If the membrane were permeable only to Na^+ , V_m would be +61 mV*
- ▶ *If diffusion potential alone by K & Na, V_m would be -86mV*
- ▶ *Additional -4 mV is contributed by Na-K pump giving net RMP of large nerve fiber of -90mV.*

Measurement of RMP

1. Cell
2. Voltmeter
3. Indifferent electrode
4. Micro pipette with silver-silverchloride electrode

