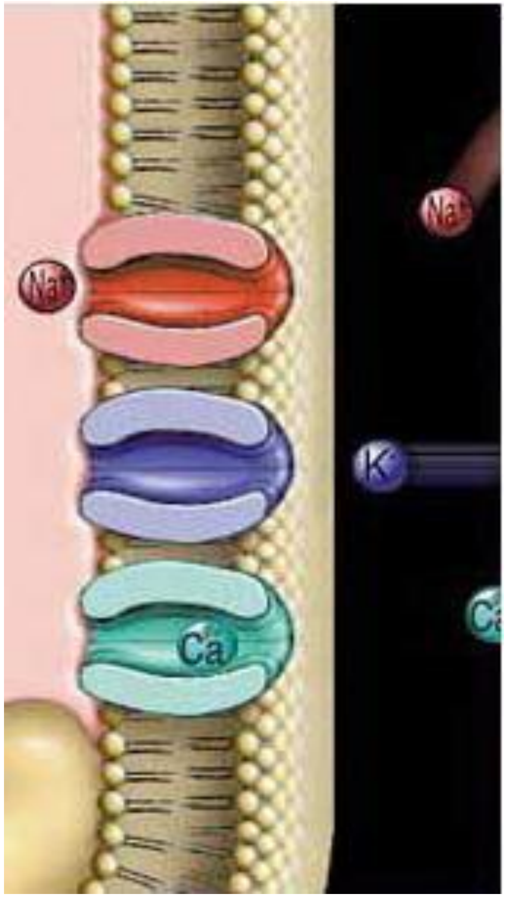
Resting Membrane Potential (RMP)

TEXTBOOK OF MEDICAL PHYSIOLOGY

GUYTON & HALL 12TH EDITION

UNIT II CHAPTER 5



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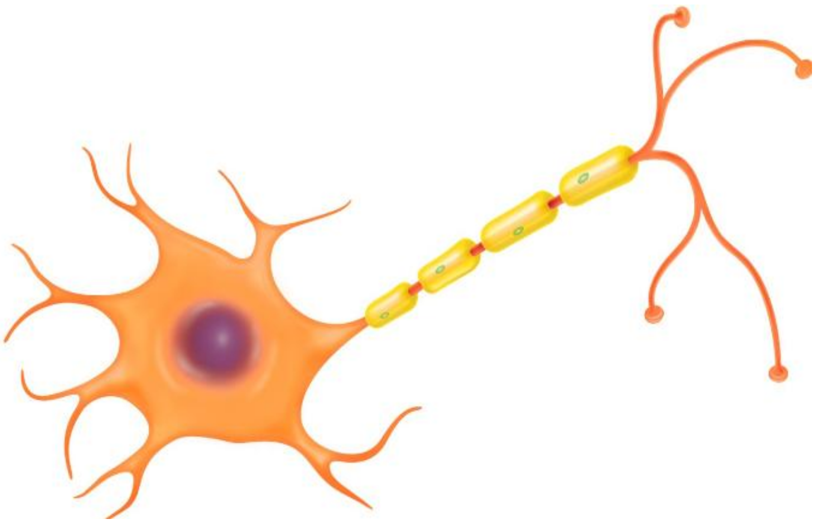
LECTURE OBJECTIVES

By the end of this lecture, you should be able to:

- Recognise the excitable tissues and their properties.
- Recognise and describe the forces acting on ions.
- Know how membrane potential is measured electrically.
- Recognise and apply Nernst equation to calculate equilibrium potential.
- Explain the origin of RMP and how it is created.

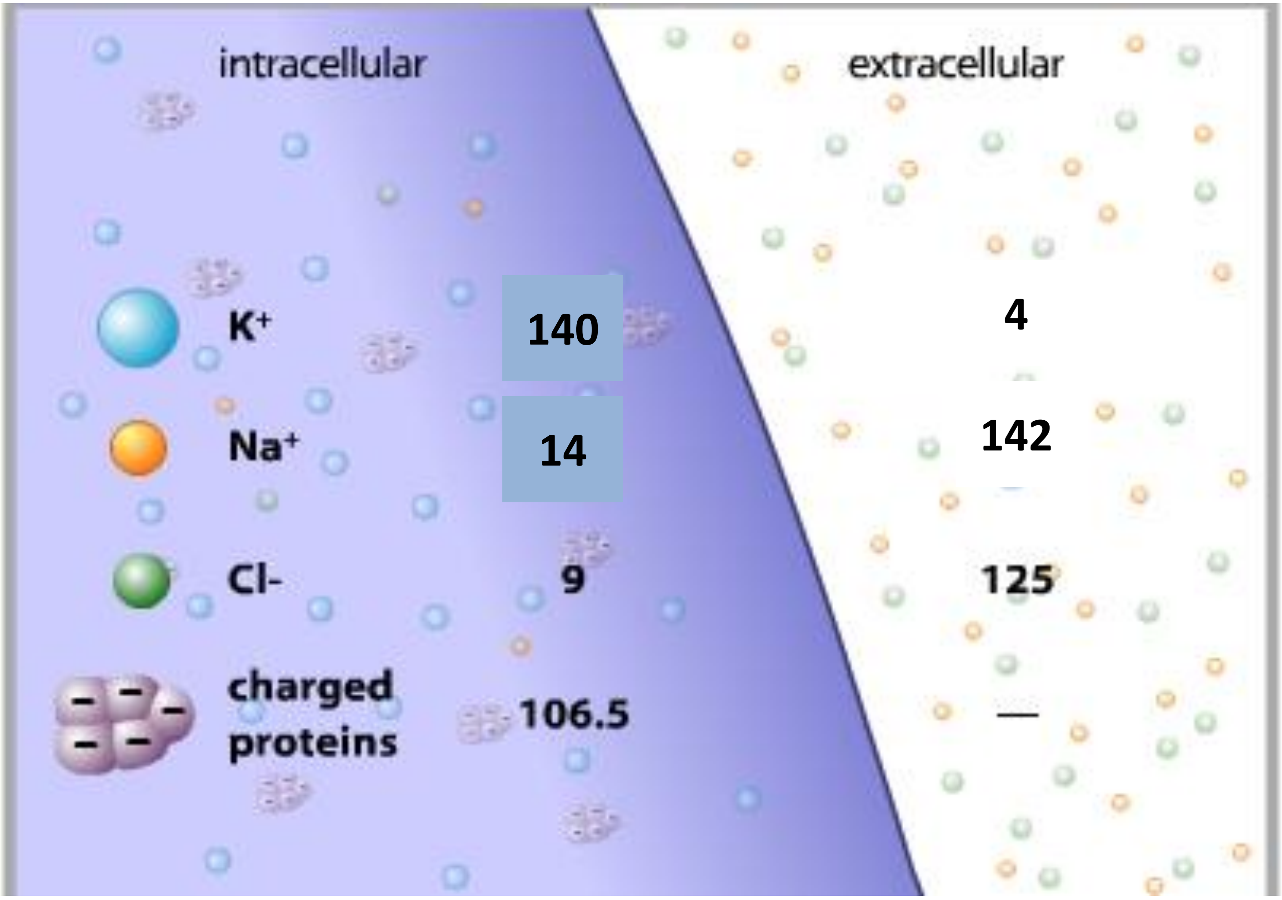
What are Excitable tissues?

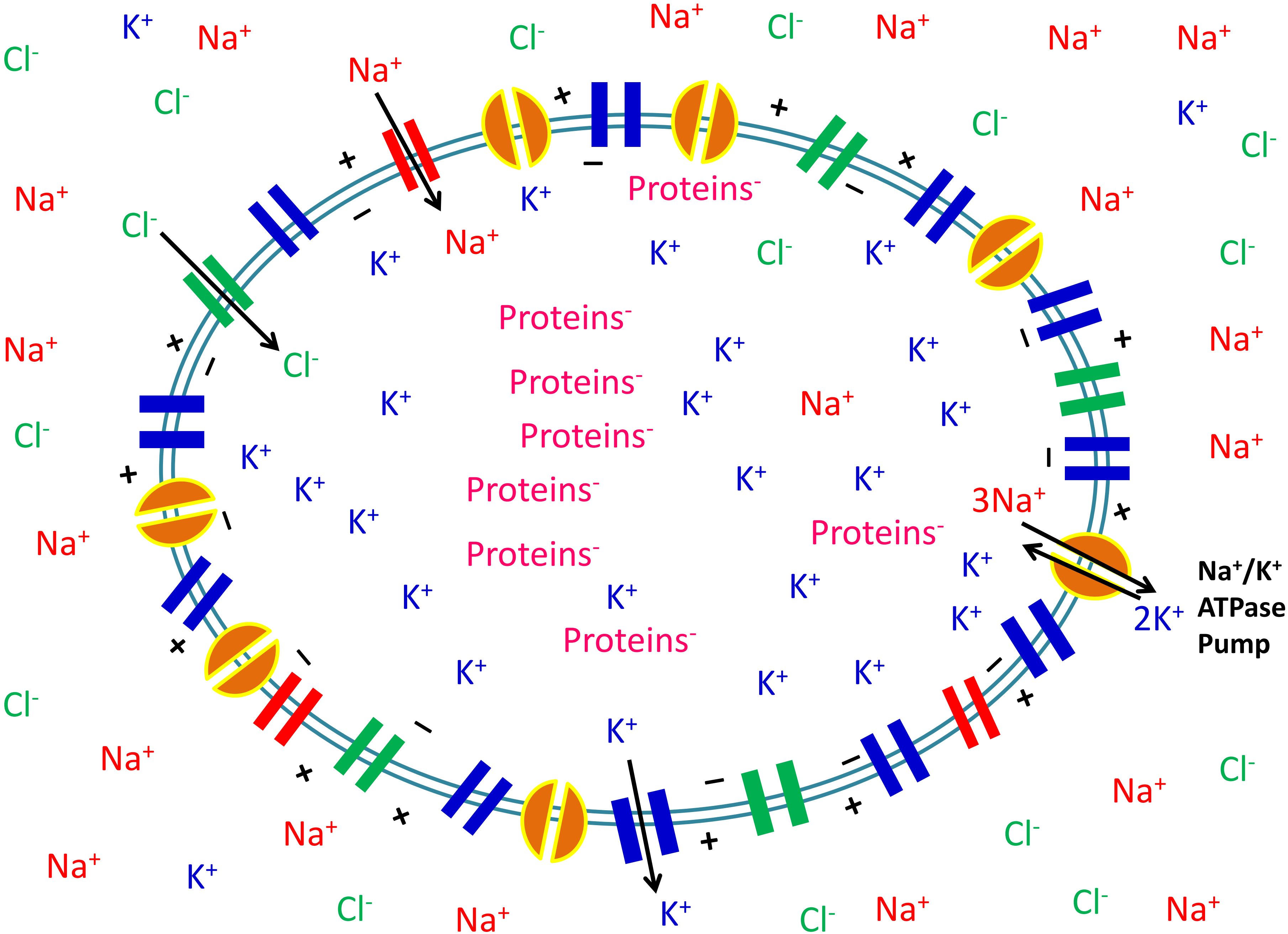


What property do excitable tissues have that makethem different from other body tissues ?

Their membrane acts as an **electric capacitor** storing opposite charges on the opposite sides of the membrane.

Ion Concentration





Cl-
K+
Na+
Cl-
Na+
Cl-
Na+
Cl-
Na+
Na+
Na+
Cl-
K+
Cl-
Proteins-
Na+
Cl-
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3Na+
Proteins-
Na+
K+
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Proteins-
K+
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Na+/K+
ATPase
Pump
K+
2K+
Proteins-
Cl-
K+
K+
K+
K+
Na+
Na+
Cl-
K+
Na+
Na+
K+
Cl-
Na+
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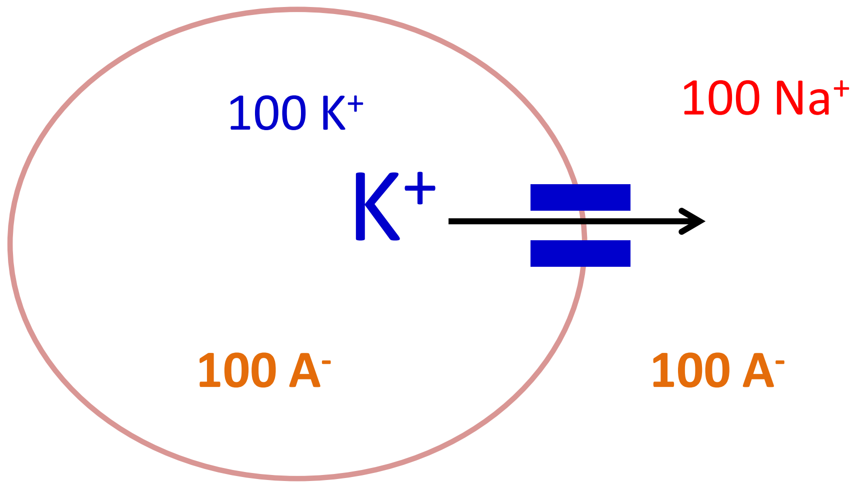
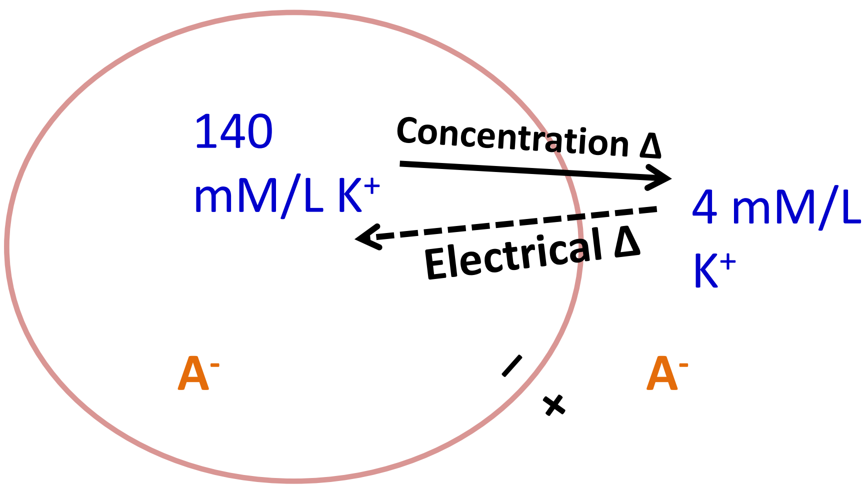
Cl-
Na+
Na+

RESTING MEMBRANE POTENTIAL

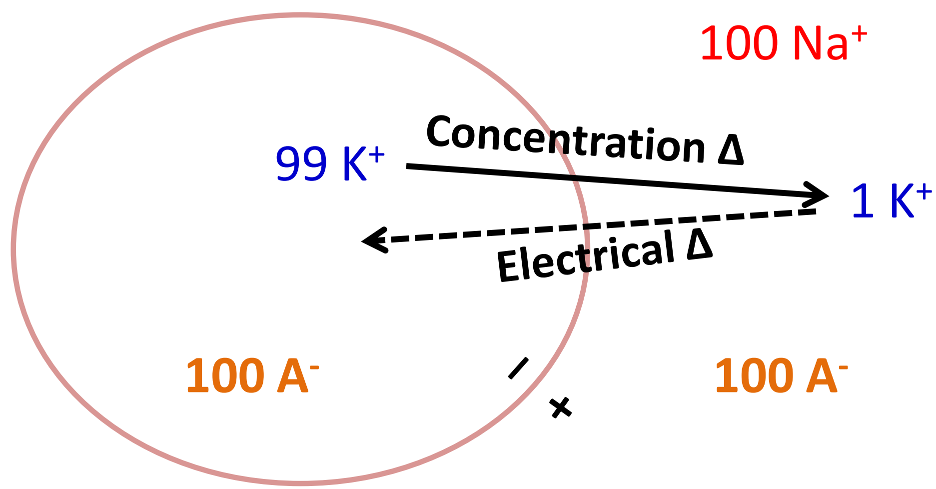
Given:

- ✓ Concentration of ions inside and outside the cell as shown
- ✓ Only K^+ can diffuse across the cell membrane





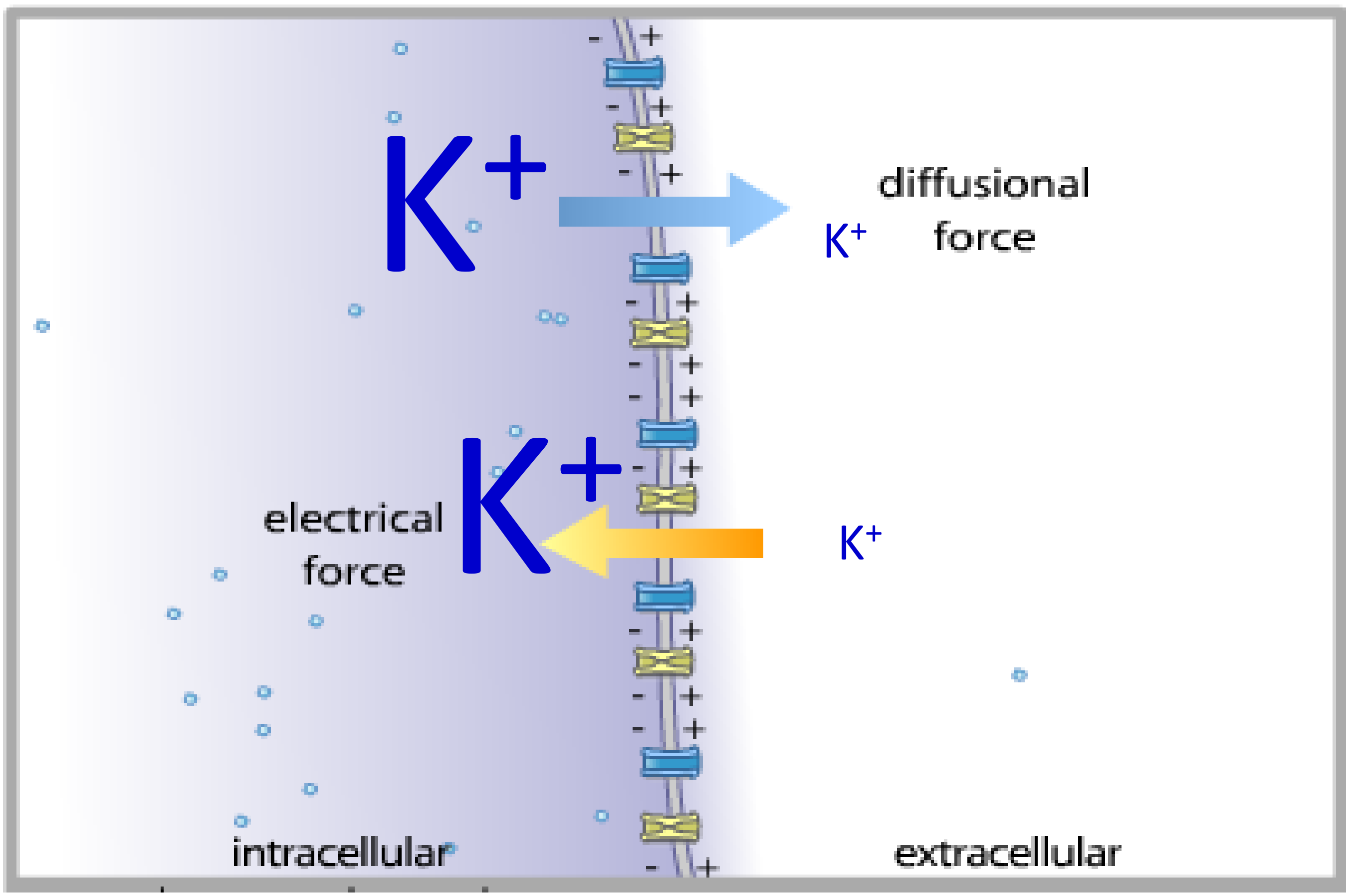
Equilibrium Potential



Opposing Forces Acting on Ions

- Only electrolytes are important because they are electrically charged.

- Oxygen, Carbon dioxide ?



NERNST EQUATION

The Potassium Nernst (Equilibrium) Potential

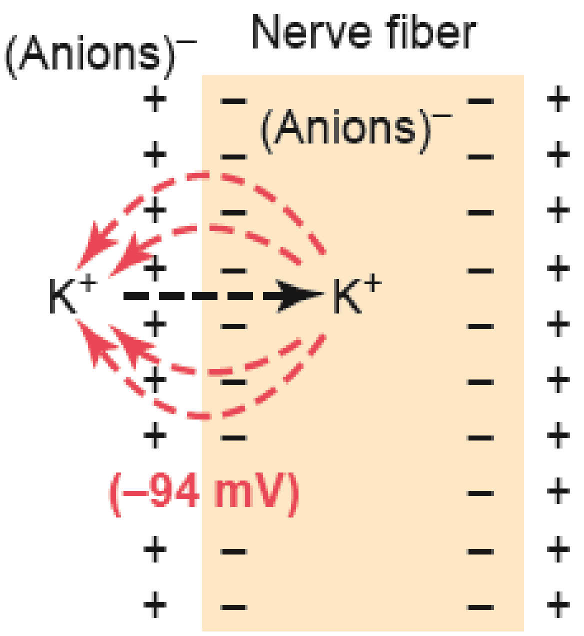
Nernst calculated the level of concentration potential of ions across the membrane that prevent net diffusion of ions to inside or outside

Nernst made a hypothesis which said that if we suppose that

(1) The ECF and ICF contained ONLY potassium ion

(2) And that the cell-membrane was freely permeable to K+

→ Then K+ will diffuse down its concentration gradient (via the K+ leak channels) from inside the cell to outside , carrying with it +ve charges to the outside



*When this electrical gradient (electrical force) , which tends to keep K+ inside equals (=), the concentration gradient (which tends to push K+ outside) → there will be no net K+ movement across the membrane .

$$\text{EMF (millivolts)} = \pm \frac{61}{z} \times \log \frac{\text{Concentration inside}}{\text{Concentration outside}}$$

The RMP in that case is called:-

Nernst Potential for K+ (or K+ Equilibrium or Diffusion Potential)

$$\text{EMF (mV)} = -61 \log \text{K+} \frac{\text{Conc. Inside}}{\text{Conc outside}} = -94 \text{ mV K+}$$

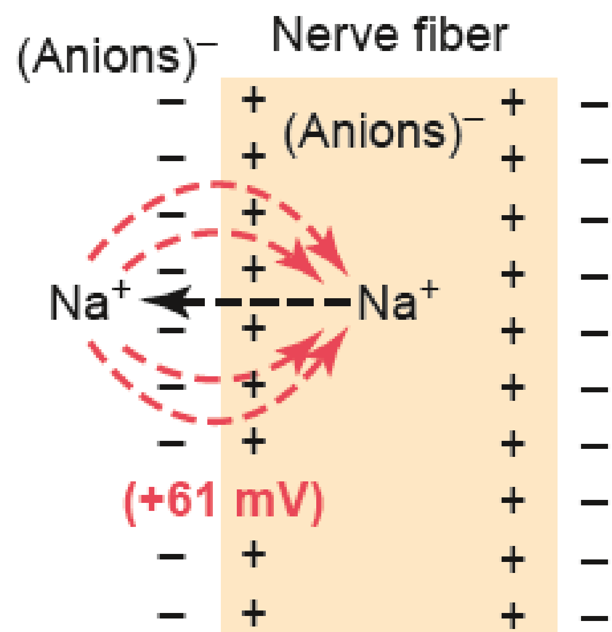
The Sodium Nernst (Equilibrium) Potential

Nernst made a hypothesis which said that if we suppose that:-

(1) the ECF and ICF contained ONLY sodium ions

(2) and that the cell membrane was freely permeable to Na+

→ Then Na+ will diffuse down its concentration gradient to the Inside of the cell, carrying with it +ve charges , and progressively decreasing the negativity inside the cell.



When this electrical gradient (force) , which tends to drive (PUSH) Na+ outside equals = the concentration gradient (which tends to push Na+ in) → there will be no Na+ movement across the membrane .

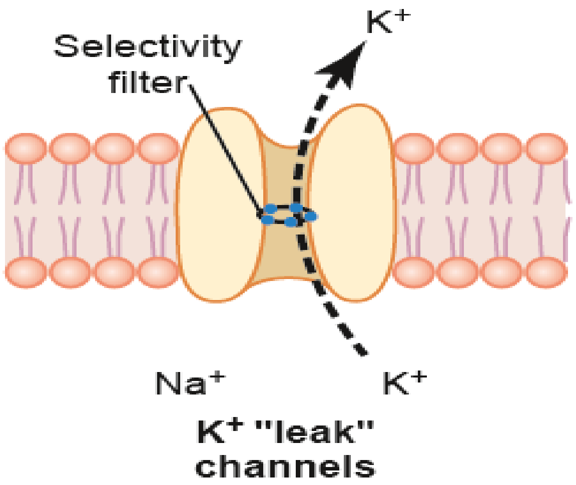
Nernst Potential for Na+ (or Na+ Equilibrium or Diffusion Potential) = +61 mV

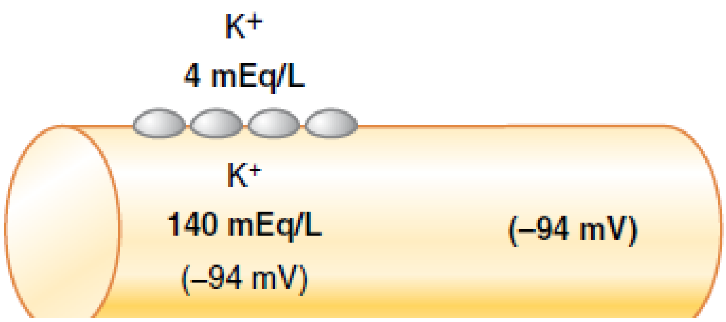
Origin of RMP:

1- Contribution of K diffusion potential:-

K+ leak channels → more K+ diffuses to outside than Na+ to inside

- **The ratio of potassium ions from inside to outside the membrane is 35, and this gives a calculated Nernst potential for the inside of the membrane of -94 millivolts.**





2- Contribution of Na diffusion potential:-

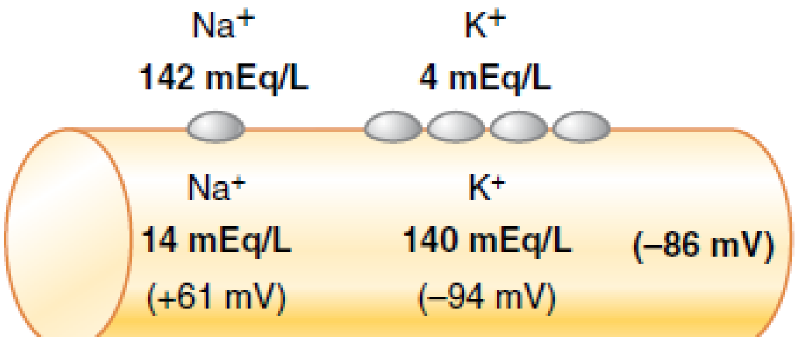
- **Na leak channels:- have very slight permeability to Na ions from outside to inside.**

- **The ratio of sodium ions from inside to outside the membrane is 0.1, and this gives a calculated Nernst potential for the inside of the membrane of +61 millivolts.**

Using this value in the **Goldman equation** gives a potential inside the membrane of **−86 millivolts**,

EMF (millivolts)

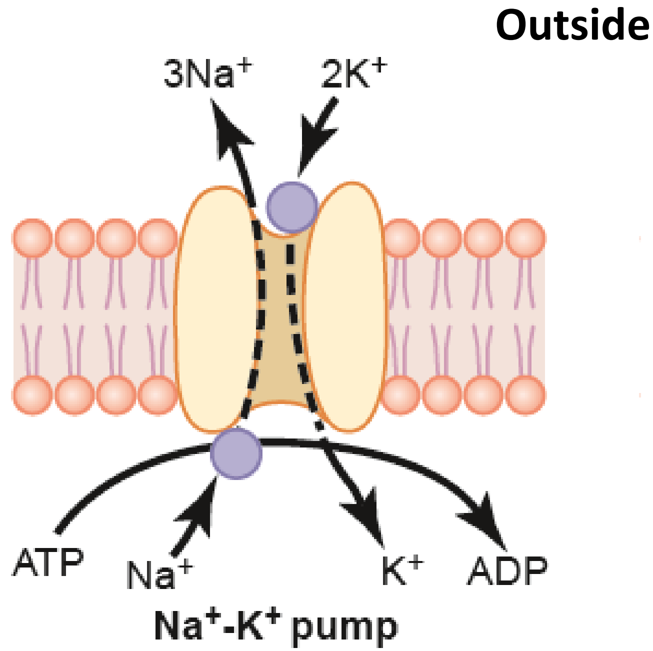
$$= -61 \times \log \frac{C_{Na_i^+} P_{Na^+} + C_{K_i^+} P_{K^+} + C_{Cl_o^-} P_{Cl^-}}{C_{Na_o^+} P_{Na^+} + C_{K_o^+} P_{K^+} + C_{Cl_i^-} P_{Cl^-}}$$



3- Contribution of Na/K PUMP:-

- This is a powerful ***electrogenic pump*** on the cell membrane.

- It pumps 3 Na to outside & 2 K to inside, causing → net loss of +ve ions ,loss of + ve charge from inside , create negativity about - 4mV inside



-So <u>**NET MEMBRANE POTENTIAL**</u> **will be :-**

Diffusion potential (caused by K & Na diffusion) + *Electrogenic* Na/K pump

<u>**(-86 mV) + (- 4mV) = -90 mV**</u>

4- Effect of Large intracellular anions(negative ions)

(proteins , sulphates & phosphates), very low effect.

Measuring Membrane Potential

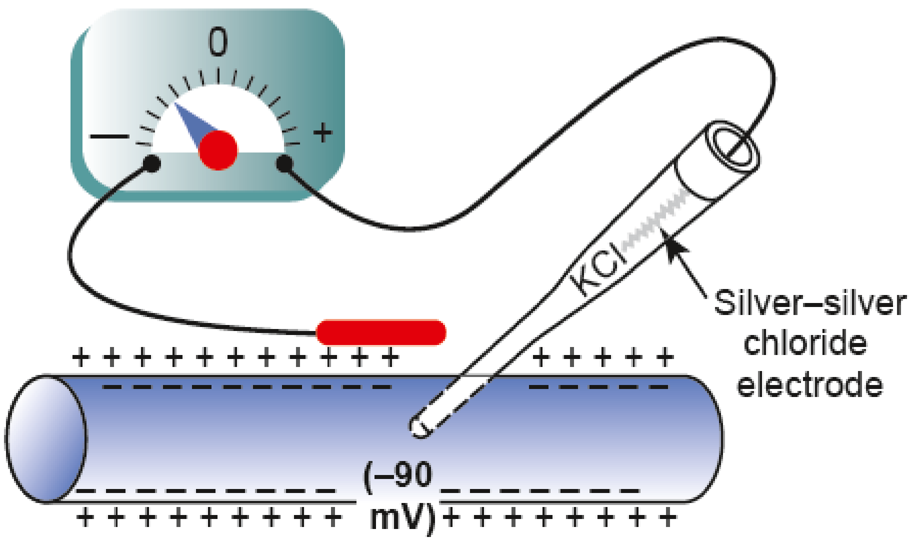
- **VOLTMETER**

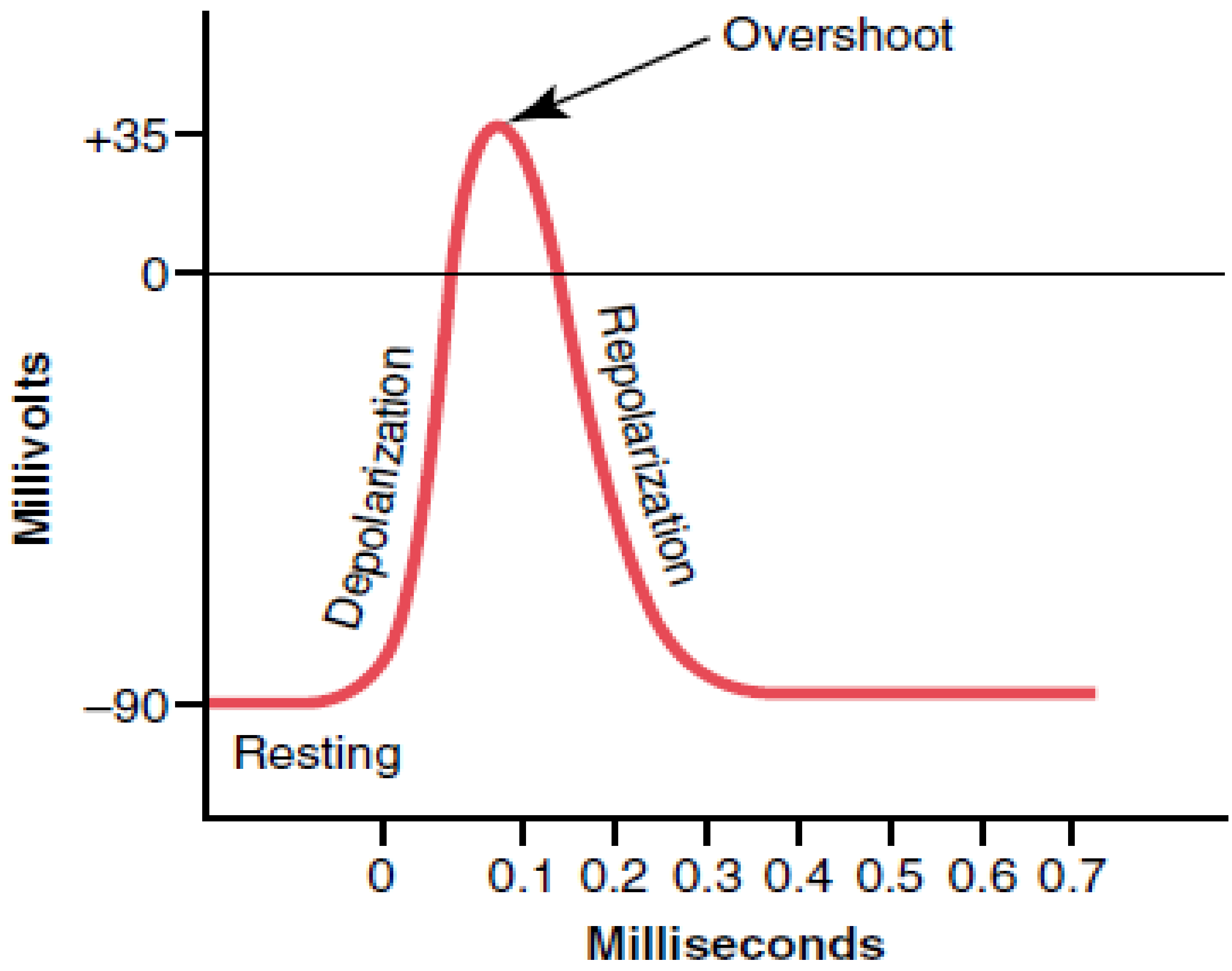
To measure very small membrane potential difference between inside & outside as resting membrane potential .

How?

All excitable cells exhibit an electrical potential (voltage) called resting cell membrane potential (-70 to -90mV)

- **A small filled pipette (microelectrode) containing electrolyte solution is inserted inside the nerve fiber & another electrode is placed in the outside & *membrane potential difference* between inside & outside is measured using the voltmeter**




Overshoot
+35
0
–90
Millivolts
Depolarization
Repolarization
Resting
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Milliseconds