Nernst potential and Resting membrane potential

OBJECTIVES

- At the end of this lecture you should be able to describe:
- 1. Ionic distribution across the cell membrane
- Nernst potential
- Different types of channels present in the cell membrane.
- Role of different ions in the development of Resting Membrane Potential

Excitable Tissues

Definition:

Tissues which are capable of responding to stimuli to highest degree than other tissues of the body in the form of electrical signals.

Imp.

Excitable tissues have LOW Threshold of Stimulation

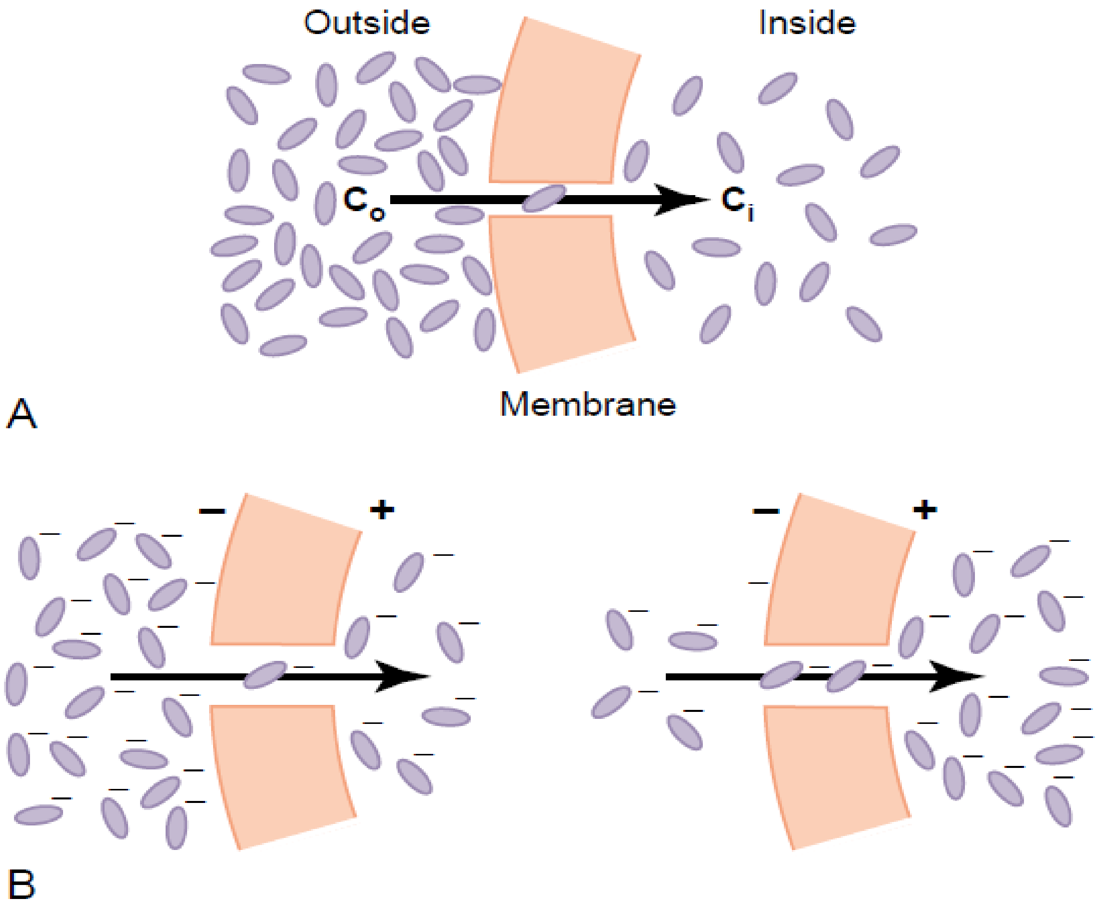
- -Nerve
- -Muscle

Resting Membrane Potential

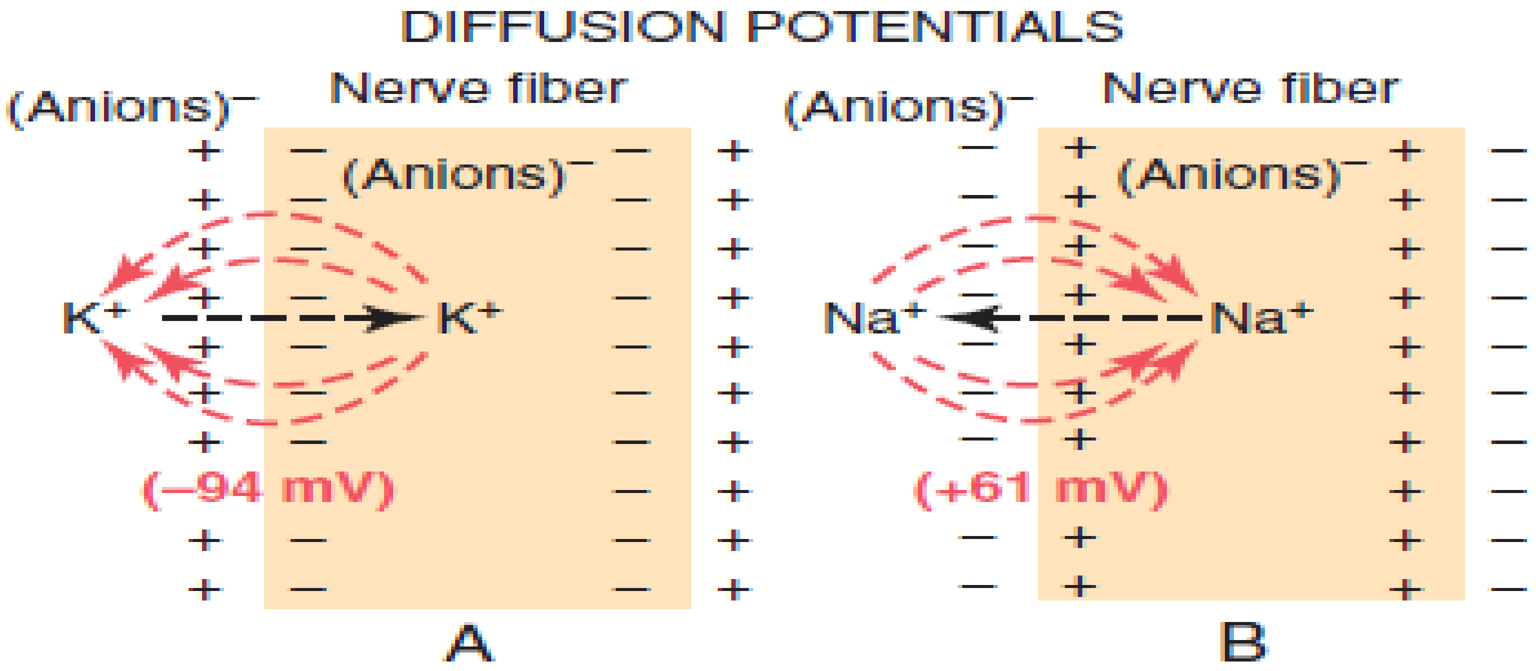
- Definition
- Potential difference existing across the

  cell membrane under resting condition

Effect of concentration difference and electrical potential difference on movement of ions



- **MEMBRANE POTENTIALS CAUSED BY ION CONCENTRATION**
- **Differences Across a Selectively Permeable Membrane**



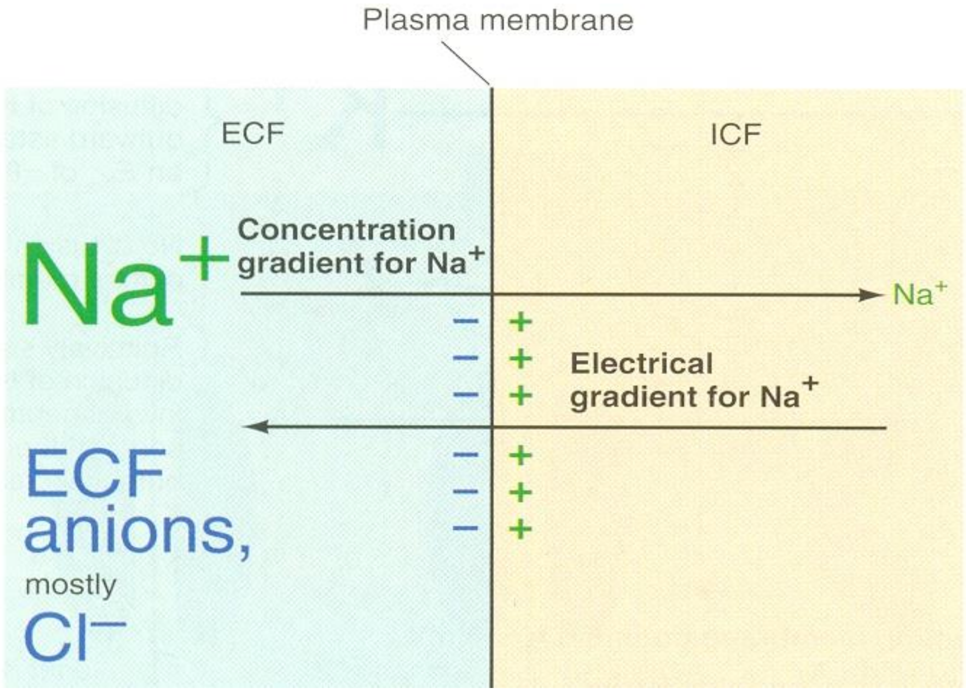
igure 5-1. A, Establishment of a diffusion potential across a nerve iber membrane, caused by diffusion of potassium ions from inside he cell to outside through a membrane that is selectively permeable

Equilibrium (Nernst) Potential for Na^+

Na^+ outside = 142 m **Eq/L**

} 61x log 0.1 = +61mv

Na^+ inside = 14 m **Eq/L**

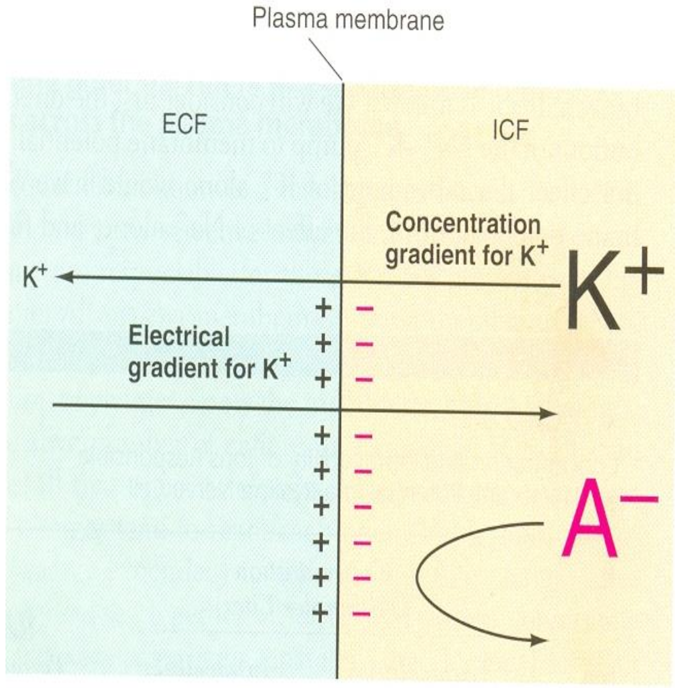


Equilibrium(Nernst) Potential for K^+

K^+ outside = 4.0 m **Eq/L**

}61x log 35= –94mv

K+ inside = 140 **m Eq/L**



Nernst Potential

- **The potential across the cell membrane at which the net diffusion of ions across the cell membrane due to concentration gradient stops**.

- **Nernst Equation**:

$$EMF = \pm 61 \text{ x } \log (C_{in} / C_{out})$$

Where **61** is constant & is = **RT / z F**

Where R= Universal Gas constant

T = Absolute Temp, **z** = ion Valence

F = Faraday, an electrical Const

- **Nernst potential for K+ ions**

Conc of K+ ions inside the cell=140 mEq/l

Conc of K+ ions outside the cell= 4 mEq/l

$$EMF(mv) = -61 \log \frac{140}{4}$$

$$= -61 \log 35$$

$$= -94mv$$

Nernst potential for Na+ ions

Conc of Na+ ions inside the cell=14 mEq/l

Conc of Na+ ions outside the cell= 142 mEq/l

$$EMF(mv) = -61 \log \frac{14}{142} \quad = -61 \log -1$$

$$= +61 \text{ mv}$$

- **The Goldman Equation Is Used to Calculate the Diffusion Potential When the Membrane Is Permeable to Several Different Ions**

Goldman Hodgkin-Katz- Equation

EMF(mv)=

$$-61\log \frac{CNa^{+}_{in}\, PNa^{+} + CK^{+}_{in}\, PK^{+} + CCl^{-}_{out}\, PCl^{-}}{CNa^{+}_{out}\, PNa^{+} + CK^{+}_{out}\, PK^{+} + CCl^{-}\ in\ \ PCl^{-}}$$

Where ‘C’=Concentration

P= Permeability

Goldman Hodgkin-Katz- Equation
Uses

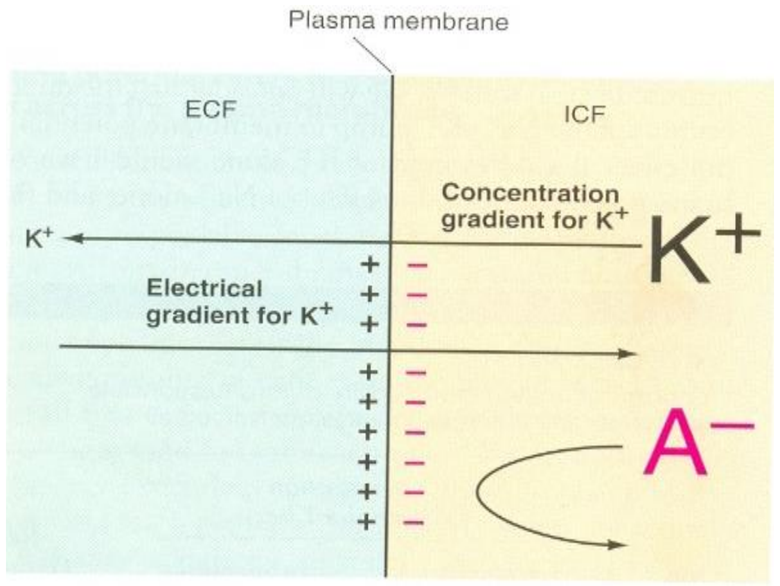
- **Is used to calculate the Diffusion potential when the membrane is permeable to different ions and depends mainly upon three factors:**
    1. **Polarity of electrical charge**
    2. **Permeability of the membrane to ions**
    3. **Concentration of the respective ion on inside or outside**

1. The concentration gradient of sodium, potassium, and chloride ions across the membrane help determine the voltage of the membrane potential.

2. Quantitative importance of each of the ions-- if the membrane has zero permeability to potassium and chloride ions---Membrane potential---- concentration gradient of sodium ions alone

3. Third, a positive ion concentration gradient from *inside* the membrane to the *outside* causes electronegativity inside the membrane.

4. Permeability of Na and K channels change rapidly during nerve transmission



Resting nerve potential of Nerves

Na^+ - K^+ PUMP (ATPase)

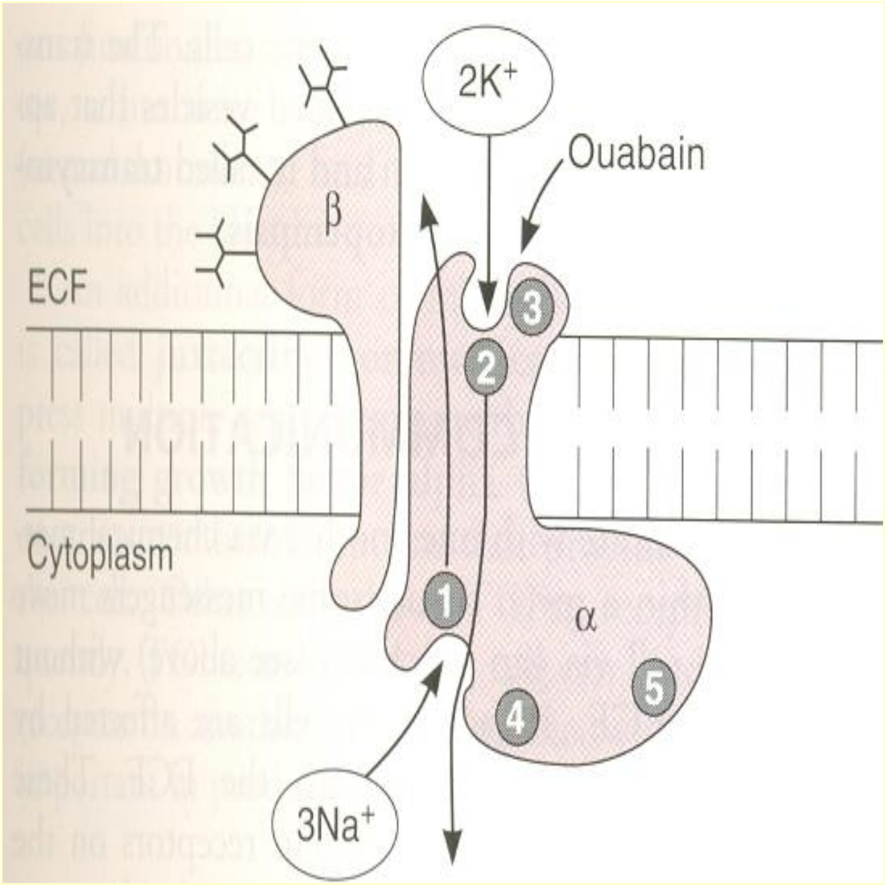
Intracellular portion of alpha subunit has:

Na+ binding site (1),
Phosphorylation site (4), &
an ATP binding site (5).

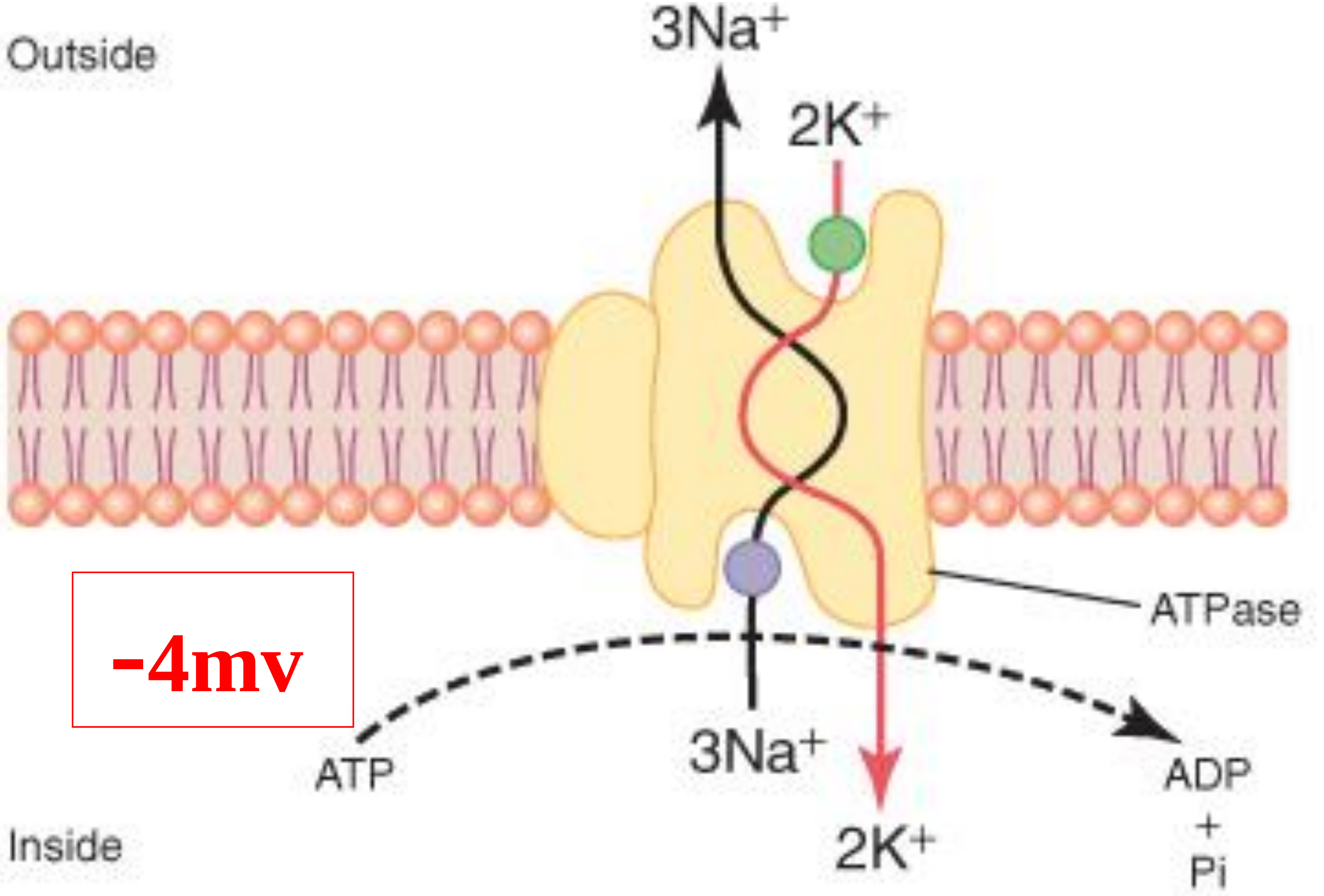
Extracellular portion has :

K+ binding site (2) &

Ouabain site (3)



Contribution of Na^+-K^+ Pump



Functions of Na+ - K+ Pump (ATPase)

- 1. As an Enzyme (Cleaves ATP to ADP)
- 2. Electrogenic. (Contributes -4mv in RMP)
- 3. Homeostasis of Main Electrolytes and Water & hence volume of the cell.

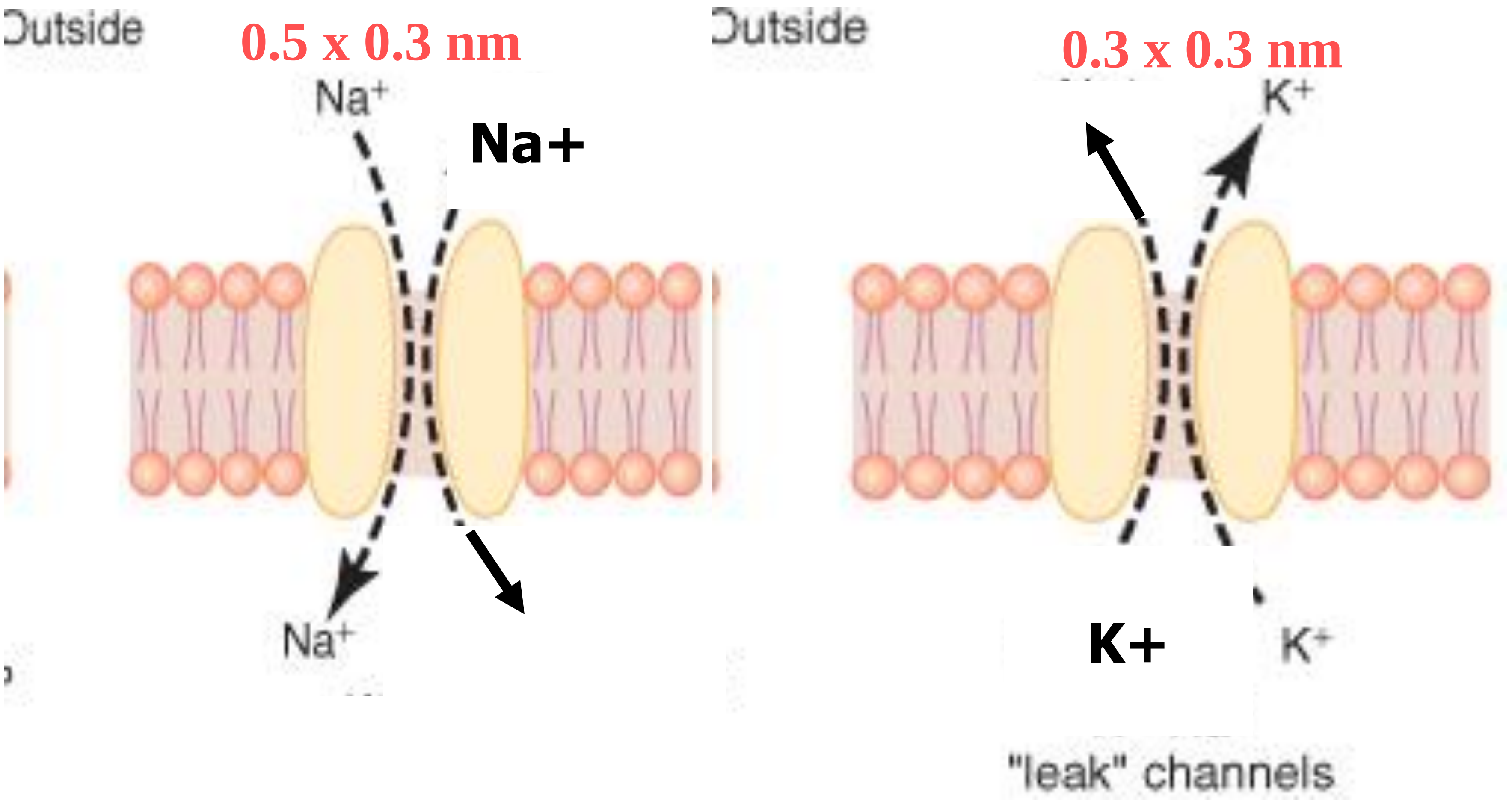
Hormones Increasing functions of ATPase

-Thyroxin, Aldosterone & Insulin.

- Dopamine decreases its function

Leak Channels

Why K+ Leak Channels are More Permeable than Na+ Leak Channels



Origin of Resting membrane potential

Na+ mainly extracellular---
142 mEq/L

K+ mainly intracellular-----
140 mEq/L

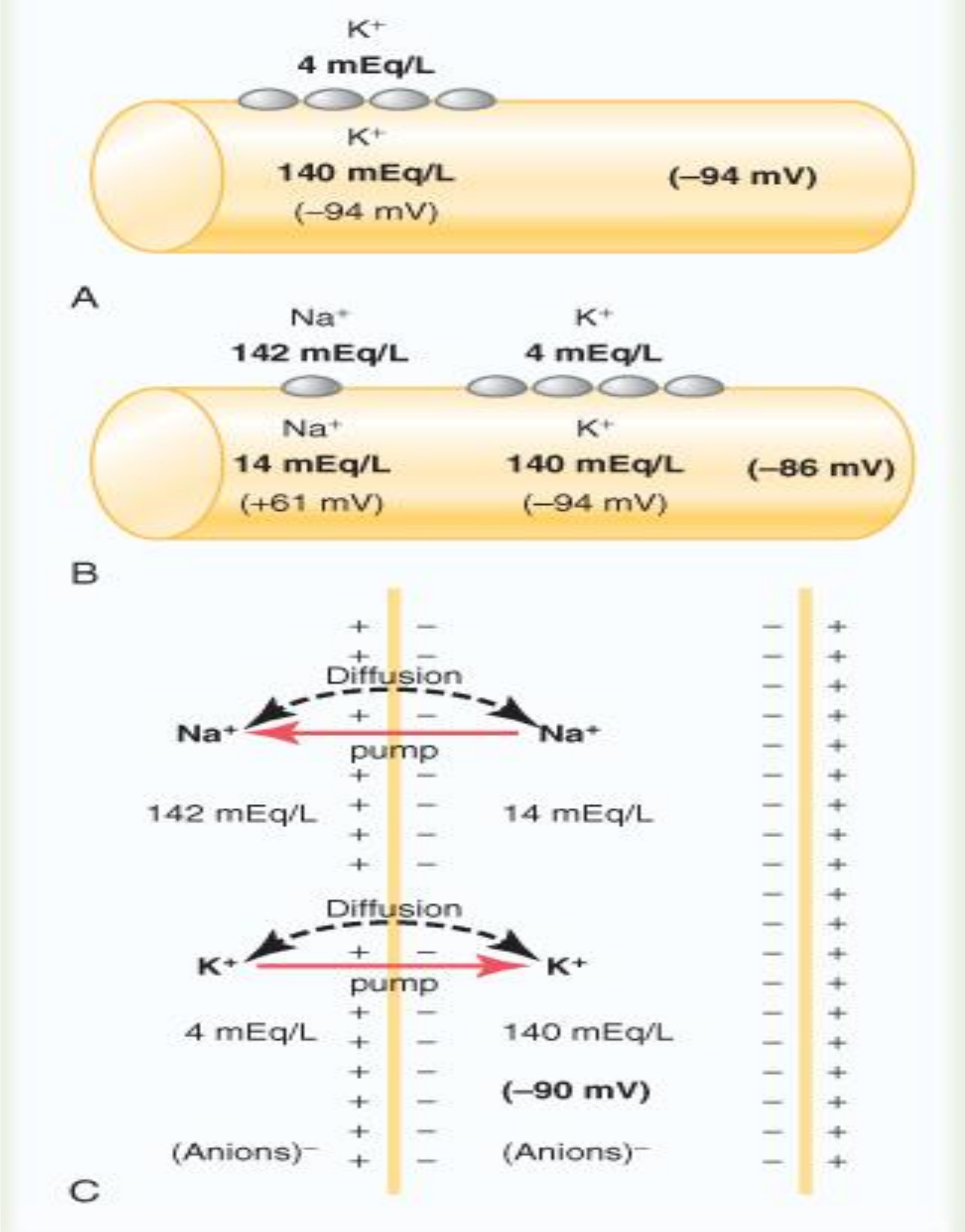
Cl^- mainly extra cellular–
108 mEq/L

Non-diffusible intracellular anions.

-- HPO4 –

-- SO4--

---Intracellular proteins
(4 times as in the plasma)



- If the membrane is highly permeable to potassium but
  only slightly permeable to sodium

  ↓

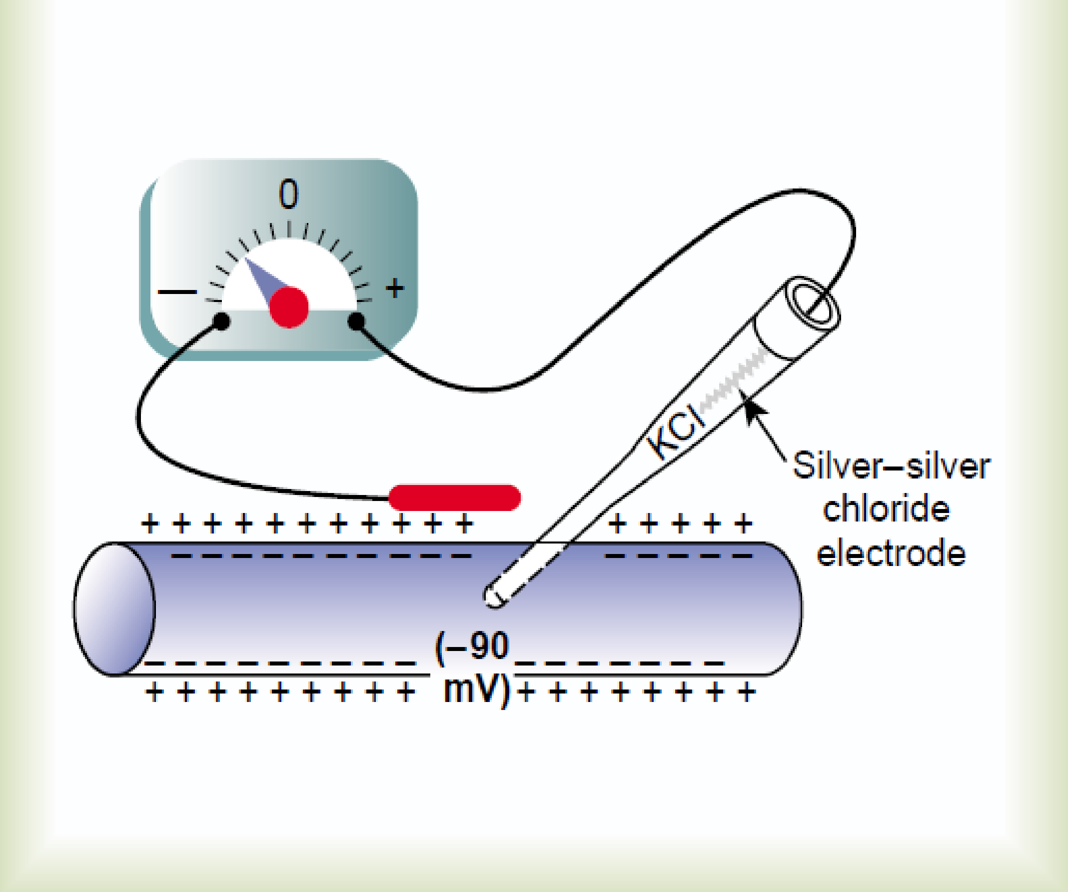
  diffusion of potassium contributes far more to the membrane potential
- In the normal nerve fiber, the permeability of the membrane to potassium is about 100 times as great as its permeability to sodium.
- Goldman equation gives a potential inside the membrane of −86 millivolts, which is near the potassium potential

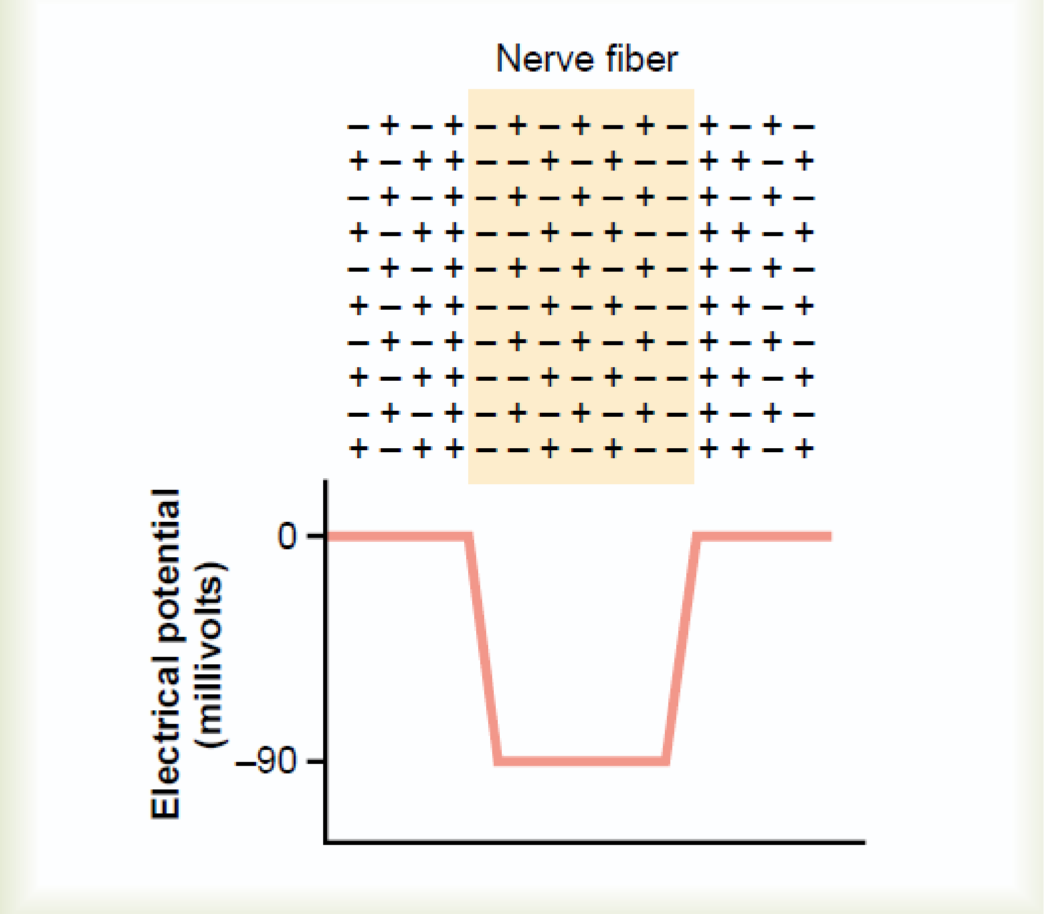
- Nernst potential for Potassium -94mv
- Nernst potential for Sodium +61mv
- Putting these values in Gold man equation, gives a value of -86mv

Which is nearer to K+ diffusing potential

- Na- K pump provides - 4mv
- i.e adding -86 and -4mv= -90mv
- Resting membrane potential in nerves is -90 mv

Measuring the membrane potential of the nerve fiber





Types of Channels in the cell Membrane

- **Leak Channels (Slow)** → **Na+**
  → **K^+**

- **Voltage gated channels (Fast) — For Na^+ & K^+**

  Slow Ca^{++} - Na^+ Channels

- **Ligand Gated Channels --- Neurotransmitters, Hormones**

- **Mechanical Gated Channels – Hair Cells (inner Ear)**

Resting Membrane Potential in Various Excitable Tissues

- Large Myelinated Nerve fibers
- Skeletal Muscle Fibers = -90mv
- Ventricular Muscle fibers

- Smooth Muscle fiber & } = -55 to -60 mv
- Self Excitatory Tissues

Types of Disturbances across the Cell Membrane

- TWO Types:
- 1. Non-Propagated Potentials

  - Synaptic
  - Generator
  - Electrotonic { Catelectrotonic / Anelctrotonic
- 2. Propagated – Action Potential

MCQ

1. The main contributor for development of resting membrane potential is
   A. Na+ ions
   B. K+ ions
   C. Proteins present inside the cell
   D. Cl- ions

2. Resting membrane potential in self excitatory tissue is
   A. -90 mv
   B. -110 mv
   C. -55 mv
   D. -70 mv

3. During resting condition, there is a slight excess of negative charge inside the cell membrane which is due to:

A. Cl- ions
B. Unequal distribution of K+ ions
C. Unequal distribution of Na+ ions
D. Non diffusible SO4 - & PO4 –

4. Related to Sodium Potassium Pump , all of the following are true except:

A. maintains the volume of the cell .
B. does not utilize energy for its function
C. Electrogenic
D. Acts as ATPase.

Choose the one correct answer

6. Na-K Pump is the main contributor in the development of negativity inside the cell. (T/F)

7. Potassium ions are more permeable through the leak channels than sodium ions in-spite of their large molecule weight.

   (T/F)

8. Goldman-Katz equation measure the effect of individual ions on the resting membrane potential.

(T/F)

9. Resting membrane potential in the ventricular muscle fiber is -60 mv

(T/F)

10. Sodium-Potassium pump requires energy for the movement of ions across the membrane

(T/F)

11. Resting membrane potential in smooth is the same as in skeletal muscle fiber.

(T/F)

12. Protein in intracellular fluid is 10 times more than in extracellular fluid and act as anion.

(T/F)

Thank You