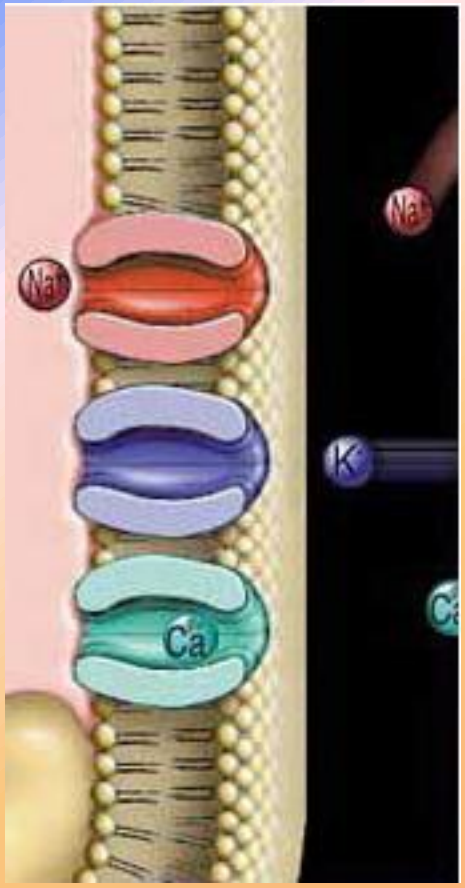

Musculoskeletal Physiology

Physiology of Excitable Tissues : Nerve and Skeletal Muscle

by

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Lecture 3

NEURON
& THE NERVE
RESTING MEMBRANE
POTENTIAL

Lecture 1: NEURON & NERVE RESTING MEMBRANE POTENTIAL

Objectives:-

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

-Identify and describe structural components of neurons and functions.

•Identify **Excitable tissues**

•Identify and describe different potentials& types of membrane ionic channels &equal or unequal distribution of ions across the membrane

• Identify cell membrane creating concentration and electrical gradients.

•Identify and describe diffusional and equilibrium potential and explain the negativity of inside of the cell.

.Apply Nernst equation to calculate equilibrium potential.

-Identify resting membrane potential (RMP)

-describe genesis of resting membrane potential (RMP) and appreciate the effect of changes in ionic composition and/or permeability on genesis of RMP and the role of ions channels, and Na^+ - K^+ pump

- Apply Nerst equation in calculating resting membrane potential

-Identify voltmeter to measure very small membrane potential difference between inside & outside as resting membrane potential.

Q **: What are Excitable tissues ?**

<u>They are nerve and muscle</u>

<u>Q: what property do excitable tissues have that makes them different from other body tissues ?</u>

A: Their membrane acts as an electric capacitor , storing opposite charges on the opposite sides of the membrane this creates a <u>RMP</u> of high value (-70 to -90 mV) compared to other body cells (in RBC , for example MP= -5 mV) .

This high RMP makes the cell-membrane function as a capacitor , that can "discharge" , producing large voltage changes (action potentials) if ionic channels are opened .

Neuron:-

-DIF;-unit of function of the central nervous system, mostly antrior horn cell in the spinal cord supply skeletal muscle

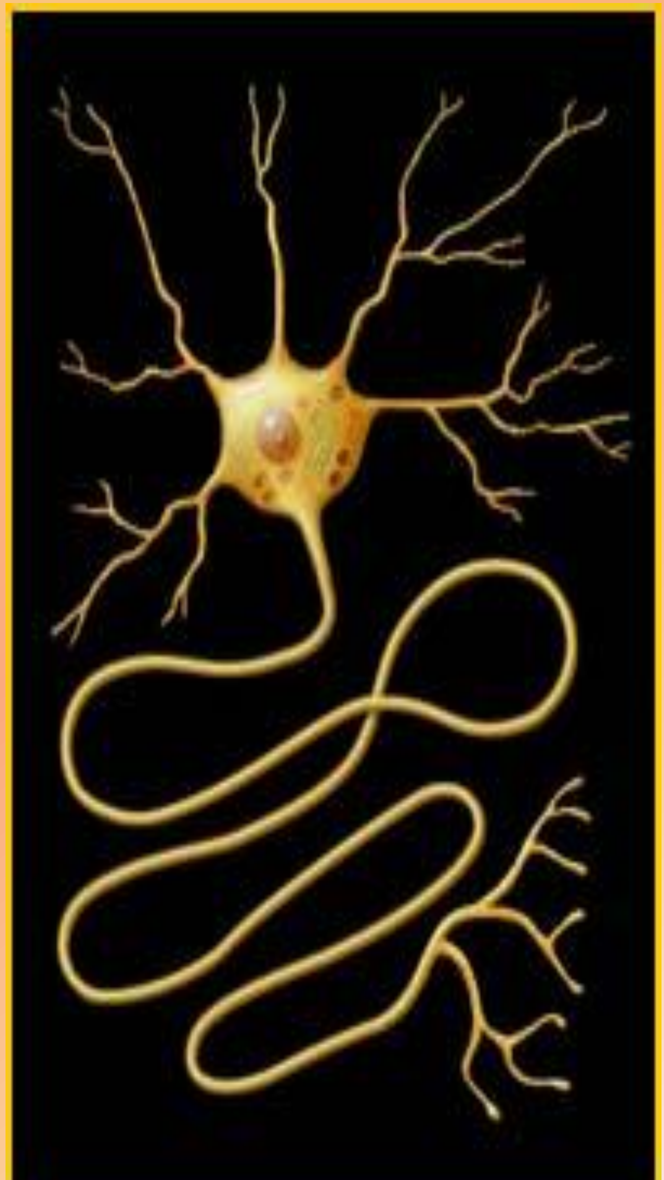
Parts of motor neuron & function of each part:

1- Soma (cell body)

2-Dendrites carry nerve impulses from surroundings to   the soma

3 Axon hillock at which nerve impulses begin &pass in one direction from soma to the axon(nerve fiber) then to axon terminal.

4-Axon and axon terminal end on skeletal muscle



Q : What is the membrane potential (MP) ?
It is the difference in potential (voltage) between the inner side & outer side of the cell-membrane
Q : What are the states of MP ?

(1) Resting Membrane Potential (RMP) : value of MP in a “ resting ” , unstimulated excitable tissue cell
It ranges between -70 and -90 mV in different excitable tissue cells, in large myelinated nerves = -90 mV

(2) Graded Potential (Local Response) : MP in a stimulated cell that is producing a local , non-propagated potential (an electrical change which is measurable only in the immdiate vicinity of the cell but not far from it) .

(3) Action potential (AP) : MP value in case of a cell that is generating a propagated electrical potential after stimulation by effective stimulus(an electrical change which can be measured even at long distances from the cell-body)

Q: What are the types of membrane ionic channels ?

(1) **Leak (Diffusion , Passive) channels: are pores in the cell-membrane which are open all the time , therefore ions diffuse through them according to the ion Concentration Gradient .**

(2) **Voltage-gated channels : open when the cell-membrane is electrically activated .**

(3) **Chemically-gated (ligand-gated) channels : opened by neurotransmitters at neuromuscular junctions&synapses .**

Basic physics of membrane potential

- Nerve has semipermeable membrane a separating the ECF from the ICF .

1- K is high inside the nerve membrane & low outside -→ therefore potassium continuously diffuses through the K^+ leak channels from inside the cell to outside .
So diffusion of k ions through membrane occurs from high conc inside to outside carrying +ve charge with it→ build up of electropositivity outside& electronegativity inside due to loss of +ve ions

2- Na is high outside membrane & very low inside membrane so the direction of the Na^+ chemical (concentration gradient) gradient is inward → and sodium continuously diffuses through the Na^+ leak channels from outside (the extracellular fluid , ECF) to inside the cell (the intracellular fluid , ICF).

NERNST EQUATION

-The Potassium Nernst (Equilibrium) potential

- - Nerst calculate 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 (chemical) gradient (via the K+ leak
- channels) from inside the cell to outside , carrying with it +ve charges to the outside ,

  -This progressively increasing the negativity on the inner side of the membrane because we are losing +ve charges from inside).

- At this goes on and on , negative charges build inside an opposing electrical potential

___ in the opposite direction , tending to prevent the exit of the +ve potassium

- ions (force tends to keep K inside) .

--When this electrical gradient (force) , which tends to keep K+ inside

= the concentration gradient (which tends to push K+ outside) →

there will be no net K+ movement across the membrane .

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

= -94 mV (The -ve charge always refers to the inside of the cell relative to the outside)

(This value was calculated by Nernst equation)

-The SODIUM Nernst (Equilibrium) potential

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

(1) the ECF and ICF contained ONLY sodium ion ,
(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 on the inner side of the membrane .

As this goes on and on , and as the positive charges build inside , an opposing Electrical Potential begins to develop , tending to prevent the +ve Na+ from entering.

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

The MP potential in that case is called Nernst Potential for Na+ (or Na+ Equilibrium or Diffusion Potential) = +61 mV .
(The charge always refers to the inside of the cell)

- What determines the magnitude (value) of the Equilibrium (Nernst) Potential ? The ratio of the ion concentration on the two sides of the membrane .

- The value of this potential EMF can be determined by :

Nernst potential = electromotive force (EMF)

= 61 x log conc of a certain ion inside / conc of this ion outside

$$\text{E.M.F (mV)} = +61 \log \frac{\text{Ion conc. Inside}}{\text{Ion Conc outside}}$$

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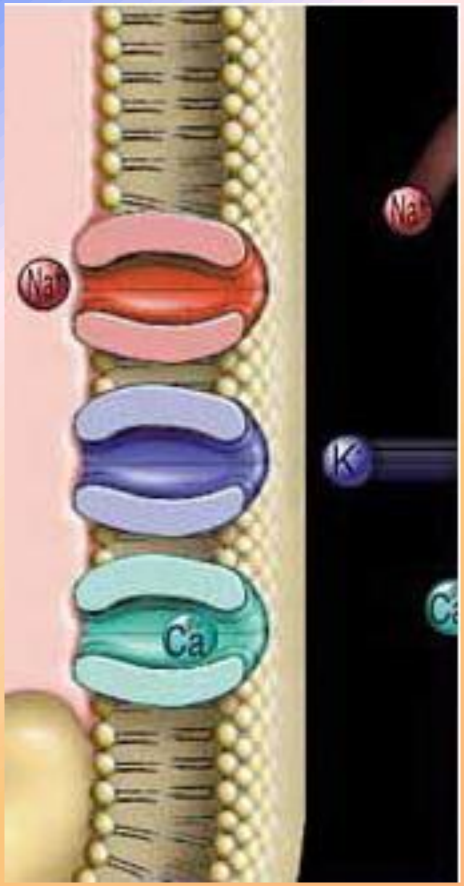
-for K = - 94 mv, for Na = + 61 mv



The resting membrane potential of nerves

RESTING MEMBRANE POTENTIAL

DIF:- it is potential difference across membrane during rest (without stimulation)

Value:- -90 mv in large nerve fibers (-ve inside)(range-70 TO-90)

(the -ve or +ve sign refres to the inside of the membrane)

-The membrane is polarized

- **Two questions should be asked :**
- Q1: What are the factors that make the inside of the cell negative ?
- Q2: and give the RMP of large myelinated nerves the value of - 90 mvolts(-70 to -90 mV)?

Depend mainly on transport properties of resting membrane , the factors that make the inside of the cell negative **:-**

1- **Contribution of K & Na diffusion potential through Na & K leak channels of nerve membrane**

2-**Active transport of Na & K ions(Na/K pump)**

3- **Negative ions inside membrane as phosphate sulphate & proteins**

Origin of RMP:

1- Contribution of K diffusion potential:-

N.B/ K diffusion contributes far more to membrane potential than Na diffusion .

(1) At rest , K inside is 35 times higher than outside

(2) K+ leak channels → more K+ diffuses to outside than Na+ to inside , because K leak channels **are far more permeable to K than Na about 50- 100 time due to small size of K molecules)**

(net **K OUTFLUX TO OUTSIDE causing –ve inside)**

(1) Applying Nernst Equation:-

-K inside is 35 times higher than outside (35/1)

- Nernst potential = - 61mv x log 35/1 (1.54) = -94 mv,

(if K is the only ion act on membrane →RMP = -94 mv with negativity inside the nerve)

- **2- Contribution of Na diffusion potential:-**
- **Na leak channels :- have Slight permeability to Na ions from outside to inside.(why slight?)**
- **- Nernst potential = + 61mv x log Na inside/ Na outside (0.1)**
- **-Nernst potential for Na inside membrane = + 61mv.**
- **(if Na is the only ion act on membrane** →RMP =
- **+ 61mv with positivity inside the nerve**

- Na diffusion potential= + 61mv & that of K = - 94 mv

-using this values in Goldman equation

(to calculate diffusion potential when membrane permeable for several ions)

**** net internal membrane potential of about**

-86 mv,

N.B/i.e potassium has the upper hand .

- **3- <u>contribution of Na/K PUMP:-</u>**

- **pumps 3Na to outside & 2 K to inside, causing → net loss of +ve ions ,loss of + ve charge from inside , create negativity about <u>- 4mv</u> inside**

-so net membrane potential will be :-

(-86 mv) + (- 4mv) = -90 mv

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?

- **-a small filled pipette containing electrolyte solution put inside the nerve fiber & another electrode (indifferent) is placed in the ECF & membrane potential difference between inside & outside measued**

Thank you
for
listening