Resting Membrane Potential
&
Nerve Action Potential

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- Important
- Further Explanation

Physiology Team 434
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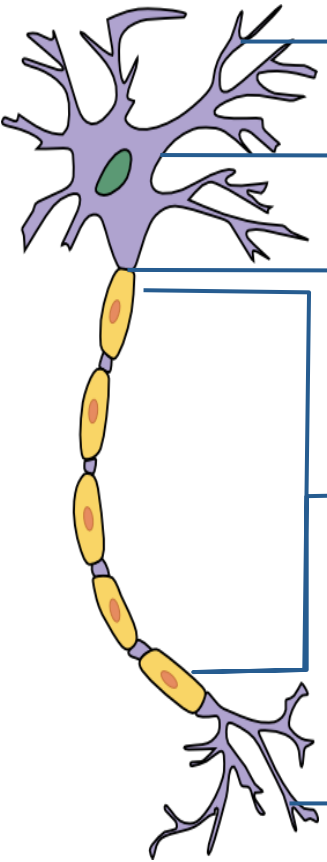
Neuron (Unit of function of CNS)



Dendrites (receive impulses, Carry them from surroundings to soma)

Soma (cell body)

Axon Hillock

Axon

Axon Terminal

Histological classification

Myelin Sheath:
-Formed by Schwann cell which deposits Sphingomyelin
-**Node of ranvier:** is the space between each myelin which allows the impulses to pas

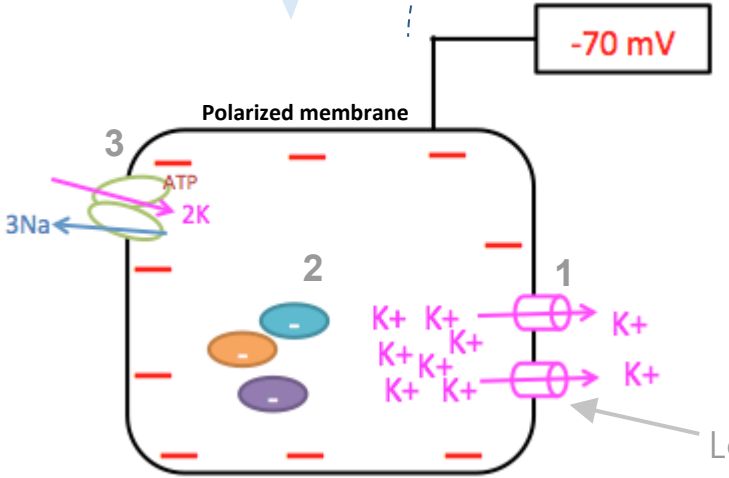
Function:
-Insulator.
-Increase conduction velocity.
- Conserve energy for axon.

Type C:
-Postganglionic autonomic
-Pain Fibers

Resting Membrane Potential

* A nerve cell in resting state without any stimulation. Connected to a voltmeter that shows a negative charge, which means that the inside of the cell is negative comparing to the outside.

Visulas that Dr.Manan Alhakbani used on **board** during class...



Why negatively charged? (RMP)

1- **Efflux of K+** (High leakage of potassium).

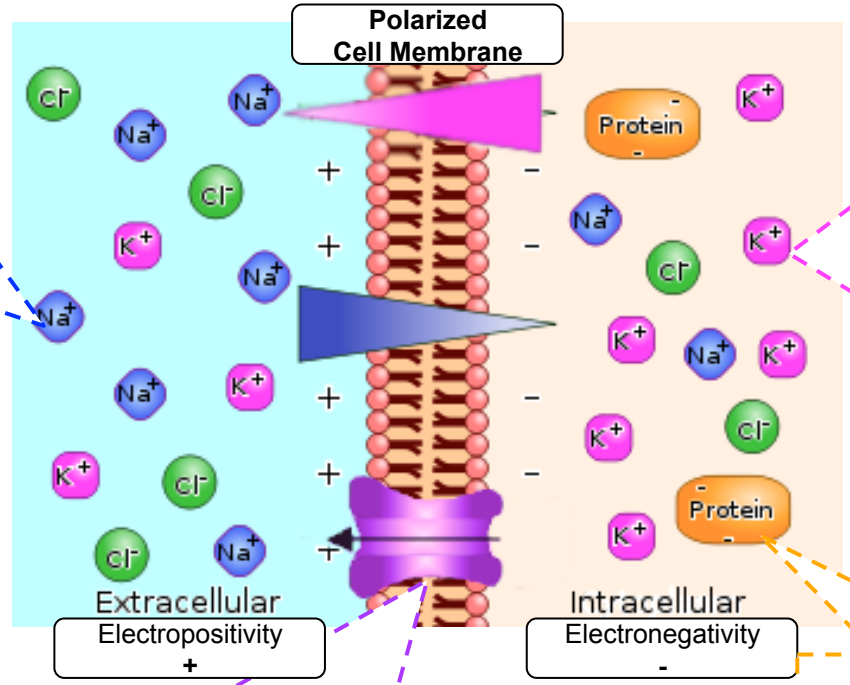
2- **Large negatively charged molecules** (such as protein, sulphate and phosphate).

3- **Sodium-Potassium pump.** (It affects the negativity but not as much as number 1 and 2)

Additional Slide

Resting Membrane Potential

(Potential difference across membrane during rest)
Value: -70 to -90 mv in large nerve fibers



Low Na+ Permeability
-Small amount of *Na+* diffuse into cell (through *Na+ leak channels*)

High K+ Permeability
-RMP is 100 time more permeable to *K+* than *Na+*
-*K+* outflux outside cell carrying +ve charge (through *K+ leak channels*)

Na+/K+ Pump
-Maintain conc. gradients of *K+* and *Na+* between two sides of membrane

Non-Diffusible Anions
-*Proteins, Sulphate,* and *Phosphate ions* can't leave cell. (Large molecules)

Nerve Action Potential

-Nerve signals (impulses) are transmitted by **action potentials** a sudden reversal (change) of membrane polarity produced (caused) by a stimulus to produce a physiological effect.

For example:

*Transmission of impulse along nerve fibres.

*Release of neurotransmitters.

*Muscle contraction.

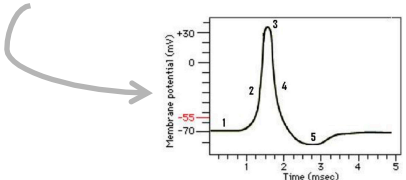
A*ctivation or inhibition of glandular secretion.

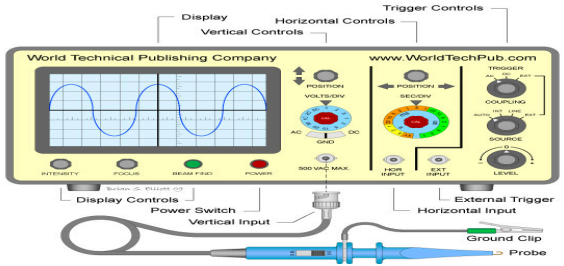
-

Nerves and muscles are the only excitable tissues that response to stimulus and give impulses.

Oscilloscope[1] can be used to measure rapid changes in membrane potential.

1: It gives us the picture of the curve that will be discussed in details

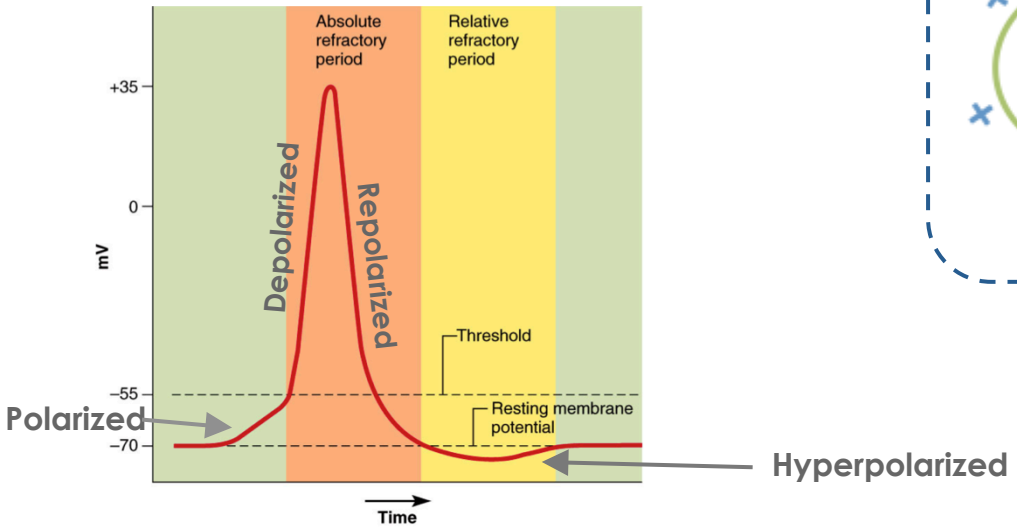


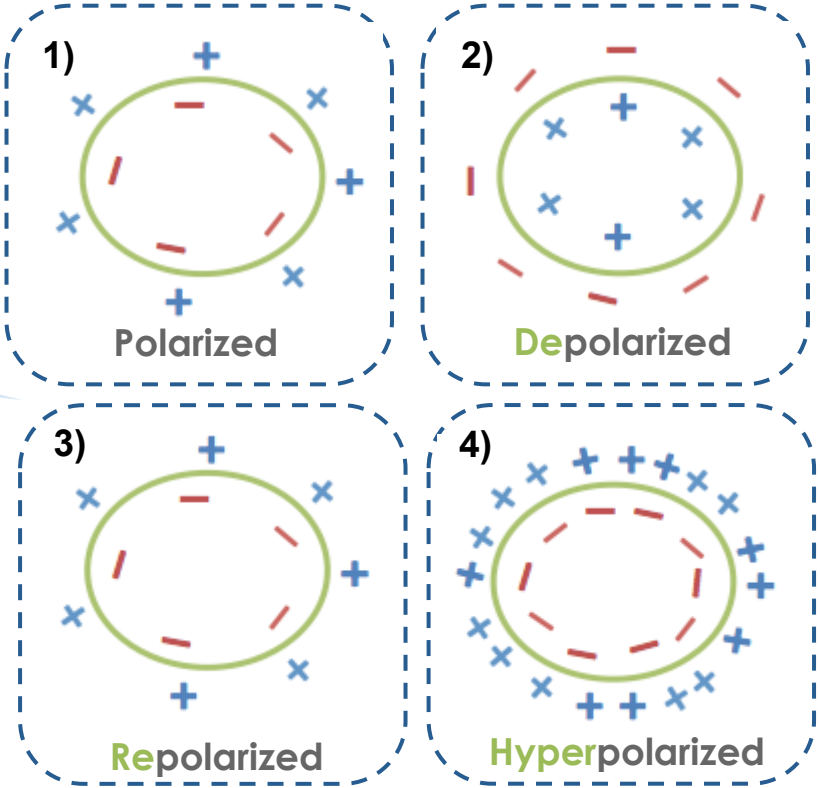


Action Potential

Visulas that Dr.Manan Alhakbani used on **board** during class...

*** How does each state look on the curve?**





*__For now__ just now what does each term of the above indicates and how does it look under the curve. Details will be discussed on coming slides :)

Additional Slide

Nerve Action Potential (Electrical change)[1]

Factors are necessary for **nerve action potential** to occur :

Sodium voltage gated channels

Potassium voltage gated channels

Threshold stimulus (-55/-56 mV)

A stimulus strong enough to move **RMP** from its resting value (**-70mV**) to the level of (**-55mV**) .which leads to production of an **action potential**

B) Subthreshold stimulus: Stimulus that result only in **local** depolarization. it's a stimuli that is below the threshold, causes a little depolarization but doesn't propagate just a local depolarization then the cell goes back to polarized state. *Read more in next slide*

C) Suprathreshold: Stimulus greater (more intense) than the threshold. But once threshold value for excitation is reached a full AP produced, its intensity can not be increased by increasing stimulus intensity[2].

1: Electrical changes (nerve AP) is conducted (propagated) along the nerve fiber as a wave of depolarization to its end (terminals).
2: The intensity of the response is determined by the repetition of the AP not the intensity of the stimulus

Graded Potential (Local Response)

SEE the picture below to understand:

Stimulation of the neuron by a weak subthreshold stimulus produces a local, non-propagated potential which is measurable only in the immediate vicinity of stimulated point, but not farther than that.

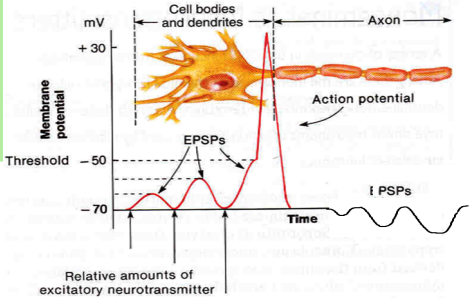
It does not obey All-or-None Law

In case of local responses:

Excitatory Postsynaptic Potential (EPSP)

If the stimulation is excitatory (opening sodium channels) It produces a depolarizing local response.. which makes the inner side of the membrane less negative

(Reduces, depolarizes the MP)



Inhibitory Postsynaptic Potential (IPSP)

If the stimulation is inhibitory (opening potassium or chloride channels) -> it increases , hyperpolarizes the membrane -> producing a hyperpolarizing local response -> (which makes the inner side of the membrane more negative) And makes the cell more difficult ton excite .

Was Mentioned in Boys' Slides

Nerve Action Potential

All-Or-Nothing principle:

States that once an action potential has been elicited at any point on the membrane of a normal fiber. The depolarization process **travels over the entire membrane** if conditions are right.

OR

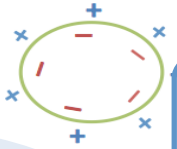
it does not travel at all if conditions are not right.

* Action potential occurs when voltage-gated channels are opened!!

Q : What opens the voltage-gated channels ?

Opened by a stimulus strong enough to depolarize them to **threshold**.

The successive stages of the action potential are as follows:



Resting stage

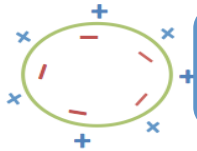
RMP before the action potential begins(-70 to-90 mV is the resting potential)

A stimulus is received by the dendrites of a nerve, If the stimulus is sufficient to drive the interior potential from -**70 mV up to -55 mV**, the process continues….

Stimulation by threshold stimulus

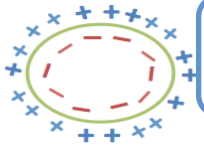
Depolarization

Having reached the action threshold, voltage gated **Na^+ channels open**. The Na^+ influx drives the interior of the cell membrane up to about **+30 mV**.



Repolarization

Na^+ channels close(depolarization ends) and the **K^+ channels open**. Due to high K flow outside(K+ outflex) which cause negativity inside, the membrane begins to repolarize back toward its rest potential.



Hyperpolarization

The repolarization typically overshoots the rest potential to about **-90 mV**. Hyperpolarization prevents the neuron from receiving another stimulus during this time, or at least raises the threshold for any new stimulus.

The **Na^+/K^+ pump** eventually brings the membrane back to its **resting state of -70 mV**

After hyperpolarization

Voltage-gated channels:

* Open quickly and close quickly

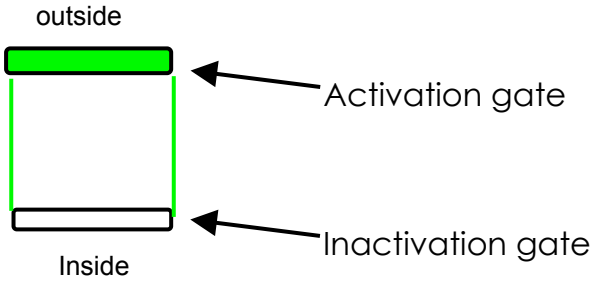
Sodium
Voltage-Gated channel:

* Two Gates:
1- **Activation gate:**
on the outer side. "sensitive for voltage."

2- **Inactivation gate:**
on the inner side. "sensitive for time"

* Consist of three states.

* During rest the inactivation gate is open while the activation gate is closed.



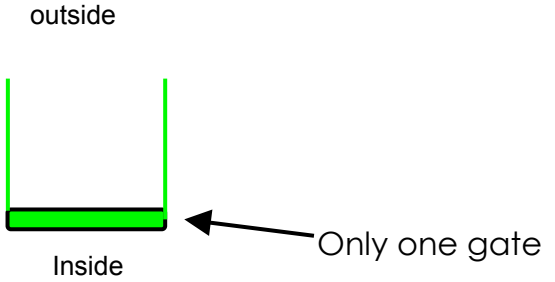
* Open slowly and close slowly

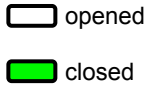
Potassium
Voltage-Gated channel:

* One Gate Only.

* Consist of two states.

* During rest the only one gate is closed



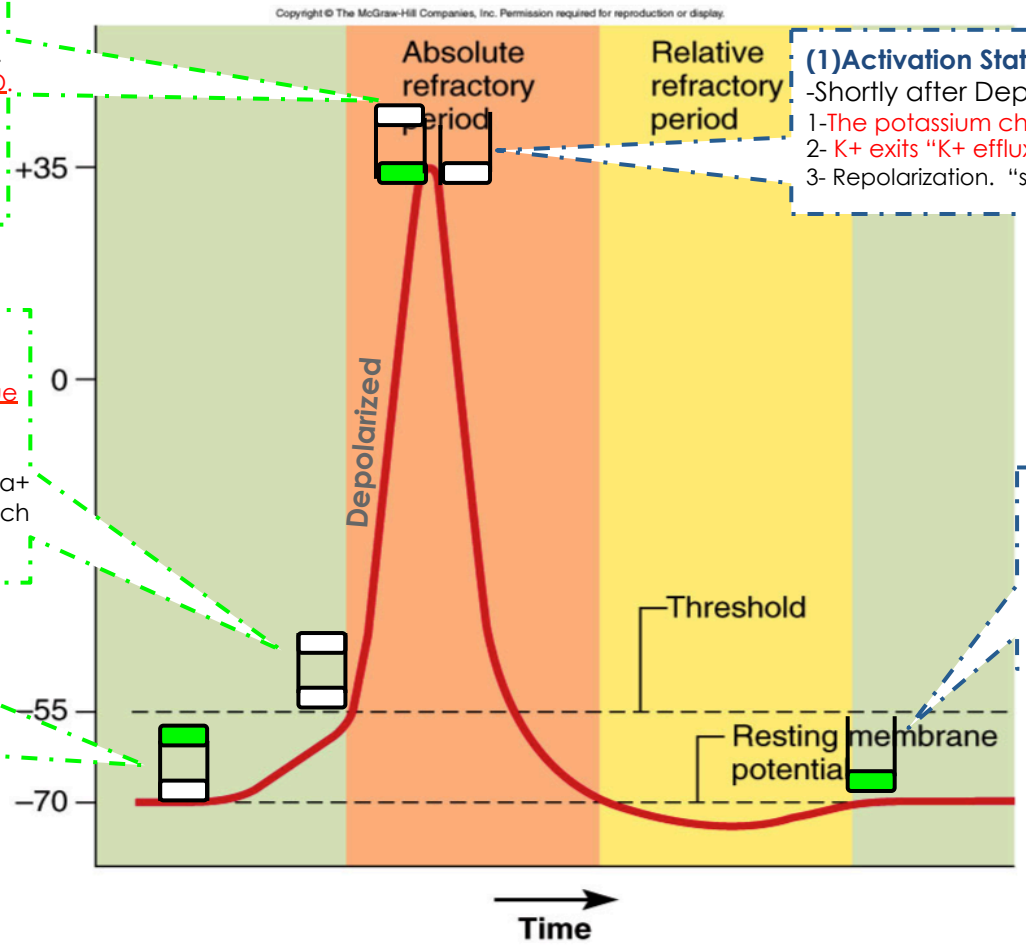


States of K and Na Voltage-gated channels:

(3) Inactivate State:
-At the peak of AP (+35mV).
-Inactivation gate is CLOSED.
-Won't open until the MP is back to its resting level.
*N.B: Activation gate is still OPENED.

(2) Activation State:
-Threshold moves MP from (-90mV) to its threshold value (-65 to -55 mV).
- Both gates are OPENED
*Increase permeability to Na+ 500 to 5000 times more. which will increase Na+ Influx.

(1) Resting State:
*MP=RMP=
-90 to -70 mV.
-In resting cell.
-Activation gate is Closed.
"prevent Na+ entry to the cell"



(1)Activation State:
-Shortly after Depolarization:
1-The potassium channel OPENS.
2- K+ exits "K+ efflux".
3- Repolarization. "slow activation"

(2)Resting State:
The potassium cannot enter through it.

opened
closed

What happens after an Action Potential?

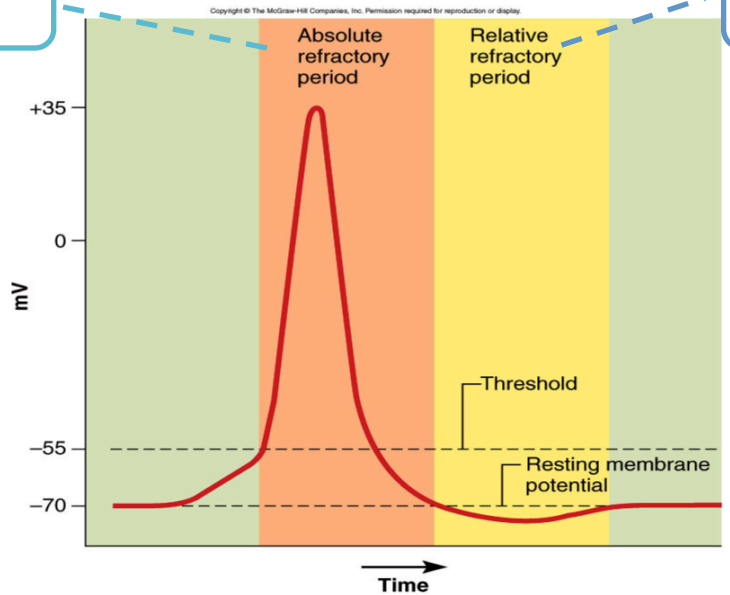
Refractory period:

Its time during which we can't stimulate neurons until recovery of resting membrane potential

It consists of <u>two</u> stages:

Absolute refractory period

<u>No</u> new action potential possible.



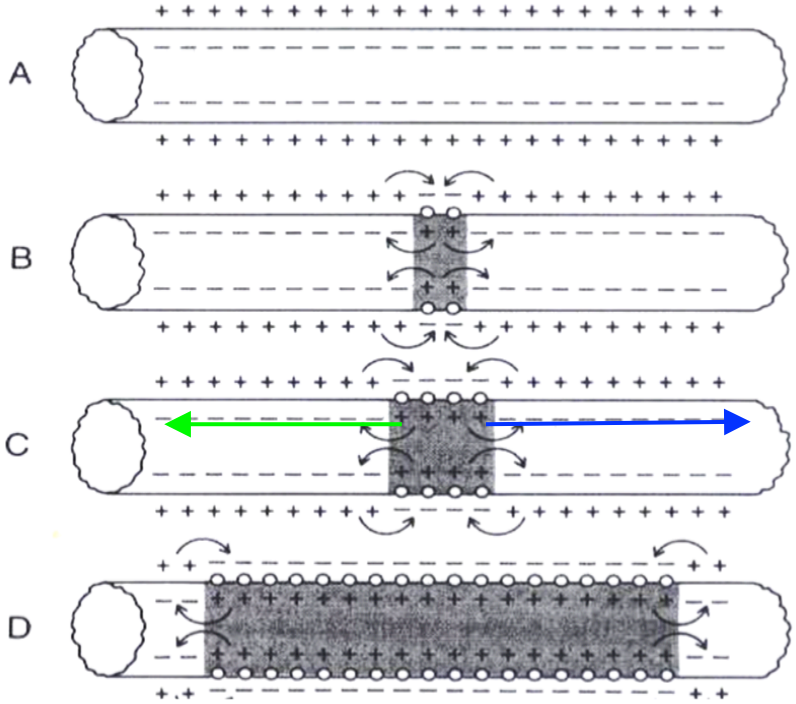
Relative refractory period

New action potential is triggered if stimulus is <u>very strong</u>.

Direction of Action Potential propagation (conduction):

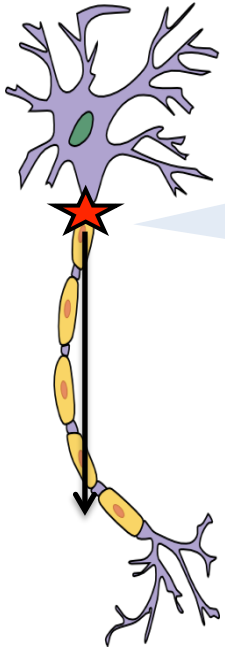
Artificial Electrical Stimulation:

*Happens in the laboratory.
*Action potential in Both Direction.



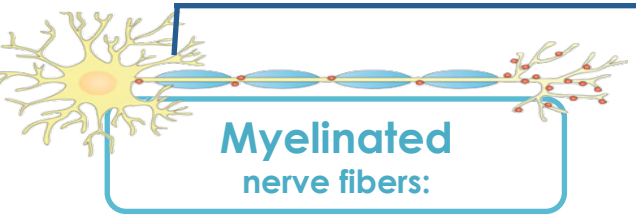
Normally

*Action potential starts in the Axon hillock & Propagate directions. One direction.



Why does action potential starts at the axon hillock?
because it's full of voltage-gated channels

Propagation of Action potential:

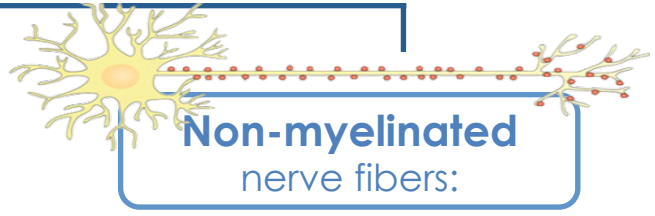


Myelinated
nerve fibers:

Saltatory conduction "**jumping**"

*Increase velocity of conduction of nerve impulses.
*Conserve energy for axon because ONLY nodes Depolarize.

Q)How do action potentials travel down the axon?
*myelinated sheaths:
-It makes transmission many times faster.
-Action Potential skips from one node of Ranvier to the next its called Saltatory conduction.



Non-myelinated
nerve fibers:

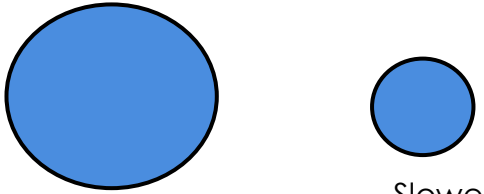
Local circuits "**point to point**"

*Depolarization pass by Local Circuits.

Q)What else influences speed of action potential?

Axon Diameter.

(Large Diameter = Faster transmission)
-Less Resistance to current flow-



Faster transduction

Slower transduction

MCQs

1. Which one of the following is true?
A) at the resting state the inactivation gate of the Na channel is closed
B) the 2 gates of K channel is closed
C) the resting state the gate of the K channel is closed
D) the 2 gates of Na channel is opened

2. One of the causes that can make RMP is the diffusible anions such as (proteins, sulphate..)
A) true
B) false

3. At +35 mV :
A) All Na channels begin to open
B) All Na channels begin to close
C) All Na channels still opened
D) there is RMP

4.Na-K pump occurs during :
A) hyperpolarization
B) after threshold stimulus
C) repolarization
D) depolarization

5. Threshold value intensity can not increase by increasing stimulus intensity :
A) true
B) false

6. The resting value is:
A) 0
B) -65 to -55
C) -55 to +35
D) -70 to -90

Answers:

1 C
2 B
3 B
4 A
5 A
6 D

YouTube Helpful Videos

* Resting Membrane Potential:

http://www.youtube.com/watch?v=P2hxGVL25OU&channel=UCYF11jAdSqdaQbsJ7ra42TA

* Action Potential:

http://www.youtube.com/watch?v=SdUUP2pMmQ4&channel=UCWZtJoFf-INn0A3j07a4MsA

* A video made by Mohammad Alkharraz:

http://www.youtube.com/watch?v=JB_UuugtcH4&feature=youtu.be&channel=UCTKz7jt577XkS7CJXsEgktw

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