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Nerve action potential & Properties of nerve fibers

•Red : important
•Black : in male / female slides
•Pink : in female slides only
•Blue : in male slides only
•Green : notes
•Gray : extra

Objectives

- Describe the mechanism of generation and propagation of AP.
- Describe conduction along nerve fibers, role of myelination and how nerve fibers are classified.

Neuron Action Potentials

Nerve signals are transmitted by action potentials.

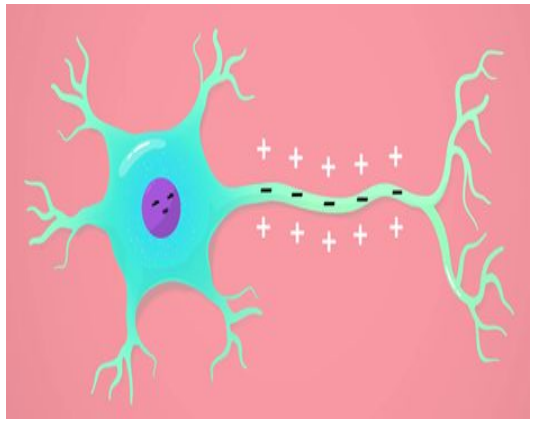
- **Action potentials:** are rapid changes in the membrane potential that spread rapidly along the nerve fiber membrane to produce physiological effects.

- Examples of **physiological effects**:

  - Transmission of impulse along nerve fibres
  - Release of neurotransmitters
  - Muscle contraction
  - Activation or inhibition of glandular secretion

Stages of the action potential:

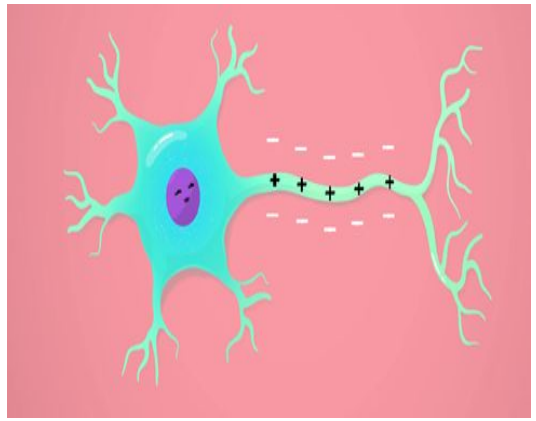
Each action potential begins with a sudden change from the normal resting negative membrane potential to a positive potential and ends with an almost equally rapid change back to the negative potential.



★ Resting Stage:

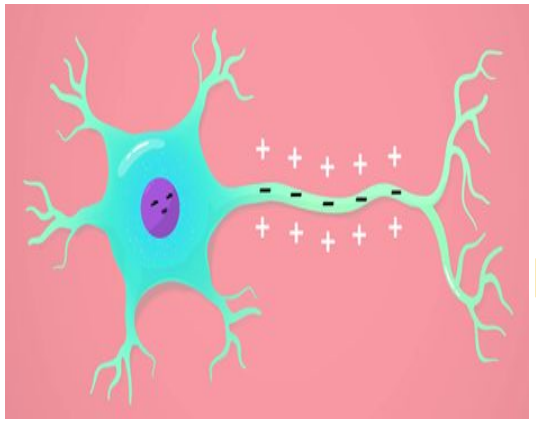
It is the resting membrane potential before the action potential begins.

➔ The membrane is **“polarized”**



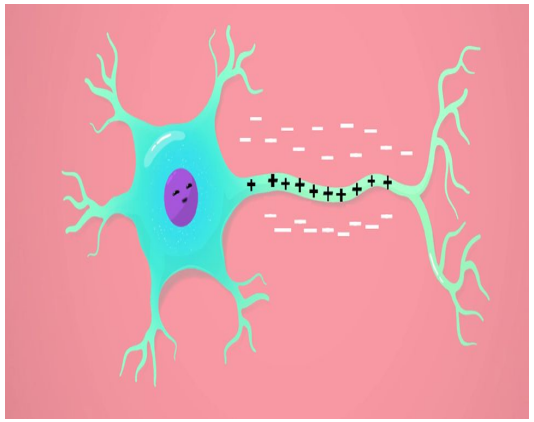
★ Depolarization Stage.

➔ The membrane suddenly becomes permeable to **Na+** ions, allowing tremendous numbers of positively charged **Na+** to diffuse to the interior of the axon **“Upstroke”**.



★ Repolarization Stage.

➔ **Na+** channels begin to close and the **K+** channels open. Rapid diffusion of **K+** ions to the exterior re-establishes the normal negative resting membrane potential.



★ Hyperpolarization Stage.

Resting state

changing in charges (stimulus)

change in voltage

1) rapid response

Open Voltage gated Na+ channels

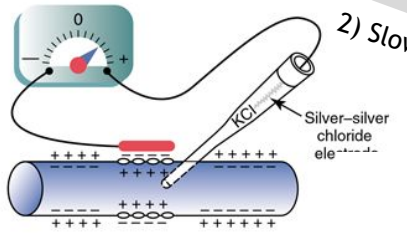
diffusion

Na+ influx

Depolarization

because Na+ has higher concentration outside the cell

2) Slow response



Open Voltage gated K+ channels

diffusion

K+ Outflux

Repolarization

because K+ has higher concentration inside the cell

Slow closing of the channel

Hyperpolarization

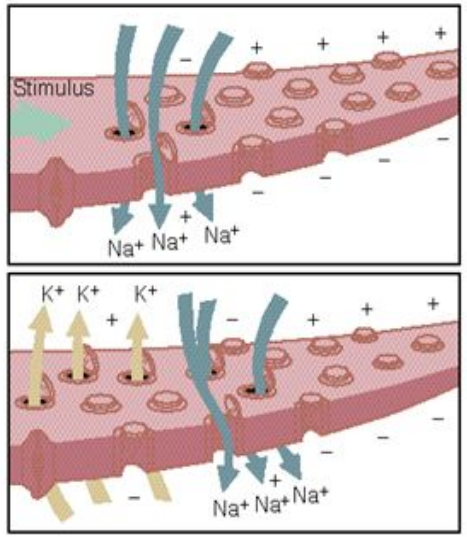
For a brief period , the K+ conductance is higher than at rest.

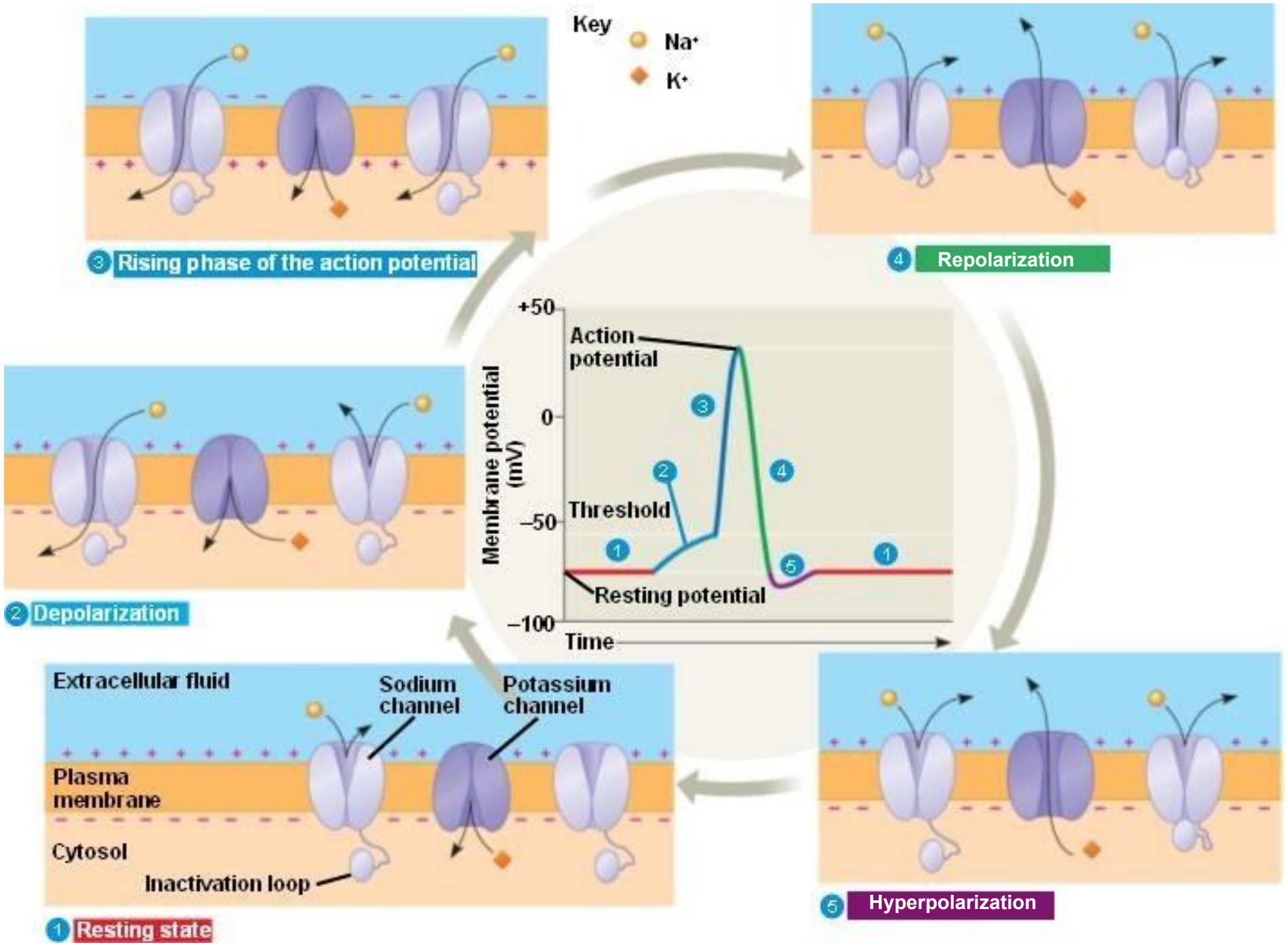
Na+/K+ ATPase pump

Resting state

لما يكون الميمبرين بحالة رست نسميه polarization لان يحاول يفصل بين داخل الخلية وخارجها بين الشحنة الموجبة والسالبة مثل قطبين المغناطيس صعب جدًا الفصل فيما بينهم

ضروري جدًا يكون في فرق بين برا وجوا الخلية لو كانوا متساوين راح تكون خلية ميتة




Key
Na+
K+
3 Rising phase of the action potential
4 Repolarization
+50
0
−50
−100
Membrane potential (mV)
Action potential
Threshold
Resting potential
Time
1
2
3
4
5
2 Depolarization
Extracellular fluid
Sodium channel
Potassium channel
Plasma membrane
Cytosol
Inactivation loop
1 Resting state
5 Hyperpolarization

Characteristics of action potential:

★ Threshold stimulus:

A point at which the membrane potential is high enough to elicit a response.

(Firing Level)

= -50 to -65 mV

★ Acute subthreshold potential:

Stimulus that results only in local depolarisation (acute local potentials) when stimulus is below the threshold.

★ All-or-nothing principle:

Once threshold value for excitation is reached a full AP is produced, its intensity can not be increased by increasing stimulus intensity.

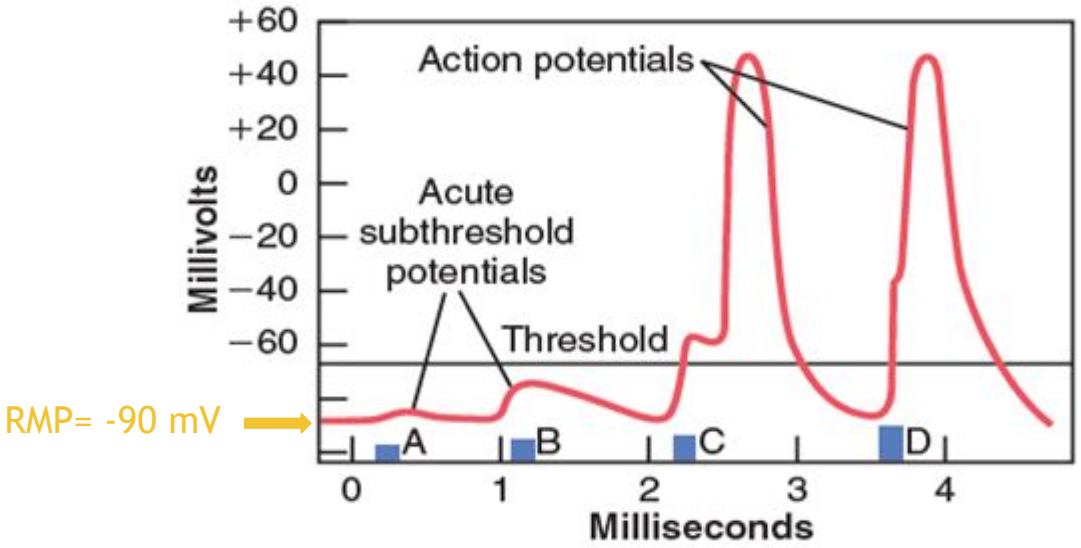
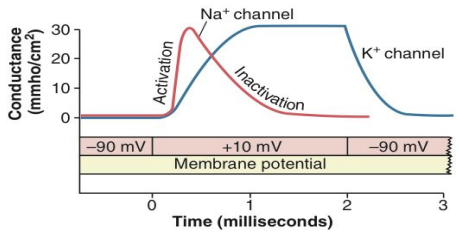


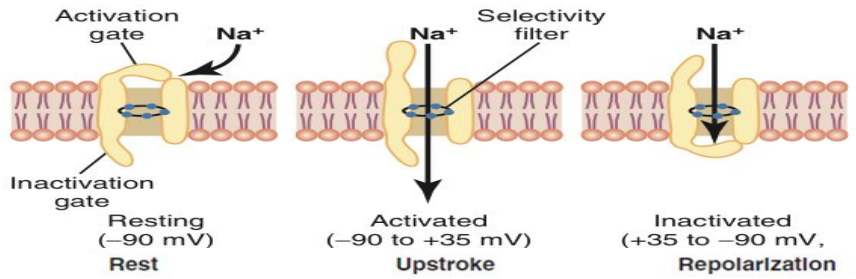
Figure 5-18. Effect of stimuli of increasing voltages to elicit an action potential. Note development of acute subthreshold potentials when the stimuli are below the threshold value required for eliciting an action potential.

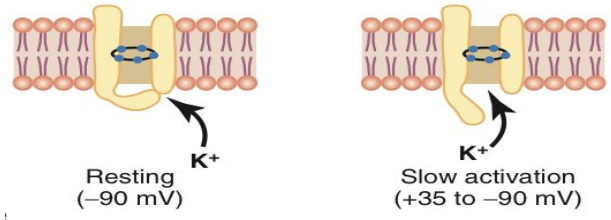
كل ما شفنا المنحنى على فوق يعني Depolarization
كل ما شفنا المنحنى نازل على تحت Repolarization
كل ما شفناه نازل زيادة تحت الرستنق يكون hyperpolarization لانه بيكون هنا مور نقيتف فبينزل على تحت

Types of transport channels through the nerve membrane:

	Voltage gated Na^+ channel **Blocked by Lidocaine**	Voltage gated K^+ channel **Blocked by Tetraethylammonium (TEA)**
No. of gates	**<u>two gates</u>:** • **Activation gate:** on the outer side of Membrane. •**Inactivation gate:** on the inner side of Membrane.	Has one gate only .
Resting state	when the MP = RMP = -70 to -90mV the activation gate is closed and the inactivation gate is open. <u>"this prevents entry of Na+ to the interior of the cell through this gate."</u>	the gate of the potassium channel is closed and potassium ions are prevented from passing through this channel to the exterior.
Depolarization	both gates are open and Na+ flows into the cell down its electrochemical potential gradient.	Shortly after depolarization, when the sodium channel begins to be inactivated, the potassium channel opens
Repolarization	the activation gate remains open but the inactivation gate is closed. Cannot elicit new AP	happens when the K+ exits (Efflux)







Activated State of Sodium Channel

- when a Threshold Depolarizing Stimulus moves the MP from its resting value (-90 mV) to its Threshold value (-65 to -55mV)
- this opens the activation gate , and now the Na+ channel is said to be in the Activated State
- (NB in this case BOTH the activation gate & inactivation gate are <u>open)</u>
- permeability to Na+ becomes increased 500 to 5000 times Na+ influx
- Na+ flows into the cell in large amounts

Inactivated State of Sodium Channel

- A few milliseconds after the activation gate opens , the channel becomes inactivated
- At the peak of AP the inactivation gate will close and will
  not open by a second stimulus
- “the cell becomes Refractory ممانعة to another stimulation”
- This goes on until the MP has gone back to its resting (RMP) level (-70 to -90mV).

Refractory Periods

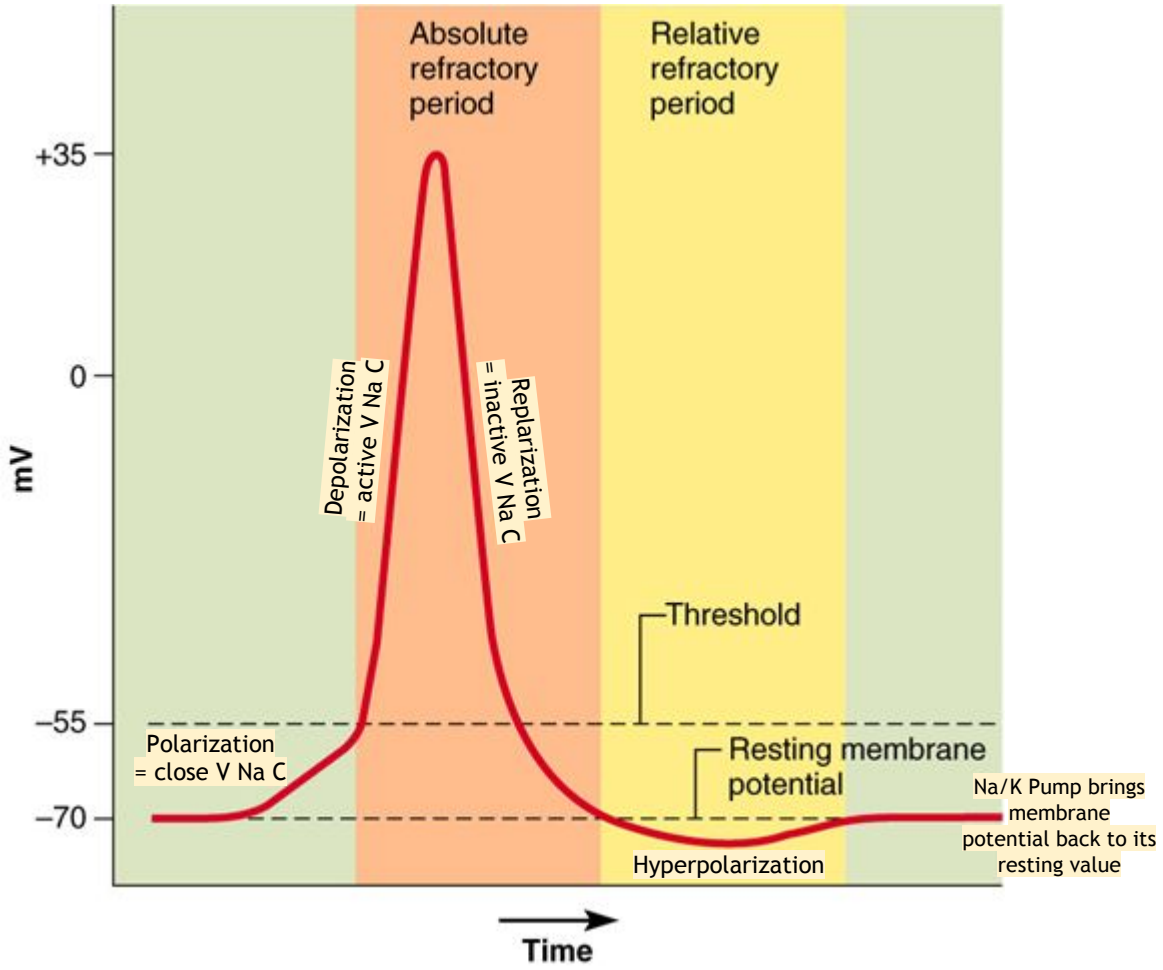
Time during which the neuron can't be stimulated a second time

★ Absolute refractory period
The period during which a second action potential cannot be elicited, even with a strong stimulus.

★ Closure of the inactivation gates of the Na+ channel

★ Relative refractory period
Can trigger new action potential if stimulus is very strong.

★ Higher K+ conductance than is present at rest



More positive = more active
More negative = less active

كل خلية بالانسان عندها threshold خاصة فيها عشان كذا الانسان عنده حساسية كبيرة للاشياء البسيطة مثل الضوء احيانًا حتى واحنا نايمين نحس فيه.
الخلايا العصبية threshold حقها -55 لو قل عنه وصار مثلًا -70 ما حتكون فيه اجابة ولو زاد عنها وكان -40 راح تكون نفس استجابة -55 يعني الاستجابة ما تزيد بزيادة الاستثارة

V Na C: voltage Na+ channel

Propagation of the action potential

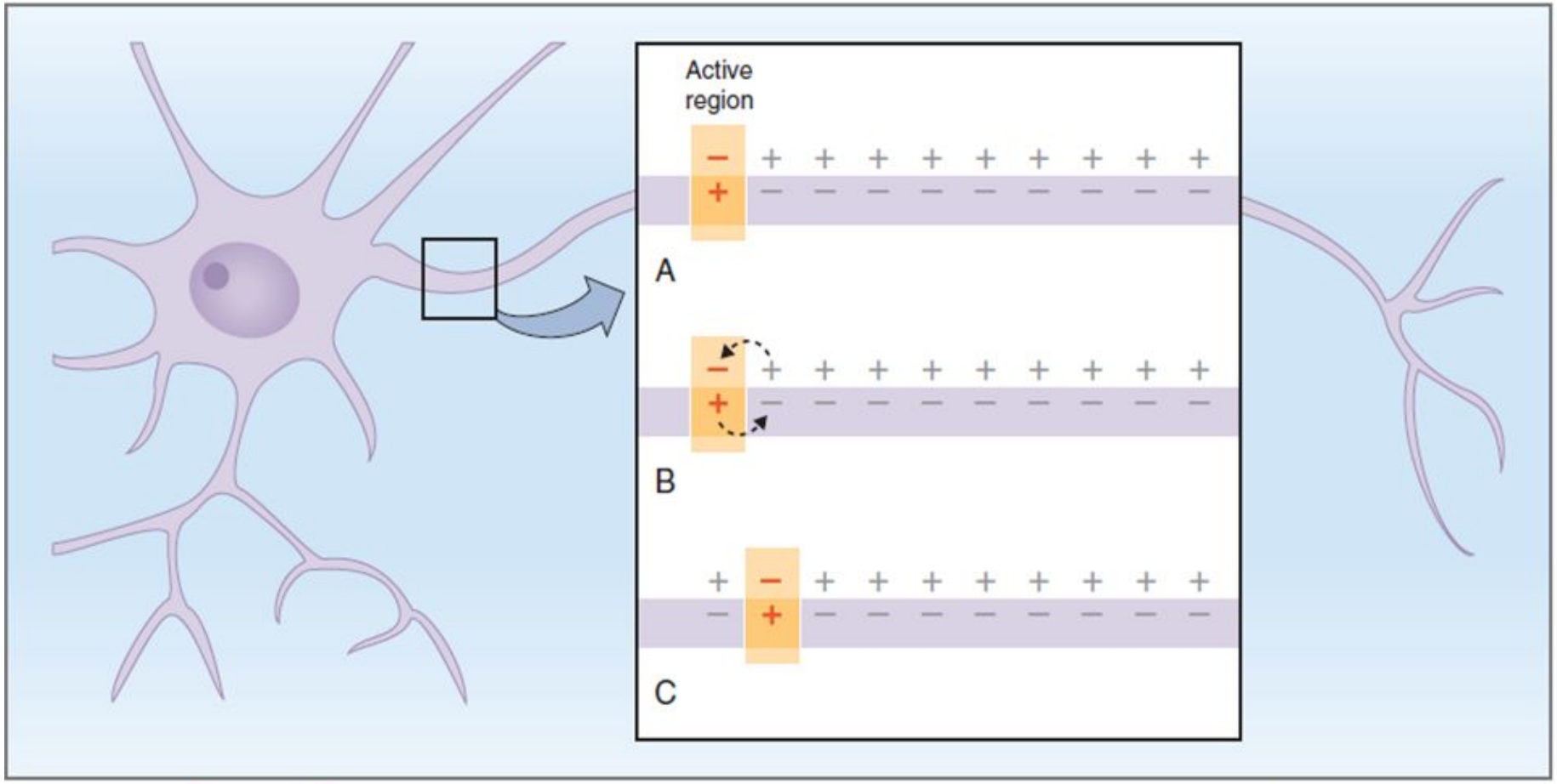


Figure 1–15 **Spread of depolarization down a nerve fiber by local currents. A,** The initial segment of the axon has fired an action potential, and the potential difference across the cell membrane has reversed to become inside positive. The adjacent area is inactive and remains at the resting membrane potential, inside negative. **B.** At the active site, positive charges inside the nerve flow to the adjacent inactive area. **C.** Local current flow causes the adjacent area to be depolarized to threshold and to fire action potentials; the original active region has repolarized back to the resting membrane potential. Point to point and go in one direction

PROPAGATION OF THE ACTION POTENTIAL

From Guyton
(Not included in the slides only for your information)

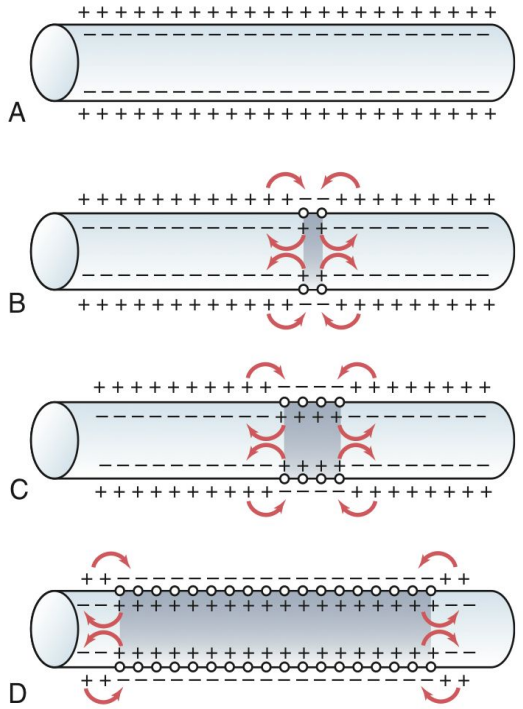


Figure 5-11. Propagation of action potentials in both directions along a conductive fiber.

the action potential as it occurs at one spot on the membrane.

However, an action potential elicited at any one point on an excitable membrane usually excites adjacent portions of the membrane, resulting in propagation of the action potential along the membrane

Direction of Propagation.

As demonstrated in Figure 5-11, an excitable membrane has no single direction of propagation, but the action potential travels in all directions away from the stimulus—even along all branches of a nerve iber—until the entire membrane has become depolarized.

All-or-Nothing Principle. (Important)

Once an action potential has been elicited at any point on the membrane of a normal iber, the depolarization process travels over the entire membrane if conditions are right, but it does not travel at all if conditions are not right. his principle is called the all-or-nothing principle, and it applies to all normal excitable tissues. Occasionally, the action potential reaches a point on the membrane at which it does not generate sufficient voltage to stimulate the next area of the membrane. When this situation occurs, the spread of depolarization stops. herefore, for continued propagation of an impulse to occur, the ratio of action potential to threshold for excitation must at all times be greater than 1. his "greater than 1" requirement is called the safety factor for propagation.

Conduction Velocity

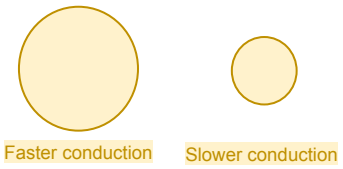
It is the speed at which action potentials are conducted (propagated) along a nerve or muscle fiber.

Mechanisms that increase conduction velocity along a nerve:

Nerve diameter

The larger the diameter, the faster the transmission.

★ Because: Large fiber offers Less resistance to local current flow & more ions will flow.

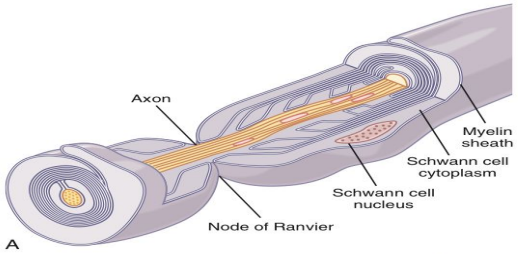


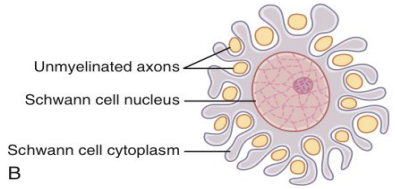
Myelination.

Myelin is an insulator that makes it more difficult for charges to flow between intracellular and extracellular fluids.

★ The layers of **Schwann cell** membrane contain the lipid substance **sphingomyelin** which is an excellent electrical insulator that decreases ion flow through the membrane.

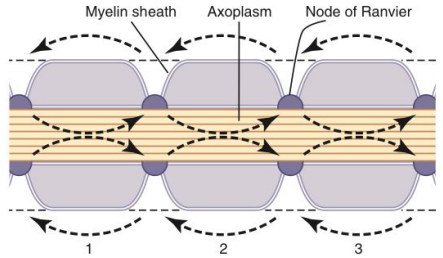
★ **Node of Ranvier**: small uninsulated area where ions can flow with ease.





Saltatory Conduction

It is the jumping of action potentials from one node of ranvier to the next as they propagate along a myelinated fiber.



★ Value:

1- Increases conduction velocity.
2- Conserves energy for axon because only nodes depolarize.

➢ What happens if myelination is lost?

Scar tissue (sclerosis) replaces some damaged cells

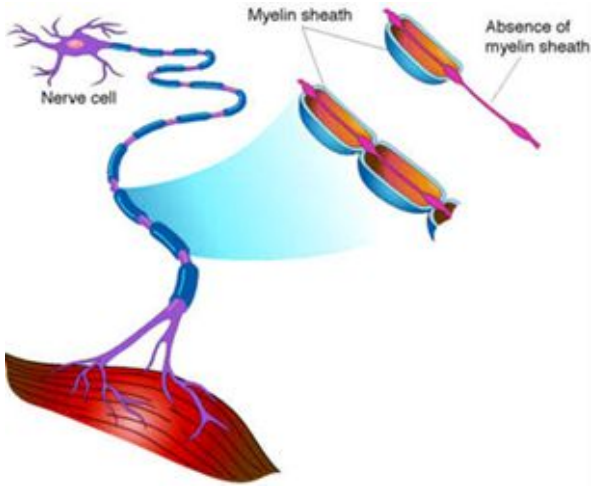
Ultimately paralysis

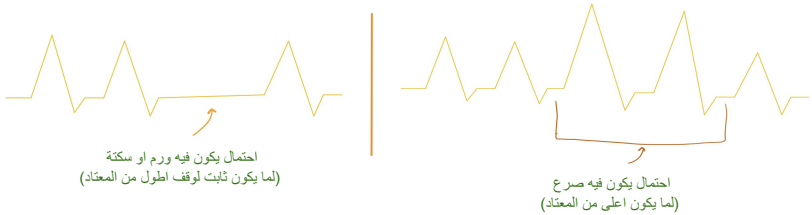
Multiple sclerosis ⇨ Usually in young adults

Autoimmune disease

(Immune system attacks the myelin sheaths surrounding axons as well as the axons themselves)
مثل التصلب اللويحي

Blindness, problems controlling muscles





بجهاز ECG لما يطلع التخطيط مثل الصور
- الخلايا العصبية دائمًا نشطة وحتى في وقت النوم
فتوقفها يعني فيه خلل معين بالجسم

Quiz

SAQ

Q1- What opens the voltage-gated channels ? (From slides)

Q2- list the gates of Voltage gated Na+ channel

Answers

SAQ1- Opened by a stimulus strong enough to depolarize them to threshold

SAQ2- 1-Activation gate 2-inactivation gate

1)which of the following stages is called the upstroke stage?		2) which of the following causes repolarization?	
A.	Resting Stage	A.	Na+ influx through Voltage gated Na+ channel
B.	Depolarization Stage.	B.	Na+ outflux through Voltage gated Na+ channel
C.	Repolarization Stage.	C.	K+ influx through Voltage gated K+ channel
D.	Hyperpolarization Stage.	D.	K+ outflux through Voltage gated K+ channel
3) which of the following correctly describes repolarization stage in voltage gated K+ channel		4) small uninsulated area where ions can flow with ease.	
A.	the gate of the potassium channel is closed and potassium ions are prevented from passing through this channel to the exterior.	A.	Multiple sclerosis
B.	he activation gate remains open but the inactivation gate is closed.	B.	Unmyelinated fibers
C.	happens when the K+ exits (Efflux)	C.	Node of Ranvier
D.	when the sodium channel begins to be inactivated, the potassium channel opens	D.	Propagation of the action potential

Answers key: 1)B 2)D 3)C 4)C

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Thank you

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