Membrane Potential and Action Potential II

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By

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Membrane Potential and Action Potential II

Learning Objectives:

At the end of the lecture the students should be able to:

- Describe the different properties of action potential .
- Basic principles of types of conduction of action potential.
- Define excitability and describe its changes during the action potential
- Describe the recording of the action potential

Characteristics or properties of Action Potential

- Propagation
- Excitability
- Refractory period
- All or none response
- Accommodation
- infatiguability

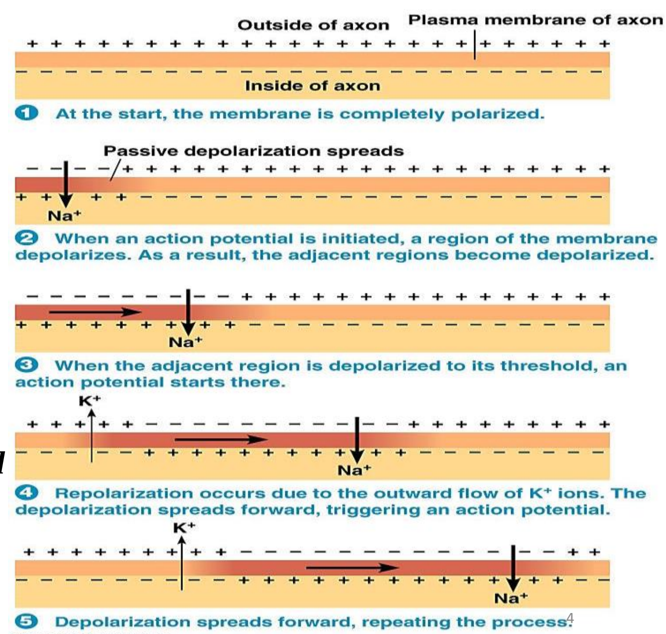
Propagation or conduction of action potential

The nerve conduction velocity depends on:

- The **diameter** of the nerve (The velocity of action potential conduction in nerve fibers varies from as little as **0.25 m/sec in small unmyelinated** fibers to as great as **100 m/sec in large myelinated** fibers).
- The **myelination** of the nerve

1- Contiguous conduction:

The transmission of the depolarization process along a thin nerve (***unmyelinated nerve***) is called a ***nerve impulse.***



2-Saltatory conduction:

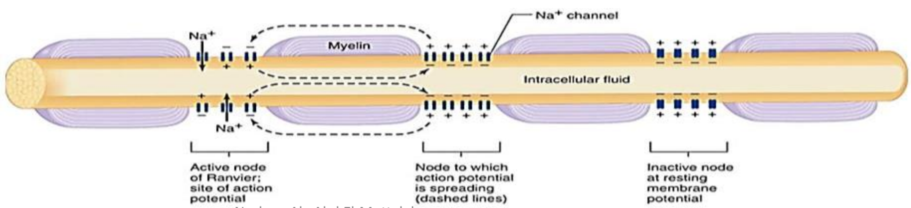
the action potentials are conducted from node to node. It occurs at:

1. **The *myelinated*** nerve fibers
2. **The *synapses***
3. **The *motor end-plate or myoneural junction***

Functions of saltatory conduction:

1-Increases the velocity of *(5-50 fold)* conduction by the process of jumping

2- Depolarization is limited to the node and so leakage of sodium is minimal to the outside of fiber. This ***saves the energy*** required by the sodium pump to expel the sodium to the outside.



Excitability

Excitability is the ability to respond to a stimulus in order to generate the action potential. The nerve and muscle are excitable tissues.

The stimulus is an change in the environment used to excite a cell, through depolarization of its cell membrane. The stimuli may be:

1. **Mechanical stimuli:** as pressure, stretch, prick or crush.
2. **Thermal stimuli:** are various degrees of heat or cold.
3. **Chemical stimuli:** are CO2 and H+, acetylcholine and norepinephrine.
4. **Osmotic stimuli:** as in the case of hydration and dehydration.
5. **Electromagnetic stimuli:** as light waves or sound waves
6. **Electrical stimuli:** It is preferred because:
   - They are similar to the nature,
   - Their intensity and duration can be easily controlled.
   - They do not damage the fiber.

Effectiveness of stimulus

1-It must be of sufficient intensity:

- A current just adequate to cause an impulse is called ***a threshold stimulus.***
- Intensities below threshold are referred to as ***sub-threshold stimulus.*** The application of sub-threshold stimulus produced a local, non-propagated potential, referred as ***the local excitatory state.***

2-Rate of application *(accommodation or adaptation)*

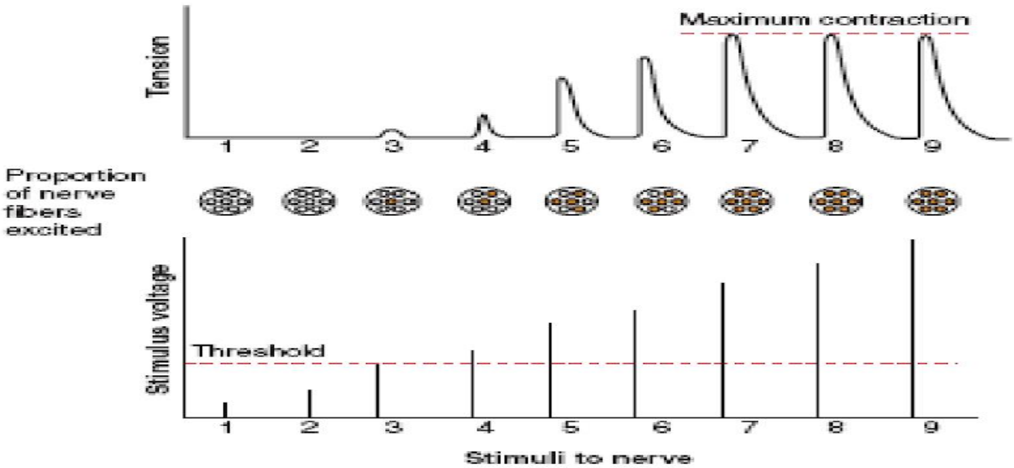
Sudden onset of stimulus is more effective than the slowly applied stimulus. Slowly rising currents fail to fire the nerve because it adapts to the applied stimulus as it undergoes an ***accommodation.***

3- Number of stimulated fibers

- When a **single nerve fiber** is stimulated with threshold stimulus, it will respond maximally as it obey the **All or None Law** which occurs in:
  1- A single nerve fiber
  2- A single skeletal muscle fiber
  3- The cardiac muscle (act as a syncytium)

- In the case of a **nerve trunk** they do not obey the all or none law and the effectiveness of the stimulus depends *on:*
  - Its rate of application.
  - Its duration.
  - Its strength.

- **Minimal stimulus** exits only a few fibers near the electrodes and produces a weak response.
- **Sub-maximal stimulus** produces intermediate responses between the minimal and maximal.
- **Maximal stimulus** excites all the fibers and produces a maximal effect.
- **Supra-maximal stimulus** does not produce a bigger effect than the maximal.



Strength of stimulus affects the response.

The strength-duration curve

It is the relationship between the strength of a stimulus and the time needed by this stimulus to produce a response.

From the curve, we can get the following:

1-The stimulus duration normally range between 300 and 0.01 milliseconds (msec). There is a little change in the curve between 300 to 1 msec, but the curve rise fairly steeply between 1 and 0.01 msec.

2- Rheobase is the ***minimum stimulus*** strength required to activate the muscle, below which no excitation occur whatever the duration may be prolonged.

3- Utilization time is the time required for any voltage to stimulate the fiber.

4- Chronaxie is the ***time*** needed by ***double the rheobase*** to give a response.

Uses of chronaxie:

1- Measurement of tissue excitability.

2- Comparison of various tissue excitability.

For example, the chronaxie of: 1. **Large myelinated** nerve fibers is about 0.0001 sec.

2. Smaller myelinated nerve fibers is about 0.0003 sec,
3. Non-myelinated nerve fiber is about 0.0005 sec

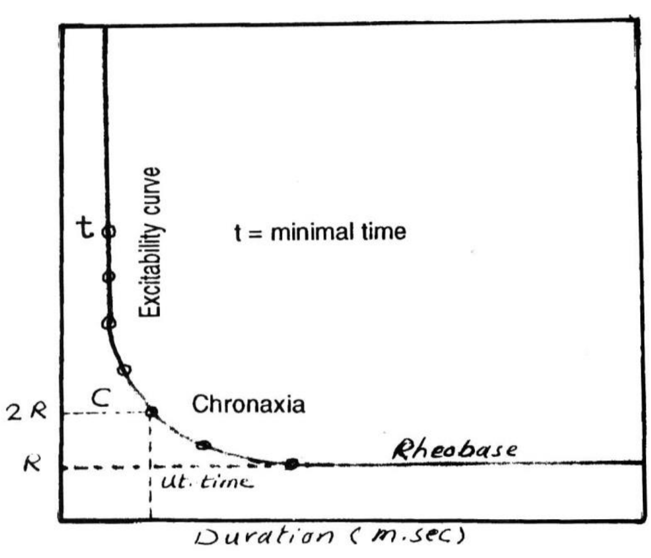
Significance's of strength-duration curve

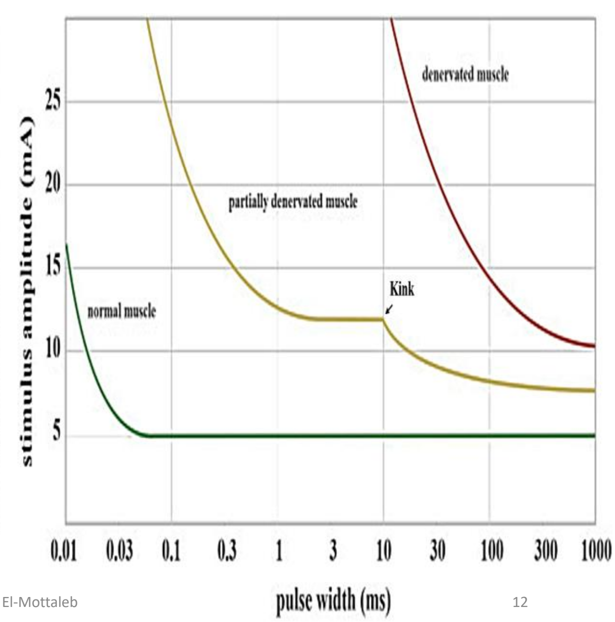
1-Normal innervation when all the fibers supplying the muscle are intact, the shape of the curve is smooth and normal.

2. Complete denervation, when all the nerve fibers supplying a muscle have degenerated. At 100 msec the curve rises steeply and is further **to right** than that of normally innervated muscle.

3. Partial denervation, when some of the nerve fibers supplying a muscle have degenerated, while others are intact. The impulse will stimulate both innervated and denervated muscle fibers. The curve may show ***kink*** and it has been demonstrated that these result from the combination of two curves, left one derived from innervated (indirect stimulation) and the other right from denervated (direct stimulation) slow excitable muscle fibers. Nashwa Aly Abd El-Mottaleb 11

The Strength-Duration Curve





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Refractory Periods

If a 1st stimulus is followed by a 2nd stimulus, the muscle will or will not respond to the latter stimulus, depending on the time interval between the **1st** and the 2nd stimulus.

Phases of excitability

1-The absolute refractory period (ARP):

During which the excitability is completely abolished. No other stimulus whatever strong, can excite the fiber. A 2nd action potential can not occur because the membrane is still depolarized by the 1st stimulus. It coincides with the ascending limb of the spike.

2-The relative refractory period (RRP):

During which the excitability is being returned but is still below the normal. A stronger stimulus is needed to excite the fiber. The RRP is coincides with the descending limb of the spike.

3-Super-normal phase:

During which the excitability is higher than normal. A weaker stimulus is needed to excite and the response is powerful. It is coincides with the negative after potential.

4-Sub-normal phase:

The excitability is less than normal. It is coincide with the positive after potential.

Factors which decrease the excitability - Nerve block - Stabilizing factors

1-A **high extracellular fluid** Ca^{++} **ion concentration** decreases the membrane permeability to Na ions and simultaneously reduces its excitability.

2-Local anesthetics as procaine and tetracaine that acts directly to inactivate gates of the Na^{+} channel.

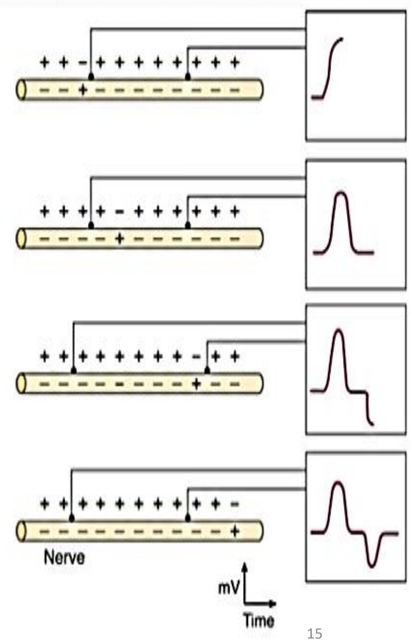
3-Neuromuscular blockers as curare that prevents passage of impulses at the motor end plate from the nerve ending into the muscle.

Infatiguability

The nerve fibers are not readily fatigued by repeated stimulations

Recording of the action potential

A- Biphasic potential



1-When the fiber is stimulated at one point, a depolarized wave will be develops at this site.

2-The depolarized wave traveled till it reaches the part under the first electrode which becomes depolarized, while the part beneath the second electrode is in a polarized state. So a current will flow from the first to the second electrode. So, the galvanometer will record ***in one direction***.

3-When the depolarized wave passes between the two electrodes, ***no recorded*** potential is observed because the membrane beneath the first electrode becomes repolarized.

4-When the depolarized wave reached the part under the second electrode, this part is now becomes depolarized. Thus, another action potential will flow from the 2" electrode to the 1st one but in ***opposite direction***.

5- When the depolarized wave passes beyond the second, no recorded potential is observed.

B- Monophasic potential

It is quit clear that the second phase of the record can be eliminated by preventing the negativity of the impulse from reaching the second electrode. This can by crushing the nerve either in the region the between the two electrodes or under the second electrode. This is called ***Current of injury.***


Thank You
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