Nerve 1

Dr. Neven Makram Aziz

EXCITABLE TISSUES

- Tissues which are capable of generation and transmission of electrochemical impulses along the membrane.
- Excitable tissues are:

✓ Nerve

✓ Muscle

- Skeletal
- Cardiac
- Smooth

Nerve

- Neuron is the structural unit of the nervous system which is composed of billions of nerve cells or neurons.

- **Excitability:**

  The ability of any living tissue to respond to a stimulus. It is a property of life.

- **A stimulus:**

  It is any change in the environment surrounding living tissue that causes it to react.

- **Types of stimuli:**

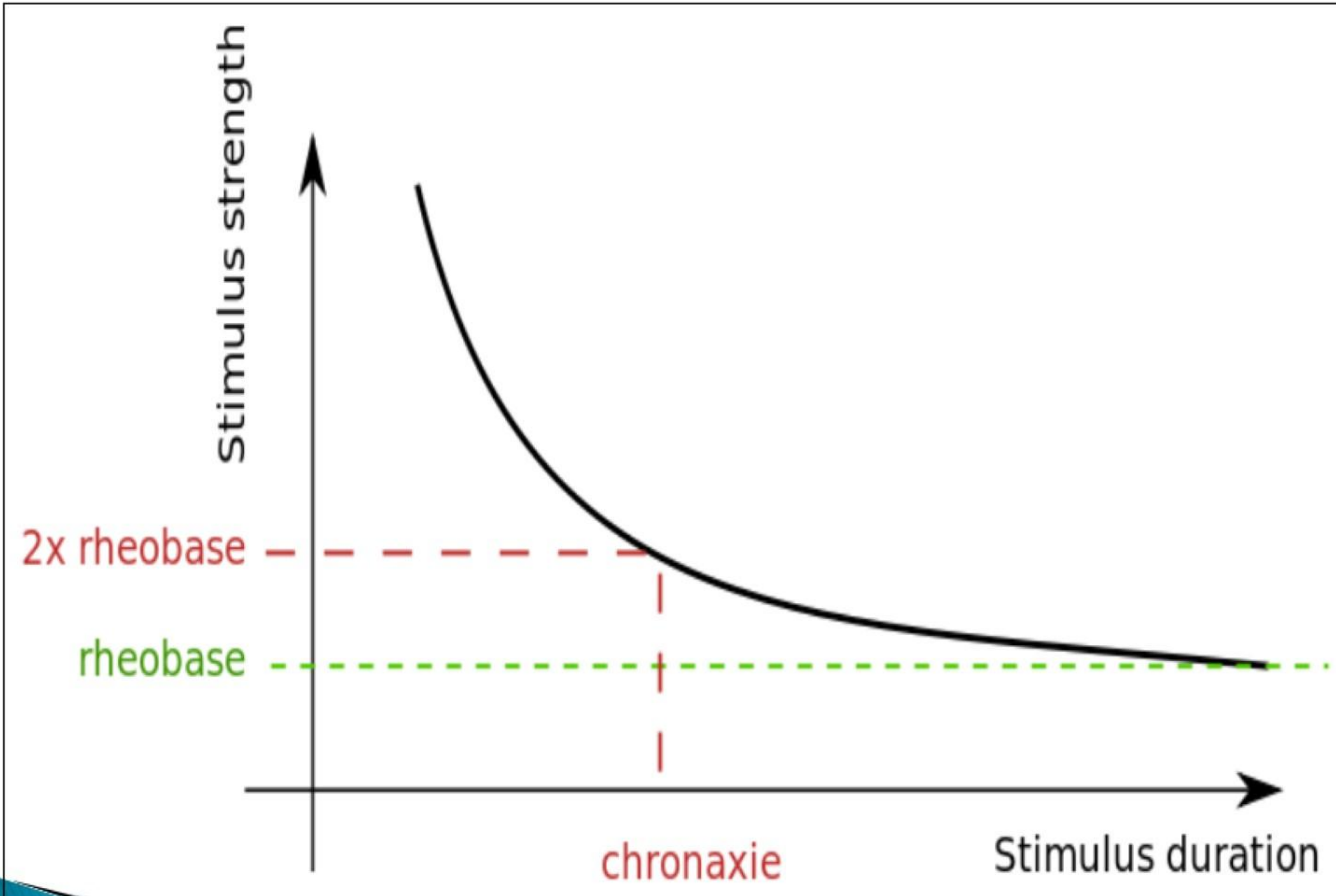
  1- Electrical. 2- chemical. 3- mechanical. 4- thermal.

- **Factors that affect the degree of response to a particular stimulus:**

1- The rate of application: A sudden change is more effective than a slowly occurring one of the same intensity.

2- The strength of the stimulus and duration of application.

- This is best illustrated by **the strength–duration curve** shown in the figure. From the figure we can conclude that:



Stimulus strength
2x rheobase
rheobase
chronaxie
Stimulus duration

1- The stronger is the stimulus, the shorter is the time needed to excite and vice versa.

2- There is minimal or threshold intensity or rheobase which can stimulate. If the intensity of the stimulus is reduced below (R), it cannot stimulate even if the duration of application is prolonged.

- **The threshold (rheobase) stimulus:** it is the minimal intensity of a current of a very long duration (as galvanic current) which can stimulate. Current of lower intensity than the threshold is called subthreshold (subminimal) stimuli.

- There are two types of current stimulation:

✓ Galvanic current: of low intensity and long duration.

✓ Faradic current: of high intensity and short duration.

3- **The utilization time (U.T):** it is the time needed by the rheobase (threshold) to stimulate.

4-There is a **minimal duration (t)** required for stimulation. If the duration of application of the stimulus is reduced below (it) it cannot stimulate however high the intensity is.

- ✓ **Significance:** it is useful for diathermy i.e. internal heating of tissue by the use of high voltage alternating current (faradic current) for a very short period of time less than (t) during each phase. They cause raid oscillation of ions leading to heating of tissue without stimulation.

5- **The chronaxia:** it is the time needed by a current of double the rheobase intensity to stimulate.

- ✓ **Significance:** it is used to compare excitability of different tissue. The shorter the chronaxia the greater is the excitability.

The excitability of the nerve > skeletal muscle > cardiac muscle > smooth muscle.

The Resting Membrane Potential (RMP):

- Under normal conditions, it is the potential difference between inner and outer surface of the membrane. It is equal −70 mV.

Causes of RMP:

1- Active Na^+ /K^+ pump:

- It is an active pump transmit 3 Na^+ outside the cell coupled with 2 K^+ inside leading to increase the negative charge inside the membrane.

2- *Selective permeability of the membrane:*

A- The resting membrane of the nerve is 50-100 time more permeable to K^+ than to Na^+ Why?

- The membrane Na^+ channels are closed under resting conditions, while the K^+ channels are open.
- Na^+ and K^+ pass through separate channels specific for each ion. The Na^+ channels are guarded by Ca^{+2} from outside that form gates, which repel Na+ and prevent its entry under resting conditions.
- The hydration energy for Na^+ is greater than that for K^+ and accordingly, the hydrated Na^+ ion is thicker than the hydrated K^+ ion, that is why Na^+ moves through the membrane with more difficulty than K^+.

B- Non diffusible ions (proteins, sulfate and phosphate) remain inside being greater than the positive ions (they are not neutralized by the +ve ions) so the inside become negative while the outside become positive developing RMP.

- **Ionic distribution:**

- ✓ Extracellular ions
  - Sodium (142mEq) mainly, small amount of Potassium and Chloride ions.
- ✓ Intracellular ions
  - Potassium (140mEq) mainly, Proteinate, small amount of Sodium and Chloride ions.

Action Potential (A.P.)

- *Definition:* it is a reverse in the resting membrane potential (monophasic, biphasic or compound A.P.).

- It is formed of:

1- A latent period

2- Spike potential (the rapid depolarization followed by the rapid repolarization).

3- After potential (Negative and Positive after potential).

1- **The latent period:**

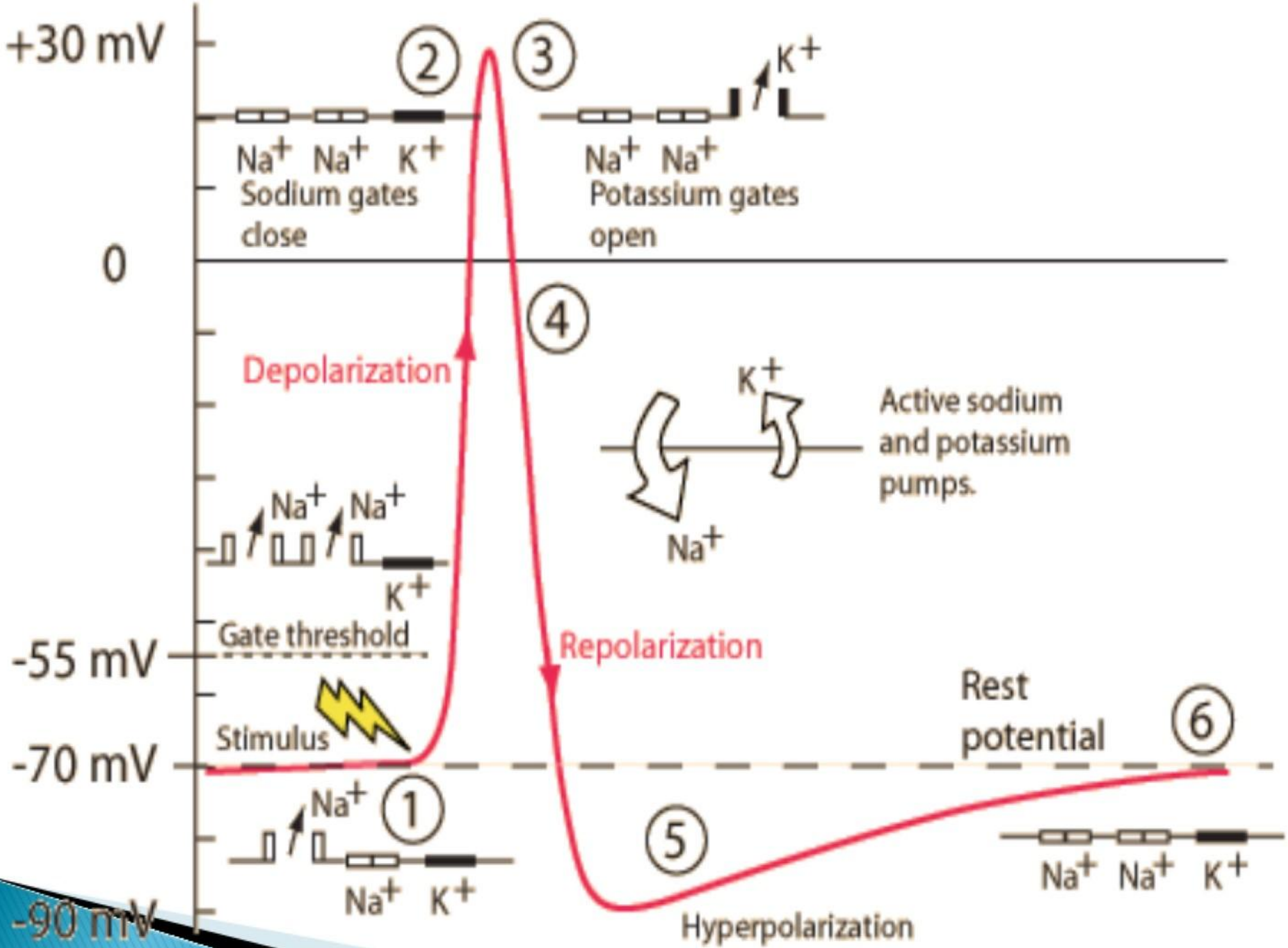
It is an isopotential period (base line) following the stimulus artifact and before the next potential change.

- **Significance:**

Detect the velocity of conduction along the nerve fiber can be calculated:

Velocity of conduction = distance/time (t)

2- **Gradual depolarization** from -70 mg to -55 mv due to opening of a few voltage gated sodium channels → sodium influx that opposed by potassium efflux from leaky channels.



+30 mV
0
-55 mV
-70 mV
-90 mV
2
3
Na+ Na+ K+
Sodium gates close
K+
Na+ Na+
Potassium gates open
4
Depolarization
K+
Active sodium and potassium pumps.
Na+
Na+ Na+
K+
Gate threshold
Repolarization
Stimulus
Rest potential
6
Na+
1
5
Na+ K+
Na+ Na+ K+
Hyperpolarization

3- The spike potential:

A- Rapid depolarization: At the membrane potential −55 mV ***(the firing level)***, the rate of depolarization increased rapidly. This is due to rapid opening of all voltage gated sodium channels → ↑↑↑sodium influx to reach the zero potential (isopotential), and continue to overshoot in the positive direction at approximately +35 mV (The inside becomes positive due to Na^+ and K^+). This is called ***reversal of polarity***.

B- **Rapid repolarization** (until the membrane is 70% repolarized): When it reaches +35 mv, Na^+ channels closes (inactivates) then voltage-gated K^+ channels open up → K^+ efflux occurs → Positive ion leaving the inside causes more negativity inside the membrane.

4- <u>After potentials:</u>

A- The negative after potential (is about 4 ms duration): the last slow 30 % of repolarization that by slower diffusion of K^+ out of the nerve cell at the end of the spike potential due to slower return of voltage-gated K^+ channels to the closed state that opposed by concentration and electrical gradient of rapid K+ efflux.

B- The positive after potential (*after hyperpolarization*): caused by

1- Prolonged increased permeability of the membrane to K^+ (slower closure of voltage-gated K^+ channels) leading to prolonged K^+ outflow and more +ve charge outside, causing the hyperpolarization (exceeding the RMP).

2- Na^+/K^+ pump restores Na^+ and K^+ concentration slowly by pumping $3Na^+$ ions outward and 2 K^+ ions inward.

It is about 40 ms duration and 1 to 2 mV amplitude that appears in the neuron after repeated conduction of nerve impulses for a long time. It represents the recovery processes in the neuron after conduction.

All or None law

- It is obeyed by a single nerve fiber (one axon), a single muscle fiber (skeletal) and the whole cardiac muscle.
- It states that: when a single nerve fiber is stimulated, either it does not respond at all (if the stimulus is subthreshold), or it responds by nerve impulse if the stimulus is threshold or more). The nerve impulse is always of the same magnitude and duration whatever the intensity of the stimulus that produced it.