Biopotential

- Biopotentials are electrical signals (voltages) that are generated by physiological processes occurring within the body.
- Biopotentials are produced by the electrochemical activity of a type of cell, called an excitable cell.
- Excitable cells are found in the nervous, muscular and glandular systems in the body.

What are the biopotential measurement?

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Action Potential

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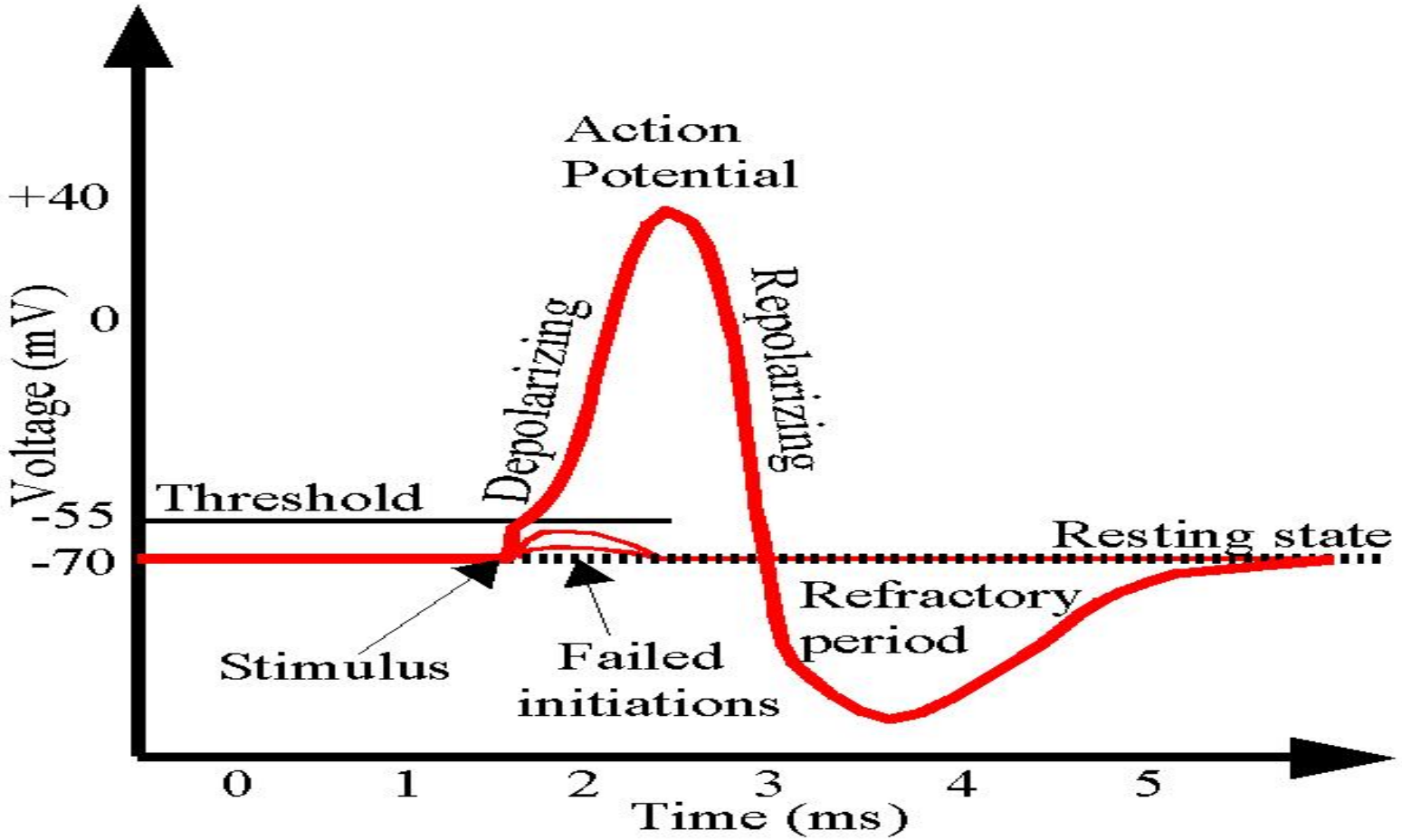
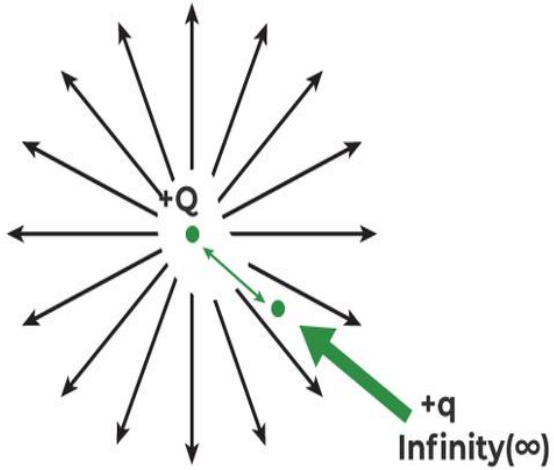


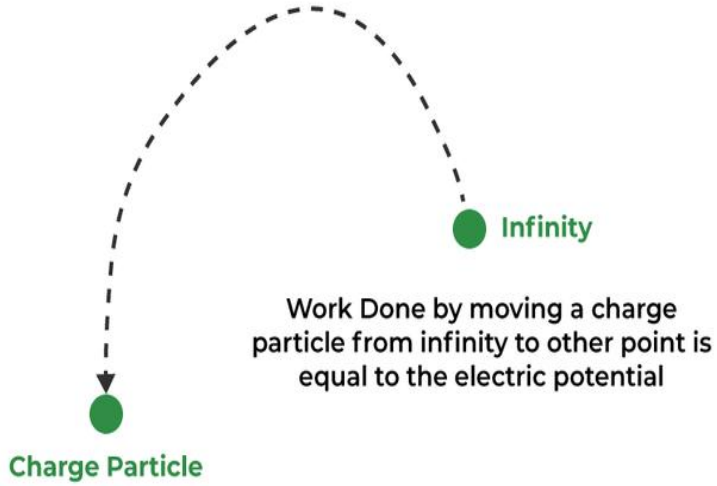
- The flow of electric charges is known as electricity, and it is responsible for producing electric current.

- Potential is the energy or work required to move a charge from infinity to a point inside field.

- The potential difference is the difference between the potential at two points.

- Potential difference between any two points of a circuit is proportional to the resistance between these two points.
- The electric potential difference is the work done per unit charge to move a unit charge from one point to another in an electric field.
- Electric potential difference is usually referred to as a Voltage difference.



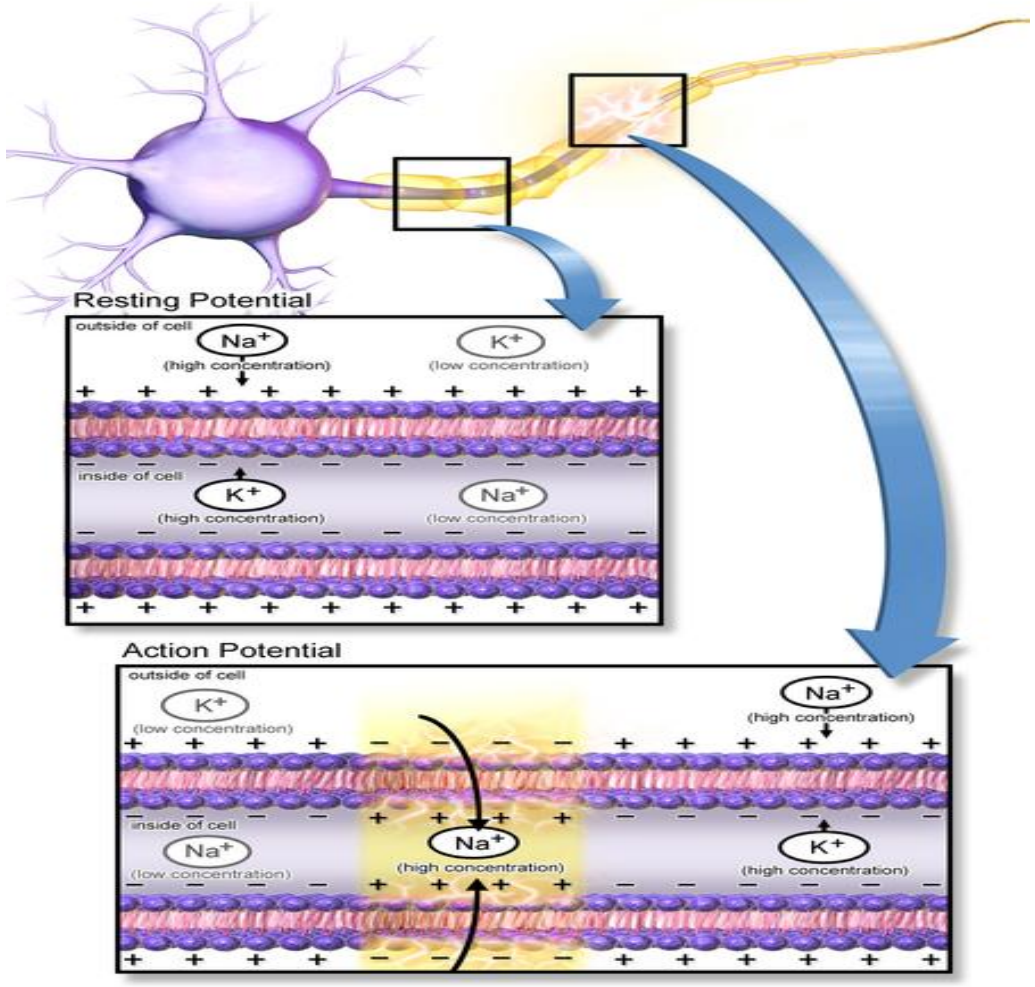


What is an Action Potential (AP)?

- A bioelectrical signal is in fact the sum of action potentials of cells at an anatomical site such as the heart, brain, or skeletal muscle.
- The AP is an electrical signal which accompanies a mechanical contraction of a single cell when stimulated by an electrical current, either neural or external.

- One of the fascinating physiological phenomena is action potential.
- An AP occurs when the membrane potential of a specific cell location rapidly rises and falls.

- The wave of propagation or excitation of the cell membrane of neurons and muscles due to a sudden change in their electric polarization is called the action potential.



- Neurons send messages electrochemically. This means that chemicals cause an electrical signal.

- Chemicals in the body are "electrically-charged" -- when they have an electrical charge, they are called ions.

- The important ions in the nervous system are sodium (Na+) and potassium (K+) (both have 1 positive charge, +), calcium (Ca++(has 2 positive charges, ++) and chloride (Cl-) (has a negative charge, -).

- There are also some negatively charged protein molecules.

- It is also important to remember that nerve cells are surrounded by a membrane that allows some ions to pass through and blocks the passage of other ions.

- This type of membrane is called **semi-permeable.**

- All cells in animal body tissues are **electrically polarized** – in other words, they maintain a voltage difference across the cell's plasma membrane, known as the membrane potential.

- This electrical polarization results from a complex interplay between protein structures embedded in the membrane called ion pumps and ion channels.

- Each excitable patch of membrane has two important levels of membrane potential: the **resting potential,** which is the value the membrane potential maintains as long as nothing perturbs the cell, and a higher value called the threshold potential.

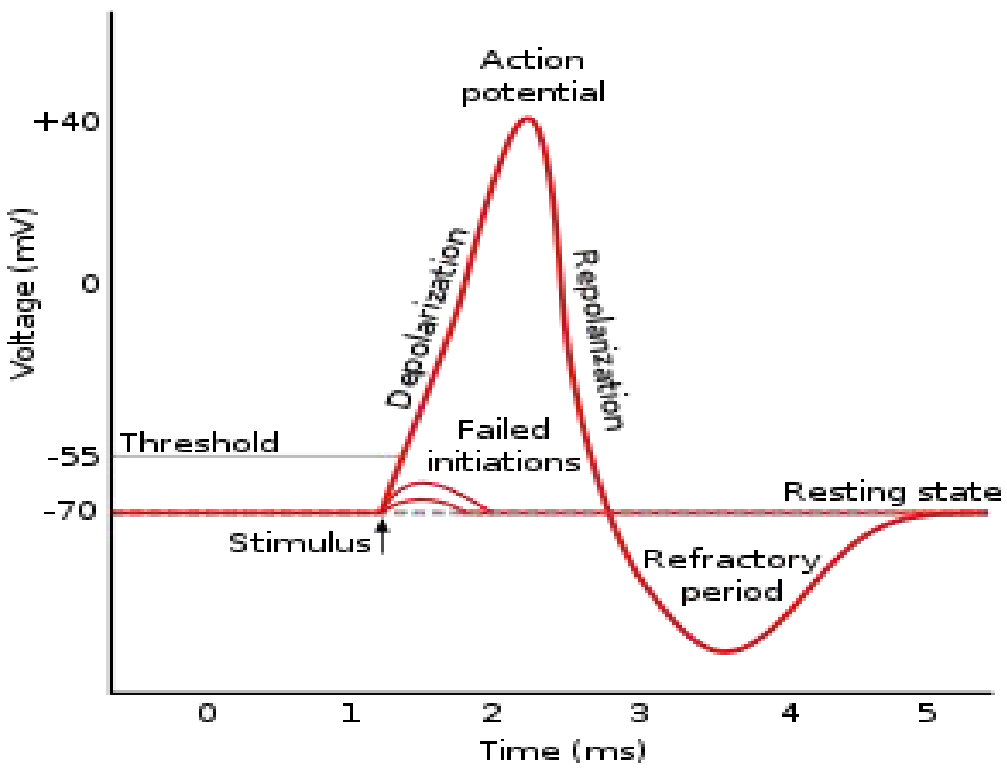
- The **resting potential is around –70 millivolts (mV)** and the threshold potential is around –55 mV.

- Synaptic inputs to a neuron cause the membrane to depolarize or hyperpolarize; that is, they cause the membrane potential to rise or fall.

- Action potentials are triggered when enough depolarization accumulates to bring the membrane potential up to threshold.

- When an action potential is triggered, the membrane potential abruptly shoots upward and then equally abruptly shoots back downward, often ending below the resting level, where it remains for some period of time.

- The shape of the action potential is stereotyped; this means that the rise and fall usually have approximately the same amplitude and time course for all action potentials in a given cell.

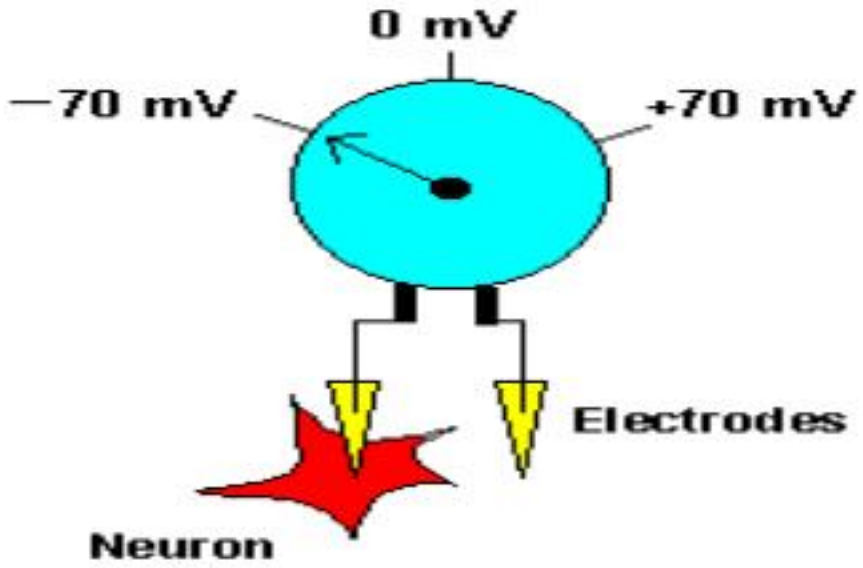


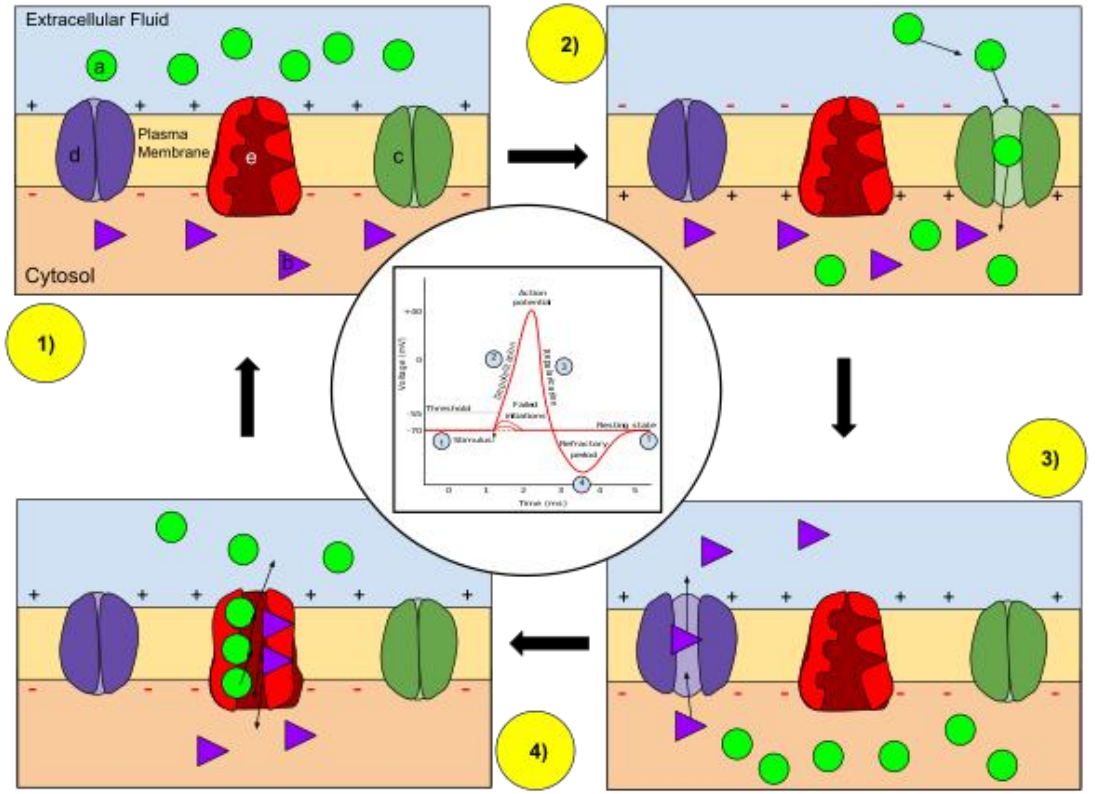
- Approximate plot of a typical action potential shows its various phases as the action potential passes a point on a cell membrane.
- The membrane potential starts out at approximately −70 mV at time zero.
- A stimulus is applied at time = 1 ms, which raises the membrane potential above −55 mV (the threshold potential).
- After the stimulus is applied, the membrane potential rapidly rises to a peak potential of +40 mV at time = 2 ms.
- Just as quickly, the potential then drops and overshoots to −90 mV at time = 3 ms, and finally the resting potential of −70 mV is reestablished at time = 5 ms.

Ion movement during an action potential.

- Key: a) Sodium (Na+) ion. b) Potassium (K+) ion. c) Sodium channel. d) Potassium channel. e) Sodium-potassium pump.

- In the stages of an action potential, the permeability of the membrane of the neuron changes.

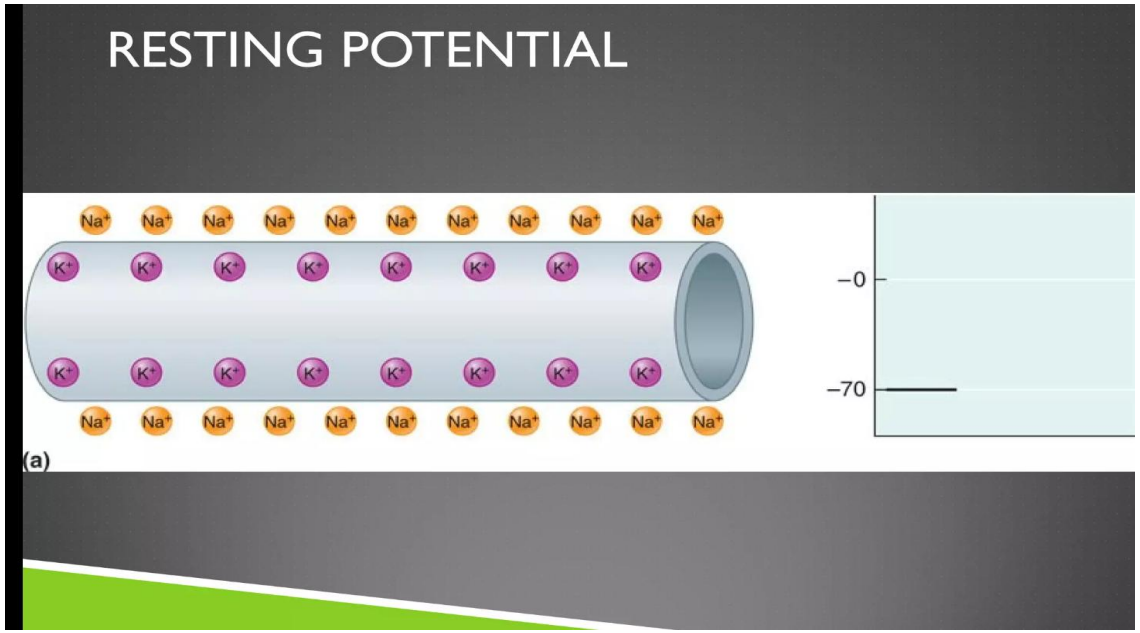




Phases of Action Potential

Phase 1: Resting Potential:

- At the resting state (1): It is the potential when a neuron is at rest.
- During this time, a small set of K+ ion pumps open to exchange these ions to maintain the electrochemical forces.
- Balance is maintained by exchanging ions across the membrane during resting potential.



- Difference in ion concentration creating aelectrical potential, and the cell siad to be **Polarized.**
- During this time, the inside of the neuron is negative relative to the outside.
- The resting membrane potential of a neuron is about -70 mV (mV=millivolt)
- At rest, there are relatively more sodium ions outside the neuron and more potassium ions inside that neuron.

Phase 2: Threshold phase:

- Once the action potential is triggered, the depolarization of the neuron activates sodium channels.
- It is then Na+ channels open letting these ions enter the neuron, resulting in a net positive charge in the neuron relative to the extracellular fluid.

- A quick increase in positive ions in that part of the neuron resulting in depolarization (the internal area becomes less negative), the resting potential to move towards 0 mV.

- An action potential can only occur when depolarization reaches a threshold value of between -40 and -55 mV.

- When the depolarization reaches about -55 mV a neuron will fire an action potential. This is the threshold.

- Now the value of action potential is 40mV. Now the cell is depolarised.

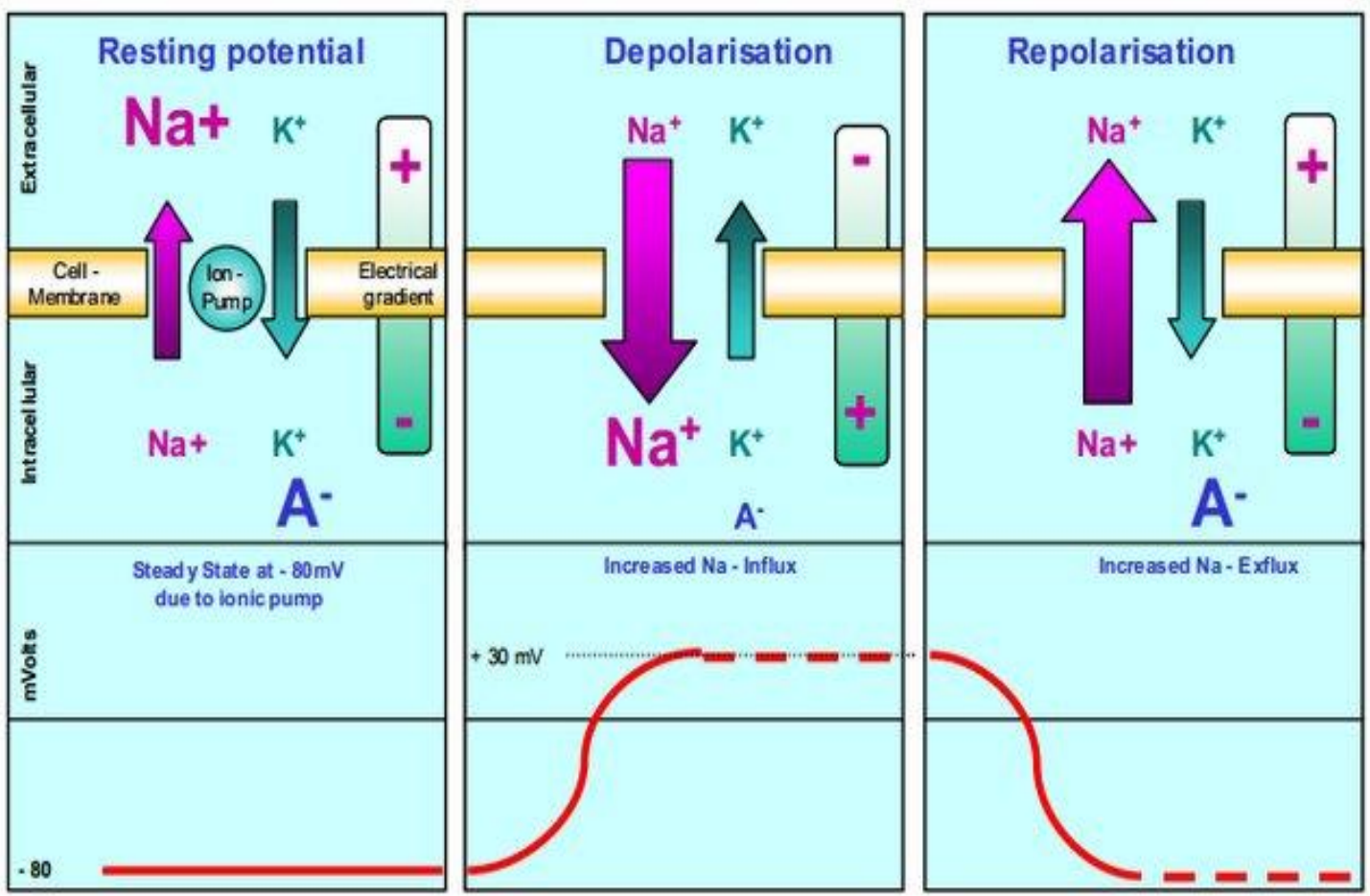
Phase 3: Repolarization

- After the action potential peak is reached, the neuron begins repolarization, where the sodium channels close and potassium channels open, allowing potassium ions to cross the membrane into the extracellular fluid, returning the membrane potential to a negative value.

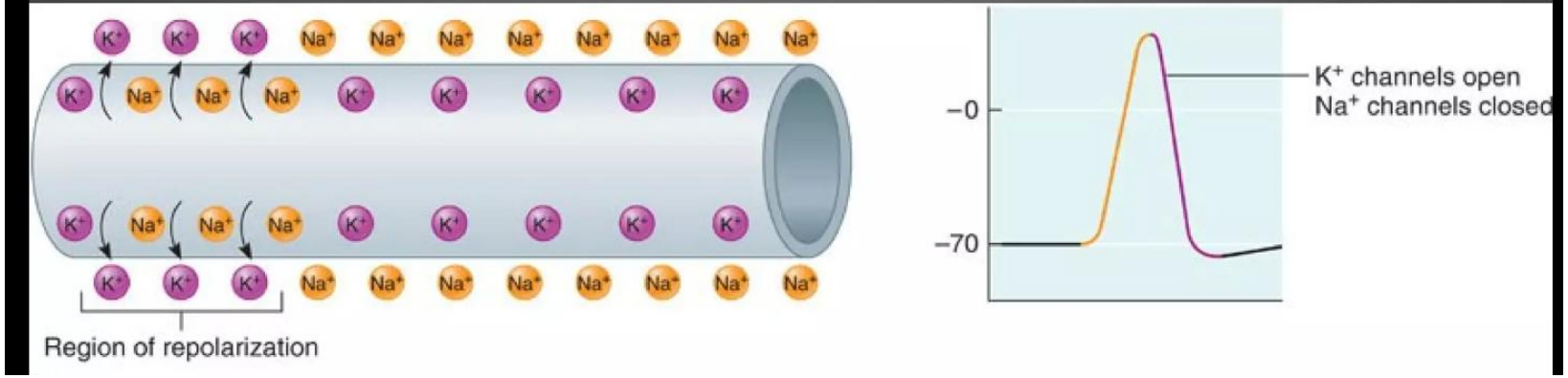
- This phase occurs after the cell reaches its highest voltage from depolarization.

- Repolarization returns the membrane potential to the -70 mV value that indicates the resting potential, but it actually overshoots that value.

- After repolarization, the cell hyperpolarizes.



REPOLARIZATION



Phase 4: Refractory period

- Finally, there is a refractory period, during which the voltage-dependent ion channels are inactivated while the Na+ and K+ ions return to their resting state distributions across the membrane.
- The refractory period is the period of time during which it is either more difficult or impossible for the neuron to fire another action potential.

- The refractory period to be 3-4 ms long, it should be noted that the hyperpolarization phase can last up to 15 ms in some neurons.

- There are two refractory periods: the absolute refractory period and the relative refractory period.

- Absolute refractory period corresponds to depolarization and repolarization, whereas relative refractory period corresponds to hyperpolarization.

- The neuron is ready to repeat the process for the next action potential.

Phase 5 The Falling Phase

- After the peak phase of the AP is over, two simultaneous processes run in the excited neuron. Most of the voltage Na+ channels close resulting in the conservation Na+ ions.

- And the K+ channels start to open resulting in the flow of these ions outside the cell.

- The spike in the positive charge starts to reside due to the loss of K+ ions and the potential starts to decrease considerably.

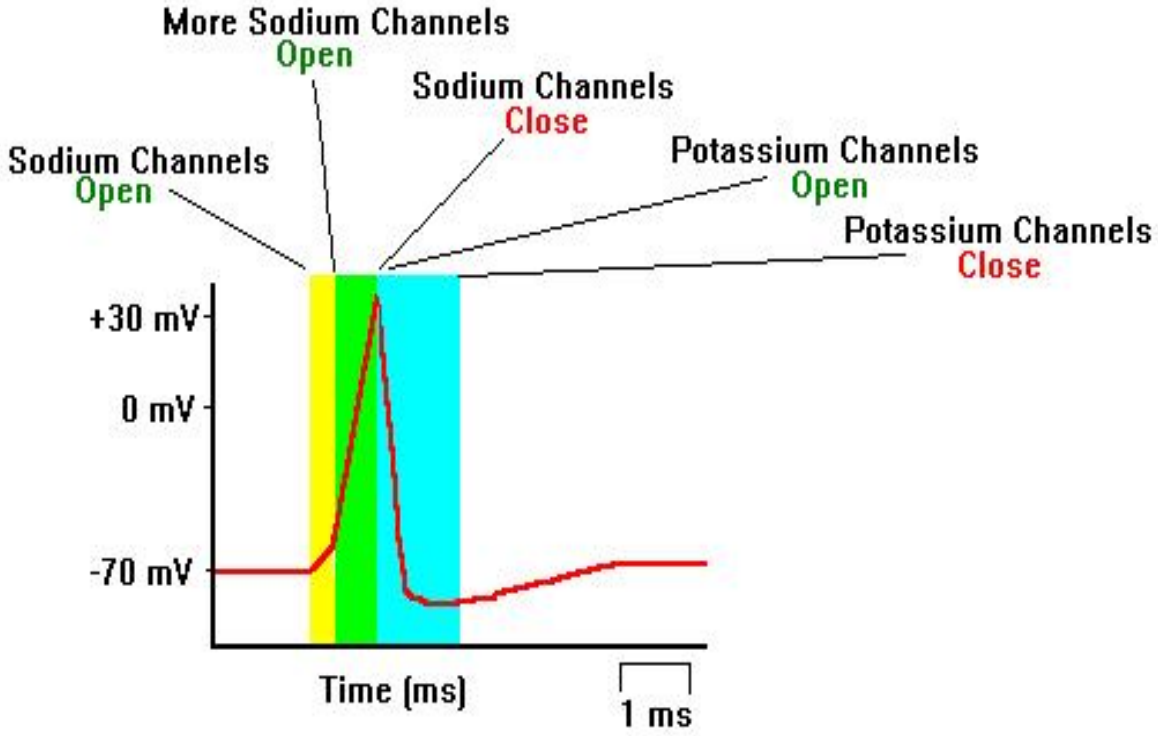
- Eventually, the neuron membrane achieves its resting potential.

- Also, when the threshold level is reached, an action potential of a fixed sized will always fire

- All action potentials are the same size.

- Therefore, the neuron either does not reach the threshold or a full action potential is fired - this is the "ALL OR NONE" principle.

- This means that any subthreshold stimulus will cause nothing



- The **"All-or-none law"** is a theory that states that a nerve cell or muscle fiber strength of the response is not contingent on the strength of the stimulus.

- A nerve or muscle fiber can exciter become activated if a stimulus is above a required threshold value.

Properties of Action Potential

- The ions involved in this action potential mechanism are Na+, K+, and Cl- (partially).
- The action potential of neuron is very short spanned. It happens only for 1 or 2 milliseconds.
- It happens due to the sudden changes in the ion concentration of the internal part of the cell membrane and in the extracellular fluid.
- It happens to produce nerve impulse and contraction of muscle cells and takes only 1/1000th of a second to complete.
- The speed of propagation can range from 3 to 300 feet per second. It entirely depends on the physiological properties and environment of the nerves and muscles fibres.

- It is also called propagated potential as the excitation wave transmits from one region to the next in neurons and muscle fibres.

- It is the reversal of the electric polarization of the regions on the nerve cell or neuron and muscle cell membrane that causes a potential difference.

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- The carrying of the nerve impulse from one neuron to the other requires a potential difference. It is created by the reversal of polarization throughout a neuron cell.

- At the end of a neuron, this action potential is then transmitted to the next neuron ending for propagation.