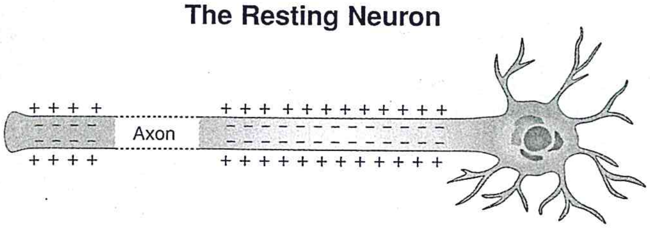
The Nerve Impulse

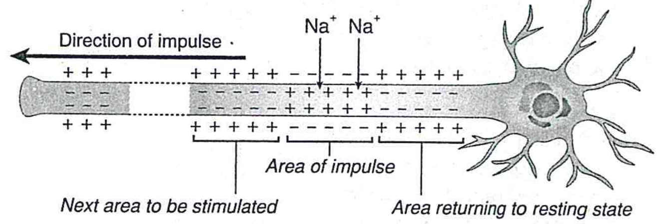
The plasma membranes of cells, including neurons, contain **sodium-potassium ion pumps** which actively pump sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. The action of these ion pumps in neurons creates a separation of charge (a potential difference or voltage) either side of the membrane and makes the cells **electrically excitable**. It is this property that enables neurons to transmit electrical impulses. The **resting state** of a neuron, with a net negative charge inside, is maintained by the sodium-potassium pumps, which actively move two K^+ into the neuron for every three Na^+ moved out (below left). When a nerve is stimulated, a brief increase in membrane permeability to Na^+ temporarily reverses the membrane polarity (a depolarization). After the nerve impulse passes, the sodium-potassium pump restores the resting potential. The depolarization is propagated along the axon by local current in non-myelinated fibers and by **saltatory conduction** in myelinated fibers. Impulses pass from neuron to neuron by crossing junctions called **synapses**.

The Resting Neuron

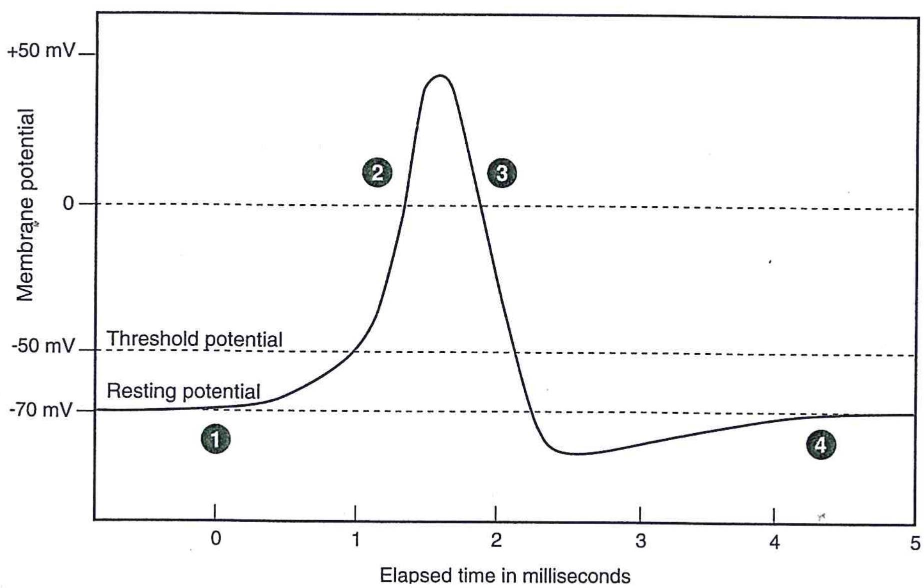


When a neuron is not transmitting an impulse, the inside of the cell is negatively charged relative to the outside and the cell is said to be electrically polarized. The potential difference (voltage) across the membrane is called the **resting potential**. For most nerve cells this is about -70 mV. Nerve transmission is possible because this membrane potential exists.

The Nerve Impulse



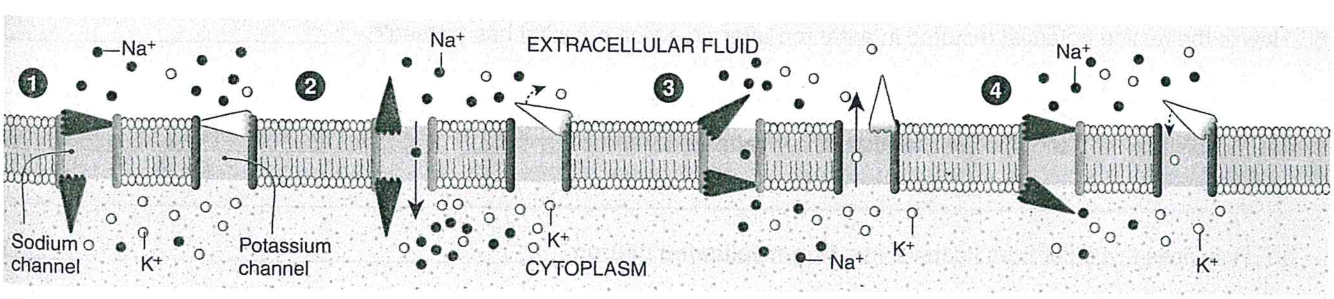
When a neuron is stimulated, the distribution of charges on each side of the membrane briefly reverses. This process of **depolarization** causes a burst of electrical activity to pass along the axon of the neuron as an **action potential**. As the charge reversal reaches one region, local currents depolarize the next region and the impulse spreads along the axon.



The depolarization in an axon can be shown as a change in membrane potential (in millivolts). A stimulus must be strong enough to reach the **threshold potential** before an action potential is generated. This is the voltage at which the depolarization of the membrane becomes unstoppable.

The action potential is **all or nothing** in its generation and because of this, impulses (once generated) always reach threshold and move along the axon without attenuation. The resting potential is restored by the movement of potassium ions (K^+) out of the cell. During this **refractory period**, the nerve cannot respond, so nerve impulses are discrete.

Voltage-Gated Ion Channels and the Course of an Action Potential



Resting state:
Voltage activated Na^+ and K^+ channels are closed.

Depolarization:
Voltage activated Na^+ channels open and there is a rapid influx of Na^+ ions. The interior of the neuron becomes positive relative to the outside.

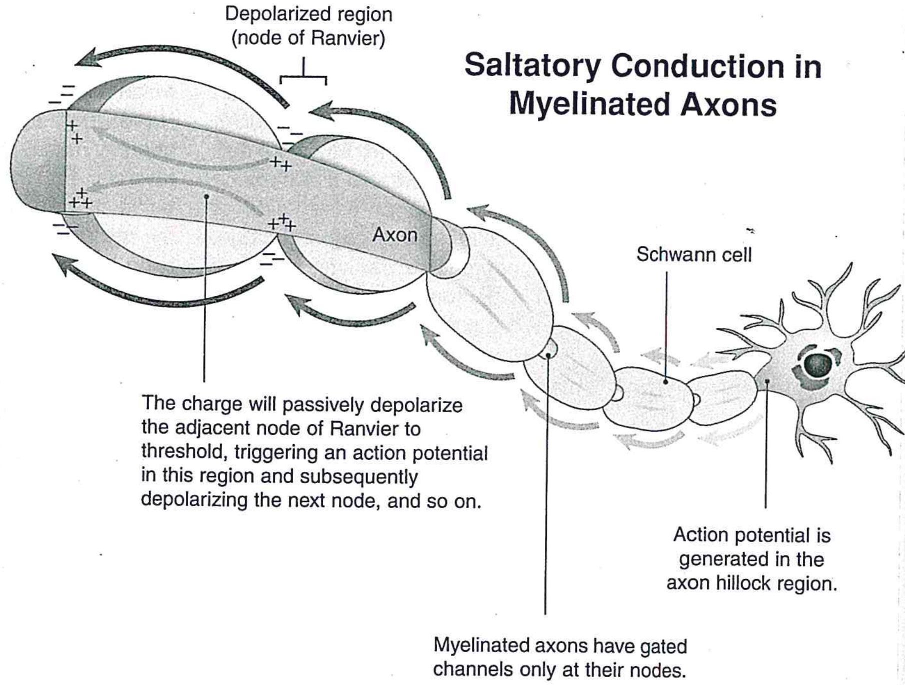
Repolarization:
Voltage activated Na^+ channels close and the K^+ channels open; K^+ moves out of the cell, restoring the negative charge to the cell interior.

Returning to resting state:
Voltage activated Na^+ and K^+ channels close to return the neuron to the resting state.

Saltatory Conduction in Myelinated Axons

Axon myelination is a feature of vertebrate nervous systems and it enables them to achieve very rapid speeds of nerve conduction. Myelinated neurons conduct impulses by **saltatory conduction**, a term that describes how the impulse jumps along the fiber. In a myelinated neuron, **action potentials are generated only at the nodes**, which is where the voltage gated channels occur. The axon is insulated so the action potential at one node is sufficient to trigger an action potential in the next node and the impulse jumps along the fiber. Contrast this with a non-myelinated neuron in which voltage-gated channels occur along the entire length of the axon.

As well as increasing the speed of conduction, the myelin sheath reduces energy expenditure because the area over which depolarization occurs is less (and therefore also the number of sodium and potassium ions that need to be pumped to restore the resting potential).



1. In your own words, define what an **action potential** is: ____________________

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2. (a) Identify the defining **functional feature** of neurons: ____________________

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(b) How does this differ from the supporting tissue (e.g. Schwann cells) of the nervous system? ____________________

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3. Describe the movement of voltage-gated channels and ions associated with:

(a) Depolarization of the neuron: ____________________

(b) Repolarization of the neuron: ____________________

4. Summarize the sequence of events in a neuron when it receives a stimulus sufficient to reach threshold:

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5. How is the resting potential restored in a neuron after an action potential has passed? ____________________

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6. (a) Explain how an action potential travels in a **myelinated neuron**: ____________________

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(b) How does this differ from its travel in a **non-myelinated neuron**? ____________________

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7. Explain how the **refractory period** influences the direction in which an impulse will travel: ____________________

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