

Fundamentals of Neuroscience: The Electrical Properties of the Neuron

Arshiya Sabharwal, Grade-12
Bright Riders School, Abu Dhabi U.A.E

Abstract

Neuroscience investigates the intricate functions of the nervous system, primarily focusing on neurons, the basic units of neural communication. These neurons possess unique electrical properties that determine their information processing and transmission capabilities. Neurons maintain a stable resting potential due to the distribution of charged particles across their membrane. Action potentials, brief electrical fluctuations, travel along the neuron's axon, allowing for speedy signal transmission. At synapses, where neurons connect, electrical signals are converted into chemical signals via the release of neurotransmitters. These neurotransmitters influence the activity of neighboring neurons, facilitating communication and shaping brain function.

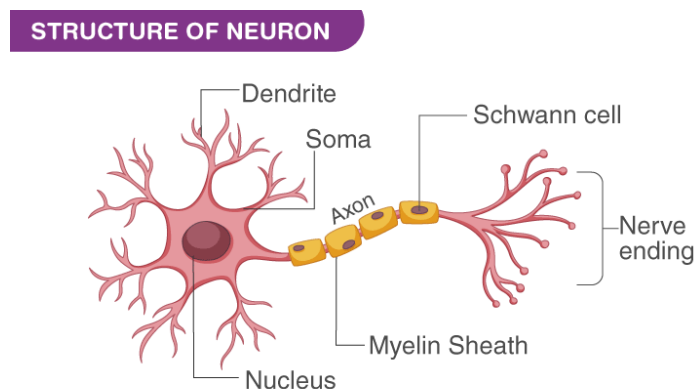
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I. Introduction

Neuroscience, a field that crosses disciplinary boundaries, delves into the complexities of the nervous system, striving to decipher the secrets of the brain and its functions. At the core of this exploration is the neuron, the cornerstone unit of the nervous system that processes and communicates information via electrical and chemical signals. Understanding the electrical behavior of neurons is essential to comprehending how the nervous system operates and how it can malfunction in neurological disorders. This paper focuses on the basic principles of neuron electrophysiology, examining its significance in neural communication and its importance in neuroscience research.

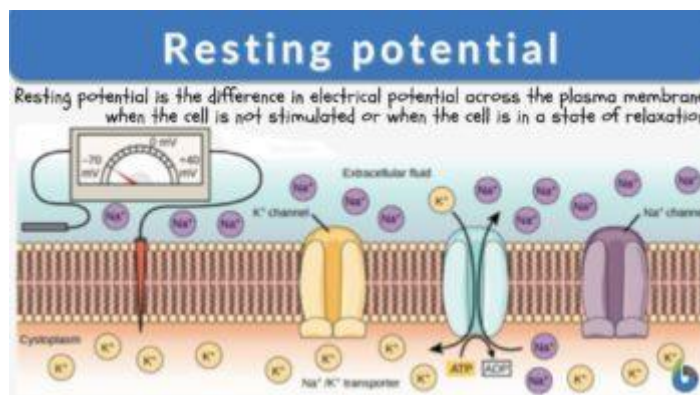
Structure and Function of Neurons:

Neurons are special cells with specific shapes and parts that help them do their job. The main parts of a neuron are the cell body, dendrites, and axon. Dendrites take in signals from other neurons or senses, and the axon sends electrical signals away from the cell body to other neurons, muscles, or glands. When neurons talk to each other or inside themselves, they change their electrical charge by moving atoms called ions across their outer membranes.



Resting Membrane Potential:

The resting membrane potential is a crucial aspect of neuron electrophysiology. At rest, neurons maintain a voltage difference across their membrane, typically around -70 millivolts (mV) inside relative to outside. This potential is largely determined by the unequal distribution of ions such as sodium (Na^+), potassium (K^+), chloride (Cl^-), and organic anions (A^-) across the membrane, established by ion channels and pumps. The sodium-potassium pump actively transports Na^+ out of the cell and K^+ into the cell, contributing to the negative resting potential.



Action Potential

Communication in neurons mainly involves action potentials, short changes in the electrical charge across the cell membrane that move along the neuron's long, thin extension called the axon. When the membrane charge reaches a certain point (usually around -55 millivolts), it triggers a chain reaction. This starts with the opening of special channels that let sodium ions flow into the cell, causing it to become even more charged. Next, other channels open to let potassium ions flow out, bringing the charge back to its normal resting state. This quick change in charge then spreads along the axon, carrying signals over long distances quickly and accurately.

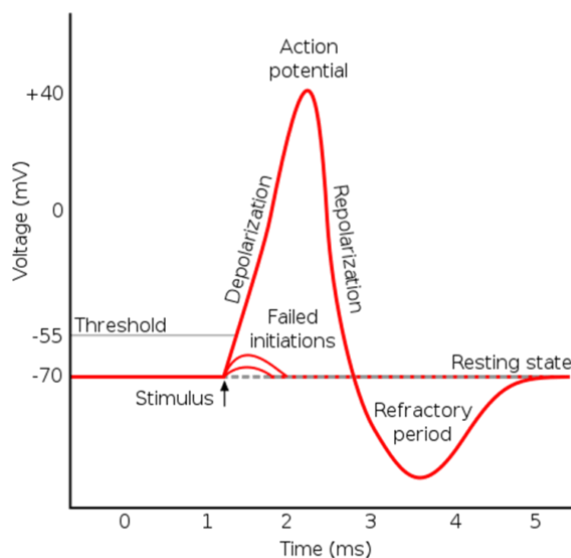


Diagram showing the phases of an action potential in relation to the membrane voltage over time.

Synaptic Transmission:

At meeting points between neurons called synapses, electrical signals are transformed into chemical signals to relay information. When an electrical impulse arrives at the synapse's "sending" side, it releases chemical messengers (neurotransmitters) into the gap between the neurons. The neurotransmitters attach to receptors on the receiving neuron's side, causing changes in its electrical potential. This can either increase the potential, making it more likely to send an electrical impulse (depolarization), or decrease the potential, making it less likely to fire (hyperpolarization). Some neurotransmitters, like glutamate, excite the neuron (promote depolarization), while others, like GABA, inhibit it (promote hyperpolarization). The balance between these two types of signals determines if the neuron will generate an electrical impulse.

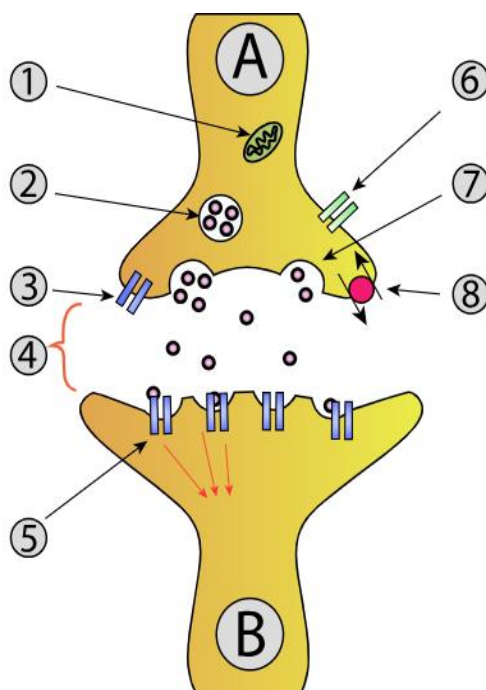


Diagram showing the basic model of neurotransmission. (A) Presynaptic neuron. (B) Postsynaptic neuron. (1) Mitochondria. (2) Synaptic vesicles containing neurotransmitters. (3) Autoreceptor. (4) Synaptic cleft. (5) Neurotransmitter receptor. (6) Calcium channel. (7) Fused vesicle releasing neurotransmitter. (8) Neurotransmitter reuptake pump.

Integration of Signals:

Neurons combine signals from multiple sources (synapses) to decide if they should send out an electrical pulse (action potential). This decision is made by summing up the strength and timing of the incoming signals. Spatial summation combines signals from different parts of the neuron, while temporal summation adds up signals that come in over time. If the total signal is strong enough (reaches the threshold), the neuron triggers an action potential. Otherwise, the signal dies out.

Role in Neurological Disorders:

Problems with how neurons conduct electricity can cause neurological disorders. For example, epilepsy is a condition where people have seizures because of issues with ion channels or neurotransmitters. Alzheimer's disease is another disorder where changes in how neurons communicate lead to memory problems and cell death. Understanding how electricity works in neurons helps us learn more about these disorders and develop better treatments.

II. Conclusion :

The electrical characteristics of nerve cells (neurons) are essential for comprehending the operations of the brain and nervous system. These characteristics, from producing electrical signals to transmitting information between neurons and combining signals, form the basis of how neurons interact. Neurologists are constantly studying the intricate electrical properties of neurons to comprehend both typical brain functions and neurological conditions. This research may result in new therapies and interventions that focus on the nervous system.

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David Cox: Assistant Professor of Molecular and Cellular Biology, and Computer Science
Harvard University