UNIVERSITY OF MORATUWA, SRI LANKA
Faculty of Engineering
Department of Electronic and Telecommunication Engineering
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BM2012 - Anatomy and Physiology for Engineers

Assignment 2
Action Potential and Nerve Stimulation Techniques

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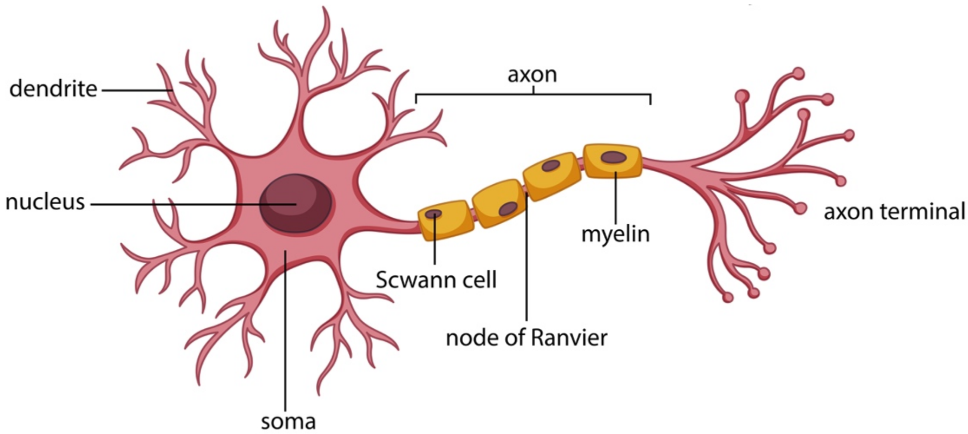
Introduction

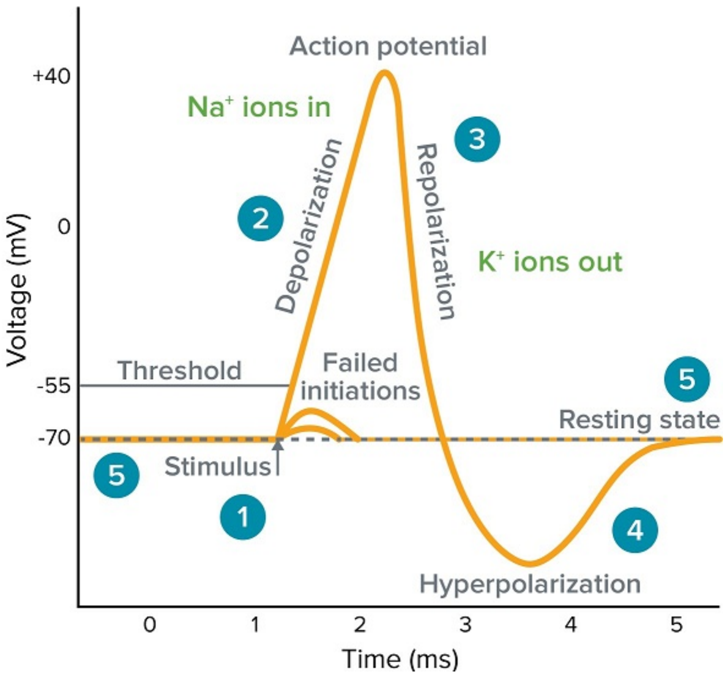
This report aims to provide a comprehensive understanding of action potentials, including the phases involved, ion movements, and polarity changes. Additionally, it explores the concept of the all-or-none principle and its distinction from graded potentials. Furthermore, the report discusses various nerve stimulation techniques used in neuroscience research and clinical applications.

What is a neuron?

A neuron, also known as a nerve cell, is the fundamental unit of the nervous system. Neurons are specialized cells that transmit and process information through electrical and chemical signals. They play a crucial role in communication within the nervous system, allowing for the transmission of sensory input, integration of information, and coordination of motor responses.



1. What is an Action Potential?



An action potential is a brief and rapid electrical signal or impulse that travels along the membrane of a neuron. It is a fundamental mechanism by which neurons communicate with each other and transmit information within the nervous system. Action potentials are essential for processes such as sensory perception, motor control, and cognitive functions.

During an action potential, there is a temporary reversal of the electrical charge across the neuron's membrane. This reversal occurs due to the movement of ions, specifically sodium (Na^+) and potassium (K^+), across the cell membrane. The action potential is initiated when a stimulus, such as a change in voltage or the binding of a neurotransmitter to a receptor, causes the neuron to reach a certain threshold. The process of an action potential can be divided into several phases.

1.1 Resting Membrane Potential

At rest, the neuron maintains a negative internal charge relative to the extracellular fluid. This resting membrane potential is typically around -70 millivolts (mV). The primary ions involved in maintaining this potential are potassium (K^+) and sodium (Na^+), which are regulated by ion channels.

1.2 Depolarization

Depolarization occurs when a stimulus causes the membrane potential to become less negative or even positive. The initial depolarization triggers the opening of voltage-gated sodium channels. Sodium ions rush into the neuron, causing a rapid increase in membrane potential (around +40 mV). This phase is also known as the rising phase.

1.3 Repolarization

Following depolarization, the membrane potential begins to return to its resting state. Voltage-gated sodium channels inactivate, and voltage-gated potassium channels open. As potassium ions move out of the neuron, the membrane potential decreases toward its resting value. This phase is known as the falling phase.

1.4 Hyperpolarization

In some cases, the repolarization phase overshoots the resting potential, leading to a brief period of hyperpolarization. During hyperpolarization, the membrane potential becomes more negative than the resting potential. Potassium channels slowly close, and the membrane potential gradually returns to its resting state.

2. All-or-None Principle

All-or-None Principle vs. Graded Potentials: The all-or-none principle states that an action potential will either occur fully or not at all, without partial activation. If the stimulus surpasses the threshold level typically around -55 mV, the action potential will be generated and propagate along the neuron's axon. However, if the stimulus fails to reach the threshold, no action potential will occur. The size or intensity of the stimulus does not affect the amplitude or duration of the resulting action potential; it remains constant. The all-or-none principle ensures consistent and reliable propagation of signals along neurons.

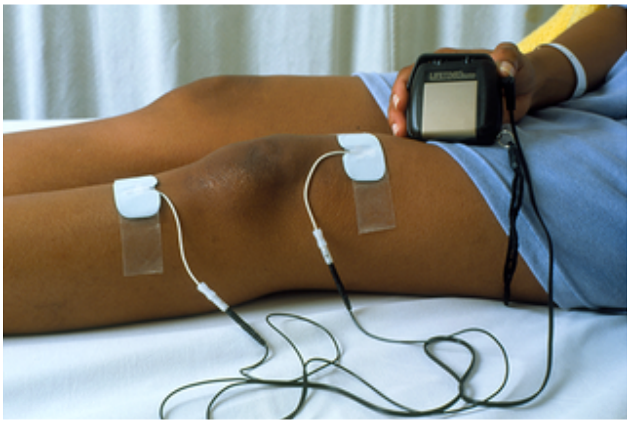
In contrast, graded potentials are sub-threshold changes in the membrane potential that vary in strength according to the stimulus. Graded potentials can either be excitatory (depolarizing) or inhibitory (hyperpolarizing), and their amplitude is directly proportional to the stimulus strength. A stronger stimulus results in a larger graded potential, while a weaker stimulus generates a smaller graded potential. Graded potentials can summate, meaning they can add together to reach the threshold for generating an action potential. Graded potentials are involved in local signaling and play a role in integrating information within individual neurons.

3. Nerve Stimulation Techniques

Nerve stimulation techniques are used in both research and clinical settings to activate or modulate neuronal activity. Some common techniques are listed below.

3.1 Electrical Stimulation

Electrical stimulation involves applying electrical currents to excite or inhibit neural activity. This technique can be applied directly to the nervous tissue using electrodes or transcranial stimulation methods. It enables precise control of the stimulation parameters and has applications in functional electrical stimulation (FES), deep brain stimulation (DBS), and transcutaneous electrical nerve stimulation (TENS).

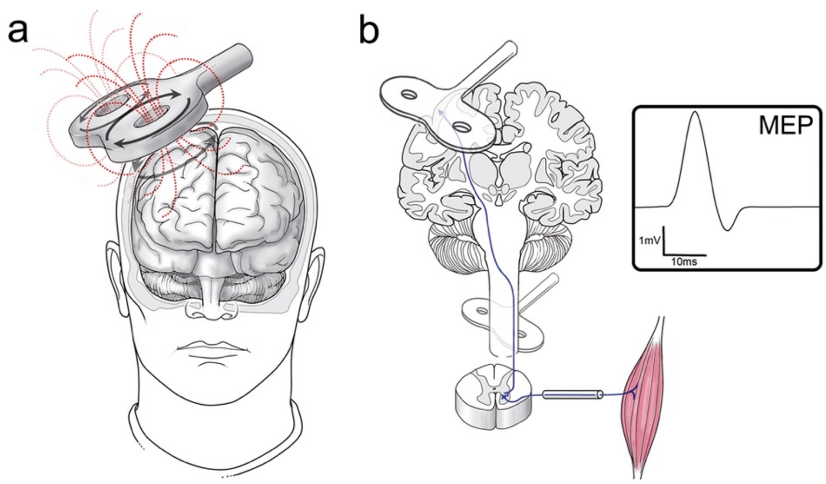


3.2 Chemical Stimulation

Chemical stimulation involves the application of neurotransmitters or other chemical agents to influence nerve activity. For example, Neurotransmitters such as glutamate or GABA, can be applied to excite or inhibit neural activity, respectively. This technique is utilized in research to study neurotransmitter systems and investigate drug effects on neural activity.

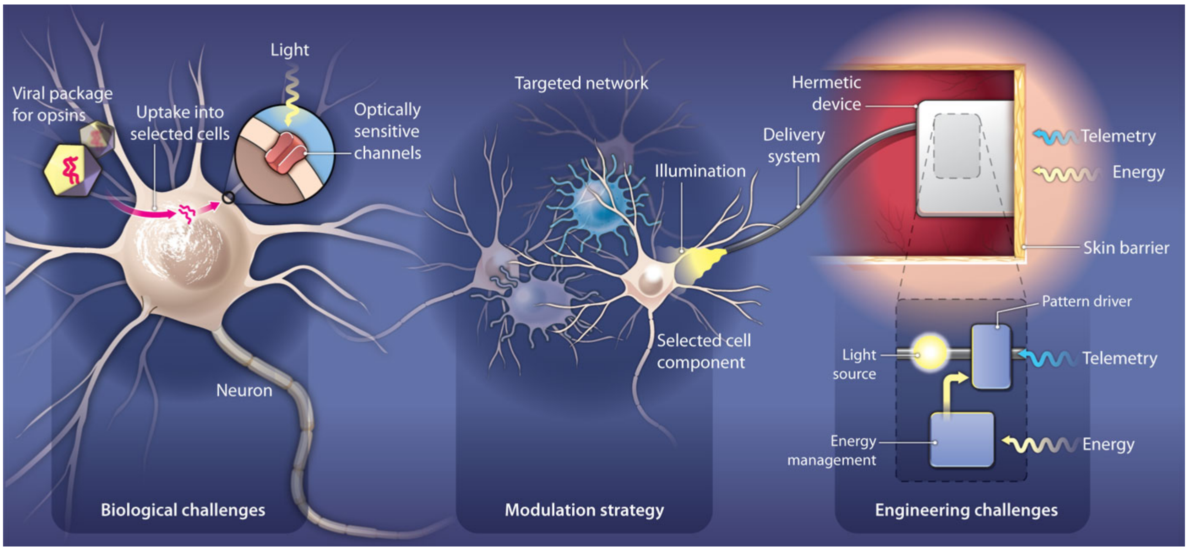
3.4 Magnetic Stimulation

Magnetic stimulation techniques, such as transcranial magnetic stimulation (TMS), use rapidly changing magnetic fields to induce electrical currents in the neural tissue. TMS can non-invasively stimulate or modulate activity in specific brain regions. It has applications in both research and clinical interventions, such as treating depression or mapping brain functions.



3.3 Optogenetics

Optogenetics combines genetic engineering and optics to control neural activity with light. Specific neurons are genetically modified to express light-sensitive proteins called opsins. When light of a specific wavelength is applied, opsins can activate or inhibit neural activity. Optogenetics offers high spatial and temporal precision in manipulating neural circuits.



Conclusion

Action potentials are crucial for transmitting electrical signals along neurons. Understanding the phases, ion movements, and polarity changes during an action potential provides insights into neuronal communication. The all-or-none principle ensures consistent signal propagation, while graded potentials play a role in local signaling. Various nerve stimulation techniques enable researchers and clinicians to manipulate and study neural activity, leading to advancements in neuroscience research and therapeutic interventions.

References

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