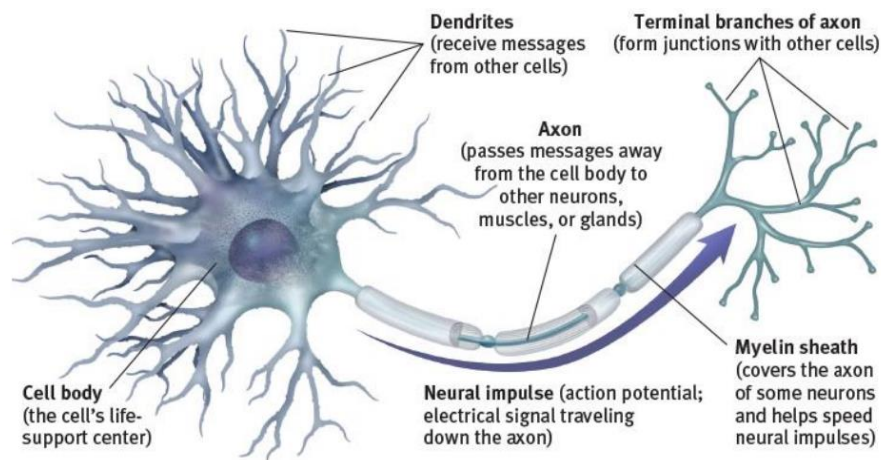**University of Tehran, Faculty of Electrical and Computer Engineering**

Fall 2023 - Biomedical Engineering Fundamentals

1. Introduction

Neuroscience is a significant field within medical sciences, particularly the study of the structure and function of the nervous system, including the human brain. This field explores how neurons interact and control bodily functions, focusing on how information is transmitted, processed, and regulated. The central nervous system, especially the brain, is primarily made up of neurons that form complex networks, constantly interacting and producing electrochemical signals. These signals allow neurons to communicate, enabling the transmission of information and control of bodily functions.

Neurons play a vital role in transmitting information and controlling activities. Each neuron consists of a cell body, axon, and dendrites. The dendrites receive signals from other neurons, and the axon transmits the signal to other neurons, creating an interconnected network.
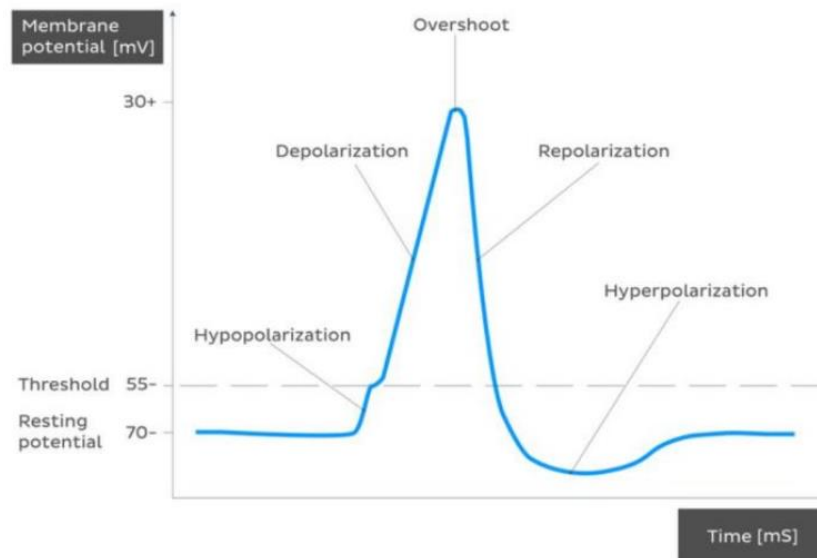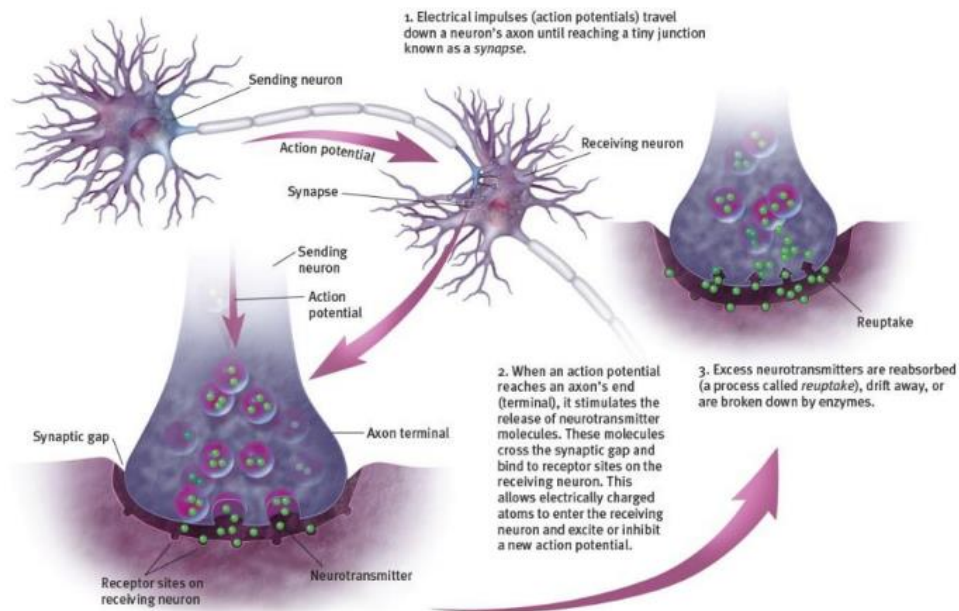
1. Electrical impulses (action potentials) travel down a neuron's axon until reaching a tiny junction known as a *synapse*.

Sending neuron

Action potential

Receiving neuron

Synapse

Sending neuron

Action potential

Reuptake

Synaptic gap

Axon terminal

2. When an action potential reaches an axon's end (terminal), it stimulates the release of neurotransmitter molecules. These molecules cross the synaptic gap and bind to receptor sites on the receiving neuron. This allows electrically charged atoms to enter the receiving neuron and excite or inhibit a new action potential.

3. Excess neurotransmitters are reabsorbed (a process called *reuptake*), drift away, or are broken down by enzymes.

Receptor sites on receiving neuron

Neurotransmitter

Membrane potential [mV]

Overshoot

30+

Depolarization

Repolarization

Hyperpolarization

Hypopolarization

Threshold 55-

Resting potential 70-

Time [mS]

Figure 1-1: Structure of a motor neuron
Figure 1-2: Communication between neurons
Figure 1-3: Action potential in a neuron

An **electroencephalogram (EEG)** records the electrical activities of the nervous system and is widely used in research and treatment. In this non-invasive method, electrodes are placed on the scalp to measure

the electrical signals produced by neurons. EEG is an important diagnostic and research tool in neuroscience and medicine, capable of assessing conditions such as:

1. **Neurological disorders**: EEG can help diagnose neurological conditions like epilepsy, strokes, brain tumors, and movement disorders.

2. **Sleep studies**: EEG is critical in studying sleep patterns, diagnosing sleep disorders, and understanding brain activity during sleep.

3. **Mental health disorders**: EEG helps diagnose psychological disorders such as anxiety, depression, and mood disorders.

4. **Brain function research**: EEG allows researchers to observe real-time brain activity in response to stimuli and study various brain functions.

In this project, we will investigate a simple application of EEG signals, particularly in the context of neurological abnormalities.

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2. Project Description

Section 2-1:

As mentioned earlier, EEG involves placing electrodes on the scalp to record brain activity. The data obtained from the EEG represents the electrical signals produced by neurons in the brain over time.

1. **Loading data**: Use the load command to import the EEG data, which is stored in mat format. The provided data spans 10 seconds of brain activity.

2. **Plotting signals**: Choose three signal channels and plot them in both the time and frequency domains.

3. **Frequency analysis**: Using Fourier transform, examine the relationship between the amplitude and frequency of the brain signals. Specifically, analyze alpha, beta, delta, theta, and gamma waves. Select one signal and apply an inverse Fourier transform to reconstruct it, then plot the brainwave over time.

4. **Signal features**: Using the EEG data, determine the key characteristics of the signal over a 10-second period. Can you identify any particular brain activities or abnormalities?
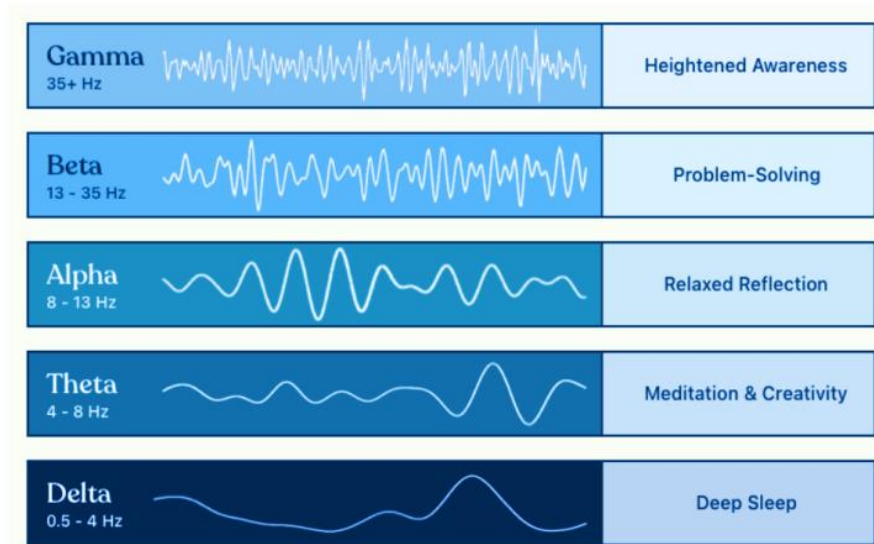
Figure 2-1: Types of brain signals

Section 2-2:

Research different sleep stages and their corresponding EEG frequencies. Refer to credible sources and bring findings into your report. Additionally, use the provided unfiltered EEG data and plot signals of interest.

1. Plot the frequency bands as in Section 2-1, and analyze their features for each sleep stage.

2. Report your observations and conclusions in your final report, discussing the power of each frequency band.

Submission Notes:

Please allocate enough time for completing this assignment. Your report will be evaluated based on the outlined criteria. Include your conclusions and code results in the final report, which can be written in Persian or English. Use the provided template to write the report, and submit all project files as a zip file named CA1_Student_Name through the ELearn platform.

In case of any questions regarding the project, contact the TA via email.