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HISTOLOGICAL STRUCTURE OF THE NERVOUS SYSTEM

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Abstract: This article presents the fundamental histological structure of nerve tissue, the structure and functions of neurons and glial cells in simple and understandable language. The nervous system serves as the control center of the organism and consists of specialized cells called neurons and supporting glial cells that maintain them. The article explains how neurons are constructed, the types of glial cells, the importance of the myelin sheath, and how nerve impulses are transmitted in simple terms. Each concept is clarified through examples and comparisons.

Keywords: nerve tissue, neurons, neuroglia, synapse, myelin sheath, nerve impulse

Introduction

We can describe the nervous system as the "control center" of our organism. Just as a computer's central processor processes all information, the nervous system controls and coordinates the functioning of all organs. The nervous system is composed of specialized tissue called nerve tissue. Nerve tissue consists of two main components. The first component is neurons, which transmit information from one location to another much like electrical wires. The second component is glial cells, which are supporting cells that assist neurons. If we compare neurons to electrical wires, we can think of glial cells as resembling the protective coating around the wires and the structures that hold them in place.

Nerve tissue develops during embryonic development from the ectoderm. The ectoderm is the outer layer of the embryo, from which both skin and the nervous system arise.

Neurons: The Principal Cells of the Nervous System

Neurons are considered the most important cells of the nervous system. Their primary function is to transmit electrical signals—nerve impulses—from one location to another. Neurons do not resemble ordinary cells; they possess a highly distinctive structure.

Structure of Neurons

Every neuron consists of three main parts: the cell body, dendrites, and an axon. This can be compared to a tree: the cell body resembles the trunk, dendrites resemble the branches, and the axon resembles the roots.

The cell body is the central part of the neuron, and its size can vary—some are very small (fifteen micrometers), while others are larger (one hundred thirty micrometers). A micrometer is one-thousandth of a millimeter. Within the cell body are the nucleus and all necessary organelles. The nucleus functions like a library for the cell—it stores all required information. In the cell body are specialized structures called Nissl bodies. These function like factories for producing proteins.

Dendrites are short processes that branch out from the cell body and receive signals from other neurons. This can be compared to a telephone's antenna or ear—they receive information. A single neuron can have thousands of dendrites, which allows it to receive signals from many other neurons.

The axon is a long process that transmits nerve impulses to other cells. The axon functions like an electrical wire. Some axons are very short (less than one millimeter), while others are extremely long—more than one meter! For example, the axon of neurons that control the movement of toe muscles extends from the spinal cord to the toe muscles.

Types of Neurons

Neurons exist in various shapes and perform different functions. They can be classified in two ways: by shape and by function.

By shape, neurons fall into four types. Unipolar neurons have only a single process and are found mainly during embryonic development. Pseudounipolar neurons also have a single process, but it divides into two branches—one receives signals and the other transmits them. These neurons are found in ganglia surrounding the spinal cord. Bipolar neurons have two processes and function in specialized sensory organs such as the eyes, ears, and nose. Multipolar neurons are the most commonly encountered type and possess many dendrites and a single axon. The majority of neurons in the brain and spinal cord are of the multipolar type.

By function, neurons are divided into three main groups. Afferent neurons, also called sensory neurons, send information from the body to the brain. For example, when your hand touches something hot, these neurons send the signal "hot!" to the brain. Efferent neurons, also called motor neurons, send commands from the brain to muscles and glands. For example, the command "throw the hand!" is sent through these neurons. Interneurons work within the brain and spinal cord and serve a bridging function between afferent and efferent neurons.

Glial Cells: The Support System of the Nervous System

Glial cells constitute the second important component of nerve tissue. If we consider neurons as primary workers, we can think of glial cells as assistants. They provide various forms of support to neurons: nourishing them, protecting them, cleaning, and maintaining them. Interestingly, glial cells are more numerous than neurons—they comprise approximately half of nerve tissue.

Astrocytes are star-shaped cells and represent the most common type of glial cell. They possess many processes, and these processes attach on one side to neurons and on the other side to blood vessels. Astrocytes function like waiters—they take nutrients from blood and deliver them to neurons. Additionally, they collect excess substances produced by neurons and clean them away. Astrocytes also participate in creating the blood-brain barrier. This barrier functions like a protective wall, preventing harmful substances from passing from blood into the brain.

Oligodendrocytes perform a critically important function—they wrap myelin sheaths around axons. The myelin sheath is a fatty protective layer surrounding axons that enables rapid transmission of nerve impulses. This can be compared to the plastic insulation around electrical wires. A single oligodendrocyte can produce myelin sheaths for fifteen to fifty axons through its processes.

Microglia are the "guardians" or "cleaners" of the nervous system. They are very small and typically remain at rest, monitoring the surroundings. However, if a harmful microorganism enters the brain or an injury occurs, microglial cells immediately become activated and engulf harmful substances. They function like police or cleaning services within the organism.

Ependymal cells line the chambers within the brain and spinal cord. Their surface possesses small cilia that set cerebrospinal fluid in motion. This fluid protects the brain and assists in nourishment. Ependymal cells function like small pumps, moving this fluid in necessary directions.

Schwann cells produce myelin sheaths around axons in peripheral nerves. However, unlike oligodendrocytes in the central nervous system, each Schwann cell wraps only a portion of a single axon. Just as a person can concentrate on only one thing, each Schwann cell wraps around a single axon section, creating a multilayered fatty covering.

Satellite cells are located around neurons within ganglia (nerve nodes) where they protect them and assist in their nourishment. They are named for their function—just like artificial satellites positioned around neurons, they provide support and protection.

The Myelin Sheath: A Protective Coating

The myelin sheath is a special protective layer surrounding axons composed mainly of fat (lipids). The myelin sheath has two important functions: protecting the axon and accelerating nerve impulse transmission.

The myelin sheath is not distributed uniformly along the axon; rather, it exists in segments. Between two segments are small gaps called nodes of Ranvier. These gaps occur approximately every millimeter.

When a nerve impulse travels along an axon, it does not move sequentially along its entire length; instead, it jumps from one node of Ranvier to the next. This is called saltatory conduction. The word "saltatory" comes from Latin meaning "to jump." This resembles the children's game of hopscotch—the child does not step on every square but skips certain squares.

This jumping greatly increases the speed of nerve impulse transmission. In myelinated axons, a nerve impulse can travel more than one hundred meters per second! This is approximately three hundred thirty kilometers per hour. In unmyelinated axons, the impulse travels more slowly—only one to two meters per second, or three to seven kilometers per hour.

If the myelin sheath is damaged, nerve impulses begin to travel slowly or cannot pass at all. This leads to various diseases. For example, in multiple sclerosis, the myelin sheath in the brain begins to disappear, and as a result, a person's muscle movements, vision, and other functions are impaired. In Guillain-Barré syndrome, the myelin in peripheral nerves is damaged, leading to muscle weakness.

Synapses: Communication Between Neurons

A synapse is a site of communication between two neurons or between a neuron and a muscle cell. A synapse is like a conversation between two people—the first neuron "speaks," and the second neuron "listens." However, neurons do not communicate with words but with special chemical substances.

Structure of the Synapse

A synapse consists of three main parts. The **presynaptic terminal** is located at the end of the axon of the first neuron and contains small vesicles. Each vesicle contains thousands of molecules of chemical substances. These substances are called neurotransmitters. The **synaptic cleft** is a very small space between two neurons, with a width of only twenty to thirty nanometers (one-millionth of a millimeter). The **postsynaptic membrane** is part of the second neuron and contains special receptors.

Signal Transmission

When a nerve impulse reaches the synaptic terminal of the first neuron, the vesicles open and release neurotransmitters into the synaptic cleft. These neurotransmitters cross the cleft and bind to receptors on the second neuron. When the receptor becomes active, the second neuron receives the message and generates a new nerve impulse.

This process occurs very rapidly—in just one millisecond (one-thousandth of a second). The neurotransmitters are then removed from the cleft because space must be cleared for the next signal.

Different neurotransmitters perform different functions. **Glutamate** is an excitatory neurotransmitter that "activates" neurons. **Gamma-aminobutyric acid** is an inhibitory neurotransmitter that "calms" neurons. **Dopamine** regulates mood and movement. **Serotonin** regulates sleep and feeding. **Acetylcholine** is used in muscle movement.

The Blood-Brain Barrier: A Protective Wall

The blood-brain barrier is a special system that protects the brain from harmful substances in the blood. It functions like a fortress wall—it allows only necessary substances to pass inside while keeping harmful substances outside.

In ordinary blood vessels, there are small pores between cells through which fluid can freely pass. However, in brain blood vessels, cells are tightly joined together with almost no pores between them. Additionally, astrocyte processes surround the vessels and provide an additional protective layer.

The blood-brain barrier freely allows water, oxygen, and carbon dioxide to pass—gases that the brain constantly needs. Glucose (sugar) is also necessary for the brain but passes through special "gates." However, many drugs, toxic substances, and microorganisms cannot pass through the blood-brain barrier.

This protection helps protect the brain on one hand, but creates a problem on the other—if the brain needs to be treated, many drugs cannot reach the brain.

Regeneration of Nerve Tissue

The regenerative capacity of nerve tissue differs between the brain and peripheral nerves.

Regeneration in the Brain

In the brain, neurons cannot undergo mitosis (division). Therefore, dead neurons are not replaced with new ones. If an injury occurs in the brain, scar tissue forms in that location and replaces the neurons. This is why head trauma or stroke is so dangerous—lost neurons do not regenerate.

However, in certain brain regions, new neurons can even be produced at advanced ages. These regions include the hippocampus (important for memory) and the olfactory bulb. However, this process is very limited and produces only a small number of neurons.

Regeneration in Peripheral Nerves

The situation is better in peripheral nerves. If a nerve is cut or damaged but the neuron cell body remains healthy, the axon can regrow. Schwann cells greatly assist in this process—they guide the path for the axon and release substances that help growth.

Axon growth is slow—approximately one to three millimeters per day. If the injury is at a great distance, regeneration may take several months or even years. However, in many cases the axon reaches its destination and function is restored.

Conclusion

Nerve tissue is one of the most complex and most important tissues in the organism. Neurons transmit electrical signals, and through these signals all organs are controlled. Glial cells assist neurons, protect them, and participate in their nourishment.

The myelin sheath is an important structure that accelerates nerve impulses by wrapping around axons. Synapses are sites of communication between neurons where information is transmitted through chemical substances. The blood-brain barrier protects the brain from harmful substances.

The regenerative capacity of nerve tissue is limited. In the brain, neurons do not regenerate, but in peripheral nerves, axons can regrow. Therefore, protecting the nervous system and maintaining its health is extremely important.

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