Topic 2.9. The Structure of the Nervous System/ Строение нервной системы

The nervous system is one of the most complex and important systems of the human body. It provides communication between the organism and the external environment, coordinates the activity of all organs and systems, and ensures the integrity of the body. The nervous system regulates metabolism, growth, reproduction, and adaptation to changing environmental conditions. Without the nervous system, perception, movement, thinking, memory, and emotions would be impossible. It controls both voluntary and involuntary processes — from conscious decision-making to automatic functions such as breathing and heartbeat.

The basic principle of the nervous system's functioning is the reflex principle. A reflex is the body's response to a stimulus, carried out through the nervous system. The structural pathway of a reflex is called a reflex arc, which includes a receptor, a sensory neuron, a nerve centre (in the brain or spinal cord), a motor neuron, and an effector (muscle or gland).

Anatomically, the nervous system is divided into two main parts: the central nervous system (CNS), which includes the brain and the spinal cord, and the peripheral nervous system (PNS), which includes cranial nerves, spinal nerves, ganglia, and nerve endings. Functionally, the nervous system is subdivided into the somatic nervous system, which controls voluntary movements of skeletal muscles, and the autonomic (vegetative) nervous system, which regulates involuntary functions of internal organs, blood vessels, and glands.

The structural and functional unit of the nervous system is the neuron. The human brain contains approximately 86 billion neurons. A neuron consists of three main parts: the cell body (soma), which contains the nucleus and organelles; dendrites — short, branched processes that receive signals from other neurons and conduct them toward the cell body; and the axon — a long process that carries nerve impulses away from the cell body to other neurons, muscles, or glands. Most axons are covered by a myelin sheath — a fatty insulating layer that increases the speed of impulse conduction. In the peripheral nervous system, the myelin sheath is formed by Schwann cells, while in the central nervous system it is produced by oligodendrocytes. The regions between myelin segments are called nodes of Ranvier; nerve impulses "jump" from node to node, which significantly accelerates signal transmission (saltatory conduction).

Neurons communicate at specialised junctions called synapses. At a synapse, the signal is transmitted chemically by neurotransmitters — substances such as acetylcholine, dopamine, norepinephrine, serotonin, GABA, and glutamate. There are three main types of neurons: sensory (afferent) neurons, which carry impulses from receptors to the CNS; motor (efferent) neurons, which carry impulses from the CNS to effectors; and interneurons, which are located entirely within the CNS and connect sensory and motor neurons.

Besides neurons, the nervous system contains glial cells (neuroglia), which provide support, nutrition, and protection for neurons. Glial cells outnumber neurons approximately 10 to 1. The main types of glial cells include astrocytes, oligodendrocytes, microglia, and ependymal cells.

The brain is the highest division of the central nervous system. It is located in the cranial cavity and is protected by the skull. The average weight of the adult brain is 1300–1500 g. The brain is surrounded by three protective membranes called the meninges: the dura mater (the outer, tough membrane), the arachnoid mater (the middle, web-like membrane), and the pia mater (the inner, delicate membrane that adheres closely to the brain surface). Between the arachnoid and pia mater circulates the cerebrospinal fluid (CSF), which cushions the brain and spinal cord against mechanical shocks, provides nutrients, and removes waste products. The brain is composed of the following major divisions:

1. **The cerebrum** — the largest part of the brain, divided into two hemispheres (left and right) connected by the corpus callosum, a bundle of nerve fibres that enables communication between the hemispheres. The outer layer of the cerebrum is the cerebral cortex (grey matter), approximately 2–4 mm thick, which is responsible for higher nervous activity — thinking, language, memory, voluntary movement, and consciousness. Each hemisphere is divided into four lobes:
    - **Frontal lobe** — responsible for reasoning, planning, personality, emotions, and voluntary motor control (the motor cortex is located here).
    - **Parietal lobe** — processes sensory information such as touch, temperature, pain, and spatial orientation.
    - **Temporal lobe** — responsible for hearing, speech comprehension, and memory.
    - **Occipital lobe** — processes visual information.
2. **The diencephalon** — located beneath the cerebrum. It includes the thalamus, which acts as a relay station for sensory signals (except olfactory) on their way to the cerebral cortex, and the hypothalamus, which regulates body temperature, hunger, thirst, water balance, sleep–wake cycles, and hormonal activity through its connection with the pituitary gland.
3. **The cerebellum** — located at the back of the brain, below the cerebrum. It coordinates balance, posture, muscle tone, and fine motor movements. Although the cerebellum represents only about 10% of the brain's total volume, it contains more than 50% of all neurons in the brain.
4. **The brainstem** — connects the brain to the spinal cord. It controls vital, largely automatic functions: breathing, heart rate, blood pressure, swallowing, and coughing. The brainstem consists of three parts: the midbrain, the pons, and the medulla oblongata. The medulla oblongata contains centres that regulate respiration, cardiovascular activity, and digestion. Damage to the medulla oblongata is usually fatal.

The spinal cord is a long, cylindrical bundle of nervous tissue that extends from the foramen magnum (the opening at the base of the skull) to the level of the first or second lumbar vertebra (L1–L2). Its length in an adult is approximately 45 cm. The spinal cord performs two main functions:

1. **Conduction** — it serves as a pathway for nerve impulses travelling between the brain and the peripheral nerves. Ascending tracts carry sensory information upward to the brain; descending tracts carry motor commands downward from the brain to the muscles and organs.
2. **Reflex activity** — it mediates reflex arcs, which are rapid, involuntary responses to stimuli that do not require the participation of the brain (e.g., the knee-jerk reflex, withdrawal reflex from a hot surface).

A cross-section of the spinal cord reveals an H-shaped core of grey matter (containing neuron cell bodies) surrounded by white matter (containing myelinated axons). The grey matter has anterior (ventral) horns, which contain motor neuron cell bodies, and posterior (dorsal) horns, which contain interneurons that process sensory information. In the thoracic and upper lumbar regions, there are also lateral horns containing neurons of the autonomic nervous system.

From the spinal cord emerge 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal. Each spinal nerve is formed by the union of a dorsal (sensory) root and a ventral (motor) root. From the brain emerge 12 pairs of cranial nerves, which provide sensory and motor innervation to the head, neck, and some internal organs.

The autonomic nervous system (ANS) regulates involuntary functions of internal organs, blood vessels, and glands. It is divided into two divisions that generally have opposite effects:

1. **The sympathetic division** — activates the "fight-or-flight" response. It increases heart rate, dilates pupils, dilates bronchi, inhibits digestion, and mobilises energy reserves. Preganglionic neurons of the sympathetic system originate in the lateral horns of the spinal cord at the levels T1–L2.
2. **The parasympathetic division** — activates the "rest-and-digest" response. It decreases heart rate, constricts pupils, stimulates digestion, and promotes energy conservation. Preganglionic neurons of the parasympathetic system originate in the brainstem (cranial nerves III, VII, IX, X) and in the sacral region of the spinal cord (S2–S4).

The sympathetic and parasympathetic divisions work in balance to maintain homeostasis — the constancy of the internal environment of the body.

The nervous system develops from the ectoderm. In the third week of embryonic development, the neural plate is formed, which then folds to create the neural tube. The anterior part of the neural tube gives rise to the brain, and the posterior part gives rise to the spinal cord. By the fourth week, three brain vesicles are formed: the prosencephalon (forebrain), the mesencephalon (midbrain), and the rhombencephalon (hindbrain). Later, the prosencephalon divides into the telencephalon (which forms the cerebral hemispheres) and the diencephalon. The rhombencephalon divides into the metencephalon (which forms the pons and cerebellum) and the myelencephalon (which forms the medulla oblongata).

In violation of the nervous system, various disorders occur: paralysis, paresis, sensory disturbances, loss of coordination, speech disorders, memory impairment, seizures, and disturbances of consciousness. Damage to specific brain regions produces characteristic deficits — for example, damage to the motor cortex results in contralateral paralysis, and damage to the occipital lobe causes visual impairment.