PHYSIOLOGY OF BRAIN NEURONS

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ABSTRACT

This paper examines the fundamental physiological mechanisms of brain neuron function, including action potential generation, synaptic signaling, ion channel function, the role of neurotransmitters, and the characteristics of interneuronal communication. It analyzes excitation and inhibition processes, the integration of input signals, the plasticity of neural networks, and the role of neurons in the development of cognitive functions and adaptive responses.

The brain is the main structural (98% by weight) and functional part of the central nervous system (CNS). The high functional activity of the brain is evidenced by the fact that, making up 2.4% of body weight, it consumes about 15% of the cardiac blood output and about 18% of the oxygen entering the body.

The brain is the main department of the central nervous system, performing the highest regulation of motor, visceral, endocrine functions and psychophysiological processes. It consists of the telencephalon (cerebral cortex, white matter, basal ganglia), diencephalon, midbrain, hindbrain (pons and cerebellum) and medulla oblongata.

Physiologists distinguish three sections in the brain stem: the medulla oblongata, the pons and the midbrain, the joint activity of which forms the main brain stem functions (regulation of muscle tone and posture, complex chain reflexes, influence of the reticular formation).

The brainstem is phylogenetically the most ancient structure of the brain. It retains some features of the segmental structure, represented by the nuclei of the cranial nerves. At the same time, the brain stem contains suprasegmental structures: the reticular formation and the nuclei of the pathways (nuclei of Gaulle, Burdach, olive, etc.).

A significant part of the trunk is occupied by the ascending and descending pathways of the central nervous system. The functions of the trunk will be discussed in relation to its basic structures. The III-XII pairs of cranial nerves emerge from the brainstem: IV,VI,XI, XII pairs are motor in function, VIII pair are

sensitive, V,VII,IX,X pairs are mixed, in which, in addition to the sensitive part, there are motor parts, III,VII,IX and X pairs are parasympathetic parts. Motor nerves are the efferent part of unconditioned reflexes and the "final path" of voluntary complex motor programs carried out by higher motor centers.

The sensitive parts are composed of two neurons: the first lies in the ganglion, the second in the sensitive nucleus of a given cranial nerve. They are the afferent link of unconditioned and conditioned reflexes and the receptor-conductor part of the corresponding analyzers:

auditory and vestibular (VIII pair), interoceptive (IX, X pairs), gustatory, tactile, temperature, pain and muscular (V, IX, X pairs).

With the participation of the brain stem, complex reflex acts are carried out, each of which involves the centers of several cranial nerves. Coordination and integration of their activities is carried out with the help of the reticular formation of the brain stem.

Some of these reflexes ensure the satisfaction of nutritional needs (sucking, chewing, swallowing reflexes), others are protective in nature (vomiting, coughing, sneezing reflexes). The reflex act of sucking ensures that a child receives milk in infancy. It occurs when lip receptors are irritated.

Afferent impulses along the fibers of the trigeminal nerve enter the sucking center of the medulla oblongata, which functionally unites the neurons of the sensory nuclei of the trigeminal nerve and the motor nuclei of the trigeminal, facial and hypoglossal nerves.

As a result of contraction of the muscles of the lips, cheeks, movements of the lower jaw and tongue, negative pressure is created in the oral cavity, and milk enters it. Sucking is based on an unconditioned reflex; in the process of human development it becomes a voluntarily controlled motor act, but its physiological significance decreases.

The reflex act of chewing ensures grinding, grinding, mixing food with saliva and forming a food bolus. The afferent part of the reflex is carried out from the tactile, taste and temperature receptors of the oral mucosa.

Irritation of the receptors of the masticatory muscles is accompanied by a reflex closing of the mouth, and a rhythmic act of chewing food is formed.

The chewing center of the medulla oblongata functionally unites the sensory nuclei of the trigeminal (V), facial (VII), glossopharyngeal (IX), vagus (X) nerves and the motor nuclei of the trigeminal (V), facial (VII) and hypoglossal (XII) nerves.

Chewing is based on an unconditioned reflex, which in the process of development of the organism becomes a voluntarily regulated act. The reflex act of swallowing ensures that food moves from the mouth to the stomach.

During the movement of a bolus of food from the oral cavity to the esophagus, sequential stimulation of the receptors of the root of the tongue, soft palate, pharynx and esophagus occurs. The impulse through the sensory fibers of the trigeminal, glossopharyngeal and vagus nerves enters the swallowing center located in the medulla oblongata.

The swallowing center is functionally connected to the breathing center, and breathing stops during each swallowing act.

The physiology of brain neurons is a key area of neurobiology that reveals the mechanisms of the nervous system at the cellular and synaptic levels.

It is neurons that form complex networks, thanks to which the brain is able to analyze sensory information, create cognitive images, control behavior and ensure the body's adaptation to changing environmental conditions.

Modern research shows that a neuron is not just a structural unit, but a dynamic system in which every molecule, every ion channel, every transmitter is involved in the formation of complex physiological processes.

The functioning of neurons is associated with the generation of action potentials, the functioning of sodium, potassium and calcium channels, the activity of receptors and enzymes, synaptic transmission, the interaction of neuronal ensembles and the processes of neuroplasticity.

Understanding the physiology of neurons is the basis for explaining the functioning of memory, attention, thinking, emotional reactions, as well as the mechanisms of development of neuropsychiatric diseases.

Thanks to the developments of modern neurophysiology, research into the mechanisms of depression, epilepsy, neurodegeneration, autism, and cognitive impairment has become possible.

The relevance of the study is due to the fact that the physiology of neurons determines the fundamental principles of brain function, and knowledge of these mechanisms allows us to develop new methods of treatment, rehabilitation and neuromodulation, as well as improve technologies for training and development of intelligence.

Fundamental to the physiology of brain neurons is the ability of these cells to generate, conduct, and integrate electrical signals that enable communication within the nervous system. A neuron consists of a soma, dendrites and an axon - structures designed to receive, process and transmit information. The electrical activity of a neuron is determined by the distribution of ions across the membrane and the operation of the channels included in it.

The resting potential is created due to the difference in concentrations of sodium, potassium, chlorine and other ions, and its maintenance is realized by the sodium-potassium pump, which forms an energy-consuming but vital gradient.

An action potential, the key electrical signal of a neuron, occurs when a threshold level of depolarization is reached. The rapid opening of sodium channels results in a surge of sodium entering the cell, causing the rising phase of the action potential.

Then potassium channels are turned on, restoring the original potential, forming repolarization. The number, activity and sensitivity of ion channels determine the speed of impulse conduction, excitability and functional properties of neurons.

Synaptic transmission is a fundamental process that mediates interactions between neurons. At a chemical synapse, the transmitter is released into the synaptic cleft and binds to receptors on the postsynaptic membrane, causing excitation (AMPA/NMDA glutamate receptors) or inhibition (GABA-A receptors).

The balance between excitation and inhibition determines the stability of neural networks and the brain's ability to maintain optimal levels of activity. Disruption of this balance can lead to epilepsy, anxiety and affective disorders.

The most important property of neurons is plasticity—the ability to change the functional characteristics of synapses in response to activity. Long-term potentiation (LTP) enhances synaptic transmission, forming the physiological basis of learning and memory.

Long-term depression (LTD), on the other hand, weakens synaptic connections, allowing selective formation of neural networks. At the molecular level, plasticity is associated with changes in the number of receptors, restructuring of the cytoskeleton, synthesis of new proteins and activation of signaling pathways such as CaMKII, CREB, mTOR.

Neurons of the brain do not function in isolation, but form ensembles—dynamic groups of cells that are capable of jointly encoding information. These ensembles work on the principle of synchronization: cells are activated within a certain time frame, forming brain rhythms (theta, gamma, alpha rhythms).

Rhythmic activity provides cognitive functions: gamma rhythms are involved in the processing of sensory information, theta - in the formation of memory, alpha - in the regulation of attention.

The neurotransmitter systems of the brain are of particular importance. Dopamine is involved in the formation of motivation, reward, regulation of movements; serotonin controls mood and impulsivity; acetylcholine is responsible for attention and learning; norepinephrine regulates wakefulness and the response to stress.

Dysfunctions of neurotransmitter systems underlie many mental and neurological diseases - depression, Parkinson's disease, schizophrenia, dementia, addictive disorders. Neuronal physiology is inextricably linked to brain development.

Neurogenesis, cell migration, synapse formation, and myelination determine early cognitive development. The adult brain also has a limited capacity for neurogenesis, especially in the hippocampus, suggesting that function can be restored after damage.

Thus, neurons are elements of a complex biological system, the work of which ensures all manifestations of human behavior and thinking.

Their properties - excitability, conductivity, plasticity, ability to integrate signals - allow the brain to function as a highly organized self-learning structure.

The physiology of brain neurons is the foundation on which an understanding of the functioning of the nervous system and all human mental activity is built. Neurons are highly specialized cells capable of electromechanical and chemical signal transmission, forming complex networks and rearranging their own connections.

They enable learning, memory, behavior, emotion, perception and consciousness.

The diversity of brain functions is based on the subtle interaction of ion channels, transmitters, receptors, synapses and neural ensembles.

The study of neuronal physiology opens up opportunities for understanding diseases of the nervous system, developing methods of therapy and neuromodulation, improving educational technologies and increasing human intellectual potential.

Neuronal physiology remains one of the fastest growing fields of science, integrating cell biology, molecular neurophysiology, cognitive science and clinical medicine.

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