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"Krasnoyarsk State Medical University named after Professor V. F. Voino-Yasenetsky»

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Department of Physiology named after Prof. A. T. Pshonik

**GUIDELINES FOR EXTRACURRICULAR INDEPENDENT WORK FOR STUDENTS**

**by discipline**

**Normal Physiology.**

**Specialty 31.05.01 – General medicine**

**TO THE PRACTICAL LESSON**

**From 06.04.2022 to 12.04.2022**

**TOPIC:**

**GENERAL PHYSIOLOGY OF SENSORY SYSTEMS. PHYSIOLOGY OF VISUAL AND AUDITORY ANALYZERS.**

1. **Questions to discuss in class:**
2. The concept of sensory systems (analyzers) of the brain. The value of analyzers in the knowledge of the world.
3. Functional organization of the analyzers. Structure, principle of operation.
4. Classification of receptors. The mechanism of their excitation. The concept of receptor adaptation and the mechanism of information encoding in the central nervous system.
5. Encoding of information in various departments of the analyzers.
6. Adaptation, fatigue of the analyzers.
7. The physiology of the visual analyzer, the structure of its departments.
8. Photochemistry of light perception on the retina.
9. Physiological mechanisms of accommodation.
10. Visual acuity. Field of view.
11. Theories of color vision (M. V. Lomonosov, Helmholtz, P. I. Lazarev). Modern understanding of color perception. The main forms of color perception disorders.
12. Methods of research of the auditory analyzer.
13. Sound-catching and sound-conducting devices of the peripheral part of the auditory analyzer.
14. The receptor department of the auditory analyzer.
15. The mechanism of the receptor potential in the hair cells of the spiral organ of the cochlea.
16. Theories of sound perception (G. Helmholtz, G. Bekeshi).
17. Features of the conductor and cortical parts of the auditory analyzer.

**Summary of the topic:**

**Sensory systems (analyzers) of the brain**

Analyzers perform the function of receiving and processing signals from the external and internal environment of the body. Each analyzer is tuned to a specific modality of the signal and provides a description of the entire set of signs of the perceived stimuli. The modal specificity of the analyzer is primarily determined by the features of the structure and functioning of its peripheral formations and the specificity of the receptors. However, to a large extent, it is also related to the structural organization of the central departments of the analyzer.

**The analyzer** is a multi-level system with a hierarchical design principle. The base of the analyzer is the receptor surface, and the top is the projection zones of the cortex. Each level of this morphologically ordered structure is a collection of cells. The axons of which go to the next level. The exception is the upper level, whose axons extend beyond the limits of this analyzer.

The projection zones of the analyzer systems occupy the outer surface of the new cortex of the posterior parts of the brain. This includes the visual (occipital) , auditory (temporal), and generally sensitive (parietal) areas of the cortex. The cortical part of this functional block also includes the representation of taste, olfactory, and visceral sensitivity. At the same time, the most extensive areas in the cortex are occupied by the sensory zone that is of the greatest ecological importance for this species (mole - sense of smell, not vision, etc.).)

The primary projection zones of the cortex consist mainly of neurons of the 4th afferent layer and have the highest specificity. For example, neurons in the visual regions selectively respond to certain signs of visual stimuli: some-to shades of color. Others point to the direction of travel. Still others affect the nature of the line (edge, band, slope, etc.). However, it should be noted that there are also multimodal neurons, and those that reflect the influence of non - specific limbic-reticular modulating systems.

The secondary projection zones of the cortex are located around the primary zones, as if superstructured above them. These neurons are characterized by the detection of complex signs of stimuli, but the modal specificity of the signal is preserved.

The primary and secondary zones make up, according to Pavlov, the central part, or core of the analyzer in the cortex.

The associative regions (tertiary zones) of the cortex are a new level of integration. The vast majority of associative neurons respond to generalized signs of stimuli - the number of elements. Spatial position, relations between elements, etc. The convergence of different modal information is necessary for a holistic perception, for the formation of a" sensory model of the world", which arises as a result of sensory learning. The associative zones are located on the border of the occipital, temporal, and parietal regions. The main part of them are the formations of the inferior parietal cortical region, which in humans has developed so much that it makes up almost a quarter of all the formations of the sensory block of the brain. The work of these parts of the cerebral cortex is necessary not only for the successful synthesis and differentiation of selective discrimination) of the stimuli perceived by a person, but also for the transition to the level of their symbolization - for operating with the meanings of words and using them for abstract thinking, i.e. for the synthetic nature of perception, which was written about by I. M. Sechenov.

**General principles** **of forming analyzers.** A common feature of most pathways of analyzers is that they give collaterals of the reticular formation and interact with it before entering the nuclear zones of the cortex, as well as pass through the thalamus.

The cortical representation of the analyzers is the primary and secondary fields, mainly located in the occipital, postcentral and temporal parts of the second block (the block for receiving, processing and storing extraceptive information) of the brain.

All analyzer systems operate on the basis of the following general principles:

1) analysis of information with the help of special neurons-detectors;

2) parallel multi-channel processing of information, ensuring its reliability;

3) selection of information in the interval from the receptor to the projection field;

4) the sequential complexity of processing information from level to level;

5) the holistic representation of the signal in the central nervous system in relation to other signals;

6) implementation of the principles of improving the reliability of processing different signal features.

The cortical sections of the analyzers are based on the primary or projection zones of the cortex (fields), which perform a highly specialized function of reflecting only stimuli of one modality. Their task is to identify the stimulus by its quality and signal value, in contrast to the peripheral receptor, which differentiates the stimulus only by its physical or chemical characteristics. The main function of the primary fields is the subtlest reflection of the properties of the external and internal environment at the level of sensation.

All primary cortical fields are characterized by the topical (screen) principle of organization, according to which any part of the receptor surface corresponds to a certain area in the primary cortex (according to the "point to point" principle), which gave rise to the name of the primary cortex projection. The size of the zone of representation of a particular receptor site in the primary burrow depends on the functional significance of this site, and not on its actual size.

The primary fields are: the 17th (for vision), the 3rd (for skin-kinesthetic sensitivity) and the 41st (for hearing). Extraceptor information enters these areas of the brain after passing through the relay nuclei of the thalamus.

Secondary fields represent cellular structures that are morphologically and functionally superstructured above the projection ones. In them, there is a consistent complication of the process of processing information, which is facilitated by the preliminary conduct of afferent impulses through the associative nuclei of the thalamus. Secondary fields ensure the transformation of somatotropic impulses into such a functional organization, which at the level of the psyche is equivalent to the process of perception.

On the surface of the brain, the secondary fields border or surround the projection fields. Secondary field numbers: 18,19-for vision, 1,2 and partially 5 - for skin-kinesthetic sensitivity, 42 and 22 - for hearing. The primary and secondary fields belong to the nuclear zones of the analyzers located at the three spatial poles of the posterior brain – the occipital, parietal, and temporal, respectively.

The tertiary fields (associative, overlap zone) take on the most complex functional load. They are located outside the nuclear zones and are mainly located in the gap between the secondary fields or along their perimeter. The largest and most important part of the tertiary fields is formed at the border of the parietal, occipital and temporal divisions, being equidistant from each of these poles, and does not have a direct exit to the periphery. Their functions are almost entirely reduced to the integration of excitations coming from the secondary cortex of the entire complex of analyzers. The work of the tertiary zones has its psychological equivalent to the perception of the world in its entirety and the combination of spatial, temporal and intensity characteristics of the external environment. All this gives reason to consider them as an apparatus of interanalytical synthesis.

The **visual analyzer** includes the peripheral part (the eyeball), the conducting part (the optic nerves, subcortical visual centers) and the cortical part of the analyzer. The **organ of vision - the eye** - includes a receptor apparatus (the retina) and an optical system that focuses light rays and provides a clear image of objects in the retina in a reduced and reversed form.

**The optical system of the eye** consists of light-refractive formations: the cornea, the watery moisture of the anterior chamber, the lens and the vitreous body. The cornea is actually a lens that refracts light. For the cornea, the refractive force is 43 D, for the lens, depending on the distance to the object in question, from 19 to 33 D.The total refractive force of the eye is 62-76 D.

The accommodation system is represented by the lens, which has the shape of a biconvex lens. The main functions are refractive and, consequently, focusing of the image on the retina (refractive power-19-33D). This is achieved by accommodation-changing the shape of the lens. With age, the lens loses its transparency and elastic properties - the force of accommodation decreases and senile farsightedness - presbyopia-appears. Violation of accommodation is associated with a violation of the nutrition of the lens.

The iris is practically not permeable to rays. In the center, it has a hole, a pupil, the diameter of which varies (similar to the aperture of the camera) from 2 to 8 mm - the light flow varies accordingly. The diameter of the pupil changes slowly under the influence of reflex mechanisms (parasympathetic-constrict the annular muscles, sympathetic-expand-radially). The main function of the pupil is the regulation of the amount of light flux, and it also passes the light flux to the central spherical part of the lens.

**The light-receiving system of the eye**. In addition to the optical and accommodation systems, the eye also has a receptive system. This is the retina; located on the back wall of the eyeball, the main role is the conversion of light into electrical potentials. The function of photoreceptors is performed by cones and rods. They have different sensitivity to color and light: cones are weakly sensitive to color, cones-provide daylight perception of light. Sticks - not sensitive to color, but sensitive to light (twilight vision). The threshold of light sensitivity of the eye is very low – 6-7 photons are already felt in the area with 50 sticks.

In humans, the receptor layer in the retina consists of approximately 120 million rods and 6 million cones, which differ from each other in characteristic histological features. The rods and cones are located unevenly across the area of the retina. The highest density of cones – the number of receptors per unit area-occurs in the central fossa, whereas for rods, the highest density is observed in the area around-near the fossa. The rods in the area of the central fossa are completely absent.

Rods and cones are similar in structure to the outer segment (segment) - they consist of about a thousand membrane disks (rods) or folds (cones).

**Visual pigments.** The process of visual reception is based on photochemical reactions. These reactions occur with the help of visual pigments. The rods contain the visual pigment rhodopsin or "visual purple". It got its name because, when extracted in the dark, it has a red color, as it particularly strongly absorbs green and blue light rays. The cones also contain other visual pigments. The molecules of visual pigments are included in the ordered structures in the double lipid layer of the membrane disks of the outer segments.

Photochemical reactions in rods and cones are similar. They start with the absorption of a quantum of light-a photon - which takes the pigment molecule to a higher energy level. Next, the process of reversible changes in the pigment molecules is started. In the rods - rhodopsin (visual purple), in the cones-iodopsin. As a result, the energy of light is converted into electrical signals - pulses. Thus, rhodopsin under the influence of light undergoes a number of chemical changes-it turns into retinol (vitamin A aldehyde) and a protein residue-opsin. Then, under the influence of the enzyme reductase, it passes into vitamin A, which enters the pigment layer. In the dark, the reverse reaction occurs - vitamin A is restored, passing through a number of stages.

**Color vision**. A person sees light rays emitted by various objects and having a wavelength of 400 to 800 mmn. The maximum absorption spectrum of rhodopsin in rods is at 500 nm – the yellow part of the spectrum. It is proved that the sticks see the world in black and white, and the cones-in color.

The main indicators of vision. The main indicators describing the function of the visual sensory system include the following: the range of perceived wavelengths, the range of perceived intensities from the threshold to the pain sensation, visual acuity, summation time and the critical frequency of merging flashes, the threshold of sensitivity and adaptation, the ability to perceive colors, the perception of the depth of space – stereoscopy.

**Visual field**. The set of points that are simultaneously visible to the eye when the gaze is fixed at one point is called the visual field. It is different for different colors. For white: 60˚ up, 70˚ down, 90˚ out, 60˚ in. For green, respectively: 20-30-40-30˚. The visual field is determined by the device called perimeter. A lesion of some part of the retina leads to the loss of the corresponding sector of the field of vision.

**The auditory system** is one of the most important distant sensory systems of a person in connection with the emergence of speech as a means of interpersonal communication and serves for the perception of sound.

Sound is the vibration of the molecules that make up the elastic medium, propagating in the form of a longitudinal pressure wave. The wave propagation velocity in the air is 335 m/s. The frequency of a sound is defined in hertz-Hz. A sound formed by a single frequency is called a tone.

**The peripheral part of the auditory system**. Sound enters the auditory system through the outer ear – the external auditory canal leading to the eardrum. Behind the eardrum, the middle ear begins, and there is air in it. In the middle ear cavity there is a chain of movably connected bones: a hammer, an anvil, a stirrup. The stirrup borders on the inner ear. The energy of sound is transmitted from the eardrum through the hammer, anvil, and stirrup to the middle ear cavity, which is connected to the pharynx by the Eustachian tube.

The auditory organ as such is the cochlea. The cochlea consists of three channels rolled together – the tympanic staircase, the middle staircase, and the vestibular staircase. The tympanic and vestibular staircases communicate at the end of the cochlea. At the base of the drum ladder there is another opening covered by a membrane, called a round window. The main membrane separates the tympanic and middle stairs. The thickening along the main membrane is a sound-receiving cortical organ containing receptors-hair cells. The total number of hair cells reaches 25,000. Hair cells are the second type of receptors and belong to the mechanoceptors. They got the name "hairy" because each sensitive cell is crowned with a bunch of hairs or cilia. One end of the cilia is attached to the lower surface of the tectorial membrane.

Vibrations of the main membrane and other structures of the cochlea cause mechanical movements of the cilia. The microdeformation of the receptor membrane is converted into a nerve impulse in the form of a receptor potential. The formation of the receptor potential is mediated by the difference in electrical potentials between the cavities of the vestibular and middle stairs. It is assumed that the formation of the receptor potential involves ion currents that occur during the oscillations of the cilia.

The resulting receptor potential causes the release of a mediator from the receptor, which excites the afferent nerve fibers. Each fiber of the auditory nerve comes from a strictly defined area of the cochlea, i.e. from strictly defined receptors. Therefore, each fiber is most strongly excited by sounds of a certain frequency. The duration of the sound stimulus is encoded by the duration of the neural activity, and the intensity is encoded by the level of activity, i.e., the pulse frequency.

The opening of only a few ion channels in the membrane of a single stereocilia is clearly not enough for the appearance of a receptor potential of sufficient magnitude. An important mechanism for enhancing the sensory signal at the receptor level of the auditory system is the mechanical interaction of all the stereocilia (about 100) of each hair cell. It turned out that all the stereocilia of one receptor are connected to each other in a bundle by thin transverse threads. Therefore, when one or more longer hairs bend, they pull all the other hairs with them. As a result, the ion channels of all the hairs open, providing a sufficient amount of the receptor potential.

**Central department of the auditory system.** The central part of the auditory system is very complex. The excitation from the hair cells is transmitted to the auditory center of the medulla oblongata-the cochlear nuclei, then switches to the neurons of the intermediate brain and then goes to the neurons of the temporal region of the cerebral cortex in the primary auditory cortex. The auditory system functions interconnected with the non-auditory parts of the brain, i.e. it has many inputs from other parts of the nervous system. Nerve pathways from the visual and motor cortex, from the cerebellum, and from the reticular formation are suitable for different levels of the auditory system.

Damage to the temporal lobes of the brain makes it difficult to perceive speech, to locate sound spatially, and to identify the temporal characteristics of sound.

Auditory sensations. The hearing range for a young healthy person is in the range from 2 to 16,000 Hz. The upper limit of the frequency of perceived sounds depends on the age of the person: over the years, it gradually decreases and the elderly often do not hear high tones. The auditory threshold depends on the frequency of the incoming sound. The human ear is most sensitive to frequencies of 2-5 kHz. Sound volume represents the subjective perception of the sound pressure level.

For the perception of sound stimuli, the duration of the sound is of great importance. If it is less than 50 ms, then the sounds are perceived as clicks and their full perception is impossible. The auditory system, like other sensory systems (other than pain), is able to adapt. This is manifested in the fact that prolonged exposure to sound causes a decrease in sensitivity and vice versa. Audibility depends on the frequency and sound pressure.

The speech range is approximately between 250 and 6000 Hz, and the RCD is from 40 to dB. The minimum strength of the sound heard by a person in half of the cases of its presentation is called the absolute threshold of auditory sensitivity. The thresholds of audibility depend on the frequency of sound (Fig. 7). The strength of sound from different sources surrounding a person in a natural and industrial environment is very different, and can range from 10 decibels (the rustle of leaves in the wind) to 120 decibels (the noise of an aircraft engine). Medium-volume speech has a sound strength of 50-60 decibels.

**Binaural hearing**. Humans and animals have spatial hearing, i.e. the ability to determine the position of a sound source in space. This property is based on the presence of binaural hearing, or listening with two ears.

**3. Questions for the input control of knowledge on the topic with standards of answers.**

1. What is called an analyzer according to I. P. Pavlov? Specify the four main groups of analyzers according to their value for the body.

**Answer**: A set of nerve formations that perceive and analyze changes in the external and internal environment of the body. External and internal analyzers, body positions, and pain analyzer.

2. Name the three departments of the analyzer and its structural elements.

**Answer**: 1) Peripheral division – receptors; 2) conductor-afferent neurons and conducting pathways; 3) cortical division – projection and associative zones of the cerebral cortex.

3. What are called the sensory organs? What is the relationship between the concepts of "sensory organ" and "analyzer"?

**Answer**: They are peripheral structures that perceive and partially analyze changes in the external environment of the body, the excitation of which leads to the appearance of sensations. The sense organ is the peripheral part of the external analyzer.

4. What is the significance of the receptor as a peripheral part of the analyzer? What process is it implemented by?

**Answer**: It is the perception of stimuli and their primary analysis. The perception of irritation is carried out by transforming the energy of irritation into a nerve impulse.

5. What is meant by primary and secondary receptors?

**Answer**: In the primary receptor, the receiving zone is the end of the dendrite of the sensitive neuron; in the secondary receptor, the receiving zone is a special receptor cell synaptically connected to the end of the dendrite of the sensitive neuron.

6. List the primary and secondary receptors.

**Answer**: Primary: all skin receptors and receptors of internal organs, proprioreceptors, olfactory receptors, thermo-and chemoreceptors of the central nervous system. Secondary: taste, phono -, photo -, vestibuloreceptors.

7. What are the local potentials that occur when the primary and secondary receptors are stimulated? Where does the action potential arise when the receptor is excited?

**Answer**: In the primary receptors – the receptor potential, in the secondary-the receptor and generator potentials. For the pulp fiber – in the first intercept of the Ranvier, for the non-pulp fiber - in the excitable region of the afferent fiber closest to the receptor.

8. List the sequence of processes in the primary and secondary receptors that lead to the appearance of pulsed excitation in the afferent nerve fiber.

**Answer**: In primary receptors-the receptor potential-the action potential. In the secondary-the receptor potential - the release of the mediator-the generator potential-the action potential.

9. What is the value of the conductor and cortical sections of the analyzer?

Answer: The conductor department ensures the delivery of information from the receptors to the central department of the analyzer and its partial processing in the neurons at the "switching stations". The cortical department provides the highest analysis and synthesis of incoming information.

10. What is the value of external and internal analyzers?

**Answer**: External people perceive and analyze changes in the external environment, which makes it possible to know the external world and form adaptive reactions in the environment. Internal-inform the central nervous system about the state of internal organs, thereby participating in the regulation of their functions.

11. How do the analyzers provide a fine, precise adaptability of the body to the external environment?

**Answer**: They are provided due to their high sensitivity to adequate stimuli, the ability to function in a wide range of irritation intensity, the presence of many different analyzers that provide a comprehensive assessment of each phenomenon.

12. List the properties of the analyzers.

**Answer**: They are high excitability, inertia, adaptation, sensitization, induction interactions.

13. What are the criteria that characterize the sensitivity of the analyzers to adequate stimuli?

**Answer**: They are the threshold of sensation, the threshold of discrimination, as well as the intensity of sensation, since it depends on the excitability of the analyzer itself at all its levels at the same intensity of irritation.

14. What is called the threshold of sensation?

**Answer**: The minimum force of an adequate stimulus that causes the excitation of the receptors, which is perceived subjectively in the form of sensations.

15. What is called the threshold of discrimination? What are the thresholds for distinguishing analyzers you know?

**Answer**: The minimum change in the parameters of the active stimulus, which is perceived subjectively. Thresholds for distinguishing the strength, space, and time of the stimulus.

16. Formulate Weber's law on the threshold for distinguishing the strength of an active stimulus. Give the appropriate formula.

**Answer**: For the sensation of an increase in the strength of the acting stimulus to occur, its strength must increase by a certain amount. ∆J/J = const, where J is the strength of the stimulus, ∆J is a noticeable increase in the strength of the acting stimulus.

17. Formulate Fechner's law, which expresses the dependence of the intensity of sensations on the strength of the stimulus. Give the appropriate formula, decipher its notation.

**Answer**: The intensity of sensations is proportional to the logarithm of the intensity of irritation E = k \* log (J/J0), where E is the intensity of sensation, J is the intensity of irritation, k is the constant, J0 is the threshold of sensation.

18. What is meant by the inertia of analyzers? Give an example.

**Answer**: The relatively slow occurrence of sensations after turning on the stimulus and the slow disappearance of sensations after turning off the stimulus. For example, the continuation of light perception after the light is turned off.

19. What is meant by the induction interactions of analyzers?

**Answer**: It is a change in the excitability of one analyzer when another is excited, accompanied by a change in the degree of severity of sensations.

20. What is information encoding (1)? In which departments of the analyzer is it performed (2)? What characteristics of the stimulus are encoded by the analyzers (3)?

**Answer**: 1) Conversion of information into a conditional form (code), convenient for transmission over a communication channel. 2) In all departments. 3) Quality (type), quantity (strength), space (scope), and duration of the stimulus.

21. What is meant by sensory modality? Give examples and their qualitative types.

**Answer**: It is the totality of sensations provided by any one analyzer. For example, vision, hearing, taste. Qualitative types: vision-different colors, taste-sour, sweet, etc.

22. How is the quality (type) of the stimulus encoded in the receptors?

**Answer**: It is encoded with the presence of various types of receptors that are most sensitive to a certain (adequate) type of stimulus and are excited in natural conditions only under the action of an adequate stimulus (with the exception of pain stimuli).

23. Due to what is the strength of the stimulus encoded in the receptors?

**Answer**: It is encoded by changing the number of excited receptors and changing the pulse frequency in each of them.

24. What kind of coding is used in the receptors when changing the size of the irritated surface area of the body and when changing the distance between the irritated points? Explain the mechanism.

**Answer**: Spatial coding: with an increase or decrease in the irritated surface area of the body, the number of excited receptors changes accordingly, and when the distance between the irritated points changes, the receptors of different parts of the body are involved in the excitation. Similar spatial changes occur at the cortical end of the analyzer.

25. What mechanism is the time of action of the stimulus encoded in the receptors by?

**Answer**: It is encoded by stimulating the receptors when the stimulus is turned on and stopping their excitation after the stimulus is turned off, as well as due to the presence of on-, off - and on-off receptors.

26. How is the information about the nature of the signal transmitted in a single afferent fiber? Is it in the nerve trunk?

**Answer**: In a nerve fiber - by a binary code: the presence of a pulse – the absence of a pulse; by a change in the nature of the pulse (frequency and number of pulses in volleys, intervals between volleys). In the nerve trunk – a change in the nature of impulses in individual nerve fibers and a change in the number of excited fibers.

27. What mechanisms are used to encode information at the cortical end of the analyzer? Give appropriate explanations.

**Answer**: It is encoded with the help of frequency-spatial coding (impulses come from receptors in certain areas of the cortex at certain time intervals) and with the help of structural and biochemical changes in neurons (memory mechanisms).

28. What characteristics of the stimulus are analyzed and encoded at the cortical end of the analyzer?

**Answer**: The quality (type) of the stimulus, the quantity (strength), the space (the area of action of the stimulus on the body of the organism and in the environment) and time – the duration of the stimulus.

29. What is the essence of the analysis and synthesis of information received in the cortical part of the analyzers from the exteroreceptors?

**Answer**: The analysis is the distinction of all the stimuli acting on the body. The synthesis is the perception (formation) of images, recognition of an object, phenomenon.

30. What is the basis for recognizing an object or phenomenon?

**Answer**: It is the comparison of the received information with the previously encoded and stored in the central nervous system using memory mechanisms.

**Visual analyzer**.

1. Name the refractive surfaces and environments of the eye and their total refractive power when viewing objects located close and far away.

**Answer**: They are the cornea (anterior and posterior surfaces), the watery moisture of the anterior chamber, the lens, and the vitreous body; 70 and 60 diopters, respectively.

2. List the refractive errors of the eye. What common phenomenon for these anomalies interferes with normal vision?

**Answer**: Myopia, hypermetropia, astigmatism. There is no necessary focusing of the image on the retina of the eye.

3. What is called myopia and hypermetropia? What is their essence?

**Answer**: Myopia is nearsightedness, the main focus is in front of the retina due to an increase in the longitudinal axis of the eye or, rarely, an increase in the refractive power of the optical system of the eye; hypermetropia is farsightedness, the main focus is behind the retina due to the short longitudinal axis of the eye.

4. What is astigmatism, what is its cause?

**Answer**: It is a defect in the optical system of the eye is the unequal refraction of rays on the cornea due to its different curvature in different areas (in different planes), as a result of which the main focus in one place may fall on the retina, in another it is in front of or behind it, which distorts the perceived image.

5. What is the essence of compensation for defects in the optical system of the eye? What eyeglass lenses are used in clinical practice for myopia, hypermetropia and astigmatism?

**Answer**: It is in combining the main focus of the refractive media of the eye with the retina. In myopia - biconvex (scattering) lenses, in hypermetropia-biconvex (collective) lenses, in astigmatism – cylindrical lenses with different refractive powers in different parts of them.

6. What is the spherical aberration of the optical system of the eye? How does the eye reduce it?

**Answer**: It is different refraction of rays in the central and peripheral areas of the lens and cornea, which leads to scattering of rays and blurred image. It is reduced by the diameter of the pupil.

7. What is the role of the pupil in visual perception?

**Answer**: It transmits light rays to the retina, regulates the amount of light flux (expands in the dark, narrows in the light) and reduces the spherical aberration of the eye.

8. What is the value of the retinal pigment layer?

**Answer**: The pigment layer (fuscin), absorbing light, prevents its reflection and scattering, which contributes to the clarity of visual perception, participates in the production of visual pigment.

9. What is called the nodal point of the eye?

**Answer**: It is the point in the optical system of the eye through which the rays pass without being refracted.

10. What is called the angle of view?

It is the angle formed by two rays coming from the two extreme points of the object under consideration or its details through the nodal point of the eye.

11. What mechanisms of the eye are necessary for clear vision of objects at different distances?

**Answer**: Accommodation, divergence, and convergence of visual axes.

12. How does the state of the ciliary muscles, cinnae ligaments and lens change when viewing objects located close and far away, that is, when the eye is accommodated?

**Answer**: When looking at closely spaced objects, the muscles contract, the tension of the ligaments decreases, and the lens becomes more convex. When considering far-away objects, the opposite phenomena take place.

13. What mechanisms does the eye use to clearly see (1) an object moving or (2) appearing in the field of view?

**Answer**: 1) Voluntary eye movements and 2) fixation reflex.

14. What is the fixation reflex?

**Answer**: It is a rapid (abrupt) involuntary movement of the eyes, aimed at combining the image on the retina with the central fossa.

15. Why is there no adaptation of photoreceptors when fixing the gaze on a stationary object, despite the fact that they are rapidly adapting?

**Answer**: Due to rapid, constant, involuntary eye movements and the transformation of a continuous irritation into an intermittent one, since the light beam is constantly shifting from one receptor to another.

16. What mechanisms does the eye have for clear vision in different light conditions?

**Answer**: 1) Pupillary reflex; 2) two kinds of photoreceptors-rods for twilight vision and cones for daytime vision; 3) splitting of visual pigments in the light and resynthesis in the dark; 4) changing the receptive field of ganglion cells (more in the dark, less in the light).

17. Name the visual pigments of cones and rods that you know.

**Answer**: Rods are rhodopsin; cones contain pigments that are most sensitive to blue, green, or red (yodopsin) parts of the absorption spectrum, which provides color vision.

18. What is called a blind spot on the retina? Name the experience with which you can prove its existence.

**Answer**: It is the part of the retina devoid of photoreceptors that corresponds to the exit point of the optic nerve and is not sensitive to light stimuli. The Marriott experience.

19. Describe briefly the experience of Marriott, which proves the presence of a blind spot on the retina?

**Answer**: The subject takes a drawing with a circle and a cross on a black background, closes one eye, looks at the cross with the other (and sees the circle), and then slowly brings the drawing closer to the eye – at a distance of 15 – 25 cm from the eye, the perception of the circle disappears.

20. Why does the perception of the circle in the experience of Marriott, when approaching the eye of a drawing with a circle and a cross and fixing the gaze on the cross, disappear when the drawing is at a distance of 15-25 cm from the eye?

**Answer**: Because at this distance, when fixing the eye on the cross, the image of the circle falls on the blind spot in the retina of the eye.

21. What is called the yellow spot and its central fossa?

**Answer**: The yellow spot is the place of the best vision, where there are mainly cones, and in its central fossa – only cones.

22. What indicator is used to determine visual acuity? What is its normal value?

**Answer**: The smallest angle of view, at which the eye is still able to see two points separately, is used.. 1 minute.

23. How is visual acuity determined and calculated and by what formula? Explain the meaning of the formula elements.

**Answer**: It is determined by using tables with letters or figures of different sizes (for example, the Golovin table). V = d/D, where V is visual acuity, d is the maximum distance to the table from which the subject is able to read this line, D is the maximum distance from which he should see this line with normal vision.

24. Why is visual acuity greater in the central fossa than in the periphery of the retina?

**Answer**: Only the cones are located here, their diameter is the smallest and they are connected to a smaller number of bipolar neurons (sometimes with one).

25. How can we see large objects in general and their details?

**Answer**: Due to the presence of central and peripheral vision, which provides a large range of viewing angles.

26. Name the mechanism of the eye that provides the distinction of the wavelength of light. What theory explaining this property of the eye has now received experimental confirmation? What is its essence?

**Answer**: Color vision. Trichromatic theory. Three types of cones were found, each of which contains a pigment that is most sensitive to blue-violet, green or red colors.

27. List the types of color vision disorders.

**Answer**: Protanopia – blindness to red, deuteronopia-blindness to green, tritanopia-blindness to blue-purple.

**Auditory Analyzer**

1. What are the characteristics of the sound stimulus encoded by the auditory analyzer?

**Answer**: The force, pitch, duration of the action, the nature of the action (for example, continuous or intermittent sound), the location of the sound source.

2. Specify the frequency range of sound vibrations perceived by the auditory analyzer. How does this range change with age? To which sound frequencies does the human ear have the greatest sensitivity? What does it matter?

**Answer**: From 16 Hz to 20,000 Hz, the upper bound is reduced by 1-4 thousand Hz. This frequency range roughly corresponds to the frequencies of sound vibrations characteristic of human speech.

3. What is the basis for a person's ability to determine the position of a sound source in space? Explain the mechanism.

**Answer**: Based on the presence of two symmetrical halves of the auditory analyzer (binaural hearing): the sound wave comes to one ear a little earlier and of greater strength from the sound source, which the auditory analyzer evaluates with great accuracy.

4. With what accuracy (in degrees) is a person able to determine the direction of the sound source in space? Describe the experiment that proves that the difference in the time of arrival of sound in the right and left ear is crucial in this case.

**Answer**: It is one degree. If you apply sound to the ears with two rubber tubes of different lengths, the sound is perceived earlier from the side where the tube is shorter.

5. Name the muscles of the middle ear and specify their value.

**Answer**: It is the muscle that strains the eardrum, and the stirrup muscle that restricts the movements of the eardrum and the stirrup. Both muscles protect the elements of the inner ear from excessive vibrations and damage during strong sounds.

6. What is the meaning of the tympanic cavity and the presence of air in it? When the Eustachian tube opens, what does it matter?

**Answer**: It contains the auditory bones, which transmit sound vibrations to the cortical organ, and air, which provides vibrations of the eardrum due to its compression. The Eustachian tube opens and closes with each gulp, which maintains atmospheric pressure in the tympanic cavity.

7. Name the two ways of sound transmission in the auditory analyzer. Prove the existence of both paths.

**Answer**: They are air and bone. The subject stops hearing the sound of the tuning fork if the external auditory passages are tightly closed, but hears the sound if the tuning fork touches the bones of the skull.

8. What is the evidence of the preservation of bone sound transmission in violation of the air?

**Answer**: The sound-conducting apparatus is damaged, but the sound-receiving cortical organ and the auditory nerve are not damaged.

9. Due to what is the sound signal amplified in the mechanical system of the ear that perceives sound vibrations?

**Answer**: It happens due to the larger surface of the tympanic membrane compared to the surface of the stirrup; and due to the fact that the tympanic membrane transmits its vibration to the longer arm of the lever formed by the auditory bones.

10. Name the three channels of the snail.

**Answer**: Upper (vestibular staircase), middle (webbed canal), and lower (tympanic staircase).

11. List the elements that transmit sound vibrations from the eardrum to the hair cells of the cortical organ.

**Answer**: Tympanic membrane-auditory ossicles-oval window membrane - perilymph of the upper canal and endolymph of the middle canal-main membrane-receptor hair cells.

12. What is the purpose of the eardrum? With the help of which bones does it perform its main function (list the sequence of their location, respectively)? Does the vibration frequency of the eardrum correspond to the frequency of sound vibrations?

**Answer**: It is the protection of the middle ear from the external environment; transmission of sound vibrations to the inner ear. With the help of the auditory bones (hammer, anvil and stirrup); strengthening of sound perception it performs its main function. It corresponds.

13. What is the purpose of the oval and round windows of the snail?

**Answer**: They provide the possibility of oscillation of the perilymph of the snail. In this case, the push of the stirrup is transmitted to the membrane of the oval window, and the presence of the membrane of the round window ensures the propagation of the traveling wave of the perilymph.

14. Describe the mechanism of irritation of the auditory receptors.

**Answer**: The action of sound causes vibrations of the main membrane and the receptor hair cells located on it. Touching the tectorial membrane, the hairs deform, which is the irritation of the phonoreceptors.

15. Specify the location of the main neurons (including cortical ones) of the auditory analyzer.

**Answer**: 1-the spiral ganglion in the cochlea; 2 – the cochlear nucleus in the medulla oblongata; 3 – the lower mounds of the quadriplegic of the midbrain; medial geniculate body (metatalamus); 4 – the temporal lobe of the cortex.

16. What is the snail microphone effect?

**Answer**: The reproduction of words and other sounds spoken in front of the ear, using a speaker connected by wires to the cochlea.

17. What facts indicate that the part of the cortical organ at the base of the cochlea perceives high tones, in the middle – medium tones, in the area of the apex of the cochlea – low tones?

**Answer**: When the whorl of the cochlea is destroyed at its base, conditioned reflexes for high tones disappear, when the top of the cochlea is destroyed, conditioned reflexes for low tones disappear, and when the middle whorl is destroyed, conditioned reflexes for sounds of medium frequency disappear.

18. How are low – frequency (up to 800-1000 Hz) sound vibrations encoded?

**Answer**: Using the spatial and frequency coding mechanism, when the frequency of impulses occurring in the receptors of the cortical organ (in the upper part of the cochlea) and the fibers of the auditory nerve corresponds to the frequency of sound vibrations.

19 What mechanism is used to encode high-frequency (over 1000 Hz) sound vibrations?

**Answer**: Using spatial coding, when with an increase in the frequency of sound, the maximum amplitude of vibrations of the main membrane shifts from the top of the cochlea to its base.

**4. Situational tasks**

**AI-1. In three patients, when determining the nearest point of clear vision, the following figures were found: 12 cm, 30 cm and 40 cm.**

1) Which of these people is older? Is it possible to name approximately their age?

2) Why do far-sighted people push the text away from them in order to read it?

3) What question (the same one) should I ask them to make sure that the reason for their farsightedness is the same?

**AI—2. The man looks out of the window directly in front of him. There are other people walking on the street, in different directions. One of them, 170 cm tall, stands in front of the window. Try to give answers to the following questions, if the distance from the retina to the nodal point of the eye of the observer is taken as 15 mm.:**

1) At what distance from the window is a person standing?

2) On the basis of what signs does a person judge the direction and speed of movement of objects moving away from him?

3) In which case will he be able to notice an object moving past the eye at a distance of 2 m earlier-when it moves from top to bottom or from right to left?

**AI-3. In the receptors, as is known, the encoding of information coming from the external and internal environment of the body is carried out, i.e., its transformation into a form that is convenient for transmission through the communication channel.**

1) Specify the characteristics of stimuli that are encoded in the receptors and how this is done.

2) How is the information in the conductor and cortical ends of the analyzer encoded?

**AI-4. On a blade of grass, right in front of the frog's nose, a fly sits motionless, but the frog does not touch it. As soon as the fly started moving, the frog shot out its tongue and caught the fly.**

1) Why does the frog see only moving objects?

2) Describe the adaptive mechanisms of the eye for clear vision in various conditions: a) when changing the distance to the object, b) when changing the illumination.

**AI-5. Electrophysiologically, it is proved that with an increase in the area of the light stimulus acting on the retina, the latent reaction period decreases and the frequency of electrical impulses in the optic nerve increases. Thus, a property of the retina was discovered, similar to the properties of CNS neurons.**

1) Name this property.

2) Can you prove this in practice without using electrophysiological techniques?

**AI-6. As a result of the huge increase in the sensitivity of the retina in the dark, we can easily navigate even at night. However, on a starry, moonless night, it is enough to look directly at a dim star to make it disappear. This feature of night vision was very well noted by the French astronomer Domenicus Arago: "to notice a very poorly lit object at dusk, you do not need to look at it."**

1) Which receptors are responsible for night vision?

2) What is this effect explained by?

**AI-7. A person is engaged in scuba diving with a breathing tube and wearing a mask. Suddenly, he heard an incomprehensible sound, lost his mask from fright and began to frantically search for the source of the sound, trying to see the surrounding objects. However, visibility has noticeably decreased.**

1) Why is it better to see under water with a mask than without it?

2) Where is it easier to determine the direction of the sound source - in the air or in the water?

**Profile tasks for pediatricians on the topic "Analyzers", lesson 1**

**A1-8p. In order to investigate the state of the visual analyzer, you sent a flashlight beam into the child's eye and followed his reaction.**

1) What are the features of the movement of the eyes and eyelids of the newborn (when opening the eyes)?

2) At what age do the protective blinking reflex for sudden light irritation and the protective reflex for closing the eyelids appear?

3) What is the visual concentration of the child, at what age does it appear, how long does it last during this period?

4) Specify the main features of the condition of the pupils and the pupillary reflex in a newborn.

**A1-9p. Examination of the child's vision with a special ophthalmoscope revealed the presence of myopia.**

1). How often do children develop myopia, at what age does it happen, and what is its immediate cause?

2). What factors contribute to the development of myopia in children?

3). Why can prolonged reading with a large tilt of the head or when the book is located closer than 30 cm from the eyes lead to the development of myopia?

**A1-10p. The study of visual acuity in a child showed that it is equal to 0.8.**

1) Is it normal if the child is 3 years old? Specify visual acuity in children aged 6 months, 1 year and 5 years.

2) Who has more visual acuity: children over 5 years old and adolescents or an adult?

3) What is the peculiarity of accommodation in children and what is its cause?

**A1-11p. Analyzer systems undergo certain age-related changes during ontogenesis. Give a brief description of these processes.**

1) At what age do the analyzers start functioning in children?

2) Which analyzer structure matures earlier, which analyzer structure matures later?

3) What factors contribute to the development and functional improvement of the analyzers?

4) By what age is it mostly completed?

**A1-12p. A pregnant woman feels the increased movement of the fetus when loud music blares. What is the reason for this phenomenon?**

1) Is it possible to perceive sound during intrauterine development,

2) What are the facts that indicate this?

3) What is the reaction of a newborn to a strong sound?

**A1-13p. Parents brought their child to the surdology room to assess his hearing, as they note that he does not hear individual sounds well.**

1) At what age does the child's hearing significantly improve?

2) When does hearing acuity become maximum?

3) At what age does the child's subtlety of distinguishing sounds reach the adult norm (3/4-1/2 tones).

4) What is the maximum frequency of sound vibrations perceived by a teenager of 14-15 years (compare with the norm of an adult)?

**Standards of answers to the tasks of the lesson on the topic "Analyzers"**

**Standards of answers to the questions of the A1-1 task**

1) With age, the nearest point of clear vision moves away from the eye. So, the second person is over 40 years old, the third is over 60. The first one is about 25 years old.

2) At the same time, a better focusing of the image on the retina is achieved.

3) You should ask the question: "Did you wear glasses in your youth?". The fact is that the cause of hyperopia can be either too short the longitudinal axis of the eye, or the weakening of accommodation with age. If both have not worn glasses before, then the reason for farsightedness is the same-age-related changes in the eye.

**Standards of answers to the questions of the A1-2 task**

1) The size of the image on the retina is smaller than the object by as many times as the distance from the retina to the nodal point of the eye is less than the distance from this point to the object. From here it is easy to calculate that the distance between people is 25.5 m.

2) Based on the rate of change in the magnitude of the image of the object on the retina and its clarity.

3) Since the size of the field of view in the horizontal plane from the outside is larger than in the vertical plane from above, an object moving from left to right will appear in the field of view of a person earlier.

**Standards of answers to the questions of the AI-3 problem.**

1) The strength and duration of the stimulus are encoded in the receptors.

2) In the conductor department, this is encrypted by the number of pulses in a packet, the distance between the packets of pulses, the number of packets based on the binary code. In the cortical end-in addition, there are other coding systems (excitation points, neurons-detectors, etc.)

**Standards of answers to the questions of the AI-4 problem..**

1) The frog sees only moving objects, since the light-perceiving elements of its retina quickly adapt and stop responding to a stationary object.

2a) The adaptation of the eye to clear vision when changing the distance to the object occurs by measuring the curvature of the lens and focusing the image on the retina (accommodation);

2b) When changing the illumination, in addition to accommodation, clear vision is achieved by changing the size of the pupil, placing the image on the most excitable areas of the retina (yellow spot), increasing the sensitivity of light-perceiving elements (dark adaptation),

**Standards of answers to the questions of the problem AI-5.**

1) This property is the ability to sum up irritations.

2) By changing the area of the light signal, you can make sure that the larger it is, the less light intensity is required for the threshold sensation to occur.

**Standards of answers to the questions of the AI-6 problem.**

1) At dusk, light is perceived by sticks.

2) More of the wand is located in the area of the outer part of the field of view, so the star, whose imprint falls on the edge of the retina, is better visible at night..

**Standards of answers to the questions of the AI-7 problem.**

1) The refractive indices of water, the cornea and the eye media are approximately the same, and the eye is adapted for the course of rays in the "air-cornea"system. Therefore, an air chamber placed in front of the eyes improves vision under water.

2) Water is a denser medium, sound travels faster in it. Therefore, the time difference between the arrival of sound in the left and right ear will be less than in the air. This will make it difficult to determine the sound source in the aquatic environment.

**Standards of answers to the questions of the problem A1-8p**

1) Eye and eyelid movements are uncoordinated, there is no smoothness of eye movements, nystagmus is observed.

2) The blinking reflex manifests itself from the first days of life, the closing of the eyelids - in 1, 5 months.

3) Visual concentration manifests itself in fixing the gaze on an object with simultaneous inhibition of all movements, appears at the age of two weeks, lasts 1-2 minutes at this age.

4) The pupils are narrow, and the pupillary reflex is expressed mainly by the narrowing of the pupil in the light. The pupil dilation in low light is not expressed enough.

**Standards of answers to the questions of the A1-9p task**

1) In 90% of newborns; the reason is the spherical shape of the eyeball (shortening of the longitudinal axis of the eye); it passes by 8-12 years.

2) Myopia develops in 30-40% of children of preschool and school age. The immediate cause in most cases is an increase in the longitudinal axis of the eye.

3. Prolonged reading in a sitting position with a large tilt of the head or when the book is located closer than 30 cm from the eyes, insufficient illumination, prolonged viewing of small objects, hereditary predisposition (insufficient stiffness of the sclera).

**Standards of answers to the questions of the A1-10p task**

1) This is the norm. Visual acuity in children at 6mc, 1 year and 5 years is equal to 0.1, 0.2 and 1.0, respectively.

2) Children over 5 years of age and adolescents, as a rule, have more than adults.

3)The size of accommodation in children is larger than in adults due to the greater elasticity of the lens.

**Standards of answers to the questions of the A1-11p task**

1) Immediately after the birth.

2) The earliest-the vestibular apparatus, later than others-the auditory and visual analyzers.

3) Rational training and rest in the process of teaching and raising a child.

4) By the age of 17-20 years of life.

**Standards of answers to the questions of the A1-12p task**

1) The fetus can hear sounds from the end of the third trimester of intrauterine development.

2) The occurrence of fetal movements and increased heart rate in response to strong sounds in the last months of pregnancy.

3) General flinching, contraction of facial muscles, closing of the eyes, opening of the mouth, stretching of the lips, reduction of the respiratory rate and pulse.

**Standards of answers to the questions of the A1-13p task**

1) At the age of 2 months,

2) At the age of 14-19, respectively.

3) At the age of 6-7 months,

4) Up to 12000 Hz (for an adult, 20,000 Hz).

**5. Practical work in the classroom**

**Watching educational films:**

1. Physiology of hearing and vision.

**Practical work No. 1. Determination of visual acuity using Golovin tables.**

Progress of work: Tables for determining visual acuity are placed on a well-lit wall or artificially illuminate it with an electric light bulb. The subject is placed on a chair at a distance of 5 meters from the table. The definition of visual acuity is carried out for each eye separately. The experimenter takes a pointer with a thin end and, pointing out the letters, asks them to name them. Start with the top lines and gradually move to the bottom. The last line, which the subject read without errors, serves for this eye as an indicator of visual acuity, which is indicated on the right side of the line.

**Practical work no.2. Definition of the field of view (perimetry).**

Progress of work: The perimeter is placed against the light. The subject is seated with his back to the light and asked to place his chin in the recess of the perimeter tripod stand. If the field of view of the left eye is determined, then the chin is placed on the right side of the stand. The height of the stand is adjusted so that the wooden end of the tripod falls to the lower edge of the eye socket. The subject fixes a white circle in the center of the arc with one eye, and covers the other eye with his hand. Set the arc in a horizontal position and start measuring. To do this, slowly move the white stamp along the inner edge of the arc from 900 to 00 and ask the subject to indicate the moment when the stamp is first visible to the motionless fixed eye. Due to the lack of time, you can limit yourself to defining 4 points (top, bottom, right and left).

**Practical work No. 3. Determining the nearest point of clear vision.**

Progress: The task is to determine the smallest distance between the eye and the pin, at which it will still be clearly visible with some increased accommodation. Make 4-5 observations and calculate the average distance.

**Practical work no.4. Blind spot detection (the Marriott experience).**

Course of work: The subject picks up a drawing where a cross and a circle are depicted on a dark background. Closing the left eye, the subject looks with the right eye at the cross and slowly brings the drawing closer to the eye. At a distance of about 15-25 cm from the eye, the image of the white circle disappears. The rays from the circle at a certain distance of the drawing from the eye fall on the blind spot and the white circle ceases to be visible.

**Practical work No. 5. Pupillary reflexes.**

Course of work: Sit the subject facing the light. After 1-2 minutes, mark the width of his pupils. Then make the following observations:

a) Close the eye with one hand and observe the appearance of a subsequent change (usually an increase) in the width of the pupil of the open eye.

b) Close both eyes for 30-60 seconds. Open both eyes at the same time and note the presence of dilated pupils. Then compare the degree of dilation of the pupils when both eyes are closed with that observed when one eye is closed. To draw a conclusion about the severity of direct and friendly reflex reactions of the pupils to light. Draw a reflex arc of the light reflex.

c) Invite the subject to fix the eyes of far-away objects and note the width of his pupils. Then place an object (finger or pencil) at a distance of 15-20 cm from the eye. Invite him to consider this subject. Observe the change in the position of the pupils. To draw a conclusion about the nature of pupillary reactions during accommodation.

**Practical work No. 6. Determination of hearing thresholds.**

The easiest way to determine the audibility of a human voice. The definition should be carried out monaurally, since the right and left ears are not completely identical and the thresholds of their excitability do not coincide.

The study is conducted as follows: the subject moves 4-5 m away, stands with his back to the researcher and covers one ear. The researcher whispers or pronounces various numbers with the volume of colloquial speech and gradually moves away from the subject until he stops repeating them correctly.

Of course, this is a rough test, the individual properties of the experimenter's voice make it an element of inaccuracy, but with hearing damage, even this method is indicative. Numbers are used because the word is inseparable from the meaning, and its perception depends not only on the sound composition, but also on how familiar it is to the subject.

Using the ticking of a clock that emits a sound from 1500 to 3000 Hertz allows you to approximately set the threshold of auditory excitability for this frequency range.

In medical practice, a set of Bezold-Edelman tuning forks is used to study hearing.

Currently, modern audio generators - audiometers-are used to determine the entire range of audibility.

**12. Recommendations for the educational and research work of students.**

**Abstract topics:**

1. Visual functions from the perspective of the age aspect.

2. Modern methods of correction of visual dysfunctions.

3. Modern methods of studying visual functions and the state of the visual organ..

4. Photochemistry of light perception by the visual organ

5. Modern methods of hearing research

6. Is it possible to create an artificial hearing organ?

7. Visual functions from the perspective of the age aspect.

8. Modern methods of correction of visual dysfunctions.

9. Modern methods of studying visual functions and the state of the visual organ..

10. Photochemistry of light perception by the visual organ

11. Modern methods of hearing research

12. Is it possible to create an artificial hearing organ?

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2. Hall, J. E. Guyton and Hall Textbook of Medical Physiology / J. E. Hall. - 13th ed., Int. ed. - Philadelphia : Elsevier, 2016. - 1145 p.

3. Sherwood, L. Fundamentals of Human Physiology / L. Sherwood. – 4th ed. – Belmont, CA, USA: Brooks/Cole, 2012. – 764 p.

4. Silbernagl, S. Color Atlas of Phisiology / S. Silbernagl, A. Despopoulos. - 7th ed. - Stuttgart : Thieme, 2015. - 458 p.

5. Wilson, L.B. USMLE Step 1. Lecture Notes. Physiology / L.B. Wilson. - Kaplan, 2013. - 423 p.