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PHYSIOLOGY OF SENSORY SYSTEMS

Lecture notes

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PHYSIOLOGY OF SENSORY SYSTEMS

Lecture notes

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CONTENTS

CHARACTERISTICS OF SENSOR SYSTEMS

Lecture plan:
1. Concepts of sensor systems.
2. Doctrines about analyzers.
3. Analyzer functions.
4. Properties of analyzers.
5. Functional parts of the analyzer.
6. Formation of sensory perception.

The existence of a living organism is impossible without information, which must come both from the outside world and from the internal environment. Both streams of information interact and are carried out thanks to the functioning of special systems - sensor systems. They transform adequate stimuli into nerve impulses that go to the central nervous system. At different levels of the brain, this information is filtered, analyzed, recognized and transformed into sensory sensations that are perceived and an image of the stimulus is created. Thus, sensory systems are structures that ensure the perception of information, its processing through analysis and synthesis, create an image of a stimulus based on its features and sensory experience and form a conscious feeling. What is the role of sensory information? The work of all internal organs is organized on the basis of sensory information. It is also an important condition for the activity of a person, one's formation and development as an individual. Sensory information is an important factor in the formation of human behavior, its adaptation to the conditions of existence.

Classification of sensory systems
1. Sensory systems associated with sense organs (visual, auditory, vestibular, gustatory, olfactory).
2. Somato-visceral sensory systems (skin sensitivity, deep sensitivity, sensitivity of internal organs).

Sensory systems provide:

1. Perception of signals from the external environment and generation of excitement.

2. Detection and recognition of signals.

3. Coding of signals, their detection and creation of an image of the source of irritation.

4. Implementation of control of behavioral reactions and activity of internal organs.

5. Creating a certain level of brain activity.

6. Formation of sensory experience.

7. Formation of a conscious feeling and perception of irritation.

Each analyzer has the following properties:

1. Analyzers are excited only by an adequate stimulus that determines the nature of the sensation.

2. Have high excitability.

3. Able to adapt, except for the vestibular analyzer.

4. Have constant background activity.

5. Have certain limits of signal perception.

6. They create specificity of sensation (sight, hearing, taste, touch).

7. Have absolute and differential thresholds of feeling, shape the quality and intensity of feeling.

8. Each analyzer has its own time threshold of irritation (light must act for 50 msec, sound – 180 msec, touch - 1.2 msec for irritation to occur).

The analyzer have some differences:

a) *multilayering* - the arrangement of nerve cells in layers, which provides the possibility of specialization of different levels in the processing of certain types of information;

b) *multi-channel* - information is transformed and transmitted through a number of parallel channels, which ensure the accuracy and reliability of the analysis;

c) *the presence of sensory funnels* - the presence of expansion or narrowing of system connections in the direction of the cortex

(narrowing limits the amount of information, expansion provides a more complex analysis of stimulus signs);

d) *the presence of feedback* that affects the lower levels of structures, changing their activity. The result of the functioning of structures of a certain kind is the formation of the modality of sensation. Modality is a type or character of sensation. There are such modalities of sensation as sight, hearing, taste, smell, touch, vibration, pain, temperature, and others. The quality of sensation is the type of sensory impressions within one modality. For example, there is a taste of bitter, sour, salty. The intensity of the feeling is a quantitative characteristic of the feeling, it corresponds to the strength of the stimulus. Properties of analyzers were studied by Weber and Fechner. They found a link between sensory perception and their thresholds. The absolute threshold of sensation is the smallest stimulus force that causes the first sensory sensation (R).

The differential threshold is the smallest addition of stimulus to the absolute threshold that causes a change in sensation. It was experimentally established that the differential threshold is equal to 1/33 of the absolute threshold. According to the Weber-Fechner law, the intensity of sensation is logarithmically dependent on the absolute and differential thresholds of sensation. This dependence is expressed by the following formula:

$$S = a*\log(R+b)$$

S is a sensation;
a is a coefficient for a given type of stimulus;
R is an absolute threshold;
b is a differential threshold.

The time threshold is the smallest period of time of the action of the stimulus, which is required for the sensation to occur.

Each analyzer structurally consists of three parts:
1. Peripheral or receptor department.
2. Conductor department.

3. Brain department.

The receptor part of the analyzer is the "window" of the nervous system. They are specialized cells or free nerve endings located on open areas of the skin and mucous membrane and respond primarily to adequate irritation. However, the brain must know not only about changes in the environment, but also about what is happening inside the body. Therefore, receptors are located in every internal organ and even in the brain itself (hypothalamus, medulla oblongata). Depending on the location, the receptors can be contact and remote. Contact receptors are excited by direct contact with the source of irritation (tactile receptors). Remote receptors receive information at some distance from the source of irritation (visual, sound, olfactory).

By localization, the receptors are divided into: exteroreceptors - receptors located in the skin; proprioceptors - receptors located in muscles, joints and tendons; interoreceptors are receptors located in internal organs.

According to the adequacy of irritation receptors are: chemoreceptors, mechanoreceptors, photoreceptors, nociceptors.

According to the mechanism of excitation, primary and secondary receptors are distinguished.

Primary sensory receptors are free nerve endings. They perceive irritation, turn it into excitation, and a receptor potential known as a type of local potential arises. The receptor potential, having reached a critical level of depolarization, turns into an action potential. Primary sensory receptors include skin, smell and taste receptors.

Secondary sensing receptors are functionally and structurally different. In their composition there is a receptor cell, around which there are sensitive nerve endings of the nerve cell. They always have their own background activity. Under the action of a stimulus, the receptor cell perceives the stimulus, a receptor potential (RP) arises in it, which leads to the release of a mediator. The latter causes depolarization of the postsynaptic membrane, which creates a generator potential (similar to the excitatory postsynaptic potential),

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when it reaches a critical level of depolarization, an action potential arises. Secondary sensory receptors include visual, auditory and vestibular receptors.

Receptors have the following purpose:

1. Detection and recognition of signals.

2. Perception of irritation.

3. Transformation of signals into action potential and encoding of the stimulus:

a) primary coding is the coding of the type of stimulus, its frequency and intensity in the form of bursts of pulses of a certain frequency, duration, certain intervals between the bursts, which creates a certain image or pattern;

b) secondary coding is the coding of the quality of the stimulus, features of the stimulus, compression of information in time (temporal coding) and compression of information in space (spatial coding). The intensity of the stimuli is coded by the pulse frequency, the nature of the irritation is indicated by the grouping of pulses, that is, the pulses come in bundles at certain intervals - a time image (pattern) is created. It contains a certain number of pulses in a bundle, it is different for each stimulus, and the intervals between pulses in a bundle and between bundles are also different. During primary coding, the number of excited neurons changes, which are localized both in the central nervous system and in the cortex of the large hemispheres.

4. Primary analysis of the received information.

5. Selection of useful information.

The conducting part of each analyzer includes, as a rule, 3 neurons.

The first neuron is located in the spinal ganglion or in the ganglion of the cranial nerve, the second neuron is located in the structures of the central nervous system, the third neuron is found only in the switching nuclei of the thalamus. The conductor department detects and recognizes signals, on the basis of which useful information is extracted. Part of the received information is completely excluded, the other part is delayed for a while due to

inhibition, the rest reaches the cortex. Out of 10 million bits of information sent to the cortex, only 1 million is received. Reticular nuclei and non-specific pathways take part in information filtering. Structurally, this process is caused by numerous branches, collaterals to various departments of the central nervous system and the cortex of the large hemispheres.

The brain section of each analyzer is located in the cortex. It has nuclear and diffuse parts. The nuclear part of the analyzer is located in a specific projection field of the cortex, and the diffuse part is located in the corresponding associative area. The brain department is responsible for decoding, detecting, recognizing signals, building an image of a stimulus and forming a sensory sensation. Detection is a selective analysis of individual signs of a stimulus. This work is performed by detector neurons of various levels, which are excited only by certain features of the stimulus. Next, recognition of the stimulus or signal occurs due to the parallel analysis of all signs of the stimulus. After that, higher detectors create an image of the stimulus and at the same time a certain sensation is formed. The formation of sensation occurs in all departments of the analyzer and ends in the brain department. Depending on the modality of the stimulus, independent sensations of touch, sight, hearing, smell, taste, cold, heat, pain, vibration, position of the body and limbs in relation to the body are formed. Sensual perception of information, its awareness, subjective relation to it in the form of emotions is formed on the basis of the totality of all sensations. As a result, a sensory experience arises, that is, a memory of the action of the stimulus is created.

Perception of information - is a reflection in the human mind of objects and phenomena of reality with their direct effect on analyzers as a whole.

Information perception mechanism

Sensory information in the form of action potentials from receptors enters the specialized areas of the cortex of the large hemispheres, which contain a large set of neurons - detectors that

specialize in recognizing various objects or phenomena in the surrounding world. At the same time, a certain number of detector neurons is excited and a "picture" (like on a carpet) is created in the cortex. Both hemispheres refer to memory structures where information about the previous action of such stimuli (sensory experience) is stored. As a result, the "picture" is filled with content, that is, it "comes to life." The right hemisphere based on the picture creates a holistic view of the object or phenomenon of the surrounding world. The left hemisphere subjects the created picture to fine analysis and synthesis, includes thinking, abstraction occurs, sensory information is realized and a sensory sensation appears.

VISUAL ANALYZER

Lecture plan:
1. General characteristics of the visual analyzer.
2. Departments of the visual analyzer, their purpose.
3. Retino-motor reactions of the eye.
4. Photochemical reactions in photoreceptors.
5. Electrical reactions in photoreceptors.
6. Optical system of the eye.
7. Pupillary reflex, its significance in the clinic.
8. Accommodation of the eye, its mechanism.
9. Adaptation of the visual analyzer.
10. Mechanism of color perception.
11. Visual acuity.
12. Electroretinogram.

The visual analyzer ensures that up to 80 % of the information from the surrounding world enters the human body. It evaluates the size, shape, volume and color of objects, the light source, the distance to objects, distinguishes light from darkness, evaluates the degree of illumination of the room, distinguishes objects during movement.

An adequate stimulus for the visual analyzer is divergent light rays with a wavelength of 300-950 nm, a frequency from $4*10^{14}$ to $8*10^{14}$ Hz. Its greatest sensitivity to light is in the range of 400-700 nm. The eyeball consists of 3 shells, the lens, the vitreous humor, the anterior and posterior chambers of the eye, filled with watery moisture. From the outside, the eyeball is covered with a white protein shell, from the front it passes into the sclera, and then into a transparent shell - the cornea. The cornea does not have its own blood and lymphatic vessels, it is rich in sensitive nerve endings of the trigeminal nerve. Its nutrition is provided by substances from the eye chambers and at the expense of the looped blood network.

The outer membrane maintains the turgor and shape of the eye, provides a protective reaction causing lacrimation and

blephorospasm. In addition, the cornea has the ability to refract light rays. Its optical power reaches 40 Diopters (D), (fig. 1).
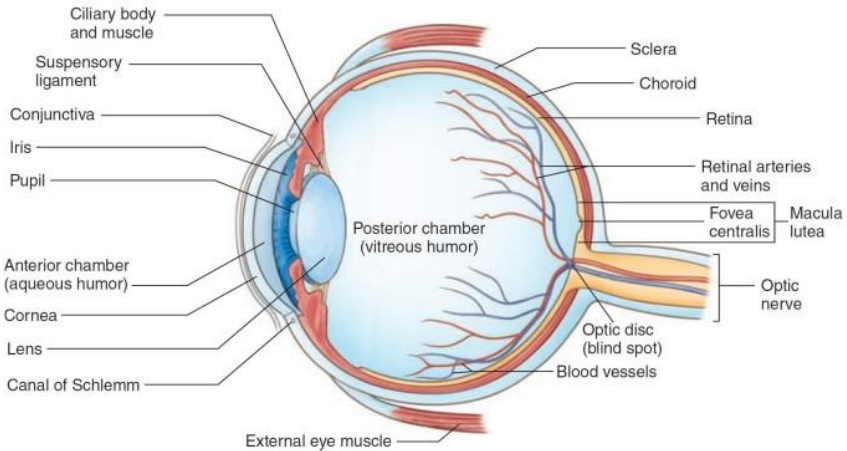
Ciliary body and muscle
Suspensory ligament
Conjunctiva
Iris
Pupil
Anterior chamber (aqueous humor)
Cornea
Lens
Canal of Schlemm
External eye muscle
Posterior chamber (vitreous humor)
Sclera
Choroid
Retina
Retinal arteries and veins
Fovea centralis
Macula lutea
Optic nerve
Optic disc (blind spot)
Blood vessels

Figure 1 − Structure of the eye

The middle membrane of the eye is called the choroid. It includes the choroid itself, the ciliary body. The choroid passes from the front into the colored part – the iris. The color of the iris depends on the number of chromatophores in the pigment layer of the retina. In the center of the iris there is a hole - i t is the pupil of the eye. It regulates the flow of light on the retina by changing the width of the pupil. The middle membrane of the eye provides blood supply to the eye, forms moisture in the eye chambers, takes part in adaptation.

The inner layer is called the retina (fig. 2). It has 10 layers of cells, of which 3 are neurons:

1 – the pigment layer, provides eye color, ensures the production of visual purple, regulates the intensity of light flow on the retina;

2 – the layer of photoreceptors. These are rods and caps, their light-sensitive segments are turned in the direction opposite to the light source;

3 – the outer boundary membrane – gives thin fibers that protect photoreceptors from destruction;

4 – the outer nuclear layer – these are the fibers and nuclei of photoreceptors;

5 – the outer plexiform layer – the free ends of visual cells connect here with processes of bipolar cells;

6 – the inner nuclear layer of cells is a layer of bipolar, amacrine and horizontal cells;

7 – the inner plexiform layer – the junction of bipolar and amacrine cells with ganglion cells;

8 – the layer of ganglion cells and neuroglia cells;

9 – the layer of nerve fibers – these are axons of ganglion cells, forming the optic nerve;

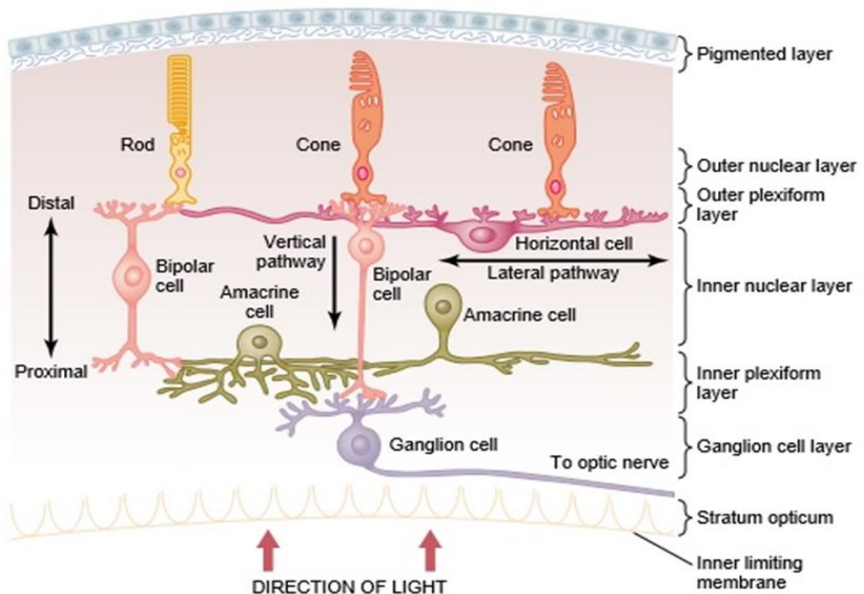10 – the internal border membrane – separates the retina from the vitreous humor.

Figure 2 − Layers of the Retina (Textbook of medical physiology / Arthur C. Guyton, John E. Hall. 2006)

The input of each ganglion cell receives signals from several bipolar cells, horizontal and amacrine cells. Their dendrites create a structural basis for signal convergence.

At the same time, the connection of one photoreceptor with several bipolar cells, and latter with ganglion cells, creates the basis for the divergence of signals.

The retina provides visual acuity, perceives light, the color of objects, and ensures adaptation of the eye.

The vitreous humor is a jelly-like mass with delicate fibrils, it fills the eye cavity, refracts light and maintains the shape of the eye.

The crystalline lens is a doubly convex lens capable of refracting light rays, providing accommodation for the eye.

Departments of the visual analyzer

1. The receptor department consists of rods and cones located in the retina (photoreceptors). Each of them consists of 2 segments: the outer one, which contains pigments (rhodopsin − in rods, iodopsin − in cones) and the inner one, which contains the nucleus and mitochondria with energy reserves. **Rods** are located on the periphery, there are up to 120 million of them in one eye. They estimate the amount of light and they are receptors for twilight (night), peripheral, colorless, blurred vision. **Cones** are located mainly in the center of the retina, there are about 7 million of them in one eye. Their highest density is in the macula (140,000 per 1 mm^2), which has a size of 1.5 mm and is located 4 mm outside the blind spot. *The blind spot* is the exit point of the optic nerve, there are no photoreceptors here. Lenses are elements of qualitative assessment of light, receptors of central, daytime, color and clear vision of objects. The opposite in the functions of photoreceptors formed the basis of the theory of the dual function of the retina. The receptor department ensures perception of irritation, its primary analysis and encoding of information.

2. The conductive department (fig. 3) ensures the selection of useful information, evaluates the level of illumination, perception of contrasting objects, moving objects, perception of colors. This

department includes 3 neurons: the first is located in the layer of bipolar cells, the second neuron is ganglion cells, their axons form the optic nerve, which after crossing (only the medial bundles of fibers above the area of the ephippium cross) form the optic tract that goes to the thalamus. The third neuron is the lateral geniculate bodies and the pillow, located in the thalamus. A third of the fibers of the optic tract enter the anterior tubercles of the quadriceps. They regulate the direction of the gaze and form an orienting reflex to light. The geniculate bodies ensure the distribution of information from the right and left eye, form stereoscopic vision.
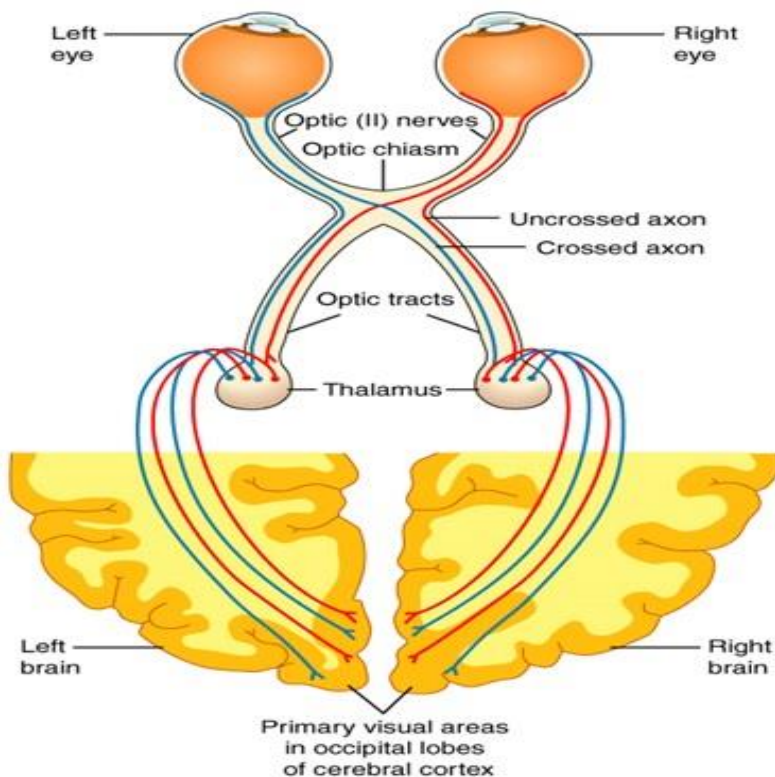

Figure 3 − Conductive paths of the visual analyzer

3. The brain section is located in the occipital cortex around the sulcus (fissura calcarina). This is the projection specific field №17, around which the associative fields are placed. Visual impulses are perceived by the corresponding areas of the retina of both eyes and, thanks to the crossing of the optic nerves, enter one hemisphere. This provides a common field of vision. Each field №17 is connected to the outer half of the retina of the same side and the inner part of the opposite side. Specific projection fields help distinguish the contours, size and shape of objects, form the feeling of light. Associative fields help to recognize objects, determine the source of light and the distance to it, control the movements of the eyes and head, fix the gaze. Impulses from photoreceptors converge on one ganglion cell (130:1), summation of excitations occurs. The interaction of neighboring retinal neurons is provided by horizontal and amacrine cells. They regulate the size of the receptor field and perform lateral inhibition for ganglion cells. One cone of the yellow spot is connected with one bipolar cell and one ganglion cell, which has a point representation in the projection field №17, which provides clarity of vision of objects. However, rods are somewhat different – only 100 rods have a point representation in the cortex.

The act of seeing consists of several processes: the rays from the object under consideration fall on the retina and cause irritation of photoreceptors, as a result of which retino-motor, photochemical and electrical reactions occur. At the same time, excitation occurs with simultaneous encoding of information, filtering of signals and creation of an image of a stimulus. All this forms a visual sensation.

Retino-motor reactions regulate the intensity of illumination of visual cells. In strong light, the cells of the pigment layer extend their processes between rods and cones. Rods pull in the internal joints, hide deeply behind the processes of pigment cells, so as not to be destroyed by the flow of light. The cones come out to meet the light and increase in volume.

Photochemical reactions occur mainly in the outer segment and are accompanied by the disintegration of the pigment in the light or its resynthesis in the dark. The best studied is the transformation

of rhodopsin. A quantum of light acts on the retina and causes a gradual transformation of rhodopsin with loss of its red color (rhodopsin → prelumirhodopsin → lumirhodopsin → metarhodopsin – 1 → metarhodopsin-2). The last one is split into transretinen and opsin.

Vitamin A is formed from transretinin under the influence of reductase.

In the dark, its aldehyde is formed from vitamin A, which is the source for resynthesis of rhodopsin. It is also an enzymatic process.

Electrical reactions. After 1 msec after the action of the light quantum, the ERP (early receptor potential) appears, it is based on the conformation of the rhodopsin molecule and the depolarization of the photoreceptor membrane. It causes the inactivation of sodium channels due to the influence of calcium ions and forms a LRP (late receptor potential), which leads to hyperpolarization of the membrane due to the release of potassium from the cell to the outside. At the same time, bipolar cells secrete a mediator, as a result of which a generator potential arises. It spreads electrotonically along the axon, informs the central nervous system about the arrival of a quantum of light, causes changes in ion channels and contributes to the formation of an action potential. In the dark, the photoreceptor membrane has a high permeability for sodium due to depolarization. Light reduces the number of open sodium channels and release of mediator.

Optical media of the eye

The ability to refract light is possessed by the cornea, lens, moist chamber of the eye, and the vitreous humor. The refractive power of the eye (refraction) is 58.6 D.

The cornea has the greatest refractive power (40 D). Normally, the length of the eye (the distance from the front pole of the eye to the place where the optic nerve exits) is 22.5-24 mm, while the front focal length is 7.5 mm, and the rear focal length is 15-17 mm. The image of the object will be reduced, actual, inverted on

the retina. At the same time, the optical power of the eye will be 58.6 D. Such eye is called emmetropic. A simplified eye model with one refracting surface with an optical power of 58.6 D is called a reduced eye. If the length of the eye changes, then it leads to a change in the optical power of the eye and the displacement of the image from the retina. This is how eye refraction anomalies occur (fig. 4).
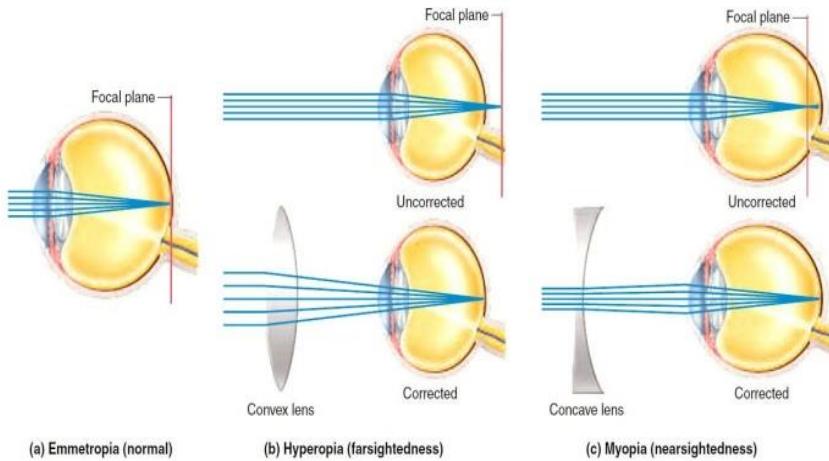

Figure 4 − Defects of refractions and their correction

Myopia is nearsightedness associated with an increase in the length of the eye, an increase in the optical power of the eye, distant objects are not focused on the retina. Image at this refractive defect will be in front of the retina. For correction, diffusing lenses are prescribed to reduce the optical power of the eye and return the image to the retina.

Hyperopia – farsightedness, the length of the eye is less than 22 mm, the image will be behind the retina, the optical power of the eye is reduced. Convex collecting lenses are prescribed for vision correction.

Astigmatism – there is no clear image on the retina due to the uneven refractive power of the cornea along the meridians, the image is distorted. In these cases, glasses are selected individually (thick

convex lenses, taking into account deviations for each meridian, respectively). Astigmatism is measured with a special device (Placido disk). The doctor looks at the patient's cornea through the hole in the center of the disc and sees miniature reflections of concentric rings on it. With astigmatism, the rings are deformed or take the form of ellipses.

Accommodation of an eye

This is the adaptation of the eye to clearly see objects at close distances. The accommodation apparatus includes: the lens, its capsule, suspensory ligaments, ciliary muscles and nerve fibers (fig. 5).
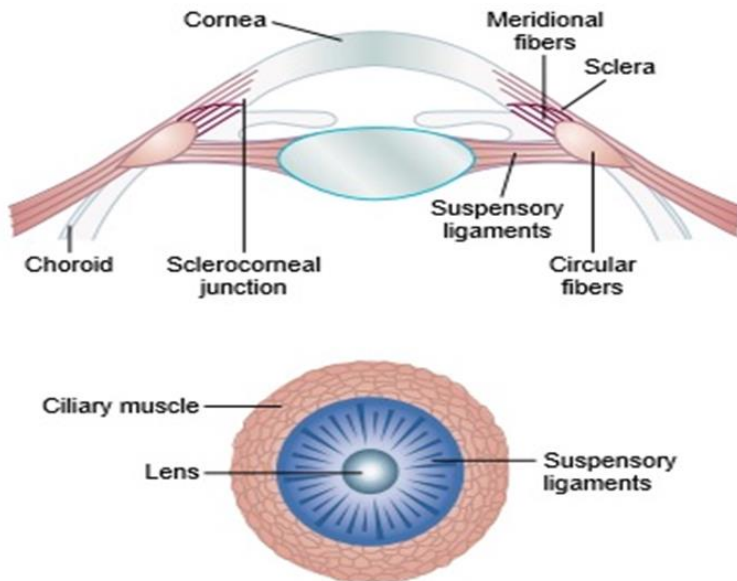

Figure 5 − Accommodation apparatus of the eye (Textbook of medical physiology / Arthur C. Guyton, John E. Hall. 2006)

The mechanism of accommodation of the eye is reflex. An adequate stimulus is a blurred image on the retina from scattered light rays coming from nearby objects. Receptors are photoreceptors,

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the sensitive nerve is the optic nerve, the center of this reflex is located in the nuclei of Edinger and Westphal-Yakubovich of the midbrain; motor nerve – parasympathetic fibers which are sent to the m.ci1iaris, to which the ciliary ligaments, connected to the lens capsule, are attached. When this muscle is shortened, the ciliary ligaments are weakened, which reduces the tension of the lens capsule and allows it to become more convex. At the same time, the optical power of the eye increases by 14 D. This is how accommodation occurs when seeing objects at a close distance. Long sight from a distance of 5 meters or more excludes the mechanism of accommodation. At the same time, the circular muscle relaxes, the ciliary ligaments are stretched, and the lens becomes flat. For a normal eye, the nearest point of clear vision is at a distance of 12 cm. With age, accommodation deteriorates, and the nearest point of vision recedes. This is called age-related farsightedness (presbyopia). It occurs as a result of lens compaction and loss of elasticity of the accommodation apparatus. At the age of 75, accommodation disappears. People of any age, who work with small objects, read a lot, notice that accommodation deteriorates over time, so reading glasses in the form of convex lenses are prescribed for correction.

Pupillary light reflex

The reaction of the eye to light (constriction of the pupil) is a reflex mechanism for limiting the amount of light on the retina. Normally, the width of the pupil is 1.5-8 mm. The degree of illumination of the room can change the width of the pupil by 30 times. When the pupil narrows, the flow of light decreases, spherical aberration disappears, which causes circles of self-scattering on the retina. In bad light, the pupil dilates, which improves vision. The pupillary light reflex takes part in the adaptation of the eye. It has a diagnostic value:

1. Dilation of the pupil with no reaction to light is a sign of biological death and an indicator of inhibition of stem reflexes.

2. Dilation of the pupil can occur due to the development of hypoxia.

3. Dilation of the pupil can be a sign of pain in the body.

4. The depth of anesthesia is judged by the width of the pupil.

Reflex arc of pupil constriction: photoreceptors → optic nerve → nucleus of Yakubovich → ciliary ganglion → oculomotor nerve → contraction of pupillary sphincter → pupil constriction.

Reflex arc of pupil dilation: photoreceptors → sympathetic fibers → sympathetic ganglion → spinal cord (C7, T1) → muscle that dilates the pupil (its contraction) → dilation of the pupil.

Adaptation of the eye

This is the adaptation of the eye to see objects in conditions of different intensity of room lighting. There are light and dark adaptations. **Light adaptation** develops when a person goes out of a dark room into the light. During the transition from darkness to light, temporary blindness occurs. Light adaptation lasts 5-10 minutes.

The basis of its development are the following mechanisms:

1. Decreased sensitivity of photoreceptors to light.

2. Narrowing of the receptor field due to breaking the connections of horizontal cells with bipolar cells.

3. Disintegration of rhodopsin (0.001 sec.)

4. Narrowing of the pupil.

Dark adaptation occurs when moving from a lighted room to darkness. It lasts 40-80 minutes. At the same time, the following processes happen:

1. An 80-fold increase in the sensitivity of photoreceptors to light.

2. Resynthesis of rhodopsin (0.08 sec.)

3. Dilation of the pupil.

4. An increase in the number of connections of rods with retinal neurons.

5. Increasing the area of the receptive field.

In the dark, new connections between rods and bipolar cells are formed due to processes of horizontal cells. As a result, more rods converge on bipolar cells. Spatial summation takes place. The area of the receptor field on ganglion cells increases. In addition,

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amacrine cells enhance the convergence of bipolar cells on ganglion cells. With a lack of vitamin A in the body, resynthesis of rhodopsin does not occur, a person can see poorly at dusk, chicken blindness (hemiralopia) occurs.

Visual acuity

This is the ability of the eye to see 2 points separately, if parallel rays of light act on the retina. At the same time, 2 cones are excited on the retina, between which there must be 1 unexcited cone (distance = 0.004 mm). Visual acuity gives a quantitative assessment of visual perception (fig. 6). Rays fall on the retina at an angle of one minute. If two cones placed next to each other are excited, there will be a blurred spot. Determination of visual acuity is carried out using the Sivtsev table from a distance of 5 m for each eye separately. The table should be evenly illuminated by side light with an intensity of 700 lux. If a person can freely read the letters of the table in the third row from the bottom or the tenth row from the top, then his visual acuity = 1.0. When visual acuity decreases, correction is carried out by choosing glasses with the appropriate optical power.
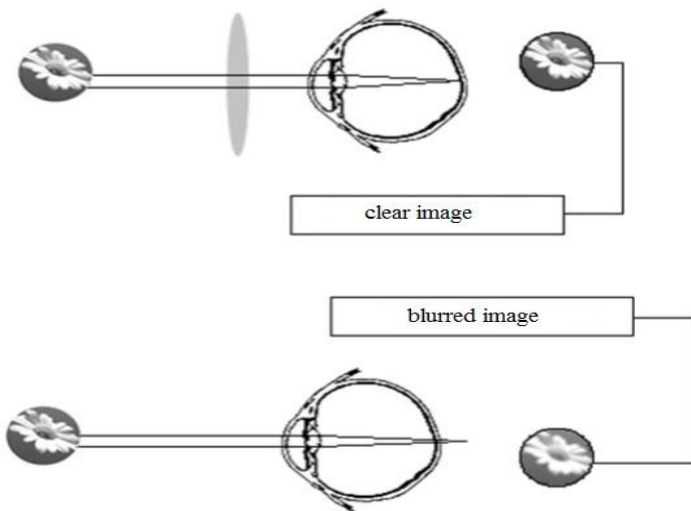

Figure 6 − Visual acuity

Perception of colors

The human eye perceives 7 basic colors and 2000 different shades. The mechanism of color perception is explained by various theories. According to the three-component theory of Jung – Helmholtz – Lomonosov, there are 3 types of cones on the retina that respond to different lengths of light rays. This creates different options for color perception. The first type of cones reacts to long waves with a length of 610 – 950 microns and gives a sensation of red color. The second type of cones responds to medium waves with a length of 460 – 609 microns and gives a feeling of green color. The third type of cones perceives short waves with a length of 300 – 459 microns, creates a feeling of blue color. Simultaneous excitation of the first and second types creates a feeling of yellow and orange colors, and the second and third types give violet and bluish colors. Simultaneous excitation of all 3 types of cones creates a feeling of white color, and their inhibition creates a black color. Hering's theory of opposing colors testifies to the presence of three types of pigment in the cones, the decay of which gives one color and its resynthesis provides the opposite color. As a result, pairs of colors are formed: red − green, blue − yellow, white − black. Granit experimentally proved that there are 7 groups of ganglion cells that respond to only one color, they are called modulators, the rest of the cells respond to all colors, they are called dominators. Chris's zonal theory combines previous theories: at the level of photoreceptors, the mechanism of color perception is explained by the first theory (three-component), at the level of the geniculate bodies, Hering's theory is legitimate, and at the level of ganglion cells − Granit's theory. The proof of the three-component theory is color perception anomalies that develop in 7-8% of people. They have a loss of perception of a certain length of light rays. Fallout creates a sense of gray color. So, protanopes do not perceive the color red, have a loss of perception of waves with a length of 490 μm; deuteranopes do not perceive the color green, have a loss of perception of waves with a length of 500 microns; tritanopes do not perceive blue-violet color, they have a loss of perception of waves with a length of 470 and 580 μm. The complete

loss of the ability to perceive colors is called anopia, while people see everything only in black and white. There is red-green blindness – the inability to distinguish red from green – this is daltonism. Determination of color perception in humans is carried out with the help of animaloscopes or Rabkin's polychromatic tables. Animals have different color perception: cats can distinguish 6 colors, horses – only 4 colors, dogs have no color vision. The potential difference that occurs on the retina is recorded in the form of an electroretinogram.

VESTIBULAR ANALYZER

Lecture plan:
1. Functions of the vestibular analyzer.
2. Characteristics of vestibular analyzer departments.
3. Mechanism of excitation of the vestibular apparatus.
4. Vestibular reactions.

The vestibular analyzer performs the following functions:

1. Provides an analysis of the position of the body in space during movement.

2. Ensures balance during movement.

3. Analyzes body parts in relation to the body.

4. Provides orientation in space when the visual analyzer is turned off.

5. Determines the direction of gravity.

6. Creates antigravity forces of the body.

The receptor part of this analyzer is located in the inner ear and is represented by two zones: the hair follicle and the semicircular canals (fig. 7).
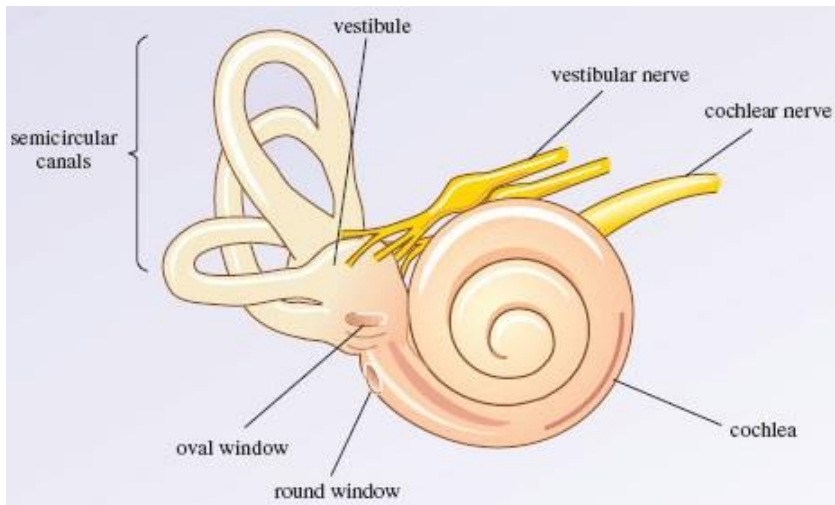

Figure 7 − Structure of the inner ear

Sensitive hair cells are located in the utriculus and the sacculus. These cells have hairs: one long hair – kinocilia, many short hairs – statocilia (60-80 on each receptor cell). The hairs are immersed in a gelatinous mass with calcium carbonate crystals (fig. 8). This is the otolith membrane. Crystals are called statoliths or otoliths (ear stones). When the body is in a vertical position, otoliths seem to sit on hairs. Sensitive cells are surrounded by nerve endings of the vestibular nerve.
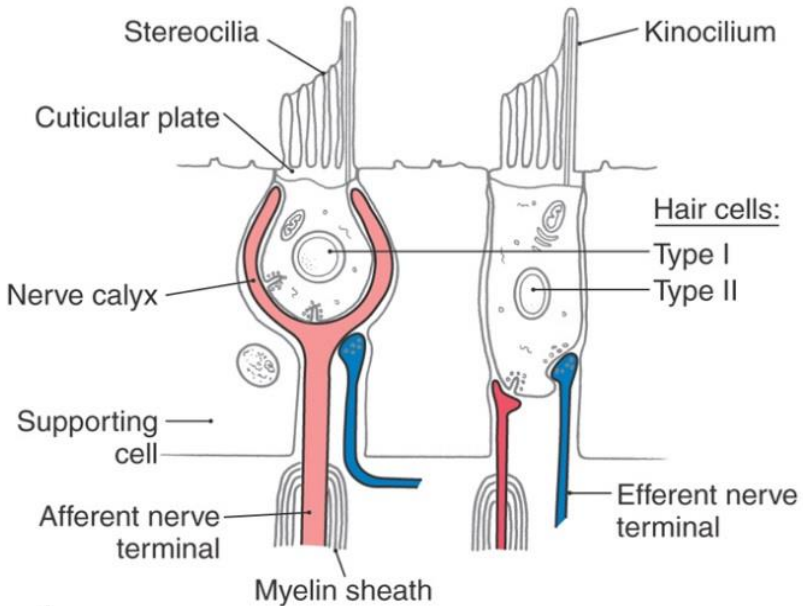

Figure 8 − Receptor cells of the vestibular analyzer

Acceleration of rectilinear movement, inclines of the head and body, changes in the direction of gravitational forces, shaking, vibration and travel sickness are adequate stimuli for the pricinia receptors, but the main stimulus is the acceleration of gravity. At the same time, the otolith membrane is displaced, which leads to stretching or deformation of hairs of sensitive cells. The otolith membrane has weight, so irritation causes the constant formation of a flow of impulses in the corresponding centers, which ensures orientation in space. Another receptor zone is the semicircular canals

(sagittal, frontal and horizontal), which are placed perpendicular to each other. The channels are filled with endolymph, which contains many potassium ions (fig. 9).
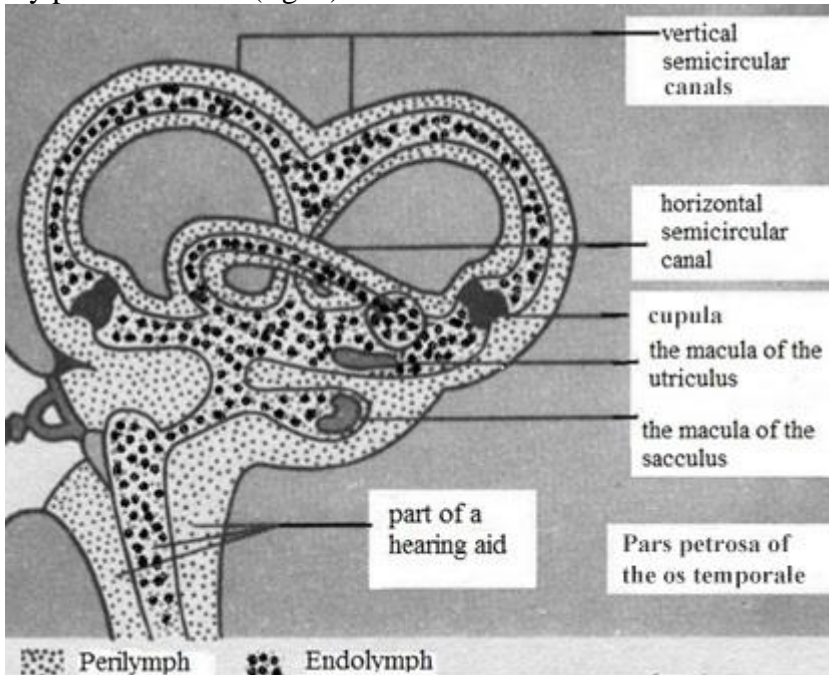

Figure 9 − Vestibular apparatus

In the expanded part of each cannal (ampulla) there is a rise (comb) on which receptor cells are placed. Their hairs are also immersed in a jelly-like mass rich in mucopolysaccharides, but without crystals. This mass is called a cupula. An adequate stimulus for these receptors is the acceleration of rotational movements (angular, centripetal acceleration). Thanks to the movement of the endolymph, the cupula changes its position and causes the hairs of the receptor cells to deform. At the beginning of the movement, the endolymph lags behind the movement of the body, because the cannal is narrow, and the endolymph is a viscous liquid. This leads to the movement of endolymph in the opposite direction. Endolymph returns back only after 20-30 seconds. At the same time, the body

leans back, maintaining balance. At the end of the movement, the endolymph continues to move by inertia, although the movement has already stopped, so the body leans forward. A receptor potential arises in the receptor cells, which causes the release of the mediator – acetylcholine. The latter causes the generation of a generator potential in the nerve endings of the vestibular nerve, which surround the receptor cells. Due to the summation of pulses, the generator potential increases, reaches a critical level of depolarization, turning into an action potential. Next, the information goes through the conducting department, which has three neurons (fig. 10).

The first neuron is located in the vestibular ganglion (g. Scarpea). From here, the afferent fibers are sent to the medulla oblongata to the vestibular nuclei (superior – nucleus of Bechterew, inferior – Rollers nucleus, lateral Deiters nucleus, medial – Schwalbe nucleus). Here is the second neuron of the conductor department of this analyzer. The third neuron is located in the posterior ventral nuclei of the thalamus. From here, signals from the vestibular apparatus enter the brain of the analyzer – in the suprasylvian and ectosylvian gyri (the lower edge of the front and back central gyri). The cortex provides awareness of vestibular information and certain orientation in space. Information about the position of the head relative to the body comes from the receptors of the neck joints to the vestibular nuclei. The central nervous system receives information about the position of the head relative to the body and takes it into account when determining the position of the body as a whole. Nerve fibers coming from the vestibular nuclei form connections with different parts of the brain: with gamma-motoneurons of the spinal cord, cerebellum, reticular formation of the midbrain, hypothalamus. These connections ensure the formation of motor reactions necessary for maintaining posture, balance, redistribution of muscle tone and corresponding eye-motor reactions without the participation of consciousness. With long-term irritation of the vestibular apparatus, vestibular reactions occur, a complex of which is called kinetoses. Vestibular reaction has 3 components: sensory, motor and vegetative.

The sensory component is accompanied by dizziness, nausea, loss of orientation in space.
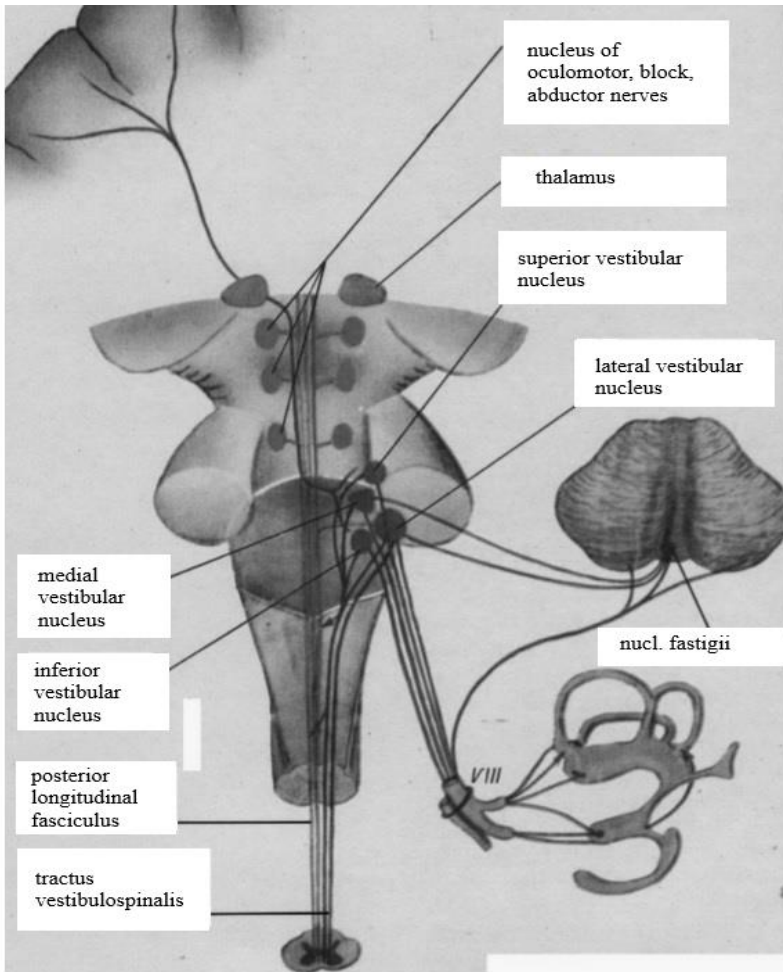

Figure 10 − Conductive department of the vestibular analyzer

The motor component includes nystagmus, redistribution of muscle tone, and imbalance. Nystagmus is a rhythmic movement of the eyes first in the direction opposite to rotation (fast component, lasting up to 10-15 seconds), and then eye movements in the

direction of rotation (slow component, lasting up to 25 seconds). Muscle tone is distributed in such a way that on the side to which the patient is rotated, the tone of the flexors increases, and on the opposite side, the tone of the extensors increases. The vegetative component is associated with a change in the work of internal organs: tachycardia, increased blood pressure, increased sweating. In a state of weightlessness, only the receptor cells of the hair follicle are irritated. Weightlessness does not affect the semicircular canals.

SOUND ANALYZER

Lecture plan:
1. General characteristics of sound waves.
2. Features of the receptor department of the sound analyzer.
3. Features of the conductor and brain departments of the sound analyzer.
4. Mechanism of sound perception.
5. Audiometry.

Sound is a sensation that occurs when longitudinal vibrations of air from the condensation or rarefaction of the molecules of the environment hit the eardrum. The result of these movements is a change in pressure on the eardrum per unit of time in the form of sound waves. They spread in the air above sea level at a speed of 344 m/sec, and in the water environment much faster – 1450 m/sec. Loudness correlates with the amplitude of the sound wave and is measured in decibels (dB). The human ear perceives sounds with an intensity from 0 to 140 dB (calm conversation – 40 dB, shouting – 80 dB, thunder – 120 dB). The pitch of a sound correlates with its frequency. The higher the frequency, the higher the tone is. An average person can distinguish up to 2000 tones of sounds. Musical exercises can significantly increase this ability. A pressure of 0.000204 N/cm^2 is taken as the threshold of auditory sensation. A person perceives sounds with a frequency of 16 – 20,000 Hz. Bats and dogs can hear sounds up to 30,000 Hz. The maximum sensitivity of the human ear to sounds lies in the range of 2000 – 4000 Hz.

The sound analyzer performs the following functions:
1. Perceives sounds with a frequency of 16 – 20,000 Hz.
2. Evaluates sounds by pitch, intensity and timbre.
3. Evaluates the source of sounds and their direction.
4. Estimates the distance to the sound source.

The receptor department of the analyzer is located in the inner ear (fig. 11).
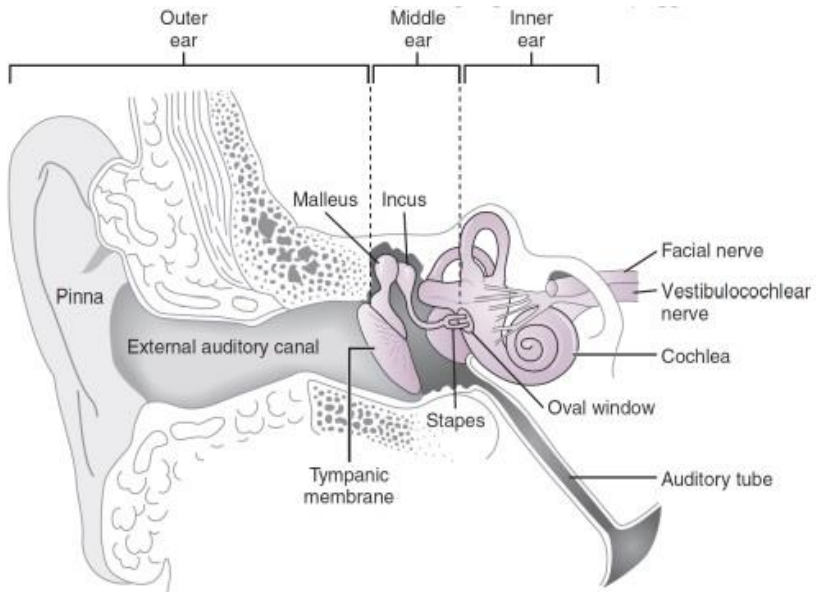
Figure 11 − Structure of the ear

This is the organ of Corti. It lies on the basilemma and consists of 4 rows of hair cells (sensitive cells). There are three layers of hair cells on the outside, in which there are from 12,000 to 20,000 cells. Their hairs are immersed in a viscous covering membrane that hangs over them. In the inner layer there are 3500 cells in one row, the hairs of which do not reach the covering membrane. 90% of internal receptor cells and 10% of external cells are suitable for sensitive fibers of the auditory nerve. In shape, part of the inner ear resembles a snail (cochlea). The snail has 2.5 whorls. A transverse section of the cochlea shows 3 canals: upper (scala vestibuli), middle (canalis cochlearis), lower (scala tympani). The upper and lower canals are filled with perilymph, which contains a lot of sodium ions, and connect at the top of the cochlea through an opening – helicotrema. The middle (membranous) canal is filled with endolymph, which contains 100 times more potassium than in perilymph. When the integument membrane oscillates, the hairs of the internal receptor cells touch it, a receptor potential arises in them,

the mediator acetylcholine is released, which contributes to the formation of the generator potential, if the latter reaches a critical level, an action potential occurs, which spreads along the auditory nerve.

The receptor department has additional anatomical formations: the outer and middle ear, each of them performs certain functions. The outer ear picks up sounds, concentrates them, directs them to the eardrum and amplifies the sound by 10 dB and transmits them to the middle ear. The eardrum moves in and out. It does not have its own oscillation frequency, so it acts as a resonator. It has a short critical decay period. In the tympanic cavity (middle ear), filled with air, there are 3 auditory ossicles connected by movable joints: malleus, anvil, stapes. The auditory ossicles act as a system of levers that transforms resonant vibrations of the eardrum into movements of the stapes. Contractions of the muscles of the auditory ossicles pull the malleus inward, and the base of the stapes outward. At the same time, the sound amplitude decreases by 22 times, and the sound strength increases by another 20 dB. From here, the sound is transmitted to the oval window in the scala vestibuli, and then through the gelicotrema in the scala tympani (fig. 12). From them, oscillations are transmitted to the endolymph in the cochlear canal. The integumentary membrane begins to oscillate first, the oscillation of the main membrane is delayed by 0.5 phases. As a result, the covering membrane touches the hairs of the internal receptor cells and causes irritation. The tympanic cavity is connected to the nasopharynx through the Eustachian tube. When swallowing, the Eustachian tube opens, which equalizes the pressure in the middle ear to the atmospheric pressure. The propagation of sounds through the eardrum and auditory ossicles is called ossicular conduction. Sound waves that cause vibrations of the tympanic membrane and the membrane of the oval window are called air conduction. The transmission of sound vibrations from the external environment to the fluid of the inner ear by the bones of the skull is called bone conduction. In everyday life, bone conduction is important only

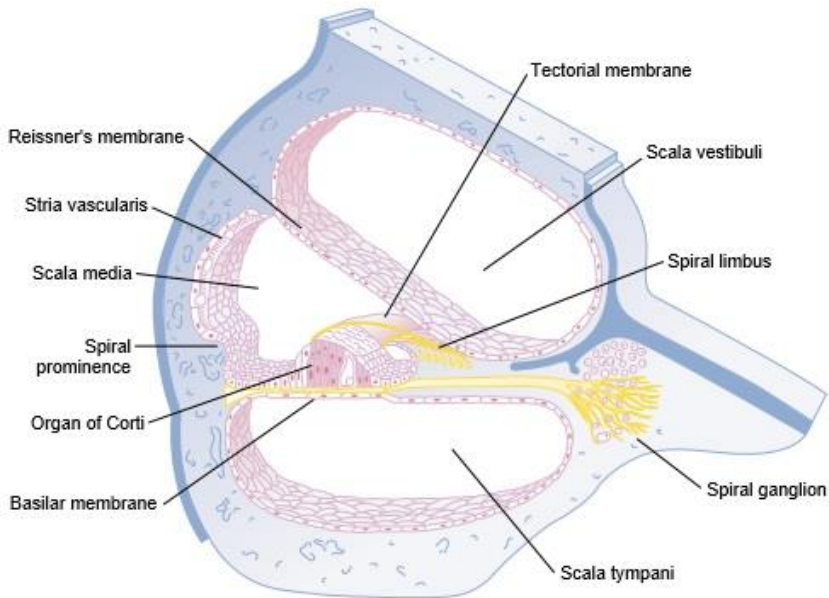when listening to one's own voice. Air conduction is longer, bone conduction is better.

Figure 12 − Receptor department of the sound analyzer (Textbook of medical physiology / Arthur C. Guyton, John E. Hall. 2006)

The conductory department of the sound analyzer has 3 neurons (fig. 13). The first neuron is located in the spiral ganglion. These are bipolar cells with two long processes. One of them goes to the receptor cells, the other is sent as part of the n.stato-acousticus to the nuclei of the medulla oblongata. The second neuron is located in the n.cochlearis dorsalis et ventralis of the medulla oblongata. The third neuron is located in the medial geniculate bodies of the thalamus. At the same time, a third of the fibers from the medulla oblongata go to the posterior tubercles of the quadriceps, where the approximate reflex to sounds is closed. Two-thirds of the fibers go to the oliva of the medulla oblongata, forming the lateral auditory loop. This ensures the direction of the sounds. The olivary bundle is the fibers of the auditory nerve, which ends on the outer hair cells.
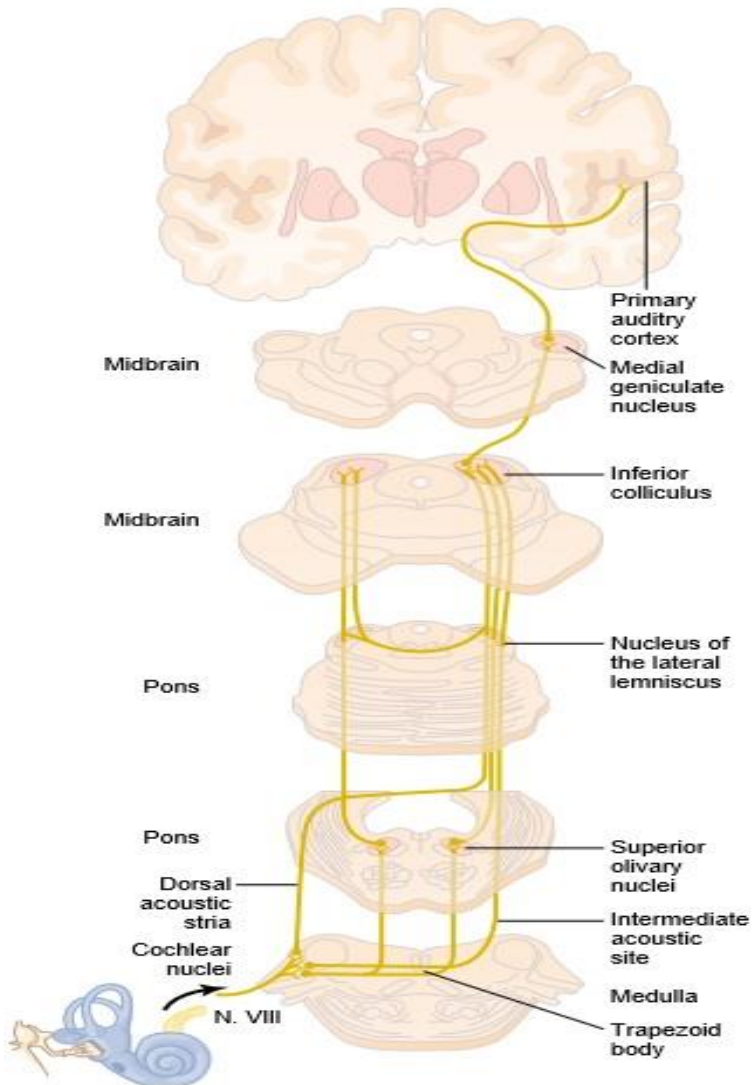
Figure 13 − Conductor department of sound analyzer (Textbook of medical physiology / Arthur C. Guyton, John E. Hall. 2006)

The brain department of the sound analyzer is located in the temporal cortex – gyrus Heschli.

The mechanism of sound perception

Low-frequency sounds up to 2000 Hz are reproduced by the auditory nerve. A higher sound frequency has a more complex sound perception mechanism, which is determined by the features of the structure of the main membrane, where the organ of Corti is located. The main membrane has three features:

1. The elasticity along the membrane is different. It is large at the base of the basilar membrane, decreases in the middle, and increases again at the apex.

2. Different widths of the main membrane: at the base it is narrow – 40 μm, and at the top it is wide, reaching 500 μm.

3. Different degree of fiber tension in the structure of the membrane: it is much less at the top.

Sounds cause oscillations of the entire main membrane, but the amplitude of the oscillation will be maximum only in a certain place of the membrane, depending on the frequency of the sounds. Under pressure, the main membrane bends more at the top, less at the base. Due to these features, low sounds create maximum vibrations at the top of the main membrane, and high sounds – at the base of the membrane. If a wave, whose maximum occurs near the base, is superimposed on the same one, the summation of the waves occurs and the amplitude of the oscillations increases. Such a mechanism was called a surge mechanism or a "running wave" mechanism (fig. 14). Hearing at high frequencies decreases with age. This phenomenon is called presbyacusis. The sound analyzer provides auditory orientation in space, that is, accurate determination of the direction of the sound source. A prerequisite for this is binaural hearing, that is, listening with both ears. At the same time, the sound reaches the distant ear later, the difference is 0.000025 seconds.
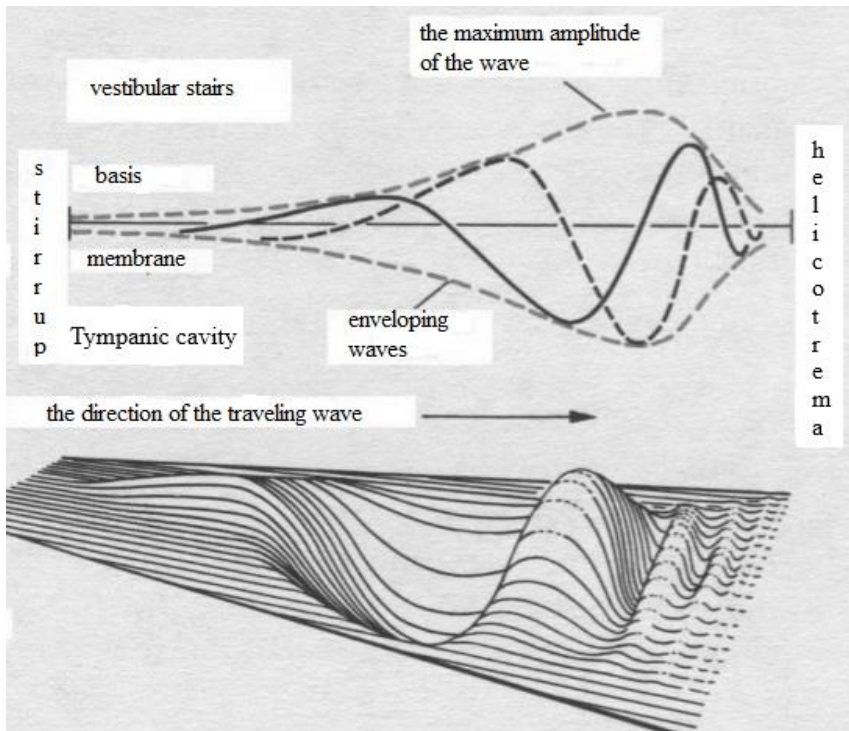
Figure 14 − Mechanism of sound perception

Audiometry

Audiometry is a measurement of hearing acuity. The examined person perceives sounds of a certain frequency through headphones. The source of sounds is an audiometer. For each sound frequency, the audibility threshold is determined, the value of which is plotted on the diagram as a ratio to normal audibility. The diagram reflects the degree of deafness and gives a qualitative description of the tonality ranges of sounds.

SOMATO-VISCERAL SENSORY SYSTEMS

Lecture plan:
1. General characteristics of somato-visceral systems.
2. Somato-visceral sensitivity.
3. Features of the conductive department of somato-visceral systems.
4. Formation of the feeling of touch, pressure, vibration, temperature assessment, feeling of pain.

The somato-visceral sensory system includes all types of skin sensitivity, proprioceptive and visceral sensitivity. This system does not form special sense organs and special nerve fibers. It has a wide receptor field in which specialized receptor cells are located. Conduction of somato-visceral information is provided by the lemniscal, anterolateral and extralemniscal systems.

Skin sensitivity ensures the formation of a feeling of pressure, touch, vibration, tickling, pain and temperature.

Deep sensitivity analyzes information from muscles, joints, and tendons, and forms proprioception:
1. sense of the position of the limbs in relation to the body;
2. sense of direction and speed of movement of limbs;
3. feeling the force necessary to hold the body or limbs, as well as the force for movement.

The main proprioceptors are:
1. Muscle spindles, which respond to the change in muscle length and the speed of its change.
2. Golgi tendon receptors that respond to changes in muscle tension and its rate of change.
3. Joint receptors that respond to the volume of movement.

The sensitivity of internal organs is provided by interoreceptors. They provide information to the central nervous system about changes in the internal state of the body, transmit information about the course of regulatory processes necessary to

maintain homeostasis, and ensure interaction and communication between internal organs.

Skin sensitivity

Skin sensitivity includes mechanoreception, thermoreception, and nocireception. Mechanoreception provides several modalities of sensation: touch, pressure, vibration, tickling, which are formed under the influence of mechanical stimuli acting on the skin. In the clinic, mechanoreception is usually called tactile sensitivity, the check is carried out including bilateral comparison.

Mechanoreceptors on glabrous skin include Meissner corpuscles, Merkel discs, Pacinian corpuscles, and hair follicle receptors, Ruffini corpuscles, Pacinian corpuscles, and tactile discs on hairy skin. (fig. 15) According to the mechanism of excitation, they are receptors of intensity, speed and acceleration and therefore are responsible for more than one sensation. For example, Ruffini corpuscles and Merkel disks are simultaneously touch receptors, sensors of the intensity and duration of the stimulus. Touch receptors and speed sensors are Meissner corpuscles and receptors of hair follicles. Acceleration sensors are Pacinian corpuscles, which respond to the acceleration of skin displacement. In addition to the specified receptors, mechanoreceptors include mechanosensitive free nerve endings. They are threshold sensors for the presence of a stimulus in a given area of the skin, carry information about weak stimuli (crawling insects), and form a tickling sensation. Their peculiarity is the ability to cause various reactions, to conduct information on unmyelinated fibers, but not to provide accurate information about the intensity of the stimulus.
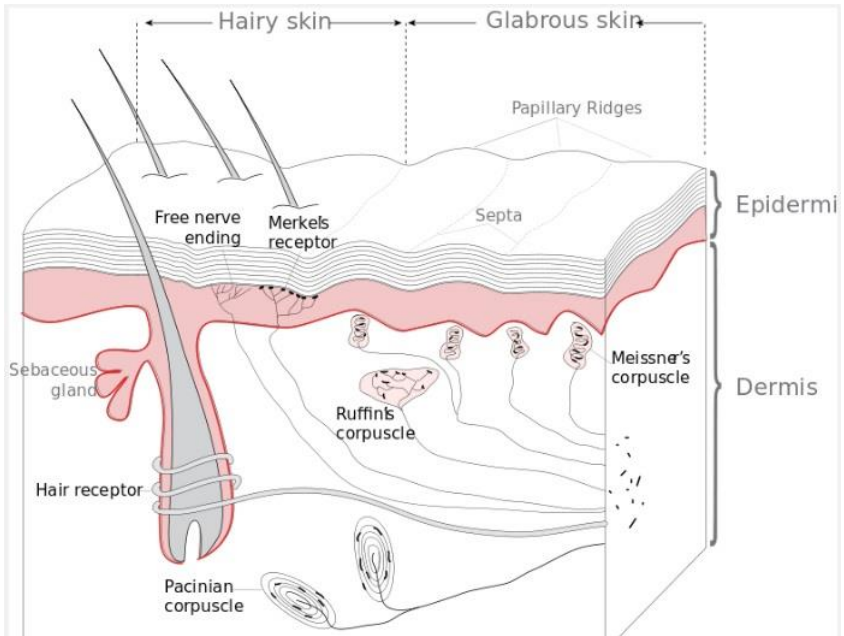
Figure 15 − Types of skin receptors

The feeling of thermoreception forms two modalities: cold and warm. The number of thermoreceptors on the skin is smaller than that of mechanoreceptors. The density of thermoreceptors in different areas of the skin is different: the greatest density of cold receptors is in the skin of the back, and heat receptors are in the skin of the front abdominal wall. The skin contains specialized thermoreceptors in the form of Ruffini corpuscles, which perceive heat and Krause's end bulbs, which perceive cold. From them, afferent information spreads at a speed of 0.4 − 20 m/sec. There are more cold receptors than heat receptors. For example, there are 16-19 cold receptors and 1-5 heat receptors per 1 cm of facial skin.

In addition, there are non-specialized thermoreceptors − these are pressure receptors, sensors of stimulus intensity. Thermoreceptors adapt to a new temperature after a few seconds, and the subjective adaptation of the skin takes place only after a few

minutes. Cold receptors are located directly in the epidermis, and heat receptors are located in the upper layer of the skin itself.

Nociception is the formation of a feeling of pain. Most scientists believe that special pain receptors do not exist. Free nerve endings or any receptors of skin and visceral sensitivity are used to form the sensation of pain, which can be excited by strong stimuli of a temperature, mechanical and chemical nature.

The sensitivity of internal organs is provided by interoreceptors. They can be chemoreceptors, mechanoreceptors, osmoreceptors, volume receptors, thermoreceptors, and nociceptors. The conductive part of the somato-visceral system includes the lemniskal, anterolateral, and extalemniskal systems (fig. 16).
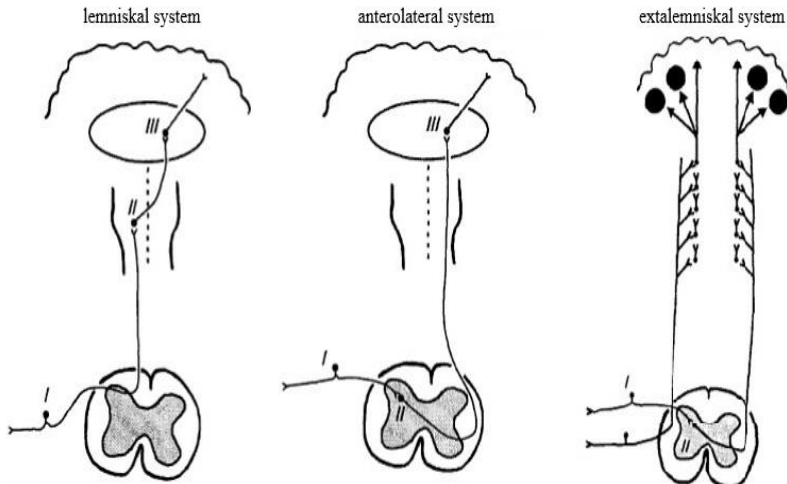

Figure 16 − Conductor departments of the somato-visceral analyzer

Lemniskal system conducts tactile and proprioceptive sensitivity along the following path: receptors − spinal ganglion − tractus spino-corticalis − medulla oblongata (n.gracilis n.cuneatus) −

medial loop – ventro-basal nuclei of the thalamus – upper three lobus parietalis of the cortex on the right and temporal areas of the cortex.

Touch, pressure, vibration are carried out by a different path: tactile receptors – spinal ganglion - ventral spinal-thalamic pathway – ventro-basal nuclei of the thalamus – posterior central gyrus.

Temperature, pain have their own route: thermoreceptors, free nerve endings – spinal ganglion – dorsal spinal-thalamic pathway – non-specific nuclei of the thalamus and reticular nuclei of the midbrain – orbito-frontal and parietal cortex.

Anterolateral system (non-spinal-thalamic tract) also conducts simple types of tactile sensitivity, acute pain, and temperature sensitivity. The first neuron is located in the spinal ganglion. The bodies of the second neurons are located in the posterior horns of the spinal cord. Their axons move segmentally to the opposite side of the spinal cord, which provides fine spatial analysis. Information from both parts of the body enters the front part of the ectosylvian gyrus.

Extalemniskal system carries information about slow pain and information from interoreceptors. The body of the first neuron is located in the spinal ganglion, from where the information enters the posterior horns of the spinal cord, where the second neuron is located. Its axons partially go as part of the ventrolateral tract and the spinoreticular tract to the reticular formation of the brainstem, and part of the fibers go to the opposite side. The third neuron is located in the posterior nuclei of the thalamus. Through collaterals, information enters the limbic system and the hypothalamus. From the thalamus, information goes to the orbito-frontal and parietal cortex.

At different levels of the central nervous system, afferent signals of visceral and somatic origin interact. Visceral signals are blocked by somatic signals on converging neurons due to their majority, which limits the access of information from internal organs to the cortex, so we do not feel the state of our organs. Increased visceral afferentation draws our attention to the internal organs. This is noticeable when the urinary bladder is full, pathological abnormalities.

Analysis of information received from receptors takes place in specific and associative zones of the cortex. The specific sensory areas of the cortex include two somatosensory areas (S1 and S11). The first is localized in the postcentral gyrus, it receives information from the opposite part of the body and has a pronounced somatotopic organization and an ordered spatial representation. Processing of information in this area provides its fine spatial analysis. The second zone is located from the lateral end of the postcentral gyrus on the upper part of the lateral sulcus. It receives information from both parts of the body, has a less clear somatotopy. The associative zones of the cortex receive information from the associative nuclei of the thalamus. There are 2 associative zones: the first is in the area of the frontal lobe in front of the precentral gyrus, the second is in the area of the parietal lobe at the border between the parietal, occipital, and temporal zones. Associative zones provide a more accurate and comprehensive assessment of any signal, determination of its biological significance. It should be noted that the completion of the formation of a sensation occurs as a result of the interaction of specific and associative zones of the cortex and a number of subcortical structures.

PAIN ANALYZER

Lecture plan:
1. General characteristics of pain.
2. Epicritic pain.
3. Protopathic pain.
4. Antinociceptive system.

Pain is a systemic reaction of the body aimed at protecting against damage. Causes of pain:

1. Damage to the receptor cell membrane.

2. Violation of cell metabolism (change in pH, excess of bradykinins, histamine, prostaglandins).

3. Tissue hypoxia – lack of oxygen.

Classification of pain:

1. Somatic:

• fast or early primary pain – time from irritation of nociceptors is less than 1 s. (tingling, pinching);

• slow or late secondary chronic pain – irritation time is more than 1 s. (a few seconds, minutes, hours) (muscle cramps, headache).

2. Visceral is a slow pain that occurs when nociceptors are activated by damaged structures of internal organs (appendicitis, ulcer, internal colic).

The pain syndrome consists of several components:

1. Sensory component – negative emotions and corresponding feelings, fear, depression

2. Motor component – screaming, suffering, crying, adopting a special posture to relieve suffering (for example, with a hip fracture, the patient acquires the frog posture) .

3. Vegetative component – pupil dilation, cold sweat, tachycardia, increased blood pressure, increased breathing rate.

4. Endocrine component – activation of the sympathoadrenal system, increased release of hormones by the adrenal glands.

5. Motivation – the occurrence of a behavioral reaction aimed at eliminating pain.

6. Activation of memory – use of previous experience of pain relief.

Most scientists believe that special receptors for pain perception do not exist. These are free nerve endings or ordinary receptors adapted to other stimuli, which are excited by strong stimuli of a thermal, electrical, mechanical and chemical nature. The chemical factor causing pain can be an excess of ATP, capsaicin, serotonin, prostaglandins, histamine, accumulation of acidic metabolic products in the body. These are algogenic substances, they can stimulate the occurrence of pain. The basis of their action is the depolarization of non-selective channels with an increase in membrane permeability for sodium and calcium. This contributes to the transmission of the flow of information to the corresponding areas of the cortex: the frontal and cingulate gyri, the cerebellum, the insular cortex and the S-II cortex. Removal of the prefrontal cortex (lobectomy) leads to the fact that a person does not feel pain, but the sense of touch is preserved. Removal of the lumbar gyrus reduces the feeling of pain, but this pain does not bother the person.

There are 2 types of pain:

1. Acute or epicritical pain.

2. Slow or protopathic pain.

Epicritic pain occurs quickly, it is short-lived, has a precise localization, quickly disappears after the cessation of the stimulus, is carried along A-delta fibers at a speed of 5 – 15 m/s. → is formed in the sensory areas of the cortex with the participation of the SNS. This type of pain has a protective value, because it warns of the danger of tissue damage.

The route of acute pain is carried out along the pathways of the lemniscal system: excitation of nociceptors → sensory fibers → spinal ganglion → cells of the posterior horns of the spinal cord → anterior lateral bundle of the spinal-thalamic tract → medial loop → paraventricular nuclei of the hypothalamus and ventro-basal nuclei of the thalamus → the anterior part of the ectosylvian gyrus (S11).

Protopathic pain – occurs slowly, lasts a long time, has no exact localization, has a high absolute threshold of sensation,

disappears slowly, is conducted by unmyelinated fibers (C-fibers) at a speed of 0.5–3 msec., is formed in the posterior ventral nuclei of the thalamus with the participation of the PSNS. This type of pain plays a pathogenic role, reminds of the presence of tissue damage and organizes protective reactions. This pain is accompanied by the release of kinins, histamine, prostaglandins E.

The route of slow pain is carried out by the pathways of the extralemniscal system: excitation of nociceptors → sensitive fibers → ventro-lateral tract → reticular nuclei of the medulla oblongata and midbrain → posterior ventral nuclei of the thalamus → orbito-frontal and parietal cortex.

There is a special system in the human body that protects the body from pain – this is the antinociceptive system. It includes three groups of substances that are produced in the central nervous system and the gastrointestinal tract:

1. Opioid substances (enkephalins, endorphins, dynorphins, dermorphins, B-lipotropin).

2. Non-opioid peptides (neurotensin, somatostatin, bombesin, angiotensin-2, vasopressin).

3. Catecholamines (adrenaline, norepinephrine, dopamine).

Opioid substances, isolated for the first time from brain tissues, are produced by the grey substance of the brain, hypophysis, hypothalamus, and adrenal glands. According to the mechanism of action, they are similar to morphine, they have the ability to bind to opioid receptors and cause postsynaptic inhibition in them, resulting in analgesia (pain reduction) and inhibition of the production of algogenic substances that stimulate the occurrence of pain. Opioids mainly stop the activity of afferent structures of nociceptive systems: nociceptors, transmission of information through sensitive pathways.

Non-opioid peptides inhibit the transmission of nociceptive signals along A-delta and C-fibers. The mechanism of their action is related to the effect on the gelatinous substance of the spinal cord. Melzack and Wall (1965) created a model of the peptide mechanism of pain termination (fig. 17).
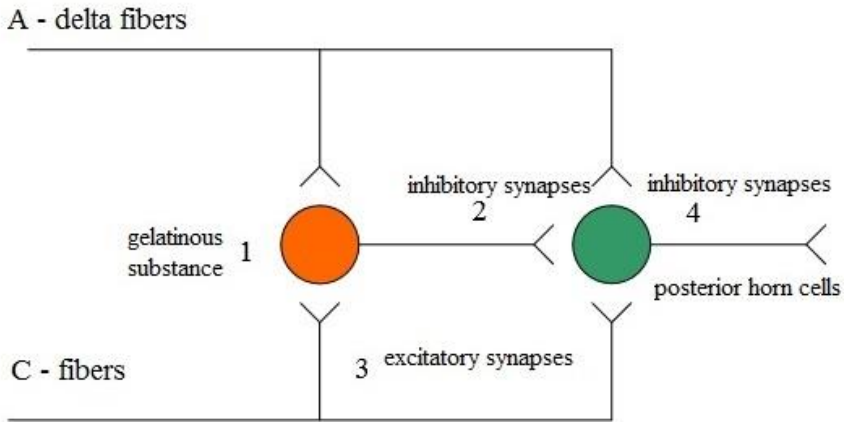
Figure 17 − Melzack and Wall model

The essence of the model is that excitation of the gelatinous substance of the spinal cord stops the flow of pain signals along A-delta fibers due to the development of presynaptic inhibition. Inhibition of the gelatinous substance facilitates the transmission of nociceptive information to the cells of the posterior horns, where the second neuron of this pathway is located. Non-opioid peptides stimulate the excitation of the gelatinous substance and analgesia occurs.

Електронне навчальне видання

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ФІЗІОЛОГІЯ СЕНСОРНИХ СИСТЕМ

Конспект лекцій

для студентів 2-го курсу спеціальностей
221 «Стоматологія», 222 «Медицина», 228 «Педіатрія»
денної форми навчання

(Англійською мовою)